Annual Report

2011-2012

सत्यमेव जयते

Earth System Science Organization
Ministry of Earth Sciences
Government of India

Contents

1 An Overview

The Earth System Science Organization (ESSO) operates as an executive arm to implement policies and programmes of the Ministry of Earth Sciences (MoES). It deals with four branches of earth sciences, viz., (i) Ocean Science & Technology (ii) Atmospheric and Climate Science and (iii) Geoscience and (iv) Polar Science and Cryosphere. The ESSO has been addressing holistically various aspects relating to earth processes for understanding the variability of earth system and for improving forecast of the weather, climate and hazards. The ESSO was established in October, 2007 as a virtual organization, subsequent to the setting up of the MoES, which was formed in 2006 by bringing all the agencies of meteorological and ocean development activities under one umbrella, recognizing the importance of strong coupling among various components of the earth, viz. atmosphere, oceans, cryo-sphere and geo-sphere.

The ESSO primarily aimed to develop and improve capability to forecast, weather, climate and hazard related phenomena for societal, economic and environmental benefits including addressing aspects relating to polar and climate change science and services. The ESSO is also responsible for development of technology towards the exploration and exploitation of marine resources in a sustainable way.

The ESSO contribute to various sectors, viz., agriculture, aviation, shipping, sports, etc, monsoon, disasters (cyclone, earthquake, tsunami, sea level rise), living and non-living resources (fishery advisory, poly-metallic nodules, gas hydrates, freshwater, etc), coastal and marine ecosystems and climate change, underwater technology. Secondly, MOES is also responsible for defining and deploying satellite-based, airborne and in-situ atmospheric, ocean and lithosphere observing systems which act as backbone for achieving the objectives. These policies/programmes are being pursued through its centres, viz., autonomous bodies and subordinate offices. The institutions (Fig.1.1), viz. 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

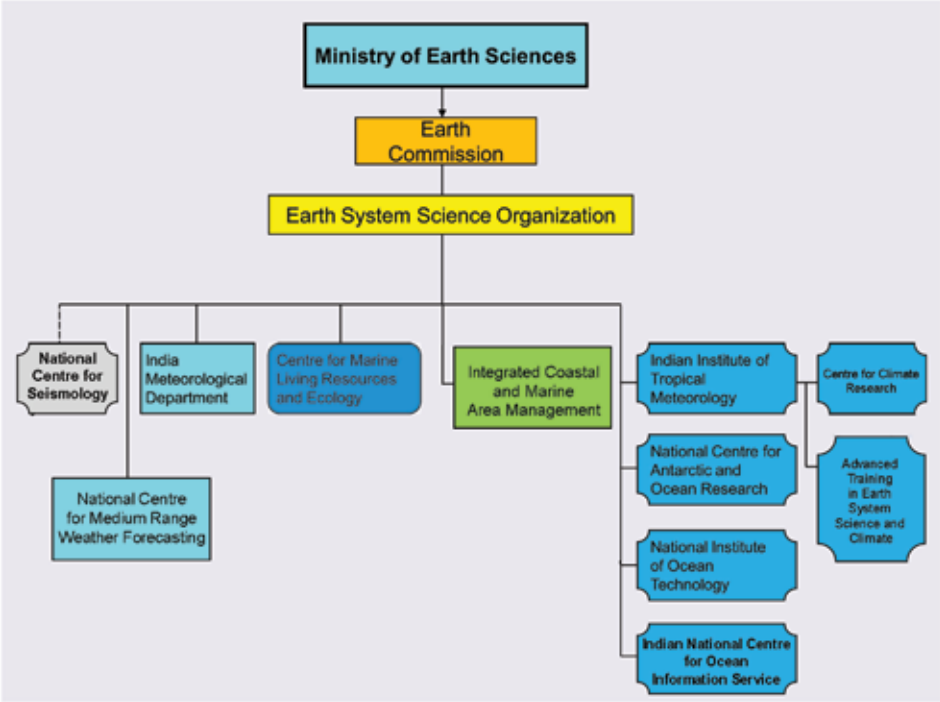


Fig.1.1 Organization Chart of MoES

Technology (NIOT), Indian National Centre for Ocean Information Services (INCOIS), Centre for Marine Living Resources (CMLRE) and Integrated Coastal and Marine Area Management (ICMAM) were grouped under the ESSO which operates through the ESSO council, an apex body to formulate policies and plans, and provide program directions for the Centres/Units and review the implementation of programmers.

The overall vision of the ESSO is to excel in knowledge and technology enterprise for the earth system science realm towards socio-economic benefit of the Indian sub-continent and in the Indian Ocean region. It has three major objectives:

- Provide scientific and technical support for both academic and applied research 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 programs.

- Support science and technology development for exploration and exploitation of ocean resources (living and non-living), ensuring their sustainable utilization.

One of the major activities has been development and formulation of 12th Five Year Plan proposals, which has been accomplished through the Working Group constituted by the Planning Commission. The exercise has been carried out based on zero-based budgeting which includes review of the ongoing schemes and identification of new initiatives proposed for next five years considering the current activities of the ESSO. Besides, selective implementation of important ongoing activities, over twenty new subjects have been proposed for implementation during 12th Plan primarily to address the process studies and capacity building activities. The draft report has also been examined by the Steering Committee of the Planning Commission.

A recent study conducted by the National Council of Applied Economic Research (NCAER) on various advisory services to farming community and fishermen have reaped enormous economic benefits. The NCAER study was aimed at assessing the economic benefit and impact of ESSO's weather (agro-met), fishery advisory services, cyclone warning service, and public Weather service. The economic benefit has been estimated by the NCAER at approx. Rs.50,000 crores and Rs.34,000 crores per year for the Agromet and Fishery Services, respectively.

Significant achievements of the ESSO for the period under various fields are outlined as below.

1.1 Atmospheric Science and Services

District-level agro-meteorological advisory service

A quantitative district-level agro-meteorological advisory service covering 560 districts, has been made operational for farmers in partnership with a number of Central Government Ministries and organizations, state level institutions, private agencies, NGOs, progressive farmers and media. This service comprise of 5 day weather forecast and advisory proposed out agricultural practices. About 30,00,000 lakhs farmers have subscribed for the information through mobile for planning their agricultural activities.

Modernization of meteorological Services

Atmospheric Observing Systems through state-of-the-art technology (AWS, ARG, DWR, GPS sonde) with high bandwidth communication systems has been set up. Over 1000 systems (541 AWS and 557 ARGs) in various part of the country for real-time monitoring meteorological parameters have been installed. Nine Doppler Weather Radars have been installed in various cities, viz., Delhi, Nagpur, Hyderabad, Lucknow, Patiala, Agartala, Patna, Mohanbari and Mumbai. Computation facilities have been substantially augmented by commissioning of high performance computing systems in various centres which has a total combining capacity of 124 Tflops.

A complete end-to-end forecasting system that includes acquisition of data from various observing systems, linkage to a central data processing system, their utilization in the numerical models, providing a state-of-the-art IT based environment to all forecasters across the country has been installed. This involves integration of all observations and overlaying them on

model outputs and synoptic charts along with proper visualization and customized dissemination of weather forecast to the end users.

Global Forecast System (GFS T382/L64) having spatial resolution of 35 km was made operational incorporating Grid Point Statistical Interpolation (GSI) scheme for global data assimilation for the generation of global scale forecasts up to 7 days in advance. The horizontal resolution of the Global Forecast System (GFS) was increased from T254L64 (50km) to T382L64 (~35km) along with assimilation of direct satellite radiances which was subsequently made operational. Experimental runs with higher resolution (T574L64(~22km) GFS) and unified model (N512L70 (25Km) with 4D VAR assimilation models) have been carried out.

Monsoon Prediction 2011: The southwest monsoon prediction 2011 turned out to be 101% against the forecast of 98% which was issued in April 2011. However the prediction given in June was 95%.

Advanced Training School: Towards human resource development in the field of earth science, an Advanced Training School was established with self contained facilities for training and research at Pune. The main objective of the Centre was to create a large pool of trained and dedicated earth system scientists with in-depth understanding and hands-on expertise on physical processes of the land, ocean, atmosphere, biosphere and cryosphere and their interaction. The first batch of 20 students was inducted in August 2011 through a national selection process.

Metro-city weather Forecast: After successful execution of a location-specific weather and air quality forecast 24 hours in advance to the Commonwealth Games in October 2010 in National Capital Region, Delhi, the facility was made operational on daily basis in Delhi. The information including current and forecasted weather information as well as information on major gaseous pollutants namely ozone (O3), oxides of Nitrogen (NOx), Carbon monoxide (CO), Benzene and other hydrocarbons, particulate matters, viz. PM10, PM2.5, and black carbon is provided based on data received from 11 air-quality stations and 34 weather stations.

1.2 Ocean Science and Information Services

Fisheries Advisories for identified Potential Fishing Zones (PFZ): One of the major activities sustained during the year was uninterrupted generation and dissemination of the multi-lingual PFZ advisories to the fishing community. PFZ advisories were issued for 14 sectors namely, Gujarat, Maharashtra, Karnataka, Goa, Kerala, South Tamil Nadu, North Tamil Nadu, South Andhra Pradesh, North Andhra Pradesh, Orissa, West Bengal, Andaman Islands, Nicobar Islands, Lakshadweep Islands. PFZ and OSF products were made available to a large section of population along the Indian coast, through hundred Electronic Display Boards (EDB) Installed all along the Indian coast.

A state-of-the-art Oceansat-II ground station was established to receive and process the data from Ocean Color Monitor onboard Oceansat-II Satellite in real-time. The ground station could cover an area of 5000 km diameter circle covering the Bay of Bengal and the Arabian Sea; and generate geophysical parameters, viz., of chlorophyll (Chl-a), suspended sediment (TSM), aerosol optical depth (AOD) and diffused attenuation coefficient (Kd 490) in near real-time. The chlorophyll data integrated with the Sea Surface Temperature from AVHRR of NOAA Satellites is being used for the generation of Potential Fishing Zone Advisory Services in shortest possible time.

Sixty three experimental Tuna Fishery Advisories were generated and disseminated by providing maps and text information similar to PFZ Advisories on every Tuesday, Thursday and Saturday except during ban period to cater to deep sea fishing industry.

A Coral Bleaching Alert System (CABS) for providing bimonthly status on 5 major coral environments of India, viz., Andaman Nicobar, Lakshadweep, Gulf of Mannar, Gulf of Kutchchh has been set up. This provides information on early signs on the coral environments that undergo thermal stress and possible bleaching.

Indian Ocean Forecasting System (INDOFOS): The Indian Ocean Forecast System (INDOFOS) was upgraded with Regional Ocean Modeling System setup at 1/8th degree (i.e. ~13km). This upgradation has significant improved the quality of the forecasts, particularly in the vertical temperature profiles and surface and subsurface currents. The system, at present, provides forecast on wave heights, wave direction, sea

surface temperature (SST), surface currents, mixed layer depth (MLD) and depth of 20^0 C isotherm up to 5-7 days in advance.

Ocean Observation Network: A set of 16-moored buoy network was established for acquisition of realtime data from the seas around India. This has resulted in substantial improvement in the observing network and data ocean data generation during the year which has been found to be useful for operational weather forecasting including providing cyclone warning besides validation of satellite data.

1.3 Disaster Support

Early Warning System for Tsunami: On October 12, 2011 a Pan–India mock drill exercise was successfully conducted as part of the Indian ocean-wide exercise in coordination with twenty nine countries of the Indian Ocean under the overall framework of Intergovernmental Oceanographic Commission (IOC) of UNESCO. With this exercise, the Indian Tsunami Warning System has been entrusted responsibility for operation as Regional Tsunami Service Provider (RTSP) for the Indian Ocean Region and has started operations to the Indian Ocean Rim countries. The Indian Tsunami Early Warning Centre (ITEWC) has reported 74 earthquakes of magnitude > 6.5 during the period. Out of 74 earthquakes the centre issued tsunami advisory for one major earthquake occurred in the Indian Ocean and one earthquake off the coast of Honshu, Japan in the global ocean.

1.4 Polar Science & cryosphere

Third Station in Antarctic: The phase I and II activities related to foundation have been completed for setting up the Third Station in the Larsemann Hills in the Antarctica. The most critical task of putting in place the infrastructure necessary for the construction of the station, without compromising the ongoing scientific and logistic activities at Maitri, was achieved successfully and the station is expected to be commissioned by March 2012.

1.5 Ocean Technology & Resources

Low Temperature Thermal Desalination (LTTD): Two more LTTD plants were commissioned on the islands of Lakshadweep, one each at Minicoy and Agatti during March 2011 and August 2011, respectively. These plants have been contributing significantly to the drinking water needs of the local population of these islands. The capacity of these plants are 1 lakh litre per day.

Deep Sea Technologies: In order to harness deep sea resources, development of various equipments such as Remotely Operable Submersible (ROSUB) to assess environmental conditions and Remotely Operable Subsea In-situ Soil Tester (ROSIS) to test mechanical properties of sea-bed has been undertaken. ROSIS has been developed and was tested at a water depth of 5462 m in the Central Indian Ocean Basin (CIOB). This test is a significant milestone in India's efforts towards demonstration of mining of polymetallic nodules from the deep oceans.

1.6 Coastal Marine Ecology

Open sea cage culture and Ornamental fishery: Ten cages (9m-diameter) were deployed at Olaikuda, Tamil Nadu (4 Nos.) Kothachathram, Andhra Pradesh (2 Nos.) and at North bay, Port Blair, Andaman Islands (4 Nos.). 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, Hatchery technology for spat development of *Pinctada margaritifera* (Black-lip pearl oyster) have been perfected at the hatchery unit in the Andamans Islands.

Marine Microbial Biotechnology: Deep sea filamentous fungi producing extracellular pigment were isolated from a depth of 400m and axenic cultures were developed.

1.7 Climate Change Science

A dedicated centre for Climate Change Research at Pune addresses various scientific issues relating climate change including impacts on sectors like health, agriculture and water. Long-term (multi-decadal) simulations of Monsoon are carried out using coupled ocean-atmospheric models.

1.8 Networking of Centres

All centres have been networked under the National Knowledge Network (NKN) for effective communication and data transfer. Telepresence system to improve communication has been effectively used for conducting various meetings, which has substantially reduced cost and time in hosting the meetings.

1.9 Outreach

With a view to propagate and bring awareness about the programmmes and achievements among the public, student and user communities, ESSO participated in major National and International exhibitions held in India and supported Seminars, Symposia, Workshop and various National Science Centers of National Council for Science Museum and States Council for Science and Technology of Governments of New Delhi, Punjab, Jammu and Kashmir, etc. The seminar Symposia, etc were supported to create platform between scientist, engineers, social scientist, and user community to exchange information and knowledge. The "Earth Day" was celebrated across the country on 22nd April 2011 and the event was organized at 32 locations across the country including schools, college and universities. The theme was Green Earth". The organizers were encouraged to arrange various competitions like drawing and painting, debate, essay, cycle rally amongst various age groups and cash prizes were offered to the students.

Participation in International Earth Science Olympiad: An entrance test was conducted on January 23, 2011 to select 20 candidates for a training camp. A training camp on Earth Sciences held at the Centre for Earth Sciences, University of Hyderabad, Hyderabad, during May 5-24, 2011 and four students were selected to represent India at the International Earth Science Olympiad, Modena, Italy held on September 5-14, 2011.

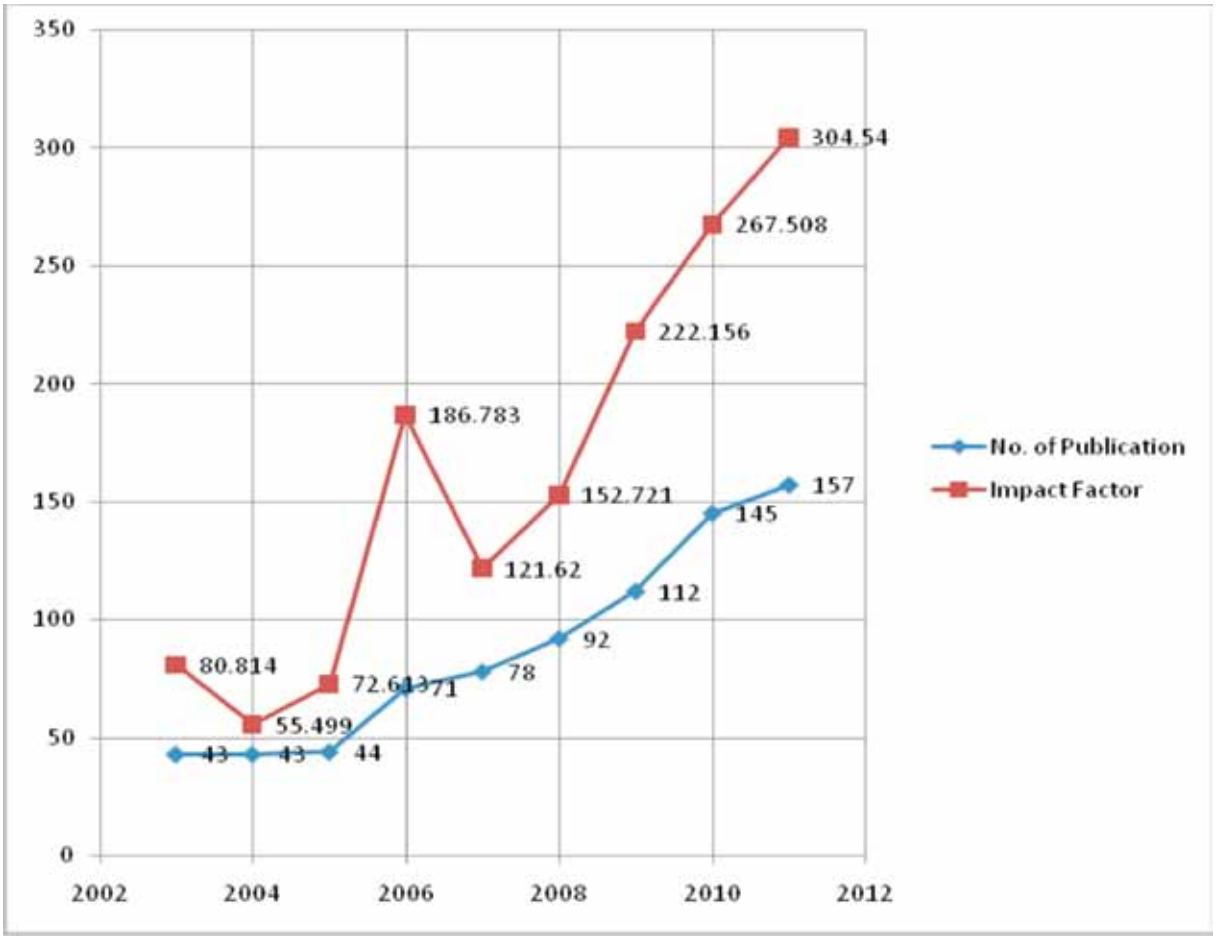


Fig.1.2 No. Publication and Impact Factor

1.10 Scientific Publications

The research publications in SCI Journals have increased. The number of publications and its impact factor during the current year are 144 and 282.8, respectively (Fig.1.2), which shows that the quality of the publications has been improved significantly over the period.

1.11 Budget and Expenditure

The approved outlays for the plan and non-plan for current year 2011-12 were ₹1220 crores and ₹347.00

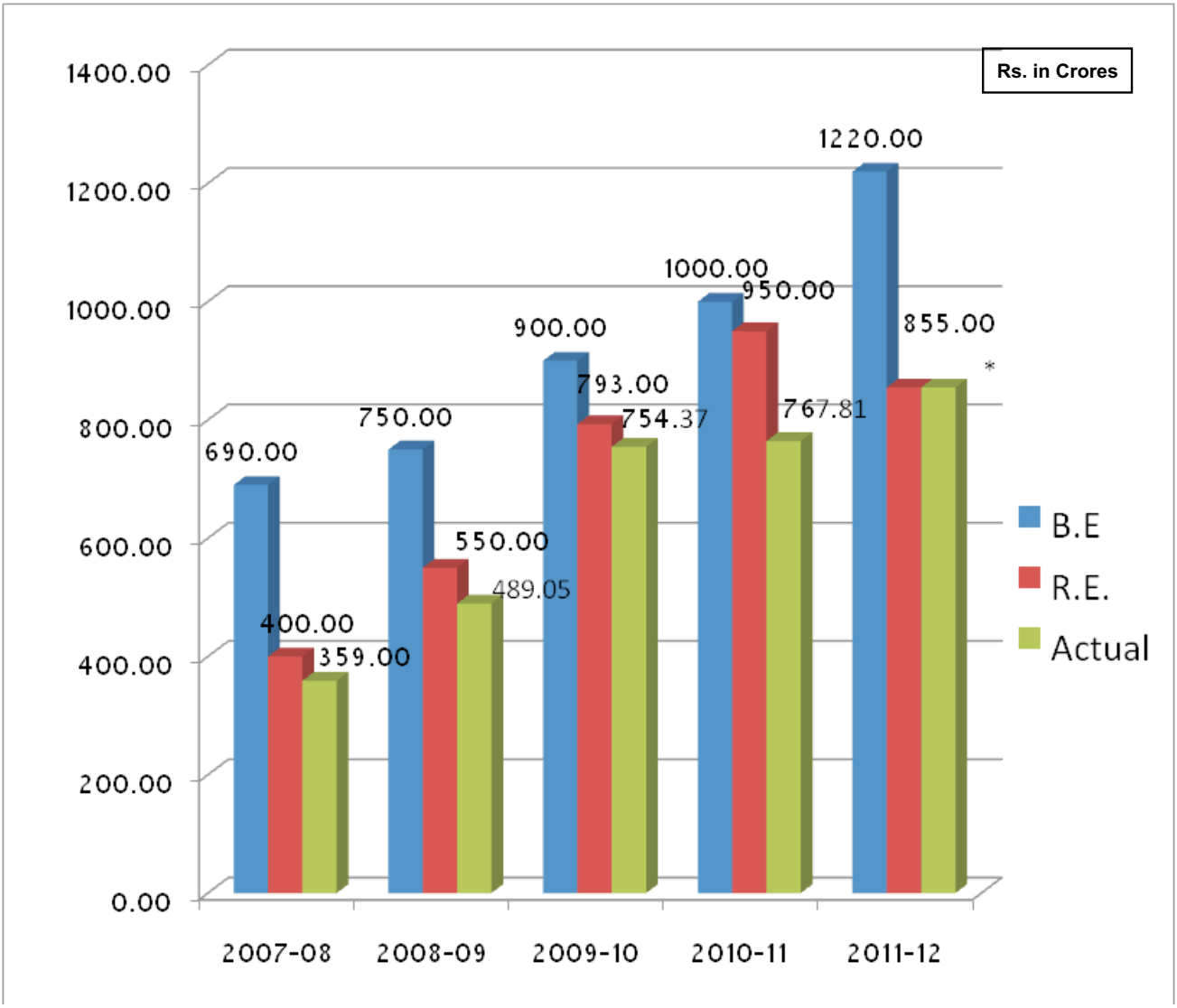


Fig. 1.3 Budget allocation & expenditure during last 5 years.
(*Projected Expenditure)

crores, respectively. The major priority areas during the year have been (i) establishment of the Third permanent Indian Station at the Larsseman Hills, Antarctica, (ii) Modernization of Phase-1 program of Meteorological Services, and (iii) setting up training centre. The trend of budget allocation & expenditure thereof, over the last 5 years is at Fig.1.3.

2.1 Introduction

The Meteorological services have significant impact on every sphere of life. Economies are sensitive to weather and climate information. The management of resources relies heavily on weather and climate services. The demand for accurate prediction of weather and climate at various time scales are increasingly becoming important. Reliable forecast of weather and climate requires integrations of in- situ and satellite observations using high-resolution dynamical models with high complexity (e.g. coupled ocean-atmosphere-land models). Thus, a combined approach involving land, ocean and atmospheric processes and the fruitful translation of their interactions in the numerical models hold the key to improve the forecasts at various temporal and spatial ranges. On the other hand, intensive and sustained monitoring of various weather systems through different platform-based observing systems including satellites provide not only the information about current weather systems but their effective assimilation in numerical models provides guidance for accurate forecasts.

2.2 Meteorological Services

2.2.1 Weather monitoring and Forecast

Weather advisories as well as precautionary warnings for adverse weather arising due to cyclonic storms, heavy rainfall, squall, heat and cold wave conditions, etc. were provided. The weather reports were disseminated to all relevant Government agencies and public through media and through website. During the winter, plains of northwest, central and east India experienced cold wave condition in mid-December and these were predicted reasonably well. The summer of 2011 did not witness any heat wave conditions and the maximum temperatures were generally above normal by 1°C only.

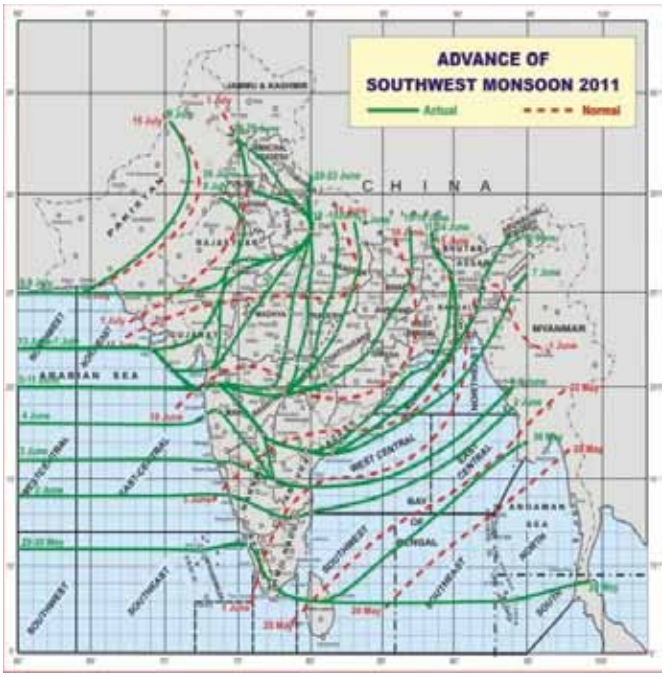


Fig. 2.1 Progress of South West Monsoon 2011

2.2.2 Monsoon monitoring and Prediction

During 2011, the southwest monsoon was delayed by 10 days over the Andaman sea, however, it set over Kerala 3 days in advance on 29th May 2011 covering the South Arabian Sea, Kerala, some parts of Tamil Nadu,

the South Bay of Bengal and the South Andaman Sea. The strengthening of cross-equatorial flow, formation of depression over the Head Bay and low pressure over Chattisgarh helped the southwest monsoon cover the entire country by 9th July, 6 days earlier than its normal date of 15th July (Fig 2.1). The southwest monsoon season (June to September) rainfall over the country as a whole was 101% of its Long period average. The cumulative season rainfall from 1st June to 30th September 2011 was excess in 7 meteorological subdivisions (21% of the total area of the country), normal in 26 meteorological subdivisions (71% of the total area of the country) and deficient in 3 meteorological subdivisions namely Arunachal Pradesh, Assam and Meghalaya, and Nagaland, Manipur, Mizoram, Tripura (NMMT) constituting 8% of the total area of the country received deficient season rainfall.

Four depressions and ten low pressure areas formed during the monsoon season. The withdrawal of the monsoon was delayed and it commenced from Rajasthan on 23rd September with a delay of more than 3 weeks and withdrew from the entire country by 24th October 2011. Table 2.1 gives the summary of the verification of the long range forecasts for southwest monsoon 2011. For the winter season 2011, rainfall for the country as a whole was 78% of its Long Period Average (LPA) value.

Second Meeting of the South Asian Climate Outlook Forum (SASCOF), was organized from 13th to 15th April 2011 at Pune. Besides the member countries, experts from India, USA, Japan, France and WMO representatives attended. The Forum deliberated on various observed and emerging climatic features that are known to influence the performance of the monsoon, such as sea surface temperature conditions over the equatorial Pacific and the Indian Oceans, winter and spring snow cover and surface temperature anomalies over the Northern Hemisphere. Based on these a tercile probabilistic forecast outlook for summer monsoon rainfall over South Asia was prepared. The outlook suggested that over South Asia, for the season as a whole, the large-scale summer monsoon rainfall is likely to be within the normal range with likelihood of below normal rainfall conditions over the northwestern parts and some northeastern parts of South Asia and likelihood of above normal rainfall over the southern parts of South Asia including the islands. In the remaining parts of South Asia, rainfall conditions would be close to the normal.

2.2.3 Agrometeorological Services

Agro-met Advisory Service(AAS) bulletins at district, state and national levels are jointly prepared with Agricultural Universities, Indian Council of Agriculture Research (ICAR) and the Ministry of Agriculture and disseminated to different stakeholders. The district-level bulletins are issued to 560 districts of the country. 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 used by Crop Weather Watch Group (CWWG). TV, radio, newspapers, SMS and Interactive Voice Response Technology (IVR) are used for dissemination of agromet advisories to the farming community in sixteen states. Agro Advisory has been

Table 2.1: Verification of Long Range Forecast of the South West Monson

Region	Date of Issue	Period	Forecast (% of LPA)	Actual Rainfall (% of LPA)
All India	19th April	June to September	98 ± 5	101
All India	21st June	June to September	95 ± 4	
Northwest India		June to September	97 ± 8	107
Central India		June to September	95 ± 8	110
Northeast India		June to September	95 ± 8	86
South Peninsula		June to September	94 ± 8	100
All India		July	93 ± 9	85
All India		August	94 ± 9	110
All India	1st August	August to September	90 ±8	108
All India	1st September	September	90 ± 15	106

extended to 30,00,000 users through mobile phone services during the current year.

In order to enhance awareness of information to user groups, participatory, cross-disciplinary approach is being carried out through organization of 76 farmers awareness programmes in different agromet field units. A new interactive website was launched to provide required information on AAS. Main features of website consists of value added medium-range weather forecast for all districts, Severe Weather Warnings, District, State and National level AAS bulletins on real-time basis twice a week, in English and Local languages, FAQ, SMS and Feedback.

2.2.4 Aviation Services

Meteorological Services for aviation are provided for national and international flights for safe and efficient operations. It includes airport specific current weather reports, various forecasts and warnings for safety, economy and efficiency of aircraft operations. Aircraft-based data is assimilated into the NWP models to give more realistic aviation forecasts. An international training workshop was organized jointly with WMO on the "Competency Standards for Aeronautical Meteorological Personnel" from 31st Oct to 4th November 2011, in which 10 countries from Asia and Africa participated.

During 2011, the observing systems at IGI Airport and NCR Delhi have been strengthened further with commissioning of eight very high resolution meso-network Integrated Auto Aviation Weather Observing Systems (IAAWS); and visibility runway visual range (RVR) meters located at various locations of three runways of the Airport. The products from these instruments along with the data from Doppler Weather Radar (DWR) have been used for 24 × 7 for monitoring various hazardous weather events especially thunderstorms, squalls and localized intense rain spells and issuing forecast/nowcast.

An improved and efficient on-line Fog monitoring system has been implemented thus enabling on-line availability of current fog information and visibility data at 10-30 minutes interval at nearly fifty airports of India. Thirteen AWS at various key locations of NCR Delhi supplement the fog monitoring system by providing hourly temperature, moisture and wind data. Verification of occurrence /non-occurrence of dense fog at IGI on an average has been found to be correct in 95% cases, forecast for onset and lifting of fog timings against the observed are within 0-2 hours in 75% cases. Verification of lowest visibility conditions has been found to be accurate within 100 m in 75% of the cases on an average.

2.2.5. Environment Monitoring and Research

A network of Aerosol Monitoring stations has been established with installation of twelve Skyradiometers at different locations in India. The Aerosol Optical Depth (AOD) calculated from the Skyradiometer data has good agreement with the MODIS derived AOD data over Indian sub-continent. The effect of aerosols on solar radiation has been studied and the results show that there is significant difference in aerosol optical properties during haze and dust days over different stations which is probably due to different aerosol components under distinct weather conditions. It is also observed that high AOD values are associated with the lower Single Scattering Albedo (SSA), which indicates significant contribution of absorbing aerosol component in the atmosphere. Average SSA at Delhi during October, November and December is close to 0.9, which indicates that aerosols over Delhi are moderately absorbing in nature.

2.2.6. Satellite-Meteorological services:

Satellite Meteorological services involve 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. The ground receiving and processing systems for NOAA/METOP and MODIS Polar orbiting satellites installed in 2010 at New Delhi, Chennai and Guwahati were commissioned during June 2011. Table 2.2 gives the accuracy of the satellite derived parameters using algorithms provided by ISRO. Validation of cloud motion vectors and water vapour channel for the month of August 2011 is also presented.

Table 2.2 Accuracy of satellite derived products

Parameter	Accuracy
1. Outgoing Longwave Radiation (OLR)	Within 5-8 watts /M^2 of NOAA OLR
2.Cloud Top Temperature	NA
3.Sea Surface Temperature (INSAT)	N A
4. Cloud Motion Vectors	**RMSE**
Low level (950-701 hpa)	~11 m/sec
Mid Level (700-301hpa)	~10 m/sec
High Level (300-100hpa)	~8 m/sec
5. Water Vapour Winds	
Mid Level (500-251hpa)	~10 m/sec
High Level (250-100 hpa)	~15 m/sec
6.Temperature Profile from NOAA satellite Surface to 100 hpa (average for all levels)	2 to 3.5^0 C validated against GPS sonde over New Delhi.
7.Humidity Profile from NOAA Satellite Surface to 300 hpa(average for all levels)	2 to 3.8 gm/kg validated against GPS sonde over New Delhi.

A new technique for the detection of fog at night has been devised using the NoAA Advanced Very High Resolution Radiometer (AVHRR) and MODIS payloads. It is difficult to distinguish between mist and fog through satellite images. This is illustrated in the Fig 2.2.

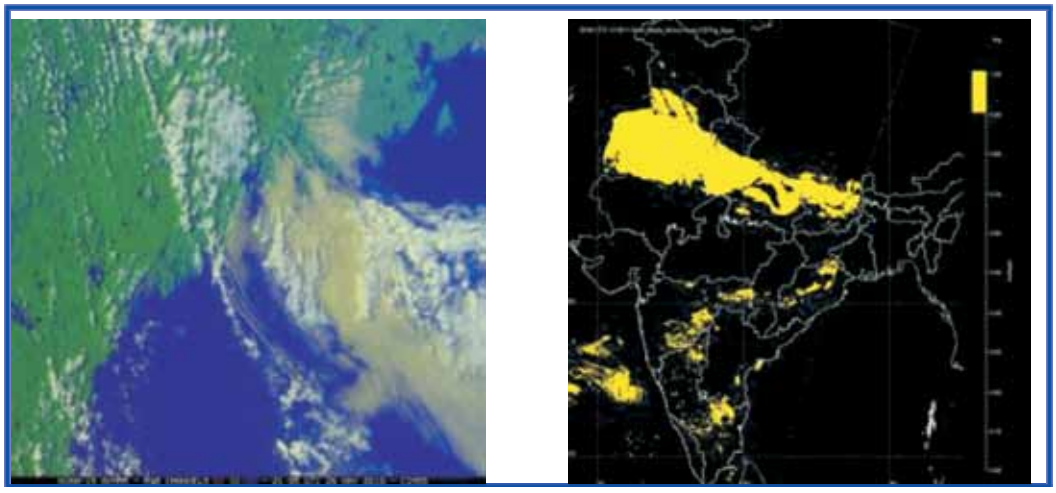


Fig 2.2 Night Time Fog

2.2.7 Climate Monitoring and Information Services

The National Data Centre (NDC) at Pune has more than 100 million records in its archive and every year about 2.5 million records are added. It publishes monthly, seasonal and annual climate diagnostic bulletins for the Indian region regularly. The data products include high-resolution-daily-gridded (1deg X 1deg) rainfall and temperature data over the Indian region, district-wise normal for various surface parameters, marine climate summaries for the Indian Ocean region, etc. Monitoring of Agricultural drought conditions during the Southwest and the 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.

2.2.8 Customized Services

Customized forecast for rainfall, temperature trends,

wind speed and direction between 600hPa to 300 hPa level for mountaineering expeditions were provided to the Indian Army during the Mt. Manaslu, Mt. Stok Kangri, Mt. Bhagirathi and Mt. Kamet Expeditions. This included continuous interactions through mobile/ phone/email during the entire course of the expedition. Forecast products were also provided for Gangotri-I to the Indo-Tibetan Border Force.

The forecasts for rainfall, wind speed at surface and 1000 ft and wind direction for "Para motor flying" in U.P. (Meerut to Lucknow) were provided to the Indian Army.

To facilitate the launch of PSLV-C17, forecasts were provided along with the meteogram (time cross-section of meteorological data, viz. temperatures, winds, pressure, etc. for a specific surface reporting station) and vertical wind profile for the Sriharikota Range (SHAR). Weather Research and Forecasting(WRF) model based high resolution (3km grid) special products (temperature, humidity, heating rate profile, etc.) were generated and provided in real time at hourly interval for undertaking cloud seeding experiments, 72 hours in advance.

2.3. Observation and Forecasting Infrastructure

For improving the reliability of weather forecasting services, a comprehensive upgradation of observation platforms, acquisition, integration and forecasting infrastructure is continuing.

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 till the month of Decemeber 2011 is given in Table 2.3.

A network of ten Surface UV absorption Ozone Photometer have also been installed for monitoring of surface ozone at different locations in India. High Wind Speed Recorder (HWSR) has been installed at Veraval and Dwarka for cyclone monitoring. All 62 Pilot Balloon stations have been equipped with new optical theodolites.

2.4 Numerical Weather Modeling

2.4.1 Global Forecast System

A Global Forecast System (GFS) T574L64 with the latest version of data assimilation scheme (GSI) has been implemented for operational weather forecasts. It has a horizontal resolution of approximately 22 km. This global modeling system represents a significant jump, not only in the improvement in the model physics, but also in the capability of decoding and assimilating more conventional and satellite observations. Major changes in assimilation system include:

(i) Assimilation of data received through EUMETCAST (data broadcasted through EUMETSAT) that is received in India. New data sets such as IASI, ASCAT ocean surface winds and European wind profiler data, etc., are being assimilated.

(ii) Flow dependent reweighting of background error variances.

(iii) Use of new version of community radiative transfer model (CRTM -2.02) with new coefficients.

The upgradation of the GFS to T574L64 from T382L64 with improvements in model physics and data assimilation and additional data have resulted in a gain of 1 day in the skill of the forecasts of zonal wind , the details of which are explained in section 2.4.3 below.

Table 2.3 Status of Installation of Observing Platforms

Observation Type	Target(under Modernization)	Commissioned up to December, 2011	Existing	Total	Data reporting
Automatic Weather Station	550	541	125	666	608
Automatic Rain Gauge	1350	557	-	557	345
GPS sonde	10	10	1	11	2*
Doppler Weather Radar(DWR)	13	11#	5	16	16

***Only 2 stations viz., Hyderabad and Chennai are reporting**

 # C-band polarimetric radar installed in Mausam Bhawan, Lodi Road, Delhi and Jaipur.

2.4.2 U.K. Met Office (UKMO) Global Unified Model (UM)

The U.K. Met Office (UKMO) Global Unified Model (UM) has been upgraded to N512L70 (Version 7.4; horizontal resolution ~ 25 km) and run everyday with the initial conditions downloaded from the U.K., and to version 7.6 with horizontal resolution ~ 25 km by including several aerosol climatology namely biogenic, biomass- burning, black carbon, sea-salt, sulphate, dust and organic carbon fossil fuel aerosols. The regional UM (horizontal resolution ~ 12 km) was upgraded with the physics of version 7.4 and the vertical levels were increased from 38 to 70. The domain corresponds to the regional specialized meteorological centre (RSMC) region. The U.K. Met Office (UKMO) 4D-VAR data assimilation scheme with Unified Model (Version 7.6) and observations downloaded from UKMO was run in parallel from July 2011. In addition, surface observations from India have also been assimilated. It is expected that this will improve the analysis of temperature and humidity at the screen level which will in turn result in realistic representation of soil moisture in the model.

2.4.3 Comprehensive Model Evaluation and Intercomparison

A comprehensive model evaluation and inter-comparison of T574L64 (~22 km resolution), T382L64 (~35 km resolution) was carried out during the monsoon season of 2011. This provides useful insight into the relative model performance during monsoon and also helps to understand and isolate the regional and local aspects of forecast errors. The RMSE of 10 day forecasts of 850 hPa Zonal Wind over the Regional Specialized Meteorological Centre (RSMC) region from the T382 (black line) and T574 (red line) GFS for the month of September 2011 are shown in Fig.2.3. The RMSE values are comparatively lower in the T574 GFS with a gain of 1 day in the skill of the forecasts. In the lower panel the line plot depicts the difference of the forecasts of Zonal Wind of the T574 GFS from the T382 GFS. The difference values outside the histograms are statistically significant at 95% level of confidence.

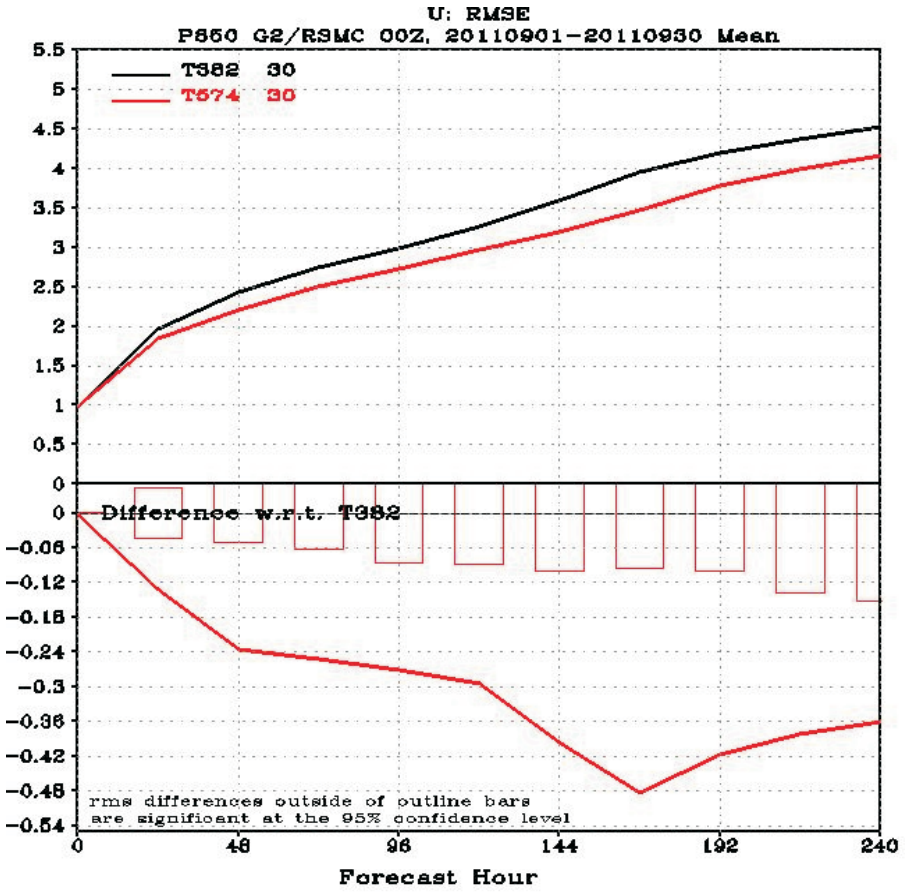


Fig. 2.3 RMSE of Zonal Wind T574 vs T382

2.4.4 The Multi Model Ensemble (MME) for Monsoon 2011

In order to take care of uncertainties in initial conditions, model dynamics and model physics, MME rainfall forecast project continued for monsoon season of 2011. This year the MME forecast algorithm was upgraded to include ECMWF model in addition to the NCEP, JMA, UKMO and NCMRWF models used in the previous years. MME forecast of rainfall was generated on a daily basis in real time. The MME products like simple ensemble mean (EMN), bias corrected ensemble mean (Bc EMN) and weighted multi-model ensemble (MME) rainfall show less bias as compared to the member models (Fig 2.4) with the Bc EMN being the best among all.

indicate that rainfall biases are significantly reduced in CFS v.2 (Fig 2.5), particularly over the Equatorial Indian Ocean region. However, dry bias over the Indian land mass is enhanced. The correlation of ISMR with SST is improved in the Indian Ocean and the Pacific Ocean. The forecast run for simulation of 2011 ISMR using initial conditions of the March month has been performed.

Diurnal Cycle Induced Amplification of Sea Surface Temperature (SST) Intra-seasonal Oscillations (ISOs) over the Bay of Bengal reveals the influence of the diurnal cycle on ISOs of the SST and underlines the need for its proper simulation in climate models. Observations have shown that the Indian Ocean is consistently warming and its warm pool is expanding, particularly in the

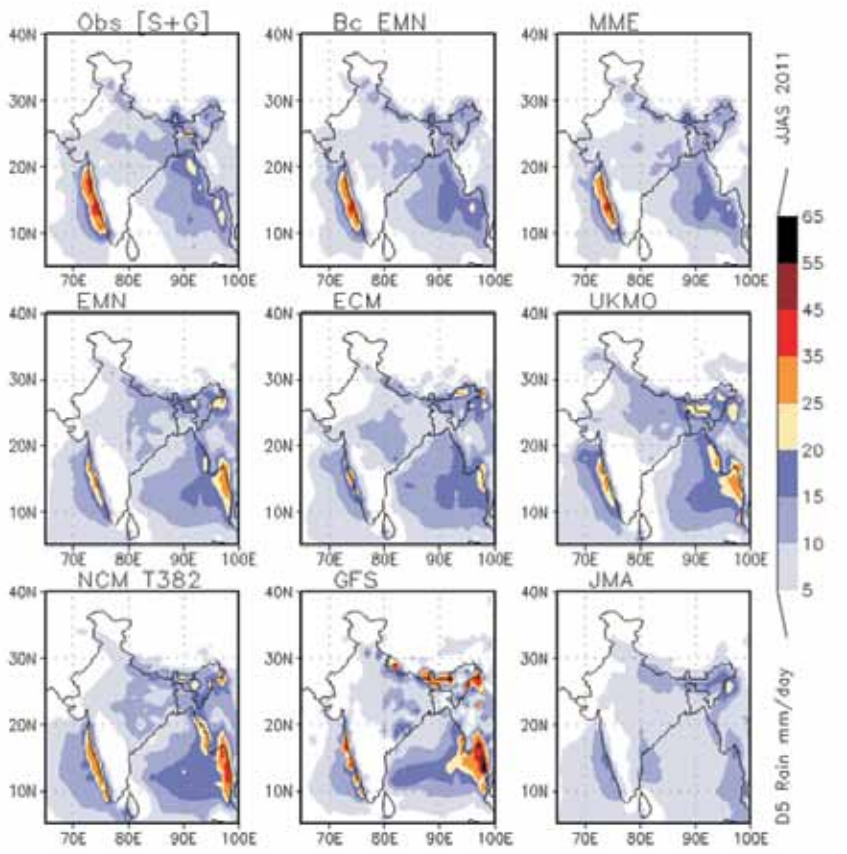


Fig. 2.4 Comparison of seasonal total rainfall for Monsoon 2011 from Observation (S+G), multi-model products (BCEMn, MME and EMN) and member (ECMWF, UKMO, NCMRWF, NCEP-GFS and JMA)

2.5 Research Activities

2.5.1 Development of a System for Seasonal Prediction of Monsoon

Dynamical Seasonal Prediction: NCEP's CFS v.2 has been implemented for dynamical seasonal prediction of the Indian summer monsoon rainfall (ISMR). The results

recent decades. Under global warming scenario, it is expected that the greenhouse gas induced changes in air-sea fluxes will enhance the warming. It is found that the ocean advection processes play an important role in warming and expansion of the Indian Ocean warm pool.

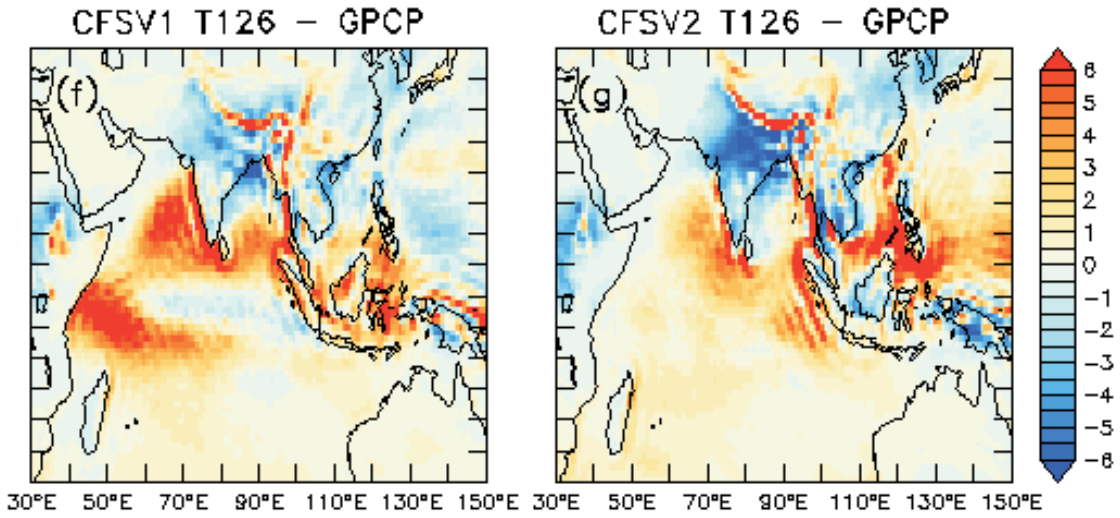


Fig 2.5: Rainfall biases (in mm/day), i.e., difference of model simulated JJAS rainfall climatology and observed (GPCP) JJAS rainfall climatology for CFS v.1, CFS v.2 simulations.

2.5.2 Development of a System for Extended range Prediction of Active/Break Spell:

During summer, the northern Indian Ocean exhibits significant atmospheric intra-seasonal variability associated with active and break phases of the monsoon in the 30-90 days band. In addition to the previously-reported intra-seasonal SST signature in the Bay of Bengal, observations show clear SST signals in the Arabian Sea related to the active/break cycle of the monsoon. As the atmospheric intra-seasonal oscillation moves northward, SST variations appear first at the southern tip of India (day 0), then in the Somali upwelling region (day 10), northern Bay of Bengal (day 19) and

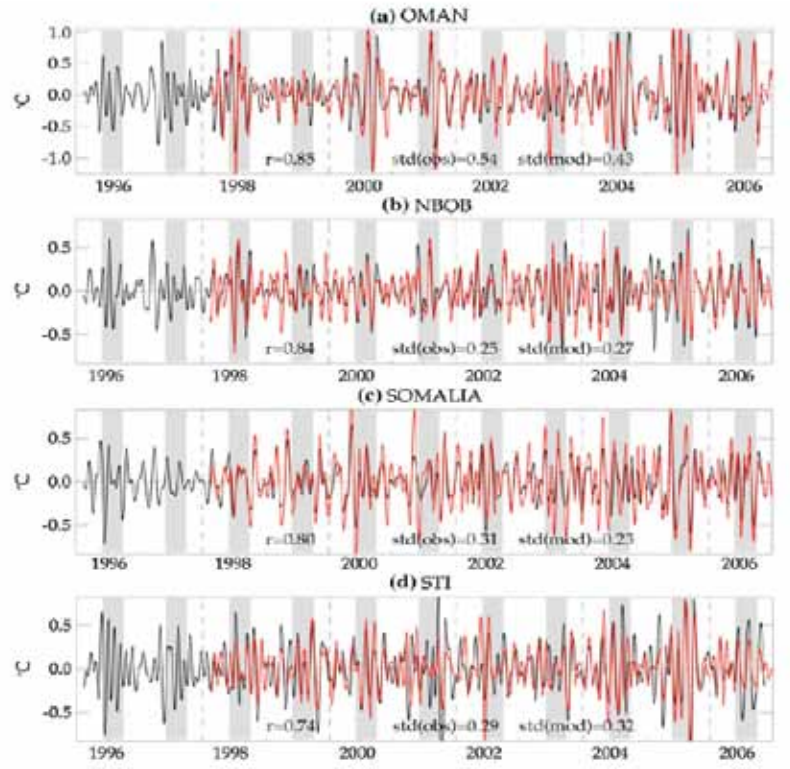


Fig 2.6: Average 30-90 days band passed SST for TMI SST observation (red) and CTL experiment (black) for the four regions: (a) Oman, (b) NBOB, (c) Somalia and (d) STI. The correlation coefficient (r) and the standard deviation (std) of observations (obs) and the model (mod) for the JJAS period are indicated in each panel.

lastly in the Oman upwelling region (day 23). The Bay of Bengal and Oman signals are most clearly associated with the monsoon active/break index, whereas the relationship with signals near the Somali upwelling and the southern tip of India is weaker (Fig 2.6). In agreement with previous studies, both observations and model results indicate a prominent role of dynamical oceanic processes in the Arabian Sea.

2.5.3 Monsoon Variability and Predictability

Growth and climate relationship in teak tree: Tree-ring analysis of teak from the Conolly's plot in Kerala has shown clear annual rings with high variability. Ring-width index and raw tree-ring data from the site reveals the good association to common forcing of environment during 1900-2003. This study shows that the Palmer Drought Severity Index (PDSI) during monsoon months (JJAS) of the previous year and pre-monsoon (MAM) of current year is the most important climatic variable in the development of the annual ring. The results suggest that teak tree is very sensitive to moisture fluctuations over the region.

ISMR variability and Arctic geophysical parameters: A study to understand association of the Indian summer monsoon rainfall (ISMR) variability with the geophysical parameters over the Arctic region is carried out. The correlation analyses of the satellite-derived sea ice data for 29 years indicate that out of 9 sectors of the Arctic region, the Kara and Barents Seas sector's Sea Ice Extent (KBS SIE) during October has a strong relationship with the All-India Summer Monsoon Rainfall (AISMR) in the following year. The study brings out that KBS SIE and some other parameters of the Arctic region can be used as potential predictors in the long-range forecasting of AISMR with a lead period of more than six months.

2.5.4 Thunderstorm Dynamics and Prediction including Role of Boundary Layer Fluxes, Electrical Forces, etc.

Changes in the convective available potential energy (CAPE) and convective inhibition energy (CINE) of 32 Indian stations for 25 years (1984-2008) were analysed. The high average value of CAPE, its increasing trend over 25 years period and increase in monsoon rainfall over the same period together indicate that the monsoon convections over India are not purely oceanic-based type but a combination of continental and oceanic-based convection. Large increase in CAPE compensates the weakening of monsoon circulation to maintain the rainfall and increase the frequency of high rainfall events.

2.5.5 Cloud Aerosol Interaction and Precipitation Enhancement Experiment (CAIPEEX)

Microphysics of pre-monsoon and monsoon clouds: Microphysical structure of deep convective clouds in situ measurements during Cloud Aerosol Interaction and Precipitation Enhancement Experiment (CAIPEEX) over the Indian peninsular region was analyzed. It is shown that droplet size distributions (DSD) in highly polluted pre-monsoon clouds are substantially narrower than DSD in less polluted monsoon clouds. It is suggested that in-cloud nucleation at elevated layers is a fundamental mechanism for producing multi-modal drop size distribution in monsoon clouds as well as in most deep convective clouds.

2.6. Positional Astronomy

Positional Astronomy Centre generates data on Positional Astronomy and brought out the annual publications namely

(i) The Indian Astronomical Ephemeris
(ii) Rashtriya Panchang in 14 languages
(iii) Tables of Sunrise, Sunset, Moonrise-Moonset

The centre fixed up dates of all India festivals for all communities for declaration of holiday by Central and State Governments. The centre also acts as national agency for attending all matters concerning to calendars and takes observation on special astronomical events.

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 and the static pages have been made bilingual (Hindi and English). All observational data and products in near-real-time are uploaded. A web based interactive tool which integrates the radar data with the GIS, is available on the website for use by the forecasters. City weather forecast for 100 cities has been automated and it is displayed on the World Meteorological Organizations's website at http:// worldweather.wmo.int/066/m066.htm, in addition to the official website of India Meteorological Department.

3 Polar Science

3.1 Introduction

Scientific research expeditions have been launched on annual basis 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 (Lat 70°05' South, Long 12°00' East) in 1983. The second permanent station, Maitri was established at the Schirmacher ranges (Lat 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 multi-institutional endeavour. Scientific investigations and researches are undertaken to understand the various phenomenon and processes at Antarctica and link of some of these with regional and global processes particularly those of climate and weather. Undertaking polar studies has been given a thrust since 2008 when a station 'Himadri' was established at Svalbard, Norway. Expeditions are taken up round the year in phases for research in various disciplines.

3.2 Indian Antarctic Programme

3.2.1. 30th Indian Scientific Expedition to Antarctica

The 30th ISEA has 65 members which included 23 scientists from organizations/institutes/laboratories from India [30 members for long-term (winter) and 35 members for Short-term (summer)] including 19 members for the Larsemann Hill expedition for undertaking activities related to the establishment of the 3rd Indian station. The 30th expedition was flagged off on 27 October 2010 from Cape Town. Shri K. Jeeva, Scientist, IIG, Shri Rajesh Asthana, Sr. Geologist, GSI and Shri J. A. A. Silveira, Dy. Chief Engineer, MPT were nominated, respectively, as the Leader of the Expedition, Voyage Leader and the Nodal Officer for the Larsemann Hills for supervision of the construction activity of the research base.

To cater to the enhanced requirements at the Larsemann Hills and Maitri, two ships, an Ice Breaker Vladimir Ignatjuk and a multipurpose cargo vessel MV Ivan Papanin, were chartered for the XXX Expedition from Murmansk Shipping Company. Similarly, the services for two helicopters Kamov 32A (LG Helicopters, Korea) and Aerospatial 350B2 were requisitioned for the 2010-11 season.

The following organizations participated and conducted and scientific investigations.

1) Geomagnetism and upper atmospheric science - Indian Institute of Geomagnetism
2) Ionospheric studies - National Physical Laboratory
3) Climatological and meteorological studies - India Meteorological Department
4) Energy balance of snow and Ice - Snow and Ava lanche Study Establishment
5) Geological and glaciological studies - Geological Survey of India
6) Seismological studies - National Geophysical Research Institute
7) Human biology and medicine - National Centre for Antarctic and Ocean Research
8) Monitoring of global thunderstorm activity using sferics – National Centre for Antarctic and Ocean Research
9) Environment studies - Sriram Institute of Industrial Research

3.2.2 Brief Scientific highlights of the 30th Indian Scientific Expedition to Antarctica (ISEA)

During XXX ISEA, Indian Scientists have carried out scientific activity largely in and around Schirmacher Oasis. In the Larsemann Hills, logistic intensive – mainly construction activity, were carried out.

Climatological and Meteorological Studies

Regular weather data was collected which is the basis for establishing climatic normal. Synoptic meteorological data was collected every three hours including visibility, sky condition, wind speed and direction, pressure, temperature, weather conditions and snowfall, if any. Aerosol optical thickness observations were taken

regularly. Radiation parameters, viz. global radiation and diffuse radiation were continuously recorded. Synoptic charts and satellite pictures were also collected regularly which are essential for weather outlook for next few days. Forecast was provided for station and the outdoor logistics/ scientific activity. Apart from above routine scientific observations, the High Wind Speed Recording System (HWSR) was installed and commissioned. It has a capacity to measures very high wind speed (>100 Knots) along with wind direction. In addition, it also measures the ambient temperature, relative humidity and station level pressure.

World Wide Lightning Network

Maitri is one of the network stations of the World Wide Lightning Network operated by the University of Washington by employing the s-ferics sensors at VLF (3-30 kHz). There about 40 numbers of sensors worldwide. Maitri is one such location. Since Maitri is in the thunderstorm free zone, the data obtained from this location can give a vital information on the changes of the global lightning activity.

3.2.3 31st Indian Scientific Expedition to Antarctica

For the 31st ISEA , NCAOR has proposed 73 members (29 members for short-term and 44 members for long- term) from organizations/institutes/laboratories from India. Shri Uttam Chand (SASE) , Dr. Rupesh Das (NPL), Shri Rajesh Asthana (GSI) and Shri J. A. A. Silveira (MPT) were nominated, respectively, as the Leader, deputy leader of the Expedition, Voyage Leader and the Nodal Officer for supervision of the construction activity of the research base at Larsemann Hills. The 31st ISEA has been launched on 26th October, 2011 from Cape Town.

To cater to the enhanced requirements at the Larsemann Hills and 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 XXXI Expedition from Murmansk Shipping Company. Similarly, the services for two helicopters Kamov 32A (LG Helicopters, Korea) and Bell 407 have been requisitioned for the 2011-12 season.

3.2.4. Establishment of 3rd Station in Antarctica

Pre-construction activities of the Third Indian Research Base was initiated during the 29th Indian Scientific expedition. The most critical task of putting in place the infrastructure necessary for the construction of the station, without compromising the ongoing scientific and logistic activities at Maitri, was achieved successfully. All the heavy earthmoving / construction material and cargo, ranging from 5 to 47 metric tons were transported from ship to shore either by the two helicopters or by vehicles over the fast ice (Fig.3.1). About 250 m long road from landing site up to the helipad was carved out using bulldozer, excavator and nonex deflagrating cartridges.

Fig.3.1 Transportation of material for 3rd Station in Antaratica

The Phase I construction activities of the Indian Research Base at the Larsemann Hills commenced during the austral (southern hemisphere) summer of 2010. The work planned under this phase was carried out. Some of the salient activities completed were :

- 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 pre-cast concrete elements and establishing thirteen tank-containers (20 feet) 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.

The phase-II construction of the research base has been taken up during current Summer 2011 and the team of 47 multi skilled personnel in Antarctica have been deployed and the station is scheduled to be completed by march 2012.

3.2.5 Cryosphere Studies

Understianding the biogeochemical process in polar regions so as to reconstruct the environmental variables during modern as well as past periods are prime goals in the Antarctic climete change research. In addition to the new expeditions conducted to the Antarctic and Arctic regions, large numbers of snow samples were collected (Fig.3.2) during the 28th and 29th IAE are being analyzed for detailed measurements of major ions, trace metals, dust/particles and isotopic parameters.

Reconstruction of Antarctic climate change using ice core proxy records from the coastal Dronning Maud Land, East Antarctica

Glaciochemical and stable isotope records of a shallow ice core from the coastal Dronning Maud Land (East Antarctica) were used to reconstruct the coastal Antarctic environmental variability during the past ~470 years (Fig.3.3). Sea salt ion data indicate a significant additional contribution of chloride ions compared to sea water values, possibly through atmospheric scavenging. The nitrate (NO_3^-) profile exhibit significant temporal shifts than that of the sulphate (SO_4^{2-}), with a major shift around 1750 AD. The changes in NO_3^- record are synchronous with the proxy record of solar activity (10Be profile from the South Pole ice core), suggesting enhanced NO_3^- values during periods of reduced solar activity like the Dalton Minimum (~1790-1830 AD) and Maunder Minimum (~1640-1710 AD).

The $\delta^{18}O$ records reveal that the more negative $\delta^{18}O$ values were coeval with several events of increased NO_3^- concentrations, suggesting enhanced preservation of NO_3^- during periods of reduced air temperatures. The $\delta^{18}O$ and δD records of the core also suggest significant short-term and long-tem variability with more negative values indicating relatively lower air temperatures prior to 1715 AD. The $\delta^{18}O$ records revealed a significant warming of 2.7°C for the past 470 years, with a warming of ~0.6°C per century.

Microbial preference for different size classes of organic carbon

While significance of carbon cycling in polar ecosystems is well recognized, bacteria in surface snow have received less attention in terms of their potential in carbon cycling. Microcosm studies on carbon utilization by bacterial communities in 3 surface snow samples were conducted over eight days at 5±1ºC to study carbon metabolism in different combinations of added low molecular weight [LMW (glucose, < 1KDa)] and high molecular weight [HMW (starch, > 1KDa)] substrates (final 20 ppm). The total organic carbon (TOC) in the snow samples decreased with time at rates ranging from nondetectable to 1.4 ppm day-1 10 with rates highest in snow samples from inland region. In addition, carbon utilization studies were also carried out with bacterial isolates LH1, LH2 and LH4 belonging to the genus Cellulosimicrobium, Bacillus and Ralstonia,, respectively, isolated from the snow samples. Studies with strain LH2

Fig. 3.2 Snow Coring at 89°S

in different amendments of glucose and starch showed that TOC decreased with time in all amendments at a rate of 0.9-1.5 ppm day-1 with highest rates of 1.4-1.5 ppm day-1 15 in amendments containing a higher proportion of starch. The bacterial isolates were also studied to determine their ability to utilize other LMW and HMW compounds. They utilized diverse substrates like carbohydrates, amino acids, amines, amides, complex polymers etc., of molecular mass <100 Da, 100-500 Da, >500 Da-1 KDa and >1 KDa preferring (upto 31 times) substrates with mass >1 KDa than <1 KDa. The ability of bacteria in snow to utilize diverse LMW and HMW substrates indicates that they could be important in the uptake of similar compounds in snow and therefore potentially govern snow chemistry.

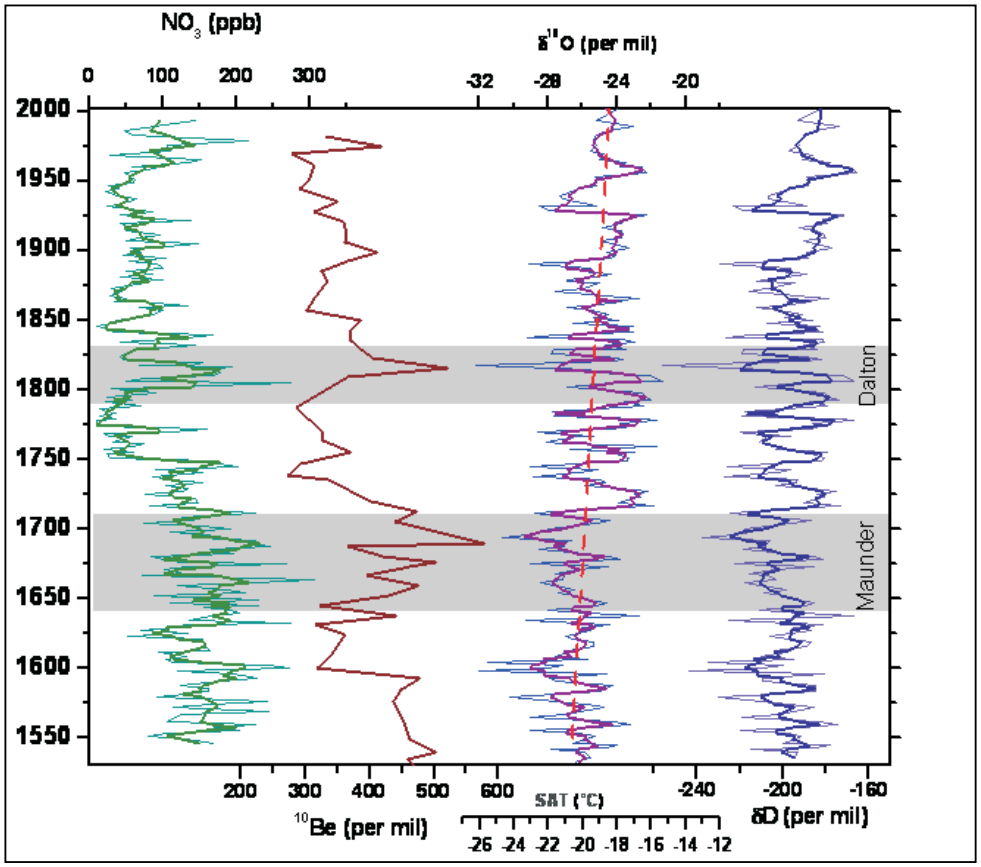


Fig. 3.3 Nitrate and Isotope record of Shallow ice case from Dronning Maud Land

3.3 INDIAN SCIENTIFIC ENDEAVOURS IN THE ARCTIC

3.3.1 Fourth Indian Arctic Expedition

The fourth Arctic expedition of the country was launched in three phases during May-June , July-August 2010 and Feb-March 2011. 21 scientists from different institutions conducted investigations in the field of Earth, Atmospheric and Biological Sciences from the Indian base Himadri at Ny-Alesund during the first two phases of the expedition. A brief account of the salient findings from the scientific investigations conducted by various national laboratories is given below:

Geomorphological mapping of the pro-glacial region of Vestre Broggerbreen glacier is a project initiated during 2007(Fig.3.4). Stakes have been fixed on Vestre Broggerbreen glaciers for monitoring of the ablation pattern of the glacier. The **Snout of Midre** Lovénbreen glacier has been mapped with respect to the markers fixed during 2007/2008. Samples for TL dating have been collected from the terminal/ recessional moraines of Austre-Vestre Broggerbreen glaciers. Snow sample have been collected and processed for trace elements, Hg, TOC and Major ions.

Biological Sciences

In order to understand the heterotrophic microbial diversity of the Arctic sea with special reference to phosphate solubilising ability of heterotrophs and their contribution to the phosphorus cycle, water and sediment samples collected from the Kongsfjord system (Fig.3.5) were processed for microbial analysis. Samples were processed to determine the load of viable heterotrophic bacteria, coliform, Actinomycetes and vibrios. No coliform bacteria were encountered in water and sediment samples. The water and sediment samples from the fjord, soil and organic samples from the hills surrounding Ny Alesund and permafrost samples from Ny Alesund, were collected for the inventorisation of the cyanobacteria from various habitats of the Arctic region using the polyphasic taxonomic approach.

3.3.2 Fifth Indian Arctic Expedition

The year 2011 witnessed a quantum jump in the research initiatives from the country's research base HIMADRI

Fig. 3.4 Morphological Studies of Vestre Broggerbreen Glacier

at Ny-Ålesund. The fifth Arctic expedition of the country have been launched in four phases during May-June, June, July-August and August-September 2011 and during these phases of the expeditions two new projects initiated and field studies of 13 continuing projects conducted. 28 scientists from different institutions conducted investigations in the field of earth, atmospheric and biological sciences during the four phases of the expedition. A brief account of these research activities is provided below:

Marine Sciences

In continuation of the seasonal monitoring of the physical, hydrological and hydrochemical characteristics of the Kongsfjorden system at Ny-Ålesund, systematic insitu measurements of physical, chemical and biological parameters of the fjord including surface sediment sampling were carried out during the months of May, June, July, August and September of 2011. Sixteen different locations (Fig 3.6) along three transects (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 occupied for the repeat measurements covering late spring, early summer, peak summer and early Fall seasons. Comparative assessment of the observed inter-seasonal variations is in progress.

Fig. 3.5 Sdiment Samples being collected

Atmospheric Aerosols

Investigations of atmospheric aerosols over the Ny-Ålesund 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 insitu and satellite data and modeling efforts would help in better understanding of the regional climate processes.

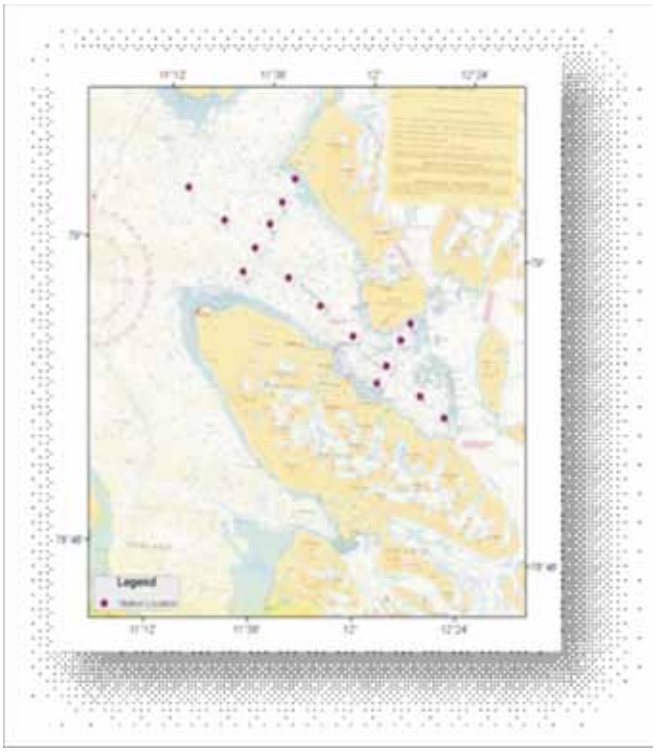


Fig 3.6 Sixteen Location of the Kongsfjorden system taken for study

Results from the variations in black carbon (BC) during the period of study indicate a high loading of BC in the atmosphere (Fig.3.7). It was also observed that the daytime BC at Ny- Ålesund is 2.4 times higher than during the night.

Earth Sciences and Glaciology

Multi-proxy geological studies were conducted for understanding the modern palynological analogs with reference to the dispersal, transportation and subsequent deposition of local and extra-local palynomorphs in the sediments. The work involved the collection of pollenif-

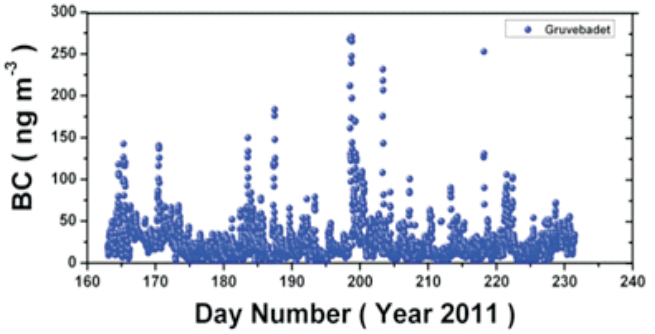


Fig 3.7 Variation of Black Carbon at Arctic Station, Ny Alesund

erous material from the flowers. The plants in the Arctic region flower for a very short duration of time, just after the snow melts and posses the maximum number of plants in their flowering state.

Glaciological studies of Vestre Broggerbreen: Vestre Broggerbreen (Latitudes N78° 55' 14.5" & 78° 53' 26.9" and Longitudes E11° 47' 23.3" 11° 38' 50.3") is a small valley-type glacier, close to the permanent settlement of Ny-Ålesund. The area of the glacier is approximately 5 km2. A medial moraine separates this glacier into two smaller glaciers, termed VB-I and VB-II. The bigger of the two glaciers, VB-I, has a prominent ice-fall, separating its Ablation Zone from the Accumulation Zone. The other glacier, VB-II, is curvi-linear, with very high left lateral moraine.

As a part of initiation of mass-balance studies of this glacier, eleven, ten-m deep stakes were installed in the Ablation Zone of VB-1 and 12 stakes in the Accumulation and Ablation Zones of VB-2.

GPR surveys using a GSSI-SIR20 GPR system and antenna of 200 MHz centre frequency were also undertaken on both the glaciers to study the depth to the bedrock (Fig.3.8 and Fig.3.9). A longitudinal traverse of 1 km was taken along the medial line of VB-1(Fig.3.10). The GPR profile shows the variation of ice thickness from 1 m towards snout/portal end to 87 m towards the Accumulation Zone. However the glacier ice thickness does not increase continuously throughout this longitudinal section.

A total of 9.88 km of GPR traverse was taken along VB-2 covering its entire length and breadth. The survey was initially taken close and parallel to the medial mo-

Fig. 3.8 GPR Survey being undertaken

raines followed by several longitudinal and transverse profiles. The GPR surveys indicate that the thickness of ice to be 30 m near the moraines. Along the longitudinal profile from the snout / portal extreme on its eastern side

Fig. 3.9 Map of the Vestre Broggerbreen Glacier showing the GPR profiles

3.4 Southern Ocean Expeditions

3.4.1 Southern Ocean Region

Southern Ocean is considered to be ocean areas from 60° southwards which has distinct physical, chemical and biological regimes which are latitudinally separated by fronts. The Southern Ocean region is regarded as one of the three high nutrient, low chlorophyll (HN-LC) areas and therefore, it plays a major role in the global carbon cycle. Furthermore, the Antarctic Circumpolar Current of the Southern Ocean provides a pathway between the major basins of the Pacific, Atlantic and Indian Oceans and consequently plays a critical role in the global redistribution of salt, nutrients, heat and other ocean properties. The multidisciplinary cruises in the

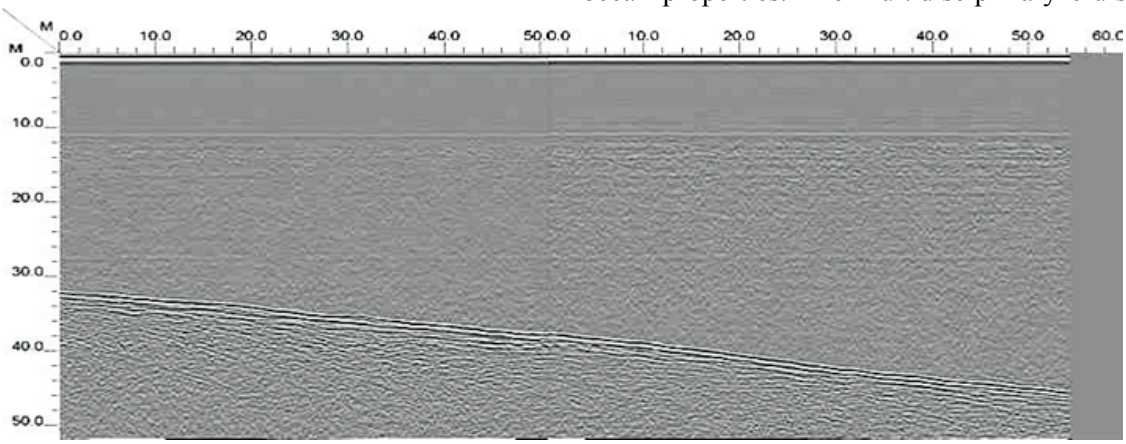


Fig. 3.10 Showing a part of the longitudinal GPR profile on B-I using antenna with 200 MHz centre frequency.

to the interior, the ice thickness is very shallow, even reaching less than 10 m thickness at places. However, the continuity of this longitudinal traverse to the neck of the glacier shows an increasing trend of ice thickness with the thickness reaching up to 50 m near the neck. This is followed by a reverse trend, as the slope of the glacier becomes steeper, with the bedrock occurring at a shallow depth of around 20 m below the surface.

Shri Pawan Kumar Bansal, then Hon. Minister for Earth Sciences and Science & Technology visited Ny-Ålesund on May,19 2011. During the tour of the various research facilities at the International Arctic Research Base at Ny-Ålesund, the Hon. Minister also visited HIMADRI, the Indian Research Station at Ny-Ålesund and interacted with the scientists on the progress of the studies being carried out by the Indian team.

Indian sector of the Southern Ocean would enable a better understanding of the oceanographic processes in this part of the Southern Ocean. So far five Southern Ocean Expedition has been undertaken. Some findings/results of previous expeditions to Southern Ocean region is as follows:

- Freshwater input in the study region is not only due to the local Ekman transport but probably melt water from the Bellingshausen and the Amundsen sea is further transported eastwards by theAntarctic Circumpolar Current.
- The presence of conventional and microbial food chain operating in distinct biological zones in the Polar Frontal (PF) region has been established, so nutrients and light are not found to be the limiting factors for primary production in PF.
- The upper 1000 m of water column of the main frontal region supported almost standing stocks of mesozooplankton during the austral summer.

• Diversity of coccolithophores in the Indian sector of Southern Ocean region progressively decreased towards pole as well as vertically, from surface to 200m depth and overall abundance of diatom distribution is shown.

An interesting observation during the 4th expedition was the contrasting biological productivity at two locations in the same front **(Polar front)**. The data suggests that, at 56^0 S the conventional food web may be stronger, while at 52^0 S, the microbial food web may be more active. However, the low chl a values was not found to limit the mesozooplankton abundance, since the highest abundance was observed at Polar Front-II which had a below detection level chlorophyll a and lowest abundance of mesozooplankton was obtained at the Subantarctic Frontal Zone which had a maximum column chlorophyll a. The maximum depth integrated bacterial biomass was at Polar Front-II and least at the Southern Subtropical Front.

3.4.2 Fifth Expedition

The 5th Indian Southern Ocean Expedition (ISOE 2011) was conducted mainly to collect multi-disciplinary data from the Subtropical to Polar Regions of the Indian sector of the Southern Ocean. A team of 17 scientists from National Centre for Antarctic and Ocean Research (NCAOR), Goa; Central Institute of Fisheries Technology (CIFT), Kochi; Central Marine Fisheries Research Institute (CMFRI), Kochi; Federal University of Rio Grande, Brazil; Jawaharlal Nehru University (JNU), New Delhi; Indian Institute of Sciences (IISc), Bangalore; Birla Institute of Technology (BIT), Mesra, Ranchi; Goa University (GU) and three engineers from NORINCO Pvt. Ltd. (Norway-India Collaboration), Chennai had participated.

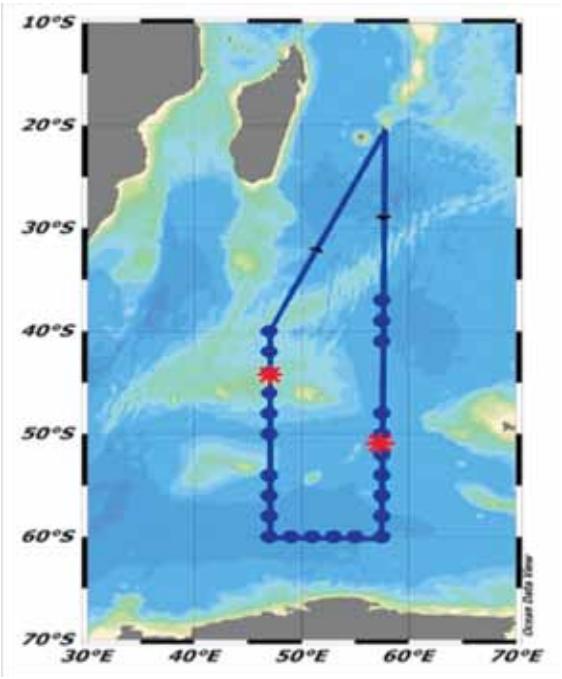


Fig. 3.11 Cruise track beginning from Mauritius

Scientific operations were carried out successfully at twenty seven stations (Fig.3.11). Instruments such as CTD (Conductivity, Temperature, Depth), XCTD, Portable CTD and Bucket thermometer were used for the acquiring hydrographic data and water samples for biological and chemical analysis. Multi-Plankton Net (MPN) and Bongo net were used to collect zooplankton samples from surface and different depth layers of the water column. C14 -experiments were done at selected locations to understand the primary productivity patterns. At each station one shallow (up to 120m) and deep cast (up to near bottom) of CTD were performed to study the deepwater thermohaline variations and water masses. Continuous underway ship measurements such as Acoustic Doppler Current Profiler (ADCP), Automatic Weather Station (AWS), Multi-beam Echo-sounder and Sub-bottom profiler were operated for studying ocean currents, atmospheric parameters and bathymetric properties. Corer and Grab operations were carried out at three locations in the shallower depth to collect the sediment samples. Ninety five XCTD operations were done between 27° 00'S 57° 50'E and 30° 00'S 48° 00'E locations at thirty miles to one degree latitudinal intervals. Ten Argo floats deployments for measuring hydrographical parameters (temperature and salinity) were also carried out at different locations from 30° 00'S to 60° 00'S along 57° 30'E.

Analyses of water samples for pH, DO and nutrients were done onboard. Apart from these, samples for Total Suspended Matter (TSM) and trace metals were collected and preserved following standard protocols. The water samples collected for chlorophyll a from seven standard depths were filtered through GF/F filters (0.70 µm) and kept in liquid nitrogen for further analysis. The phytoplankton and micro-zooplankton samples were preserved with lugol's iodine and mesozooplankton samples were stored in buffered formalin. On considering the significance of molecular taxonomy as a modern tool in plankton identification, samples from selected locations were preserved in ethanol for molecular sequencing.

In addition to the regular 27 sampling sites, two time series observations for a period of three days (72 h) were

carried out each at Sub tropical (42° 00'S 47° 30'E) and Polar front (51° 30'S 57° 30'E) to understand the diurnal variability of physicochemical and biological parameters. Onboard mesocosm experimental studies (five days duration each) were also carried out in three different regions (Polar front - 56° 45'S, 47° 00'E, Subtropical front - 42° 00'S, 47° 00'E and tropical waters- 34° 00'S, 49° 30'E) to understand the significance of trace metals on productivity pattern. Trace metals such as Fe, Co and mixture of Fe and Co in the form of sulphides in nanomolar concentrations were added and deck-incubation was carried out with proper aeration system. Sub-samples were taken on everyday for analysing pH, dissolved oxygen, nutrients, chlorophyll, trace metals, phytoplankton and bacteria. Samples collected for chlorophyll were filtered and stored in liquid nitrogen. N15 Experiment were conducted at five locations (35° 52'S, 57° 26'E; 39° 31'S, 57° 30'E; 49° 38'S, 57° 47'E; 55° 53'S, 57° 29'E; 60° 00'S, 47° 30'E) with N15 labelled tracers such as nitrate, ammonia and urea.

4 Ocean Science and Services

A wide-range of user-oriented ocean data products and advisories are being generated and disseminated to various sectors such as fishery, shipping, ports, offshore industry, academia, coastal states and island authorities. The ocean information advisories depend on sustained research of ocean processes and modelling. Real-time data acquired from a network of both insitu and remote sensing platforms are integrated using suite of global and regional ocean models to generate various products. These products and services are disseminated through web, electronic boards, radio, TV, newspapers, etc.

4.1 Ocean Services

4.1.1 Potential Fishing Zone Advisories

The generation and dissemination of the multi-lingual PFZ advisories to the fishing community of India is one of the important activities. PFZ advisories were issued for Gujarat, Maharashtra, Karnataka, Goa, Kerala, Tamil Nadu, Andhra Pradesh, Orissa, West Bengal, Andaman and Nicobar Islands and Lakshadweep Islands. The generation of PFZ advisories is hindered by clouds. Hence in cloudy days forecast is generated based on optimally interpolated (at 5 km spatial resolution) merged product of operational sea surface temperature and sea ice analysis (OSTIA) from Global High Resolution Sea Surface Temperature (GHRSST) Project. One hundred and twenty nine PFZ advisories were generated for the sectors of east and west Coast of India on every Monday, Wednesday and Friday during the year.

4.1.2 Tuna Fishery Advisory

Sixty three experimental Tuna Fishery Advisories were generated and disseminated by providing maps and text information on every Tuesday, Thursday and Saturday except during ban period. For effective dissemination, Tuna Fishery advisory in both map and text were emailed to the Tuna Long Liners.

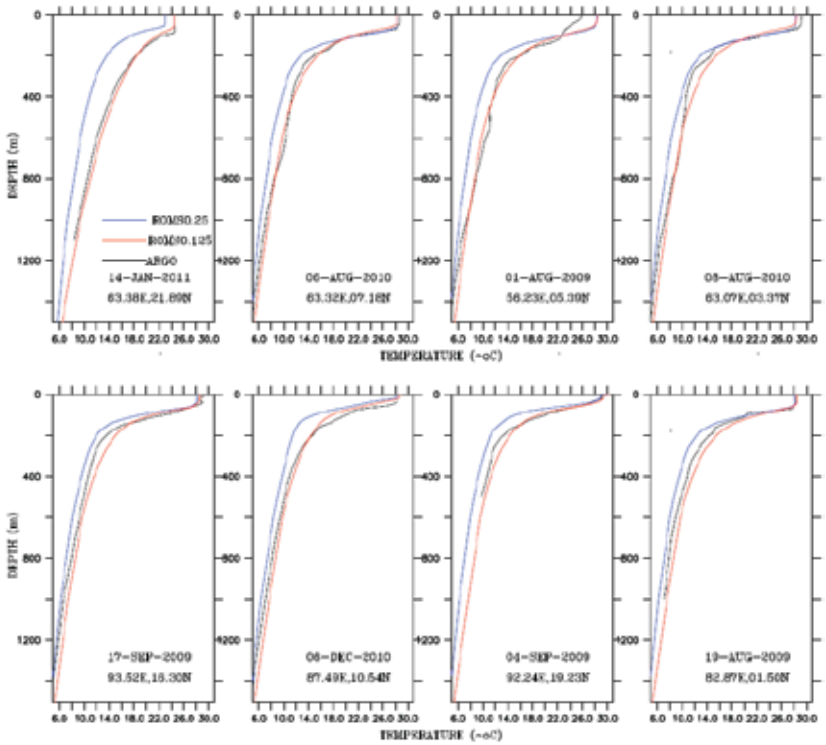


Fig. 4.1 Vertical temperature profiles from the very high resolution INDOFOS setup (red) is compared with observed ARGO profiles (black) and low-resolution INDOFOS setup (blue).

A training programme on the Tuna tagging was conducted at the Central Marine Fishery Research Institute (CMFRI) in Vishakhapattanam during September, 29-30 2011. These tags record temperature and depth while tuna fish is moving. They get detached from fish automatically on preset time-span. After self-release, the tag heads to the surface and uses Argo satellites for the data relay. The tagging operations have started from the first week of November, 2011 and 25 tuna fish will be tagged by March 2012.

4.1.3 Ocean State Forecast

The Indian Ocean Forecast System (INDOFOS) was upgraded with Regional Ocean Modeling System setup at 1/8th degree (i.e. ~13km) on March 21, 2011. This upgradation has significantly improved the quality of the forecasts, particularly in the vertical temperature profiles and surface and subsurface currents (Fig. 4.1)

The ocean state forecast service for the coast of Kerala state was setup in local language. The system provides three day forecasts of wave, wind, tide and currents for the coastal waters of Kerala as well as location-specific forecasts for the harbours including ports fishing in the state. An awareness program for the coastal community in Valiyathura/Vizingam area for the effective usage of forecast was also conducted for the local community in Thiruvananthapuram district, Kerala.

4.1.4 Early Warning System for Tsunami

The Indian Tsunami Early Warning Centre (ITEWC) has reported 74 earthquakes of magnitude > 6.5 during 01 November, 2010 to 30 September, 2011. Out of 74 earthquakes, tsunami advisories for a major earthquake occurred in the Indian Ocean and one great earthquake off the coast of Honshu, Japan in the Pacific Ocean are issued. (Table 4.1). Model simulations were analyzed for these events before issuing the tsunami bulletins.

The exchange of real-time data with the Indian Ocean Tsunami Warning System (IOTWS) and International community towards improvement in tsunami warnings has been initiated. These include, seismic data from stations operating at Minicoy, Port Blair and Shillong and real-time sea-level data from tide gauges and Bottom Pressure Recorders (BPRs). Data from other seismic stations of the Indian seismic network will be shared for all earthquakes of > 5.5 magnitude.
India has been providing Regional Tsunami Advisory Service (RTAS) Service Level – 1 (Earthquake information) service since July, 2008. Now the Service Level – 2 (Earthquake information supplemented by model out puts) for the IOTWS member countries in the Indian Ocean has been initiated.

4.1.5 Dissemination and User Interactions

PFZ and OSF products were made available to a large section of population along the Indian coast, through hundred Electronic Display Boards (EDB) installed all along the Indian coast. Ninety-one user interaction workshops were conducted to train the fishermen on how to read and use the PFZ and OSF information at various panchayats in the coastal districts.

4.2 Observation Networks

The Ocean observations include drifting buoys, XBT/ XCD, current meter moorings, ADCP moorings, wave rider buoys, tide gauges, moored buoys, Argo flats, etc. (Table 4.2)

4.2.1 Indian Argo Project

During the year, fifty six Argo floats were deployed in the Bay of Bengal, Arabian Sea, Equatorial Indian

Table 4.1: Details of the Tsunamigenic Earthquakes recorded at ITEWC

S. No	Date & Time (UTC)	Magnitude	Region	ITEWC Bulletin
1	11-March-2011 05:46:23	8.7	Near East Coast of Honshu	No tsunami threat for India
2	05-September-2011 17:55:13	6.8	Northern Sumatra Indonesia	No tsunami threat for India

Ocean and Southern Ocean, which includes fourteen Iridium-based floats and Provor floats. All Iridium floats were incorporated with Lithium batteries, in addition to alkaline, to ensure longevity.

4.2.2 Moored Buoy Network

Sixteen deep sea moored buoy network with surface (10 buoys) and subsurface sensors (six buoys) was re-established in June, 2011 for continuous measurements in the Arabian Sea and the Bay of Bengal. For the first time, such a large network of moored buoys has been continuously; for more than six months; measuring surface and sub-surface variables from the seas around India. Under the UNESCO-IOC global Pilot Project on Wave Measurement and Evaluation Test (PP-WET), inter-calibration exercise is jointly being undertaken. In this regard, one wave rider buoy and data buoy were successfully deployed off Agatti and inter-comparison exercise is in progress.

4.2.3 Bay of Bengal Observatory

The Bay of Bengal Observatory at 18^0 N and 89.5^0 E comprise cone-head buoy with 7 Micro CATS (temperature and salinity), 3 Doppler Volume Sampler (currents) in the top 100 m water column to measure currents at 10-minute intervals. Initial deployment was done in November, 2009 and was retrieved in November 2010 with one year long datasets. The sensors have been re-deployed in September, 2011 after recalibration (Fig.4.2).

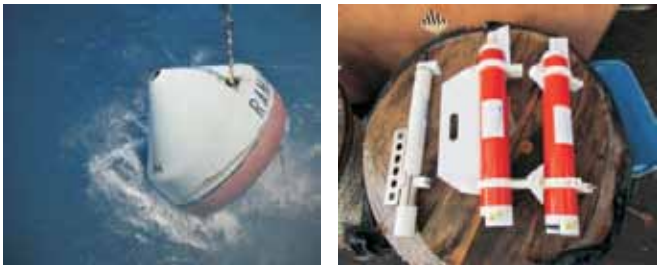


Figure 4.2: The sensors and the deployment of Bay of Bengal Observatory

Table 4.2: Details of various observation platforms deployed/serviced

Platform	Activity	Location	Number
Drifting Buoys	Deployment	Arabian Sea	24
XBT/XCTD	Deployment	Indian Ocean	268/87
Current meter Moorings	Servicing	Eq. Indian ocean	7
ADCP – Moorings	Re-deployment	Indian Ocean	8
Rama Moorings	Service	Indian Ocean	17
Tsunami Buoys	Deployment	Bay of Bengal	1
Directional wave rider buoy	Service/Deployment	Near Karwar coast	5
Remote wave height meter	Installation	Sagar Nidhi	1
Sediment Trap	Deployment	Eq. Indian ocean	1
Automatic Weather Stations (AWS)	Deployment	Research Vessels	5
Sea level Gauges/ tide gauges	Installation	Along the Indian Ocean	21
Moored OMNI Buoy Network	Installation	Bay of Bengal and Arabian Sea	16

4.3 Research and Modelling

4.3.1 Ocean analysis

INCOIS-GODAS-MOM was made operational for open ocean reanalysis for the Global Ocean. The analysis is updated once in a month and it is being made available at the website (www.incois.gov.in). Experiments were conducted to study the impact of use of different observations in the GODAS system,

(a) Experiments with and without Temperature and Salinity (T, S) assimilation,

(b) Experiments to test the impact of observed vs synthetic salinity,

(iii) Experiments to study the impact of Indian moorings and XBTs,
(iv) forcing with satellite derived winds.

The preliminary results indicate that the assimilation of temperature and salinity profiles significantly improves, the temperature simulation in the upper water column above 2000 m. However, the currents marginally degraded when compared to those without assimilation.

High resolution regional Indian Ocean model has been developed in collaboration with NOAA and IISc, Bangalore using a state of art Modular Ocean Model (MOM4p1). The lateral boundary conditions are taken from inter-annual solutions from global model forced with Co-ordinated Ocean-Ice Reference Experiments (CORE- II) inter-annual forcing fields.

4.3.2 HYCOM Improvements During 2011

Considering the evolving operational requirements a basin scale HYCOM model with 1/120 spatial resolution has been set up. Inter-annual run was made using an adapted restart file from global HYCOM of same resolution.

4.4 Ocean Science

Satellite-derived ASCAT wind vector for the Indian Ocean were validated with in-situ RAMA and moored buoys and QUICKSCAT winds. Root mean square (RMS) difference between the total winds of ASCAT and QUICKSCAT over the Indian Ocean was 1.6m/s. The comparison with RAMA reveals that ASCAT data is better than QUICKSCAT data over the Indian Ocean region. RMS differences and correlation between ASCAT and RAMA total wind speed (zonal, meridional) are 1.14 (1.35,1.54) and 0.92 m (0.97, 0.9), respectively.

The level-2 data products from Medium-spectral Resolution Imaging Spectrometer (MERIS) and MODIS-A were analyzed in the Indian coastal waters. The comparison of remote sensing radiance (Rsr) from MERIS and MODISA against the in situ Rsr in indicated that Rsr from MODIS are accurate than that measured by MERIS. OC3M algorithm works best for the estimation of Chlorophyll-a from MERIS and MODISA in the coastal waters of India.

The El Nino/Southern Oscillation (ENSO) and its relation to the Tropical Cyclone (TC) activity (frequency, genesis location and intensity) in the Bay of Bengal (BoB) during the post-monsoon season (October to December) were studied for the period between 1993-2010. The study showed that Accumulated Cyclone Energy (ACE) constructed from a 6-hourly best-track dataset in the BoB, is negatively correlated with Nino 4.3 sea surface temperature anomaly (SSTA) (Fig 4.3). The analysis shows the existence of low level cyclonic (anticyclonic) vorticity and enhanced (suppressed) convection associated with anomalous atmospheric circulation pattern, which provides a favorable (unfavorable) condition for the TC activity in the Bay

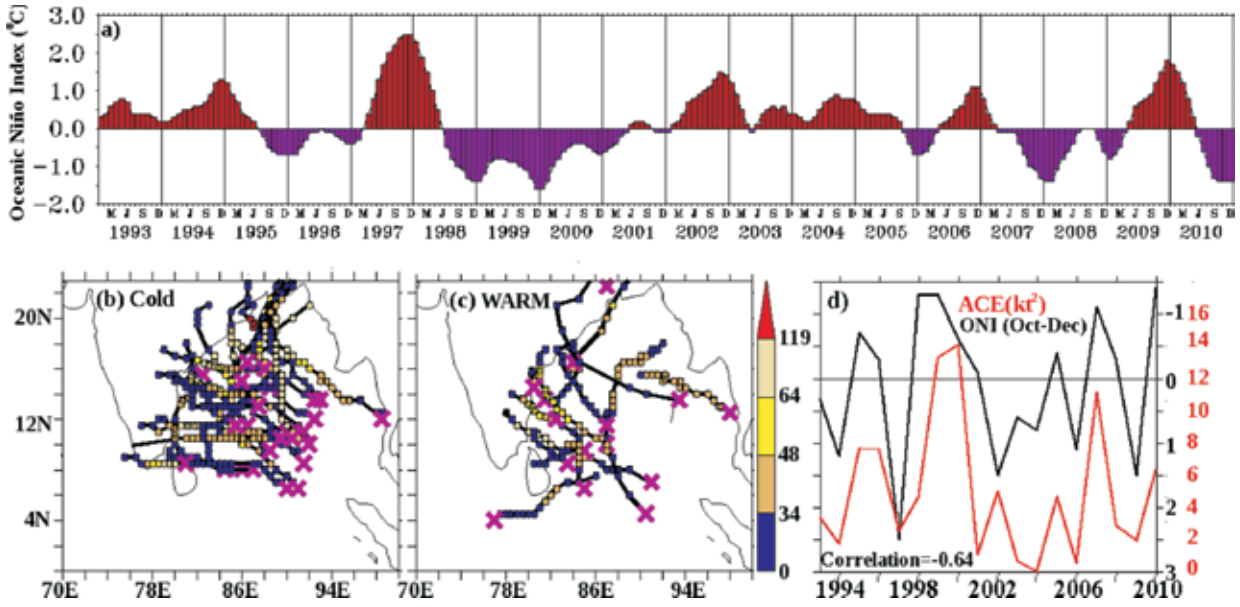


Fig. 4.3: Interannual variation of post-monsoon ACE (kt2) (red line) and ONI (oC) (black line) during 1993-2010.

during cold (warm) regimes. The anomalous westerly (easterly) winds during cold (warm) regimes in the Equatorial Indian Ocean (EIO), is associated with active (suppressed) convection in the eastern EIO.

Weakening of Wyrtki Jets during 2006-2010

Beginning in 2006, the Indian Ocean experienced climatologically anomalous conditions, due to large scale coupled air-sea interaction: A positive Indian Ocean Dipole mode (IOD) in 2006 followed by a IOD and a concurrent La Nina in 2007 exerted a profound influence on oceanic processes and deviated them from the climatological mean state. Concurrent results from HYCOM simulated currents and evidences from observations demonstrated that WJs were persistently weak during the past 5 years and was even westward during 2008. (Fig. 4.4)

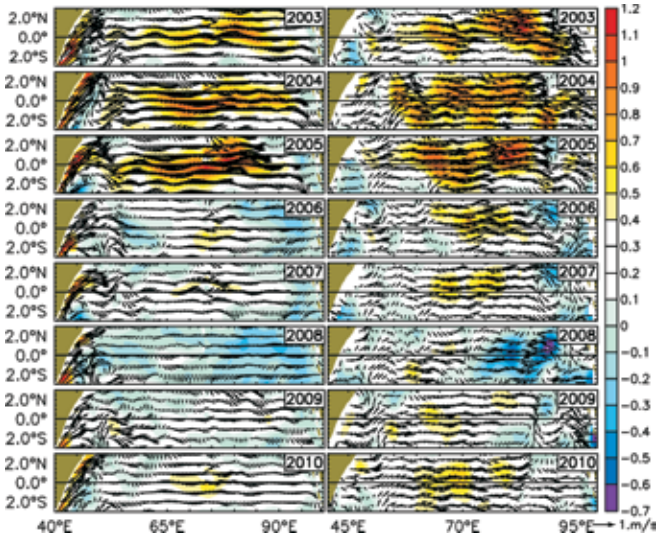


Fig. 4.4: Weakening of Wyrtkijets demonstrated by Hycom currents (left) and OSCAR Currents (right)

These weakened jets were found to occur in conjunction with the latitude of zero zonal wind (LUZ) close to equator during these years resulting in weak winds at the equator from 2006 and onwards. Prior to 2006 the LUZ was located south of the equator while strong westerlies were present along the equator. The harmonic analysis of the years prior to 2006, when compared to analysis of later years, revealed that the variance explained by the semi-annual harmonic is reduced to half (30-40%) at the core of WJ after 2005, in comparison with the pre-2006 years when it was 70-80%.

4.5 Satellite based Coastal Research

4.5.1 Multi-hazard Vulnerability Mapping

A study has been under taken to assess the possible inundation by the multiple hazards in the coastal zone. Parameters such as extreme water levels, sea level change, shoreline change and high resolution topography as well as parameters such as land use, buildings, roads, etc. were selected for generating the risk maps and evacuation planning. Case studies using these techniques for the Nellore and the Cuddalore regions have shown that maps are intuitive and critical input to coastal managers. These studies have indicated that detailed knowledge of topography and demography can further be synthesized to obtain risk maps.

4.5.2 Coral Bleaching Alert System (CBAS)

The coral bleaching warning model was tested for the Indian coral environments using the NOAA AVHRR SST data. Two case studies for the bleaching events April-May, 2005 and May, 2010 were carried out and the results strongly correlate with the in-situ observations. The Coral Bleaching Alert Service (CBAS) is operational with routine generation of the bleaching alert products of the Indian coral reefs. Total 112 bleaching advisories were issued during the reporting period.

4.5.3 ChloroGIN -IO

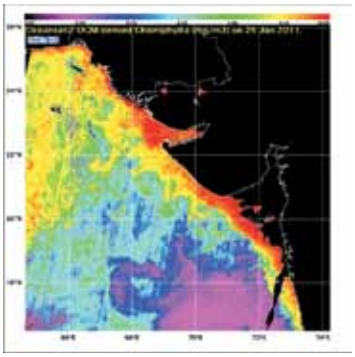
An Automatic Data Processing Chain (ADPC) has been re-designed and improved with new logic for generation of ocean colour products. The new products included in ADPC are Angstrom exponent, photosynthetically available radiation (PAR), instantaneous photosynthetically available radiation (IPAR), fluorescence line height (FLH), particulate organic carbon (POC), particulate inorganic carbon (PIC) in addition to previous products of chlorophyll (CHL-a), downwelling diffuse attenuation coefficient at 490 nm (Kd490), sea surface temperature (SST), aerosol optical thickness at 869 nm (AOT869), CDOM_ index and Quasi-True Color Browse imagery (FCC). The processing domain includes entire Indian Ocean. The generation of value added products such as three days, seven days, 30 days, 30 days anomaly product, total suspended matter (tsm_clark) and bloom indices (BI) were also continued.

4.6 Ocean data management & dissemination

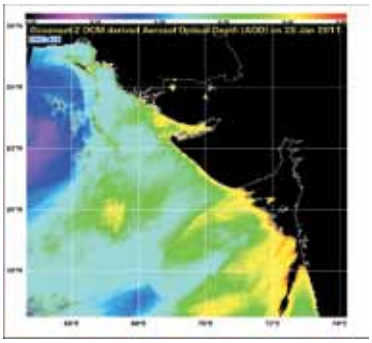
4.6.1 In-situ data reception and processing

The data centre has sustained and strengthened the real-time data reception, processing, quality control of surface meteorological and oceanographic data from a wide variety of ocean observing systems such as Argo floats, moored-buoys, drifting buoys, wave rider buoys, tide gauges, wave height meter, ship mounted autonomous weather stations and HF radars. Further, surface met-ocean data were disseminated to various operational agencies in the country through email/ web-site/ftp in near-real time. In addition to, the data received from ocean observing systems moored buoys, RAMA buoy, drifting buoys, ship mounted AWS, wave rider buoys and HF Radar in real-time. The data centre also received data from various agencies in delayed

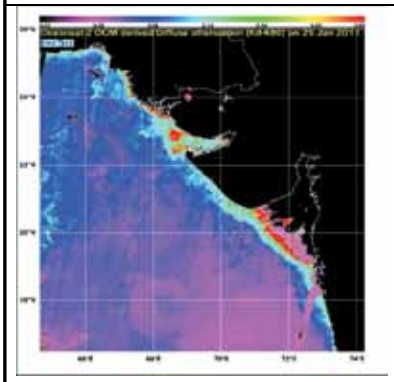
Figure 4.5: Inauguration of Ocean Sat – 2 ground station by Shri VilasRao Deshmukh, Hon'ble Minister S&T and Earth Sciences in the presence of Sri. N. Kirankumar Reddy, Hon'ble Chief Minister of Andhra Pradesh.



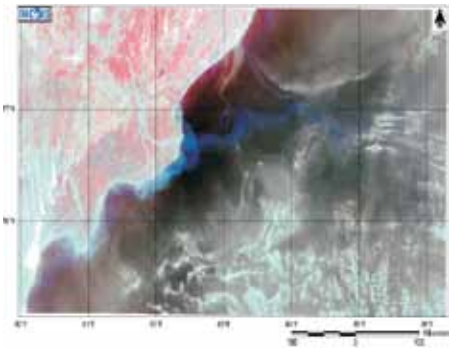
Chlorophyll-a of 25Jan2011



Aerosol Optical Depth of 25Jan2011.



Diffuse Attenuation coefficient (Kd490) of 25Jan2011.



Eastward advected Suspended Sediment Plume (~400 Km) due to the flood water flush through Godavari and Krishna rivers, observed on 29Sptember 2011.

Fig. 4.6: Oceansat-II products generated at INCOIS ground station

mode or temperature and salinity profiles, sea level, wave direction period, surface met observations and biogeochemical parameters. The Live Access Server (I-LAS) was upgraded with improved processing and storage capabilities with the addition of new data sets. These are 28,000 users all around the world.

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4.6.2 Remote sensing data acquisition and processing

The existing L/X band ground station continued to receive, process and archive the remote sensing data from AVHRR (NOAA-18 and 19) and MODIS (Aqua and Terra) data in real time. Further, the existing ground station was upgraded to receive AVHRR data from METOP-2 satellite. The satellite data were provided in real-time for in-house operational activities like potential fishing zone advisory services. Various remote sensing data products from AVHRR and MODIS sensors were generated and published on website. In addition to the online data services, the data centre also provided data services to various government and private agencies.

The ground station could cover an area of 5000 km diameter circle covering the Bay of Bengal and the Arabian Sea; and generate geophysical parameters, viz., of chlorophyll (Chl-a), suspended sediment (TSM), aerosol optical depth (AOD) and diffused attenuation coefficient (Kd 490) in real-time(Fig.4.6).

The chlorophyll data integrated with the Sea Surface Temperature from AVHRR of NOAA Satellites is being used for the generation of Potential Fishing Zone Advisory Services.

4.6.4 Ocean Biogeographic Information System (OBIS)

The data centre for the Ocean Biogeographic Information System (OBIS), a repository of marine species datasets collected from all of the world's oceans is being established.

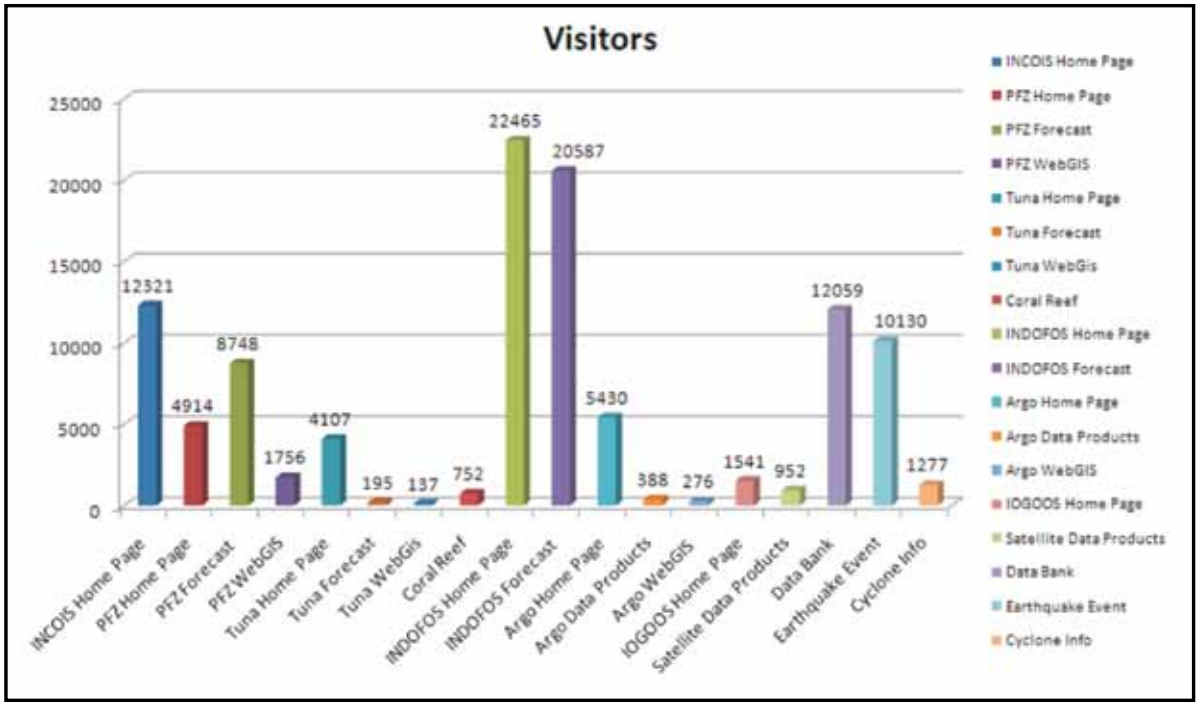


Fig.4.7: Website Statistics for reporting period

4.6.3 Establishment of Oceansat-2 Ground Station

A state-of-the-art Oceansat-2 ground station was established to receive and process the data from Ocean Color Monitor onboard Oceansat-2 Satellite in real-time(Fig.4.5).

4.7 Users

The Ocean products and services users through web are more than 60,000 (Fig.4.7).

5 Ocean Survey and Resources

With over 2 million sq. km Exclusive Economic Zone (EEZ) supplemented with the continental shelf extending beyond the EEZ, the survey and exploration remains an important activity. The quest for resources continues to interest mankind and ocean minerals are no longer exception. Gas hydrates need to be investigated in detail considering their potential. The programme on polymetallic nodules has matured from survey and exploration to technology development, while new minerals and associated marine ecosystems surrounding the hydrothermal vents and cobalt-crusted seamounts have caught the attention of scientists.

5.1 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 million square km wherein India enjoy the exclusive legal right to utilize all living and non-living resources. The project mainly focuses on mapping the entire EEZ of India using the state-of-the art technologies of multibeam survey apart from systematic sediment sampling and its analysis. The entire EEZ have been divided into two areas, viz. deep water areas (> 500 m water depth) and shallow water areas (< 500 m water depth).

The comprehensive detailed bathymetric map of the EEZ is helpful to mariners, navigators, planners, fisheries and mineral resource, researchers and many more. The status of survey is given below (Table 5.1).

Some of the significant results are highlighted below:

- Detailed analysis of the acoustic sediment profiling data collected from the Western Andaman region revealed the presence of a channel-levee system in the lower fan region near the Ninety degree East ridge. The levee is characterized by highly variable sinuosity on a low channel slope and channel avulsions within the system leading to cut-off loops. A completely buried levee also has been observed.

- Sediment core analysis from the Arabian Basin indicates that organic carbon preservation in Oxygen Minimum Zone (OMZ) region is higher compared to shelf and deeper regions.

- The strong negative correlation of the CaCO3 and aluminium indicates that the terrestrial sediment input inhibits CaCO3 preservation.

- An improved algorithm using Artificial Neural Network (ANN) was developed to predict bathymetry from multiple satellite altimeter based gravity data. The study demonstrates that the ANN technique can be a powerful tool to predict bathymetry from satellite altimeter based gravity values and the output has improved over the

Table 5.1 Status of EEZ survey

	Survey completed upto 2010-11 (in lakh sq km)	Survey done in 2011-12 (in lakh sq km)	Total (in lakh sq km)	Area
Deep water beyond 500 m (Total area 15 lakh sq.km)	5.26	0.48	5.74	The Bay of Bengal-Western Andaman sector, The Arabian Sea- Western Offshore region of India and The Bay of Bengal- Eastern offshore region of India.
Shallow water Upto 500M (Total area 5 lakh sq.km)	0.14	0.04	0.18	Off Marmagoa, off the Bombay High and the Karnataka coasts off, the Vengurla offshore, the Arabian Sea, off the Vengurla / Malwan offshore, the Arabian Sea, the West coast of India. Off the Chennai,Cheyyur,Marakkanam, Cuddalore Coasts

global model bathymetry products with certain exemptions.

- A study carried out to quantify the effect of Surface Sound Velocity (SSV) on the multibeam bathymetry revealed that non-inclusion of SSV leads to erroneous beam angle calculation particularly for bending beams. This has significant effect on outer beam footprints and comparatively less effect in nadir angle and narrow angles.

- Signature of water flow and huge sediment transportation were identified at the position of Lat. 12^0 28' 21" N, Long.80^0 30' 40" E to Lat.12^0 16' 30" N, Long. 80^0 21' 29" E off the Palar River mouth. Sand ripples that form under the action of waves/currents in coastal regions play a major role in sediment acoustics and are main contributors to the seafloor roughness.

5.2 Delineation of outer limits of continental shelf

The Indian Continental Shelf 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 under the provisions of the United Nations Convention on the Law of the Sea (UNCLOS). India made its first partial submission for an extended continental shelf under the provisions of article 76 to the Commission on the Limits of the Continental Shelf (CLCS) in May 2009. A second partial submission under the provisions of the Statement of Understanding of UNCLOS has also been finalised and submitted to the Ministry of External Affairs for further action.

5.3 Indian Ocean Deep-Drilling Program (IODP)

Under this program, Indian scientists participated in three IODP expeditions and attended the Science Planning Committee (SPC) meeting and the International Working Group (IWG+) meeting. An international workshop on scientific drilling in the Indian Ocean under IODP was organised by NCAOR, Australia IODP and IODP-MI in Goa on 17-18 October, 2011. The workshop provided a unique platform for scientists from countries like India, USA, Japan, Europe, Australia, New Zealand, Indonesia, etc. to interact and prioritize existing ideas as well as to explore new research frontiers having larger societal relevance such as climate change, earthquake hazards, biotechnology and natural resource potential, etc. A total of 150 scientists participated in the workshop to deliberate on different aspects of the scientific drilling in the Indian Ocean.

5.4 Gas Hydrates Exploration

The programme on gas hydrates is being implemented with a view to explore the gas hydrates and for this purpose the programme was divided into two ocomponents, viz. science component and technology component. While, the details of science component are enumerated below, information about the technology developments for gas hydrate exploration is provided in the chapter on Ocean Technology. Under the Science component, the data collected under the continental shelf programme was utilized for identifying the possible locations towards undertaking a detail survey. Accordingly, the Krishna-Godavari and the Mahanadi Basins have been identified, where detailed seismic survey was carried out. The details are given below.

(i) Acquisition Multi-Channel Seismic (MCS) and Ocean Bottom Seismometer (OBS) data in the Bay of Bengal

The Marine MCS data were acquired in the Krishna-Godavari (KG) and the Mahanadi basins for the exploration of gas-hydrates. A total of 7500 line km of MCS data were collected, and the preliminary analysis exhibits wide-spread occurrences of Bottom Simulating Reflector (BSR) (main marker for gas-hydrates) in both the basins. A sample seismic section is displayed in Fig.5.1. For the first time, the OBS data in a 10 km by 10 km block was acquired in each basin for detailed investigation of gas-hydrates. The results of travel time tomography of Ocean Bottom Seismometer (OBS) data show 'velocity increase' and 'reduction' across the BSR, indicating gas-hydrates and free-gas, respectively. Seismic attributes, special processing, modeling and inversion of these data are in progress with a view to delineating the prospective zones of gas-hydrates and assessing the resource potential over there.

(ii) Gas-hydrates stability thickness map along the Indian margin

By incorporating the data from the published literature and available documents, the gas-hydrate stability thickness map along the Indian margin was prepared. This has not only filled the data gap but shows the gas-hydrates stability thickness in the Andaman region also. Since the BSR is often associated with the base of gas

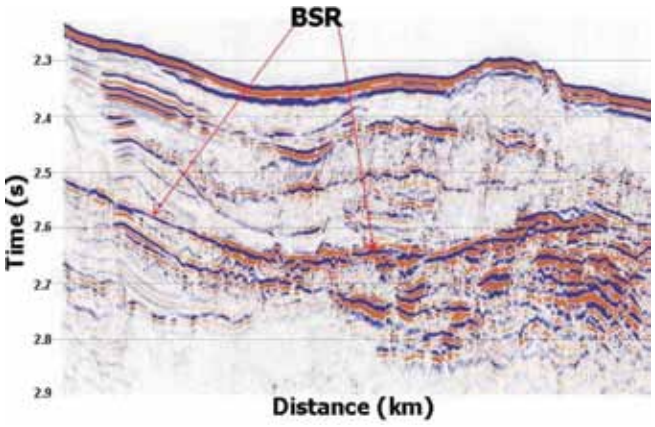


Fig. 5.1: Seismic section in the KG basin showing the BSR.

hydrates stability field, this map helps for identifying gas-hydrates using seismic, and other geological, geochemical and microbiological methods.

(iii) Heat flow constraints in the KG basin from gas-hydrate system

The heat flow constitutes important parameter which is normally collected using heat flow probes. This has been derived using BSRs. The BSR-derived heat flow varies from 30 to 102 mW/m2, and increases oceanwards.

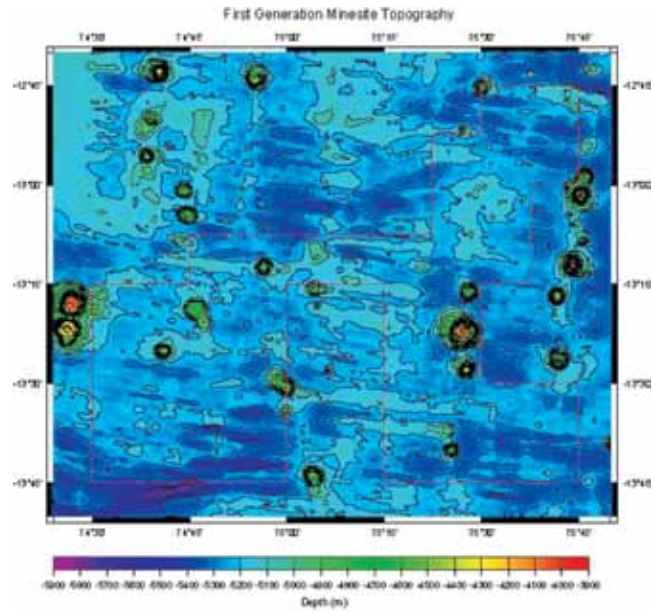


Fig. 5.2 : First Generation Minesite topography map of the FGM area with contour interval of 100 m.

5.5 PolyMetallic Nodules (PMN)

India is a pioneer investor and have 75,000 sq.km in the Central Indian Ocean Basin (CIOB) for harnessing the polymetallic nodules lying on the seabed at 4000 to 6000 m water depth. These potato shaped nodules contain Copper, Nickel and Cobalt which are strategically important elements. The Polymetallic Nodules Programme consisting of four components, viz. Survey and Exploration, Environmental Impact Assessment (EIA) Study, Technology Development (Mining and Extractive Metallurgy).

5.5.1 Survey & Exploration

Multibeam data processing has been carried out over the First Generation Minesite (FGM) area in the Central Indian Ocean Basin to generate high quality bathymetric contour map and slope angle map of the FGM area. After identification of potential FGM of about 7860 sq. km, the area was sampled at close intervals (grid of 6.25 km2). Continuous resource evaluation was carried out based on the nodules recovered from close-grid sampling. Further, slow-scan multibeam mapping of this candidate site was carried out to get a higher resolution bathymetric data (Fig. 5.2). The bathymetry map shows a chain of seamounts in the eastern part of the FGM area. The south western part of the FGM area is the most potential area in terms of abundance, grade and bathymetry. The slope angle map of the FGM area was generated using the multibeam bathymetry data. The slope angle varies between 0° to 31° with maximum area having a slope of 0° to 6°. High slope angle values were encountered near the seamounts (Fig.5.2)

5.5.2 Environmental Impact Assessment Studies (EIA)

The environmental impact assessment studies were carried on characterization of nodules associated sediments. For this study, sediment cores (20-38 cm) and nodule samples (>100 nodules, abundance =1-15 kg/sqm) were collected and analysed from 3 locations in CIB (5200 m depth) using box cores for the following parameters:

- Geochemistry of sediments and porewaters
- Geotechnical properties
- Macrofaunal diversity
- Microbiol and biochemical properties
- Fungal diversity

These studies have shown that environmental condi-

tions 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 activities such as seabed mining.

Observational program in the CIOB

5 current meter moorings at depths of about 5 km were deployed for undertaking observations on oceanographic parameters in the designated first generation mine-site grid (M3) in the CIOB. The CIOB moorings were deployed in May 2011.

5.5.3 Technology Development (Mining)

The details are described in chapter on Ocean Technology (section 6.1.4)

5.5.4 Technology Development (Extractive Metallurgy)

The Institute of Minerals and Materials Technology, (IMMT) Bhubaneswar and National Metallurgical Laboratory (NML), Jamshedpur are engaged for optimizing the process routes for extraction of Cu, Ni, Co and Mn from the polymetallic nodules under Polymetallic Nodules (PMN) programme.

IMMT focused their research in the following four activities related to improvement of the existing flow-sheet and to develop a flow-sheet using pressure leaching:

- Extraction /recovery of copper, zinc and cobalt from manganese nodule leach liquor using Hollow fiber non-dispersive extraction unit:
- Preparation of Electrolyte Manganese Dioxide(EMD) from Manganese Cake
- Process development for extraction of metal values from Mn nodules by HPAL
- Electro chemical splitting/Lime boil for ammonium sulphate splitting to recover ammonia:

The NML is presently involved on recovery of valuable metals from sea nodules by reduction smelting-matte formation- ammoniacal pressure leaching –hydrothermal reduction route. The major outcome is as under:

- Slag with high Mn/Fe ratio produced from sea nodule smelting was further smelted to produce standard grade Fe-Mn/Fe-Si-Mn.
- Standard grade Fe-Si-Mn was produced with more than 70% Mn recovery.

5.6 Studies on Cobalt Crusts Exploration:

5024 line km (39000 km2) multibeam data collected during two expeditions (ABP32 & ABP37) merged with 1200 line km data from X-Plan survey have been processed.. About 20 million data points processed using MB System and GMT software in the Fedora Platform. Overlapping beams between survey lines were optimized to reflect true bathymetry. Digital Terrain Model (DTM) of the area was achieved using further processing like making grid with optimum grid size and specialized script routines in GMT. All the data have been reprocessed to generate the first precise bathymetric map of ANS (Figure 5.3)

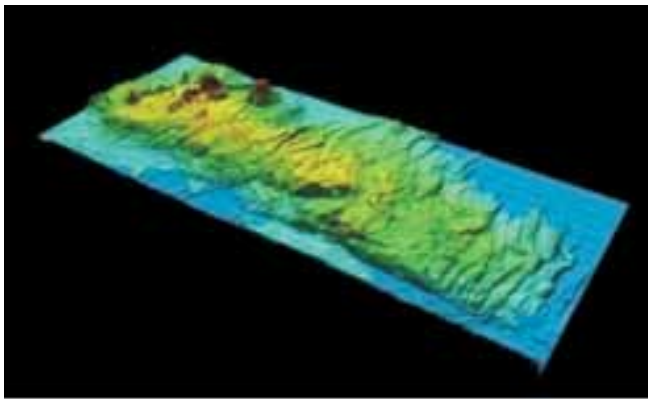


Fig.5.3 3-D map (vertical exaggeration = X6) of the ANS generated from multibeam data.

Fascinating structural features such as E-W lineations and sharp N-S Fault on western border indicate tectonically very active ANS in the past. In particular, the western large fault-plane (Fracture Zone) is intriguing.

Summary of the analysis of various data and elements processed from the samples from ANS are as under:

- Average Co content is (~0.6 %), enrichment up to 0.9 %.
- Ni and Cu are depleted (<0.3 % each) compared to abyssal nodules
- Strong Ce-enrichment (up to 0.3 %, Av.~0.2 %)
- Platinum enrichment up to 1 ppm (Av. ~0.5 ppm)
- Tellurium enrichment up to 115 ppm (Range 20-115 ppm: Av of 57 ppm based on 37 analysis).

5.7 Studies on Hydrothermal Sulphides

The programme carried out first deep-sea AUV (capable of diving up to 6000 m) cruise over the Central Indian Ridge in 2010. A 40 mile segment of the Central In-

dian Ridge between 10°10'S to 10°50'S was surveyed. Shipboard multibeam, CTD (Conductivity, Temperature and Depth) and MAPR (Miniature Autonomous Plume Recorder) surveys were conducted prior to the deployment of Autonomous Underwater vehicle (AUV). The dive locations were selected based on the shipboard multibeam and CTD-MAPR data. AUV dives consisting of two mapping missions and one dive of photography have been completed. High resolution bathymetry, temperature, turbidity and Eh data have been collected. Based on the CTD-MAPR-AUV investigations, a zone of high turbidity and anomalous Eh was located in the region. Significant achievements are as follows:

- Significant hydrothermal plumes were discovered over the Carlsberg Ridge using deep CTD casts and Miniature Autonohmous Plume Recorders (MAPRs).
- The existence of two active vent sites over the Carlsberg Ridge is being investigated.
- Further, a significant hydrothermal plume at 10°30'S over the Central Indian Ridge was documented during the first ever deep-diving AUV (6000 m) survey onboard RV Sagar Nidhi (SN-48).

5.8 Vessel Management

A fleet of six scientific research vessels to conduct the oceanographic research programmes/projects are under operation; undertaking scientific research activities in the Arabian Sea, Bay of Bengal and the Indian Ocean (Table 5.2).

Table 5.2 Utilization of Vessels in 2011-12

Name of the Vessel	Days at Sea/ Utilization	Maintenance/Inspections/Scientific Logistics/ Cruise Preparation	No. of Cruise	No. of Port Calls/ Port Stay
ORV Sagar Kanya	246	60	13	60
FORV Sagar Sampada	187	143	16	36
TDV Sagar Nidhi	221	124	10	21
BTV Sagar Manjusha	134	202	13	30
CRV Sagar Paschimi	199	97	25	70
CRV Sagar Purvi	130	200	23	36

1. Oceanographic Research Vessel (ORV) Sagar Kanya has undertaken scientific programmes in the areas of survey and exploration of non-living ocean resources. During this year, significant cruises were undertaken by the vessel for the deep swath bathymetric surveys in the Indian Exclusive Economic Zone (EFZ), studying biogeochemistry and hydrodynamic of the Tropical Indian Ocean (TIO) during summer and winter; PMEL-INCOIS RAMA mooring, Equatorial current-meter moorings and UNEP-SACEP training programme, (ICARB-Winter campaign and Satellite Validation), etc.

2. Fisheries Oceanographic Research Vessel (FORV) Sagar Sampada has undertaken research cruises to assess environment and productivity patterns along Indian EEZ, understand the dynamics of harmful algal blooms and associated biogeochemical changes, deep-sea fishery resources, etc.

3. Technology Demonstration Vessel (TDV), Sagar Nidhi, a state of art ice-class adopted with Dynamic Positioning System, is used essentially for demonstration of ocean technology research. The Conductivity, Temperature, Depth recorder (CTD) Rosette is also commissioned to collect water samples at different water depths up to 6000 meter along with chlorophyll, Rhodamine, pH, etc. profiler. Separate sampling room is built adjacent to the wet lab and geological core cutter lab. Scientific winches like hydrographic winch, CTD winch, Active heave compensation winch, etc. are available onboard for deployment and retrieval of scientific equipments. All winches are facilitated with 6000-meter length rope. The following significant cruises undertaken during this year.

i. Southern ocean Expedition, NCAOR

- CTD X CTD operated to collect water samples, physical, chemical and oceano graphic data
- Multi plankton net and Bongo net operated for the Biological study Carried out Argo floats de ployment

ii. Deployment and retrieval of Tsunami buoys , Data Buoys and Omni Buoys

iii. Testing of ACS was carried out off Chennai and Vizag

iv Testing of Soil Tester, Crawler , NIOT

4. Buoy Tender Vessel (BTV) Sagar Manjusha is actively involved in providing the logistics for timely execution of desalination projects in the Lakshdweep Islands and the National Data Buoy programmes. The vessel was deployed for 'transportetion of heavy machinery and equipment for establishment and commission of desalination plants to generate fresh water' at the Agathi, and the Minicoy Islands. It was also deployed for ADCP mooring and retrieval for data collection and servicing.

5. Coastal Research Vessel (CRV's) Sagar Purvi & Sagar Pachimi are used for the implementation of Coastal Ocean Monitoring and Prediction System (COMAPS) and Integrated Coastal and Marine Area Management (ICMAM) programmes.

Various technology developmental activities are being carried out towards harnessing the resources from oceans in sustainable manner. Details of significant technology developments are provided below.

6.1 DEEP SEA TECHNOLOGY and OCEAN MINING

6.1.1 Remotely operable Insitu soil tester

In order to harness deep sea resources, development of various equipments such as Remotely Operable Submersible (ROSUB) to assess environmental conditions and Remotely Operable Subsea In-situ Soil Tester (ROSIS) to test mechanical properties of sea-bed has been undertaken. The information provided by these equipments will be utilized to develop mining equipments. ROSUB has already been developed and tested beyond 5000 m. A Remotely Operable Subsea In-situ Soil Tester (ROSIS) has been developed and was tested at a water depth of 5462 m in the Central Indian Ocean Basin (CIOB). This test is a significant milestone in India's R&D efforts towards demonstration of mining of polymetallic nodules from the deep oceans.

The test was done at the proposed First Generation Minesite for assessment of soil properties to facilitate safe deployment of deep subsea mining machines. All the tests were done in the deep ocean floor for about 4 hours duration. Acoustic Positioning System transponders and deep subsea transceivers which would provide proper path control for mining machines were also deployed and studied for performance. A solids pumping system has also been tested for subsea performance. Most of the subsea electrical systems tested in this trial, viz. terminations, connectors, transformers, electronic sensors like altimeter, motion reference unit, temperature, depth sensors, underwater illumination, vision cameras, data acquisition and control systems, qualified in these tests will be used in the development of deep-sea mining machines. other tests conducted include sub bottom profiling, multibeam survey, and sound velocity profile measurement.

Clear videos of sea floor showing the nodule abundance and topography were also obtained (Figure 6.1 a & b). Cone and Shear Vane testing was done on the top surface of the sea floor to ascertain the extent of bearing area required for crawler tracks for operation with minimum machine sinkage. The bearing pressures measured varied between 5 kPa at the surface to 20.6 kPa at 492 mm depth (Table 6.1). Maximum shear strength of 5 kPa was obtained at 492 mm depth.

Fig. 6.1a & b. Polymetallic Nodules spread over the sea floor

Table : 6.1 Bearing and shear strength of soft seabed (Test Site : Lat : $13^0$42.3'S, Long : $74^0$51.6'E)

Sl. No.	Depth of Penetration (mm)	Bearing Strength (kPa)	Shear Strength (kPa)
1.	0	4.57	-
2.	100	8.72	-
3.	200	11.84	-
4.	300	12.86	-
5.	400	15.34	-
6.	492	20.68	5

6.1.2 Remotely Operable Submersible (ROSUB 6000)

After successful deep water qualification trials of the Remotely Operable Submersible (ROSUB 6000) capable of operating at a water depth of 6 km, system improvements have been carried out for further exploration sea trials. A new Fibre Optic Rotary Joint (FORJ) has been tested for temperature variations. A new firing circuit for underwater rectifiers has been incorporated to improve the reliability. A new video camera has been interfaced for obtaining better images.

6.1.3 Autonomous Coring System

The objective was to collect 100m long cores at gas hydrate sites using an Autonomous Coring System (ACS) of 3000m depth rating. Towards achieving this, ACS was acquired and the first shallow water trial of ACS was conducted last year off Chennai. Based on this experience, Technology Demonstration Vessel (TDV) Sagar Nidhi winch modification for enhancing the capacity of the winch has been carried out and winch has been qualified for 18.5 tons load. A site for deep water trials of ACS has been identified.

6.1.4 Ocean Mining

Design and development of Deep Sea Mining Machine capable of collecting and mining poly-metallic nodules from 6000 m water depth is a major technological challenge. As part of the mining system, testing and qualification of underwater collector and crusher system has been completed in the first phase. Critical sub-systems like solids pumping system capable of pumping large solids at 160 bar pressure has to be developed. Presently, development of other systems like undercarriage traction systems, electrical motors, acoustic positioning systems are in progress.

6.2 Low Temperature Thermal Desalination (LTTD) Plants

The 2nd desalination plant based on Low Temperature Thermal Desalination technology plant utilizing the temperature difference between the sea surface water and deep sea water with a capacity of producing 1 lakh litre of fresh water has been successfully commissioned at Minicoy in March 2011. It was inaugurated by Honorable Minister of Parliamentary Affairs, Science & Technology and Earth Sciences, Shri Pawan Kumar Bansal on April 22, 2011 (Fig. 6.2). The plant is continuously producing fresh water and it is being distributed to island community by the local authorities. The plant performance, in terms of various parameters, is being monitored.

Fig. 6.2 LTTD Plant set up at Minicoy producing fresh water

In Agatti, the cold water pipe was re-deployed and upon rectification of damaged structure in wave breaking area another desalination plant was set up. One lakh litre of fresh water per day is being generated on continuous basis and serving the island community. This is the third plant in the Lakshadweep Islands after Kavaratti and fourth plant based on Low Temperature Thermal Desalination Technology. The freshwater produced is having Total Dissolved Solids (TDS) level of about 150 ppm against the prescribed limit of 2000 ppm set by the drinking water standard, IS: 10500. Various process parameters are being monitored to evaluate the plant performance.

6.3 Development of Suction Pile

Development of Suction pile has been taken up as it is widely used in mooring applications and offshore oil industry. Model pile of 300 mm (Fig. 6.3) and 500 mm diameter, for diameter to length ratio 1:1.5 was tested using complete instrumentation. Pullout tests were also conducted on these piles at 15° and 85° to the horizontal. Normalized pullout results were found to be consistent. Further tests using larger diameter model piles are planned within the Royapuram breakwater in similar soft soils.

Fig. 6.3 Suction pile 3m dia x 4.5m long

6.4 COASTAL AND ENVIRONMENTAL ENGINEERING

6.4.1 Demonstration of shore protection measures

The coastal areas are subjected to geomorphologic changes due to natural changes and man-made activities. The objective of the project is to develop environment friendly solutions at selected sites through engineering interventions. The two considered sites are Kondurupalem (near SHAR from Andhra Pradesh Forest Department) and Pondichery. At Kondurupalem site hydrodynamic data (tide, wave and currents) at inlet and as well as coastal waters of Kondurupalem were collected for the South West monsoon period to analyse the circulation pattern at inlet. Nearshore bathymetry and inlet mapping were carried out using DGPS to asses morphological changes. Grain size analysis of bed sediments and suspended sediments were also observed and analyzed to assess the sediment transport.

At Pondicherry site, bathymetry data was collected for a coastal stretch of 16 km. The data on beach profiles and shoreline mapping was carried out using mobile Differential Global Positioning System. Studies on Short-term solutions for the northern part of the Pondicherry Coast (Chinna Mudaliar Chavadi) are being initiated. Long term shoreline change study through satellite images was completed.

6.4.2 Engineering Investigations for the Kalpasar Project

The Kalpasar project aims at construction of a dam across the Gulf to impound the water of the Narmada river which otherwise drains into the Arabian Sea. The scope of work includes geophysical, geotechnical/ bathymetric surveys, grab sampling, establishment of observatories, installation of tide gauges, vertical control survey and numerical modelling. Multi Beam Echo Sounder survey, Single Beam Bathymetry survey and Side Scan survey have been completed. Establishment of observatories is under progress. Data processing and analysis are in progress.

6.4.3 Break water studies for Poompuhar fishing harbour

Modification of breakwater design, as per the Tamil Nadu Fisheries Dept. requirement has been carried out for Poompuhar fishing harbor. The annual and seasonal variability of wave parameters at the proposed break water location is prepared using MIKE21 model. Wave tranquility studies for modified breakwater layout completed for Poompuhar.

6.5 OCEAN ACOUSTICS

As acoustics is the most effective means of exploring the oceans. Research efforts that are both scientific and technology oriented have been taken up in the area of ocean acoustics.

The objective is to develop fully automated ambient noise measurement system for time series measurements. The ambient noise measurement system was deployed off Cochin and Goa in shallow waters during pre-monsoon and monsoon seasons in 2011. The environmental parameters such as wind speed / direction, rainfall, sound velocity profiles and sediment samples have been collected at many sites. Data processing and analysis have been carried out to study the fluctuation of the noise speed and its properties during the monsoon. Also the derivation of the rainfall parameters using inversion algorithm for ambient noise data are taken up.

6.6 ENERGY GENERATION

The main objective is to develop turbines to harness power using different forms of ocean energy. Towards this, development of OTEC turbine, current turbine and wave energy turbine have been taken up. A 2 kW ammonia turbine working on closed cycle OTEC principle is being developed and design of turbine rotor with cutting blades has been completed. The working model of current turbine with six inclined straight fiber

Fig. 6.4 BBDB deployed off the Ennore Coast

reinforced plastic blades is tested for performance at the North Chennai Thermal Power Station.

A new unidirectional impulse turbine was fitted on the backward bent ducted buoy (BBDB) and first phase of sea trials was successfully conducted in April 2011 (Fig. 6.4), the second phase of sea trials with improvised instrumentation has commenced in September 2011.

6.7 MARINE SENSORS AND INSTRUMENTS

Development of underwater sensor technology for marine applications is very important and as part of this activity the Buried Object Scanning Sonar (BOSS) is being developed. A preliminary design of the tow body which can accommodate all the underwater electronic subsystems and hydrophone array of the Buried Object Scanning Sonar (BOSS) has been completed.

Indigenous development of data acquisition and processing unit for tsunami system has been completed, tested and successfully deployed in August 2011. The indigenous tsunami deep ocean pressure recorder system for tsunami detection and surface buoy electronics were developed (Fig. 6.5). The field trials of DOPR were carried out at 810 m off the Minicoy Island during March 2011 and 1920m off Chennai during September 2011. The system needs further trials to transfer the technology to industry.

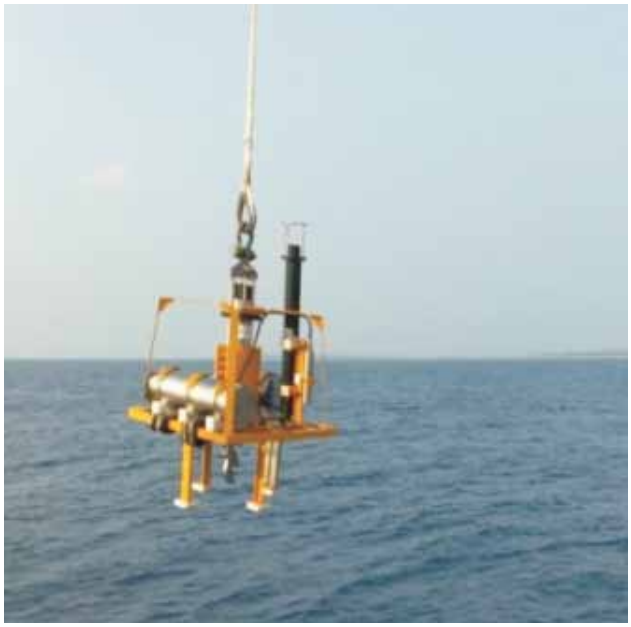


Fig. 6.5 Deep ocean pressure recorder

A test rig for laboratory simulation of Tsunami along with ocean tide was also developed.

6.8 MARINE BIOTECHNOLOGY

6.8.1 Marine Micro Algal Biotechnology:

Marine micro algal strain 5F-1 (NIOT -45 isolated from the Andaman Islands) was tested for large scale production of lutein in bubble column photobioreactor in outdoor mixotrophic culture conditions using ammonium nitrate, urea and sodium acetate as carbon source. Experiment on the effect of Ultra Violet light induced mutation for lipid accumulation and ultra structural changes has been completed. UV-mutated culture showed lower chlorophyll and increased lipid content. Solar powered DC motor system for raceway paddle wheel operation was successfully installed and trial run of the same is in progress.

6.8.2 Open sea cage culture

Ten cages (9m-diameter) were deployed at Olaikuda (Tamil Nadu) (4 Nos.), Kothachathram (Andhra Pradesh) (2 Nos.) and at North bay, Port Blair (Andaman Islands) (4 Nos.). Culture of sea bass, parrot fish and milk fish is in progress using formulated feed imported from Taiwan. Cages for fresh water fish culture in dams and reservoirs were designed.

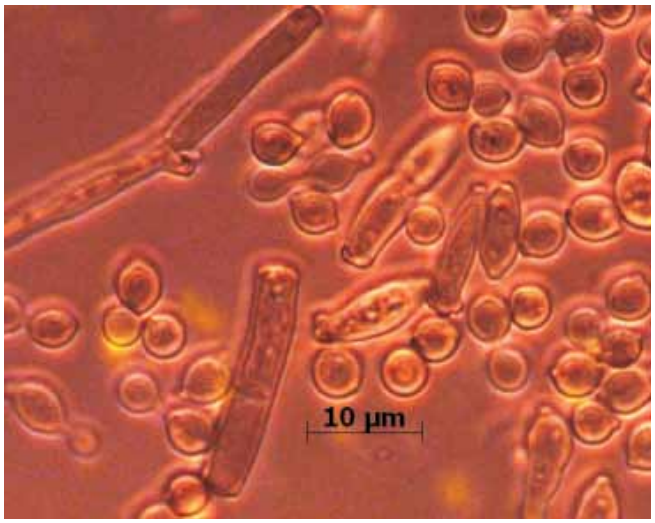


Fig. 6.6 Microphotograph of fungus

6.8.3 Marine Microbial Biotechnology

Deep sea filamentous fungi producing extracellular pigment were isolated from a depth of 400m and axenic cultures were developed. Microphotograph of fungus is

shown in Fig. 6.6.

6.8.4 Development of Potential Drugs from Ocean

Eighty two samples were collected. Taxonomic identification of 22 samples was completed. HPLC analysis was completed for 31 samples. Fifty nine samples received from collaborating laboratories were tested for antibacterial activity. Sixty four internal samples were examined for antibacterial activity.

6.8.5 Biodiesel from marine micro algae

B10 biodiesel was produced from transesterified algal oil and its properties are being tested at a private lab as per ASTM standards.

7 Coastal and Marine Ecology

7.1 Introduction

The coastal ecosystem of India with a coastline of 7500 km is rich in marine biodiversity connected to different marine environment, namely the Bay of Bengal on the east coast and the Arabian Sea on the west coast. Some of these coastal regions are highly productive and ecologically sensitive, harboring numerous fauna and flora. The coastal regions of India often experience a wide range of natural disasters like cyclones, tsunami as well as man-made activities contributing to considerable coastal erosion. The major thrust has been on shoreline management, ecosystem modeling, monitoring of coastal water quality and marine living resources.

7.2 Development of Shoreline Management Plans

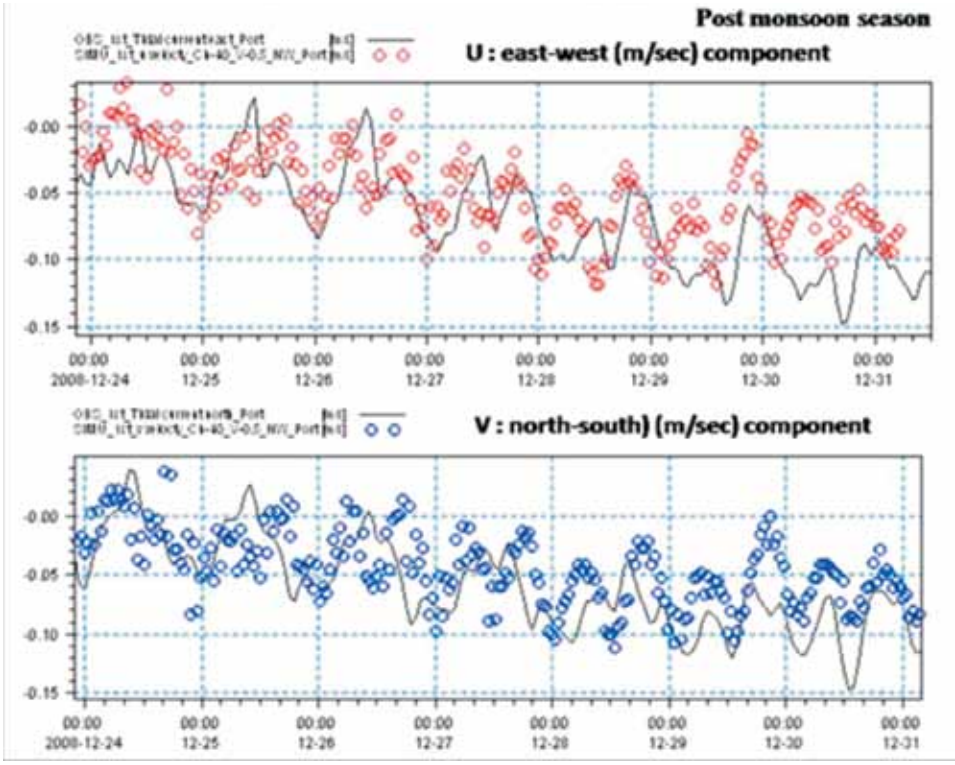
The project is aimed to understand and analysis of the problem of erosion and develop the site specific shoreline management plans (SMP). It is being implemented for three sites along the Kerala coast (Muthalpozhi, Vadanappally and Marad-Kozhikode) and four sites along the Karnataka coast (Devbhag, Karwar, Pavinkurve, Honnavar Kundapur kodi) and a site each on the Andhra (Gangavaram) and the Orissa (Gopalpur) coasts. Besides, a project on performance of coastal protection structures along the North Chennai coast has been undertaken to study the impact of these structures on the shoreline. The oceanographic data (waves, currents, tides, shoreline variations; profile changes; sediment characteristics), beach profile survey and shoreline mapping work, which is primary requirement to develop the SMP plans has been completed at all locations except at North Chennai. The highlights include:

i) The siltation in the Muthalapozhi harbour is a major problem followed by erosion on the northern sector. The study revealed that net annual transport is towards north and is being trapped in southern sector due to presence of a breakwater. To reduce the siltation problem it is proposed to provide three short transition groins (40, 30 and 20m from 120m, 220m and 300m south of breakwater, respectively) so that these sediments are available for redistribution during other seasons. The minor erosion along the north of the breakwater can be tackled by sand bypassing. For the Vadanapally and Tirussur sectors, modelling work in progress.

ii) Along the North Kanara coast, shoreline changes for four locations studied using 20 years satellite data. It was found that the changes (~200m), were mainly confined in the vicinity of the river mouths. Most parts of 200 km long coastline remained almost stable.

iii) Along the coast of Gangavaram located south of Visakahapatnam, net erosion on the northern part of Gangavaram is evident. The rocky promontories near the south and north of the Gangavaram Port are acting as natural barriers to sediment transport and reduces flow towards north causing erosion along the Visakapatnam coast. Modelling studies in progress estimate quantity of reduction in sediment movement.

iv) In Gopalpur, the volume of long-shore sediment transport (LST) based on monthly observed wave data indicates that during southwest monsoon (May to September) seasons were 1.25 and 0.99 x 106 m3 and rest of the year was 0.14 and 0.11 x 106 m3 per year. The gross transport rate varies in between 1.29 and 1.11 x 106 m3 per year. The transport is predominantly unidirectional and northward as a result gradual accretion on the south and erosion on the north beaches of the port are recorded. Deposition and/or erosion events are mostly confined to 2km to the north and south, respectively, of the existing groin field. The beaches are comparatively stable farther from groin. The beach erosion events at the Gopalpur tourist beach and Rushikulays olive ridley rookeries are mostly natural. Beach profile indicates the volume of sand trapped on the south of southern groin is the order of 0.70 x 106 m3/ year and 2.5 times more the rate of erosion on the north of the port. Hydrodynamic model simulated currents are reproduced well with reasonable accuracy by the depth averaged two dimensional model (Fig.7.1). Spatial and temporal comparison between the measured water level and model results demonstrate good performance of the hydrodynamic model. Beach nourishment appears to be the ideal solution to arrest the problem of erosion on the northern side.



(-) Model simulation (o) Observations.

Fig. 7.1. Calibration of east-west (u) - upper panel and south-north (v) - lower panel components

7.3 Ecosystem Modeliing

Ecosystem Modelling for the Chilika lake: Development of Ecosystem models to predict primary productivity and subsequently secondary production through carbon flow method have been continued in the Chilika lagoon and the Kochi backwaters. Ecologically and hydrologically, zones characterising fresh-brackishwater and marine waters have been idenfied in both the water bodies. The highlights of activities carried out include, estimation of nutrient inputs into the system through rivers during the wet season, enrichment in the water through biogeochemical processes in dry seasons and flow of nutrients from one zone of these systems to other zones. The modelling has sequence of hydrodynamic, water quality and ecological models. Hydrodynamic model essential to understand flow and mixing patterns have been developed and are being validated. Parellelly development of water quality models using monthly field data as inputs are in progress. The hydrodynamic model developed for the Chilka tides could be well simulated, where as currents and salinity to a fair degree of accuracy.

7.4 Coastal Ocean Monitoring and prediction systems (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 twenty locations are being collected with the help of seven academic and research institutions upto 5 km from the coastline of the country. The highlights of results obtained from observations made during 2011 pertaining are as given below:

Gujarat : Water quality of Vadinar is observed to be good with normal values of DO (6-8mg/l) and nutrients. Water quality of the upper Tapi Estuary shows build up of nutrients and absence of DO. While in middle and lower estuaries, though DO was normal, levels of nutrients were high, indicating that the estuary is in stress condition during premonsoon. DO was normal and nutrients were high off Hazira indicating contamination due to industrial and domestic wastes.

Maharashtra : The monitoring of water quality was carried out at the Thane creek, Mumbai. Levels of nutrients were observed to be high in the upper Thane creek (NO3: 20–80 µmol/l) indicating organic load is being discharged into the creek. However water quality in sea off Mumbai showed normal DO and moderate levels of nutrients.

Karnataka : At Mangalore, DO (4–6 mg/l) and levels

of nutrients were in normal range. Higher incidence of pathogenic bacteria (SFLO: 140-380 CFU/ml) indicates contamination due to domestic sewage and riverine discharge.

Kerala : At Kochi, though DO (5–6 mg/l) was in normal range, increased levels of nutrients (nitrate: 8 µmol/l; phosphate-3 µmol/l) and pathogenic bacteria (SFLO: 200-1840 CFU/ml) indicate continued influence of domestic wastes.

Tamil Nadu and Puducherry : The coastal waters of Ennore, Puducherry and Tuticorin indicated good levels of DO, (4-5 mg/l). The nutrients were within normal range though occasional high values of nitrate > 4 umol/l was noticed. However, significantly high levels of pathogenic bacteria >1000 CFU/ml were continued to be observed at many shore locations, indicating contamination due to domestic sewage.

Andhra Pradesh : Levels of DO and BOD were moderate to normal both in Visakhapatnam (DO:3-6 mg/l, BOD: 0.1-3.6 mg/l) and Kakinada (DO: 5-7 mg/l, BOD: 2-3 mg/l) indicating pollution stress. The Dissolved Petroleum Hydrocarbon concentration was comparatively lower in Visakhapatnam (1.1-9.3 µg/l) than in Kakinada (2.1-9.5 µg/l) due to close proximity of the port activities. Levels of nutrients were high both at Visakhapatnam (NO3: 10-28 umol/l; IP: 1-3 umol/l) and Kakinada (NO3: 4-17 umol/l; IP: 1-7 umol/l) and high pathogenic bacteria indicating terrestrial organic load.

Orissa : The coastal waters of Paradip are characterized by continued high DO values (6 – 8 mg/l). Level of nitrate was within normal range. Level of phosphate at Paradip was higher (IP: 2-5umol/l) (IP: 1-2 umol/l) indicating contamination, possibly from industrial sources. However, high levels of pathogenic bacteria indicate contamination due to domestic sewage.

West Bengal : The coastal waters of Sandheads and Hooghly estuary continued to have high levels of DO (6-8 mg/l) indicating good water quality. However, increase in levels of total nitrogen was observed (10-30 umol/l; 20–50 µmol/l) at Sandheads. High level of TN was also observed (12-26 umol/l; 38–63 µmol/l) at the Hooghly estuary. High levels of pathogenic bacteria at Sandheads (SFLO: ND–7400 CFU/ml; 300-31500 CFU/ml) indicate contamination due to domestic sewage. However, at the Hooghly estuary levels of bacteria were relatively less (SFLO: ND–2050 CFU/ml; Jul'11: ND-45 CFU/ml).

Andaman & Nicobar Islands : The coastal water quality at Port Blair and Wandoor is observed to be good with normal levels of DO (4–7mg/L) and nutrients. However, increase in levels of pathogenic bacteria at Junglighat, Phoenix bay (SFLO: 38–420 CFU/ml) due to receipt of low levels of sewage was observed. In general, coastal water quality of Port Blair is observed to be good.

Data collected under this programme over the years have been compiled and organized into databases and hosted on INCOIS website for dissemination.

7.5 Oil Spill Modelling

Oil Spill |modeling project is aimed to strengthen the capabilities of oil spill trajectories prediction and to develop habitat specific model. The trajectory model was used in forecast mode to predict the likely path of spilled oil, its fate for sunken ship "MV Rak Carrier" at 22 NM west of Mumbai during 7-11 August, 2011. The model predicted the patch will take 24-48 hours to reach the shore near the Juhu and Colaba areas. The information was provided to the Indian Coast Guard (ICG) for their use in oil combating and preparedness purposes. The feedback received from ICG confirmed the model trajectories were nearly accurate. MIKE-21 generated currents were incorporated in NOAA model successfully along with ROMS model output (INCOIS) for Indian Ocean and NCMWRF forecasted wind data to Oil Spill model.

Primary oceanographic data collection, hydrodynamic, oil spill modeling and sensitivity mapping are the main tasks involved for habitat specific modelling. Data collection work completed along Chennai, Kakinada, Vizag, Dahanu-Mumbai, Goa, Neendakara, Kanyakumari. Sundarban, Hooghly & Lakshadweep is planned. Oil Spill models are constructed for Chennai, Goa, Dahanu and Cochin. Oil Spill sensitivity mapping and risk assessment is completed for Chennai.

7.6 Marine Ecotoxicology

The programme aims to develop safe Seawater Quality Criteria (SWQC) for Cadmium, Copper, Zinc, Lead and Mercury for the Ennore creek and adjacent coastal waters of Chennai and for similar metals in the Gulf of Mannar. It is also proposed to develop criteria for organophosphorus insecticide Monocrotophos which is widely used in agriculture. Through simulated bioassay experiments, draft seawater quality criteria (SWQC) have been developed for few metals the Cadmium, Copper, Mercury , Zincand lead. Development of SWQC for above metals in progress for the Gulf of Mannar.

7.7 Harmful Algal Blooms (HABs)

During the year, 10 algal blooms were observed along Indian EEZ, viz. *Rhizosolenia setigera* and *Pseudonitzschia seriata* in inshore waters of Goa (April,), *Trichodesmium erythraeum* off Goa (May,), *Asterionella japonica* off Kochi (June,), *Thalassiosira partheneia* off Trivandrum (June,), Red *Noctiluca scintillans* off Kochi (Aug,), *Skeletonema costatum* and *Microcystis sp.* in inshore waters of Goa (SW monsoon,), Green *Noctiluca* and *Haslea* spp. in northeast Arabian Sea (Feb-March). DNA extraction and PCR protocol of the 9 HAB species standardized and DNA barcoding was done for 7 Dinoflagellates- *Ceratium furca,Neoceratium fusus, Dinophysis caudata, D. acuminata, D. fortii, Prorocentrum lima and Noctiluca scintillans;* 1 Haptophyta-*Phaeocystis globosa;* and 1 Cyanobacterium (from Kochi Backwaters) – *Microcystis aeruginosa.*

7.8 Marine Living Resource Programe (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.

Assessment of Environment & Productivity patterns in the Indian EEZ: Focused research on cold core eddies of the Bay of Bengal, warm pool in and around the Lakshadweep Islands and estimation of tertiary production using a trophodynamic model were undertaken. A matured northern cyclonic eddy (NCE) epicentered at 17°N; 86.3°E was identified in the northern Bay of Bengal (BoB) during early winter monsoon with 200-300 km dia spinning at 45 cm s-1 which is an annual recurring feature in the BoB. Analysis of monthly Sea Surface Height Anamoly (SSHA) maps shows that NCE was developed in July, grew and intensified in the subsequent months, and finally gets dissipated in January (Fig 7.2). A close look at the forcing mechanisms revealed that local wind stress curl is the driving force for the formation of NCE during summer while it is sustained till December by the westward propagating Rossby waves. The upliftment of nutrient rich sub-halocline waters under the influence of NCE forced an 8 fold increase in primary production and a 2 fold rise in mesozooplankton biomass. The complex dynamics of NCE influences the ecological structure of the generally oligotrophic BoB making it biologically more productive.

Satellite-based studies showed the persistent occurrence of the Arabian Sea Warm Pool (anti-cyclonic eddy) in and around the Lakshadweep Island ecosystem during November-December (winter monsoon) which with the progression of season is dissipated to give many small eddies up to March. The observed mass bleaching of Lakshadweep corals during 2009 was mainly due to the increased intensity of this warm pool which in turn was to a great extent influenced by then prevailing El-Nino conditions.

Maximum Sustainable Yield (MSY) of fishery resources from within the Indian EEZ has been revalidated through Trophodynamic modeling approach. Tertiary

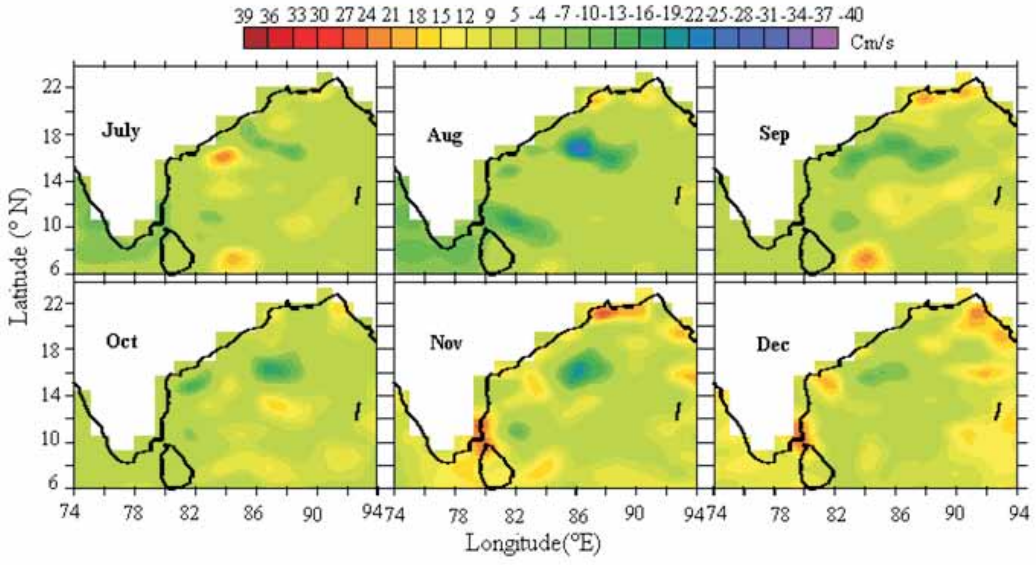


Fig 7.2 Monthly variation of SSHA showing 6 months existence of northern cyclonic eddy in the Bay of Bengal

production potential for Indian EEZ was modeled using satellite derived chlorophyll-a values in conjunction with time-series insitu observations on primary, secondary and benthic productions and by applying appropriate energy transfer efficiencies between the trophic levels. The domain of the model was divided to 5 ecosystems, viz. northeastern Arabian Sea, southeastern Arabian Sea, northern Bay of Bengal, southern Bay of Bengal and Andaman Sea. The carbon flow was estimated at each level and ecosystem to get cumulative tertiary production. As per the first order model results, the MSY from the Indian EEZ was found to be at 4.32 million tons of fish.

Deep-Sea and Distant water Fishery : Four fishery cruises were conducted onboard FORV Sagar Sampada along the west coast, east coast and the Andaman waters of 27 deep sea trawl operations. The CPUE recorded was 31.14 kg/hr, 294.69 kg/hr and 83.95 kg./hr from these regions, respectively. The 200-300 m depth zone registered maximum catch. Record catches of deep sea prawn *Aristeopsis edwardsianna* off Trivandrum at a depth of 1000 m (14 kg/hr) and a mixed catch of *M. andamanesis* and *S. hextii* off Karwar at a depth of 214 m (100 kg/hr) were found. Potential fishing grounds for deep sea prawns, *Pleisionika spinipes* and *M. andamanensis* along the SW coast and *solenosera hextii* along the NW coast and H. gibbosus from Andaman Waters at a depth range of 200-400 m and for deep sea fishes such as *Priacanthus sp, Bembrops sp.* and *chlorophthalmus agassizi* along the SW coast at a depth range of 200-400m were identified.

Biochemical composition of the myctophid *Diaphus watasii* showed that *D. watasei* has high protein as well as fat content making it a potential source of alternative protein and fat. Various products like fish meal, fish oil, fish protein hydrolysate, fish silage, dry fish, battered and breaded products were also developed using myctophids. Acoustic experiments were conducted on three species of Myctophids, *D. watasei, Lampedna luminosa* and *Neoscopelus microchir.*

IndOBIS & CoML: Indian Ocean Biogeographic Information System (IndOBIS) and Census of Marine Life (CoML) activities were initiated. Under IndoBIS, a web module has been developed for query and display. Additional 1400 records were added to the IndoBIS holdings. Voucher specimens of IndoBIS are maintained at the Referral Centre (Fig. 7.3)

Discovery of three possible new species, viz, a deep sea brittle star *Asteroschema sampadae,* deep-sea shark *Mustelus mangalorensis* and finfish, *Harpadon* spp. and the reporting of several new records which include deep-sea fin fish *(Glyptophidium oceanium, G.macropus, Neobythites multistriatus, Dicrolene nigricandis, Bassozetus robustus, Pcynocraspedum squamipinnae),* 3 species of deep sea sharks *(Halaelurus lutarius, Etmpterus pusillus, Apristurus canietus)* and 2 species of chimeras *(Chimaera jordani and Hydrolagus mirabilis)* from Indian EEZ are the major contributions during the year.

7.9 Ornamental Fish Culture

Technology for breeding and rearing of 4 species of clown fish and one species of Damsel fish was devel-

Fig 7.3 Voucher Specimens of IndOBIS at CMLRE Referral Centre

oped in hatchery in Agatti, Lakshadweep Islands. A batch of 20 islanders from Agatti were given hands on training for six months on the technology for breeding and rearing of ornamentals.

7.10 Pearl Production

Technology for black pearl production using the Andaman black-lip pearl oyster, Pinctada margeritifera have been developed (Fig 7.4) by modifying the spat production, farming and implantation techniques on par with the practice adopted in Polynesia. An undersea long line with oyster kept in chaplets enclosed in rigid mesh baskets, use of christmas tree settlers and improved implantation techniques using 7 mm nuclei biocoated with antibodies were the major changes introduced. A training on hatchery protocols for production of black lip pearl oyster spats was held at Marine Hill, Port Blair during Feb 2011.

7.11 Aquaculture and Mari culture

To study tuna migration, a prototype archival tag has been designed and developed (Fig 7.5). The prototype

Fig 7.4. Black pearl production using the Andaman black-lip pearl oyster

has microchips to detect the location, depth, temperature, pressure, light and salinity at set intervals. Prototype with encapsulation weighs 15.4 g which compare quite well or perhaps better than other commercially available archival tags.

Fig 7.5 Prototype archival tag

7.12 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 R & D institution across the country participating in this programme. More than 14,000 extracts of marine samples have been screened for wide spectrum bioactivity including anti-diabetic, antii-hyperlipidemic, anti-malarial, anti-HIV, anti-cancer, anti-osteoporosis properties. Many hits have been identified having potential and being optimized for various diseases.

Material for CDR-134 and CDR-267 were processed for the isolation of their fractions 194 and 018, respectively, and were submitted to TNMC, Mumbai for secondary screenings in diabetic complications like nephropathy, retinopathy, neuropathy, cataract, impaired angiogenesis and insulin resistance. The study to assess the efficacy of the Effective/Therapeutic Dose (ED50) and twice the ED50 dose, i.e. 90 and 180mg/kg of CDR-267-F018 in the diabetic neuropathy model (6 months duration) has demonstrated a gradual reduction in the sugar levels at the end of 6 months as compared to the disease control. However the effect was less than the standard control (α-lipoic acid). Both the doses exhibited a significant increase in MNCV as compared to the disease control group and demonstrated decrease in serum and nerve MDA levels.

Single dose and sub-acute toxicity of an anti-dyslipidemic agent, CDR-267-F018 were completed in rodents. The sample was safe even at the maximum dose of 500mg/kg. Moreover, dose range finding toxicity studies with the same sample were also completed and an oral dose up to 500mg/kg was found safe in the rats.

Regulatory toxicity studies with CDR-267-F018, an anti-dyslipidemic agent have also been completed. in Rhesus monkeys. No adverse effect of CDR-267-F018 was evident on body weight, food and water consumption, ECG, haematological parameters, urine analysis, blood biochemistry and gross pathology up to the maximum dose of 250 mg/kg (po).

CDR-134-F194, an anti-hyperglycemic cum anti-dyslipidemic fraction has been approved by DCGI to conduct Phase-I Clinical Trial. Complete monograph on CDR-134 has been submitted to Ayush for its inclusion in Extra Ayurvedic Pharmacopeia, approval for same is under process.

8.1 Climate Change

We are quite aware of the fact that human health, ecological systems, and socioeconomic sectors (e.g., hydrology and water resources, food and fiber production, coastal zones, and human settlements), all of which are vital to sustainable development, are sensitive to changes in climate—including both the magnitude and rate of climate change—as well as to climate variability. Accordingly, a high-priority Mission mode Program had been developed to address the science issues climate change by building strong linkages with leading international research groups and research centers involved in allied areas, and supported by a well equipped with state-of-the-art infrastructure facilities for inter-disciplinary research & training in the area of science of climate change.

Major Scientific Accomplishments

Multi-year baseline simulations of present-day climate have been carried out using four dynamical downscaling high-resolution climate models (WRF, RegCM, LMDZ and PRECIS). Preliminary simulations indicate that the summer monsoon rainfall along the narrow Western Ghat Mountains and the orographic slopes near Burma and the Northern Bay is well captured in some of the high-resolution climate models.

Earth System Model (ESM) development and customization has been initiated by adding some basic ESM components to the CFS-v2 global atmosphere-ocean coupled model. Several test simulations and long runs of the CFS-v2 model were also separately conducted to understand the fidelity of the climate model in capturing the observed features of global and monsoon climate.

Dynamical Seasonal Prediction involving CFS v.2 has been implemented for seasonal prediction of the Indian summer monsoon rainfall (ISMR). The CFS v.2 is an updated version of CFS v.1 with improved coupling system and has incorporated improvement in model physics. The results indicate that rainfall biases in CFS v.1 are significantly reduced in CFS v.2, particularly over the Equatorial Indian Ocean region (Fig. 8.1). However, dry bias over the Indian land mass is enhanced. Correlation of ISMR with SST is improved in the Indian Ocean and the Pacific Ocean. Forecast run for simulation of 2011 ISMR using March initial conditions has been performed.

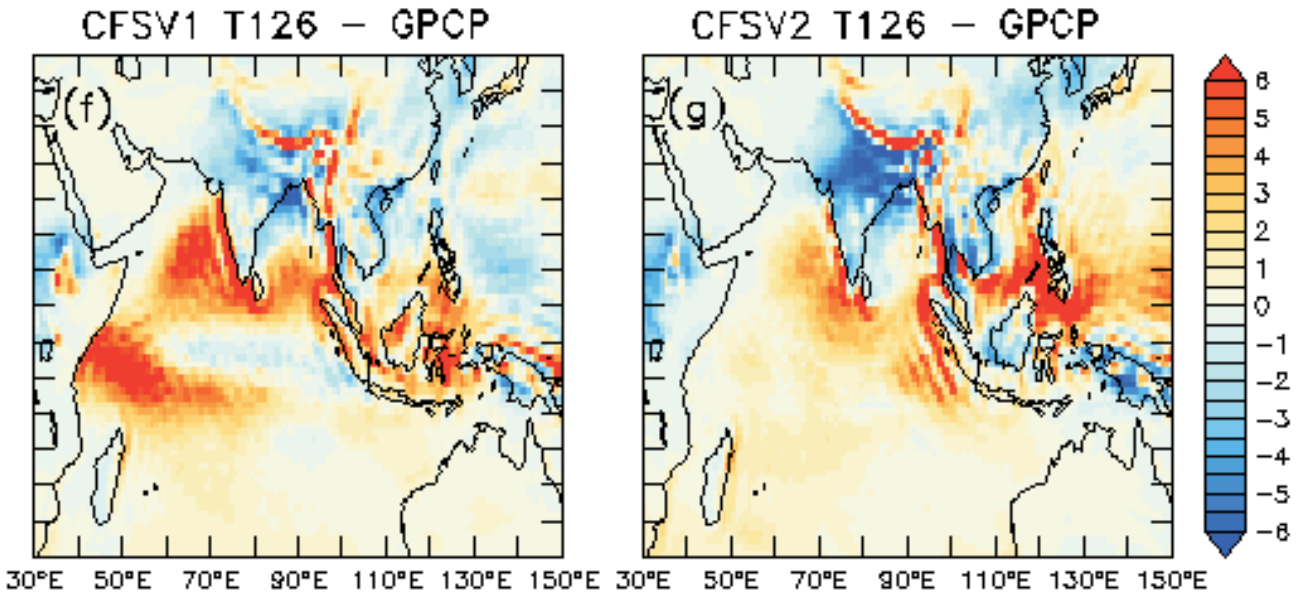


Figure 8.1: Rainfall biases (in mm/day), i.e. difference of model simulated JJAS rainfall climatology and oserved (GPCP) JJAS rainfall climatology for CFS v.1, CFS v.2 simulations.

A suite of General circulation Model (GCM) experiments was conducted to understand the dynamical response of the monsoon trough (MT) to varying populations of stratiform/convective clouds associated with the monsoon meso-scale convective systems (MCS). The role of convective and stratiform components of the MCS on the large-scale response of the MT was studied. It is found that the latent heating profile associated with stratiform clouds is more effective in promoting upward development of continental-scale cyclonic circulation well-above the mid-troposphere as compared to convective clouds. The findings indicate that the large-scale mid-level response from large stratiform populations is a manifestation of Rossby wave dispersion of PV anomalies which are generated near the level of maximum heating gradient. These results have implications for developing improved cumulus parameterization schemes for the monsoon region.

Based on the APCC operational MME hindcasts of precipitation and temperature at 850 hPa for boreal winters for the period 1981-2003, along with those of the individual models as well as corresponding observed and reanalyzed data, the use of a 'climate' filter is proposed to diagnose and improve the prediction skills. The 'filter' is based on the observed strong association between the ENSO-related Walker circulation and the tropical Pacific rainfall. The reproducibility of this relationship is utilized to evaluate the fidelity of the models. The predicted skill of a newer type of MME that contains only the 'good' models is superior to that of the all-inclusive operational MME. The difference of prediction skills between the 'good' and 'bad' MMEs varies with the region, and is significant in sub-tropics such as East Asia while most of the models perform well in tropics adjacent to the Pacific.

Analysis based on daily minimum and maximum temperatures at 121 stations over India shows increasing trends in the number of hot days and hot nights and decreasing trend in the number of cold days and cold nights over most of the stations during 1970-2003. Analysis of time series of extremes constructed for India as a whole also indicates similar result. Both the A2 and B2 scenarios of the AR4 scenarios, downscaled by the PRECIS regional model, show similar patterns (albeit with slight differences) of projected changes towards the end of 21st century. Both extremes in maximum and minimum temperatures are expected to increase in the entire year, but changes in winter are expected to be prominent.

Stable carbon isotope analysis of fossil leaves of Pachypteris indica, Otozamite kachchhensis, Brachyphyllum royii and Dictyozamites species recovered from three sedimentary successions from the Bhuj Formation, Early Cretaceous in age, western India was carried out. A chronology was established based on faunal assemblage and palyno-stratigraphy and further constrained by carbon isotope stratigraphy. Intra-leaf δ13C variability was also investigated. The overall δ13C trend ranging from mid Aptian (ca. 116 Ma) to early Albian (ca. 110 Ma) shows a progressive increase in δ13C from −26.8 to −20.5‰. Based on these measurements, the carbon isotopic composition of atmospheric carbon dioxide of the Aptian-Albian period is estimated to be between −7.4 and −1.7‰. It is revealed that the Early Cretaceous plants adapted to the prevailing high carbon dioxide regime by increasing their photosynthetic uptake.

8.2 Cloud Physics

Observational Programmes

An aerosol observational campaign was conducted at Mahabaleshwar for two weeks during 8-21 February 2011. The instruments such as Sun/Sky Radiometer (AOD, SSA, phase function), Sun-photometer (AOD, PWC), Radiation Sensors (incoming solar and longwave), Aerosol High & Low Volume Sampler (Chemical characterization), Aethalometer (Black carbon), PM10 and PM2.5 collectors (Particulate matter up to 2.5 μm and 10 μm), Aerodynamic Particle Sizer (APS) (Aerosol number size distribution), GRIMM Aerosol Spectrometer (Aerosol mass distribution), Multi-Filter Rotating Shadow band Radiometer (Global, diffuse radiation, AOD, PWC), and Cloud Condensation Nuclei (CCN) Counter were operated at the campaign. The data are being analyzed to characterize the physical, chemical and optical properties of aerosol over the site.

Integrated Ground Observational Campaign (IGOC) was conducted from June 2011, at Mahabubnagar, 90 km SE of Hyderabad to understand coupling of boundary layer with the cloud layer. A total of 30 instruments were being utilized for taking observations of boundary layer, lower and middle atmosphere. C-Band Doppler Radar is in the operation from Mahabubnagar from 16 August for cloud monitoring. RS/RW and Tethered balloon flights are being conducted from Mahabubnagar at the time of aircraft flights. A 20 meter high tower has been installed for the boundary layer measurements of winds and turbulent fluxes at the IGOC site.

The flights were conducted during August-November

from Begumpet airport, Hyderabad by a research aircraft (Aero Commander 690) and a seeder aircraft (Thrush) for aerosol, cloud microphysical observations and randomized cloud seeding over the rain-shadow regions of north-peninsular India.

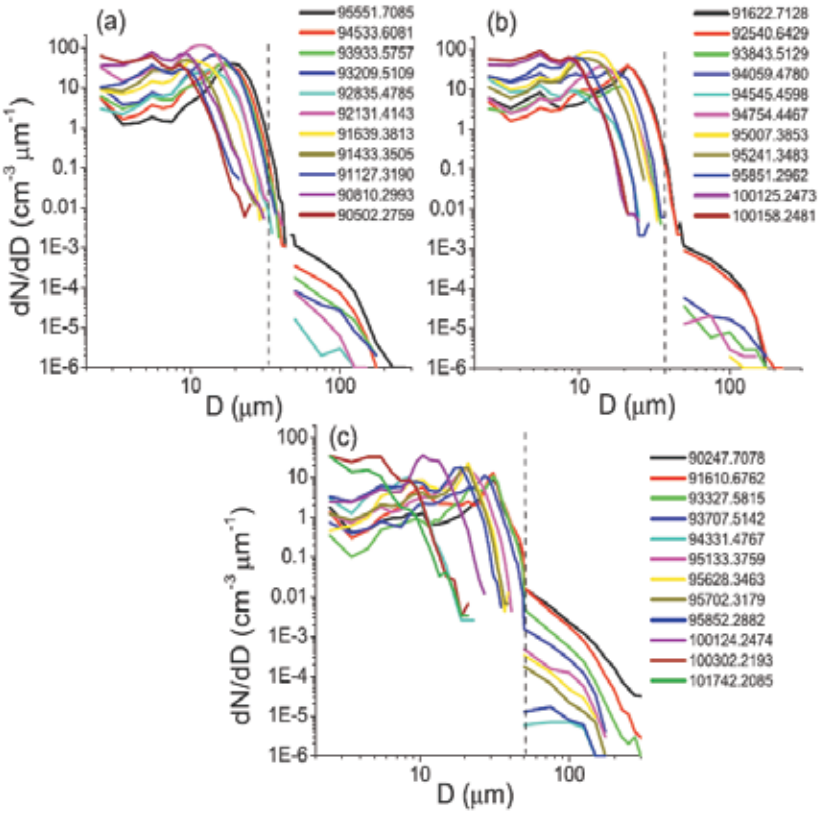


Figure 8.2: Average DSD observed for three CAIPEEX flights during monsoon transision, on (a)16, (b) 21, and (c) 22 June. Legends correspond to time (UTC: HHMMSS) and height(meters) of observations.

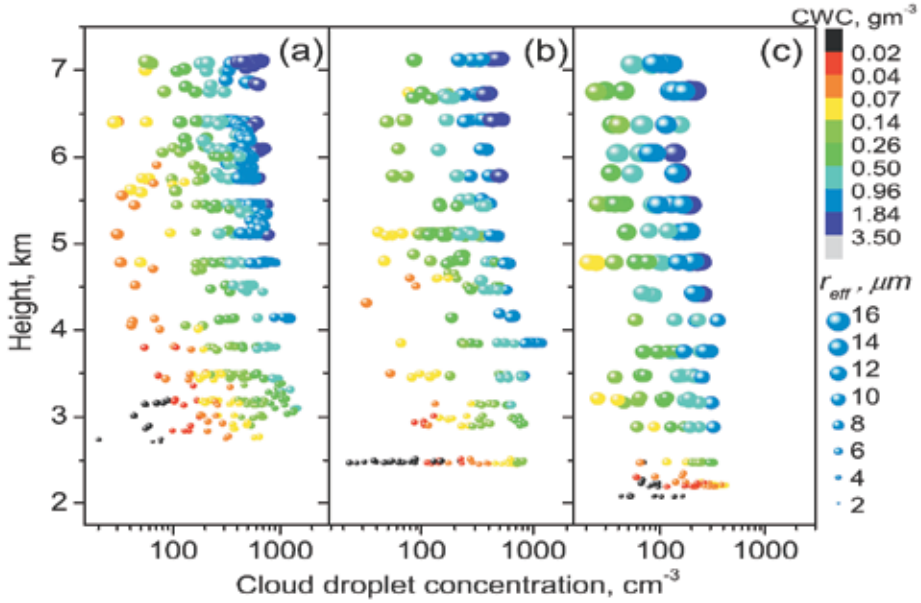


Figure 8.3: Microphysical parameters of clouds measured along airplane track on (a) 16, (b) 21, and (c) 22 Jun. Each symbol represents averaging over 1-s time increment. CWC (g m-3) is color coded; reff is given by size of symbols varying between 2 and 16 µm.

Microphysical structure of deep convective clouds in situ measurements over Indian peninsular region was analyzed. It is shown that droplet size distributions (DSD) in highly polluted pre-monsoon clouds are substantially narrower than DSD in less polluted monsoon clouds. High values of the DSD dispersion (0.3 to 0.6) and its vertical variation in the transient and monsoon clouds are related largely to existence of small cloud droplets with diameters below 10 μm which were found at nearly all height levels (Fig.8.2). Existence of a continuous generation of smallest droplets at different heights in the regions of high super-saturations is observed. In some cases, this generation of smallest droplets leads to formation of bi-modal and even multimodal DSD (Fig.8.3). Formation of bi-modal DSD is especially pronounced in monsoon clouds. It is suggested that in-cloud nucleation at elevated layers is a fundamental mechanism for producing multi-modal drop size distribution in monsoon clouds as well as in most deep convective clouds.

Environment Monitoring and Research

Multi-channel Sun Photometers having 5 channels have been installed at seven Global Atmospheric Watch (GAW) stations viz. (i) Pune (ii) Kodaikanal iii) Nagpur iv) Allahabad v) Jodhpur vi) Srinagar vii) Port-Blair.

Surface UV absorption Ozone Photometers have been installed at New Delhi, Ranichauri, Varanasi, Nagpur, Pune, Kodaikanal, Thiruvananthpuram, Port Blair, Guwahati, Maitri that determines ozone (O3) concentration by measuring the attenuation of UV light due to O3 in the absorption cell. Precipitation chemistry of the rain water is carried out through

(i) Chemical analysis for all precipitation samples of the year 2010 and partly of the year 2011 received from 11 GAW stations.
(ii) by participating in Laboratory Inter-comparison programme conducted by WMO, in April 2011.

Aerosol Studies

Quasi-periodic oscillations in the lidar backscatter signal strength due to aerosol fluctuations in the nocturnal boundary layer, studied with a high space-time resolution DPMPL and concurrent meteorological parameters over Pune, show a prominent periodicity of 20-40 min in lidar-observed aerosol variability and close association with those observed in the near-surface temperature and wind at 5 % statistical significance (Fig.8.4). The lidar aerosol backscatter signal strength variations at different altitudes indicate vertical propagation of these waves, exchanging energy between lower and higher height levels.

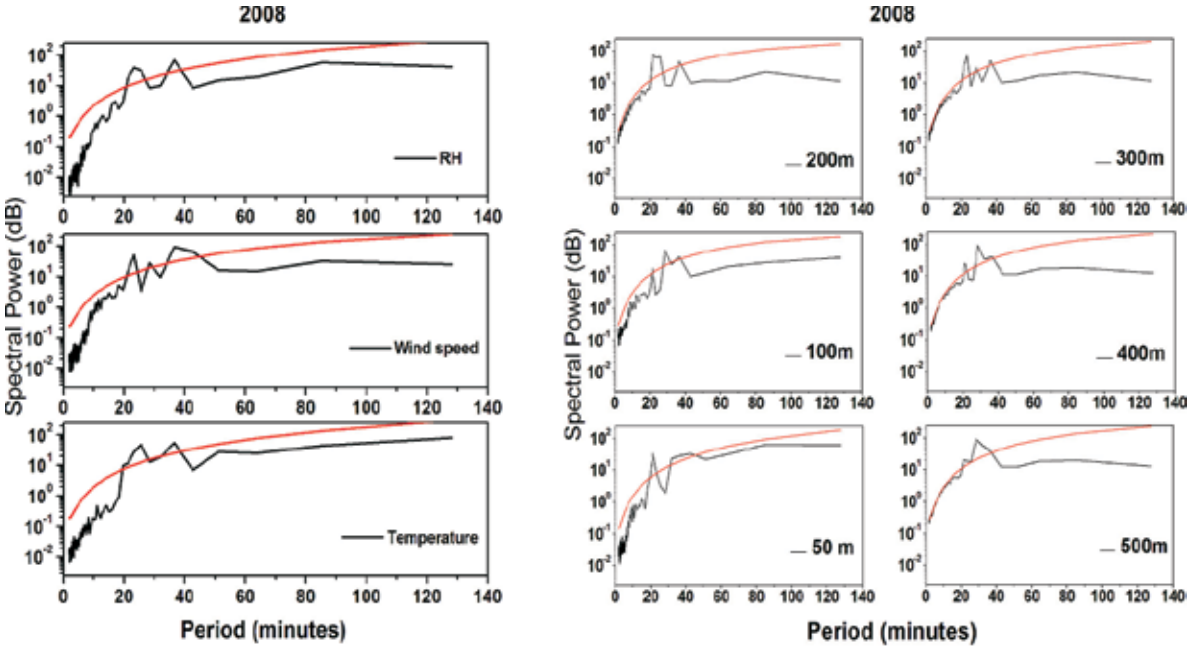


Figure 8.4: Composite spectral power for the surface temperature, surface wind speed and relative humidity for all the experimental days in 2008 (left panel). Composite spectral power for aerosol backscatter signal at 50 m, 100 m, 200 m, 300 m, 400m and 500 m, for all the experimental days in 2008 (right panel).

Diurnal variation of Black carbon (BC) during pre-monsoon was attributed to the changes in the local boundary layer as well as to the certain anthropogenic activities in and around Mumbai-Pune regions. BC aerosol mass concentration showed good correlation with temperature gradient and relative humidity in pre-monsoon. However, in post-monsoon, a weak correlation was observed with temperature gradient whereas with relative humidity, a good correlation was observed during night hours only. The wind speed and direction using NCEP/NCAR reanalysis data showed a possible transport from Pune city as well as from N/NE Indian regions during post-monsoon. BC also showed good correlation with other anthropogenic components of aerosols like non-sea salt sulphate (NssSO4), non-sea salt Potassium (NssK), NO3, and NH4; indicating a possible common source for them.

9 Disaster Support

9.1 Hydro-meteorological Services

As a part of this service, compilation of rainfall statistics, hydro-meteorological analysis of different river catchments for reservoir/command area development authorities and meteorological support for flood warning and flood control operations to field units of Central Water Commission are carried out. Design Storm Analysis, Rainfall Frequency Analysis and Quantitative Precipitation Forecast (QPF) are pursued regularly as a part of hydro-meteorological activities. Details of the activities are presented below:

i) Design Storm Studies are conducted to evaluate storm estimates (rainfall magnitude and time distribution) for 41 river catchments/ irrigation projects have been completed, for use as main input to design engineers in estimating flood flows on various rivers.

ii) District-wise Rainfall Monitoring is carried out to meet the requirements of planners, agricultural scientists, irrigation engineers, water management authorities, administrators and state agencies concerned with drought and flood. The rainfall statistics in form of reports and maps for the districts, sub-divisions, states, regions and for the country as a whole have been prepared.

- Weekly Rainfall Reports/maps ending every Wednesday
- Monthly and seasonal real-time rainfall reports/maps.
- Monthly and seasonal Updated rainfall reports/maps.
- Sub divisional rainfall statement/map during the monsoon season on daily basis.

The weekly reports also contain a comparative statement of rainfall for the corresponding week of last five years. The district-wise rainfall reports contained the statistics for all the 641 districts of India. The weekly progress report of rainfall scenario during 2011 with extra details about total no. of weeks with excess, normal, deficient and scanty & no rainfall, respectively, during the season was prepared and updated on IMD website.

iii) Flood Meteorological Service provides several inputs to the Central Water Commission (CWC). Efforts were also made in developing QPF model using rainfall products from different dynamical models over selected river basins during flood season and detailed analysis is carried out for the various temporal frequencies.

9.2 Thunderstorms, Squalls and Gusty winds Monitoring, Warnings and Nowcast system at IGI Airport Delhi

At IGI Airport, very high resolution meso-network of eight Integrated Auto Aviation Weather Observing Systems (IAAWS)/Visibility-Runway Visibility Range (RVR) measuring meters located at three runways of the Airport and Doppler Weather Radar (DWR) have been commissioned for continuously monitoring various aspects of severe weather developments in and around Delhi. All these products have been successfully utilized for rendering enhanced quality aviation support services, viz., thunderstorms, squalls and localized intense rain. Similar fog monitoring systems at Jaipur, Amritsar, Lucknow are expanded through the commissioning of RVRs for providing minute to minute fog information and its intensity. The current fog information and visibility data of nearly fifty airports of India updated at each 10-30-minutes intervals (http://121.241.116.157/Palam1.php).

Fog climatological information System consists of monthly fog climatology of number of days and hours, daily average total hours of occurrence, onset timings, dispersal timings, etc. computed based on different intensity of fog types with hourly visibility data corresponding to 1000m, 500m, 200m and 50m ranges of visibility for aviation purpose for December and January months since 1981.

These inputs have been helping the Airport Operator, ATC and Airlines operator for implementing an effective Fog mitigation preparatory plan well in advance during each winter.

Fog related information and forecasting have been disseminated to various user agencies mainly through IMD HQ Website in http://www.imd.gov.in with various us-

ers friendly suitable Sub-headers such as Fog Forecast, past RVR and Visibility, Current Visibility of IGI and METAR at IGI and alternate airports. Regular uploads of instantaneous Live RVR from various location of runways are also provided. The performance of fog forecasting system is given in Table 9.1

All RVRs of IGIA worked excellently during fog season of 2010-2011 and also its forecast system. Skill of Dense fog forecasts when visibility <200m) with a lead time of 12-18h. (Fig. 9.1)

9.3 Cyclone Warning Services

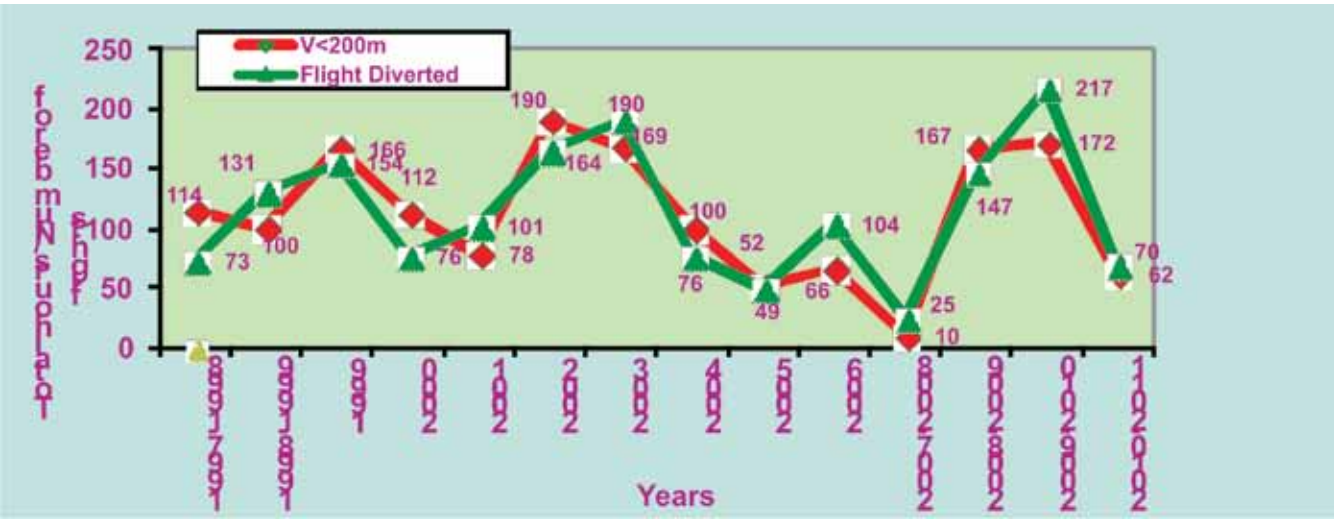


Figure 9.1: Fog Detection, Monitoring and Forecasting System of IGI Airport and its real time Performances in 2008-2011

Table 9.1 Performance Evaluation of Fog Forecasting System

Types	December			January		
	2008	2009	2010	2009	2010	2011
Bias for occurrences (Bias Score)	1.33	-	1.66	1.6	0.96	1.14
Critical Success Index (Threat Score)	0.56	-	0.60	0.51	0.84	0.88
Percentage Correct	74%	94%	94%	58%	81%	96%

9.3.1 Cyclonic Disturbances

The north Indian Ocean witnessed the formation of seven cyclonic disturbances including one in winter, three in monsoon and three in post monsoon season. Four systems have generated over the Bay of Bengal and three over the Arabian Sea. The lone cyclonic storm (KEILA) developed over the Arabian Sea during 29 October to 4 November and dissipated over west central Arabian Sea off the Oman coast.

The cyclonic activity has been subdued this year in terms of both genesis and intensity of cyclonic disturbances over the north Indian Ocean. There has been genesis of 8 systems against the normal of 13. It included only one cyclonic storm against the normal of five.

9.3.2 Significant achievements

i) The Standard Operation Procedure(SOP) manuscript for High Impact Weather Events has been prepared for operational use.

ii) With the cooperation of the WMO and Japan Meteorological Agency, Ensemble Prediction System (EPS) for track forecast of cyclonic disturbances over the North Indian Ocean is implemented. It has now the capability to assess the strike probability of cyclones and also the location specific probabilistic assessments.

iii) The average track and landfall forecast error of cyclonic storms during 2011 are presented in Table 9.2.

Table 9.2: Average track forecast error (km)

Systems	Basin of Formation	Landfall/ Dissipation	Lead Period (hr) & Corresponding Track error in Km.					
			12	24	36	48	60	72
Deep Depression (19-20 Oct 2011)	BOB	Crossed BDS coast near Cox's Bazaar	43 (3)	55 (1)	*	*	*	*
Cyclonic Storm 'KEILA'(29 Oct - 4 Nov 2011)	AS	Crossed Oman coast near Salalah, then emerged into WC AS	89 (4)	177 (4)	260 (3)	397 (3)	336 (1)	*
Deep Depression (6-10 Nov 2011)	AS	Dissipated over WC AS off Oman	69 (3)	111 (3)	238 (2)	349 (1)	*	*
Deep Depression (26 Nov to 1 Dec)	AS	Dissipated over WC AS off Oman	39 (6)	121 (6)	160 (6)	174 (6)	209 (4)	245 (2)
VSCS, THANE (25-31 Dec. 2011)	BOB	Crossed Tamil Nadu coast	43 (17)	77 (15)	129 (13)	160 (11)	175 (09)	181 (07)
Annual Average			49 (33)	103 (29)	162 (24)	208 (21)	196 (14)	195 (9)

* : Forecast not issued due to short life of the system; Figures in the parentheses indicate the number of six hourly forecasts verified based on 00, 06, 12 and 18 UTC observations

BOB : Bay of Bengal; AS : Arabian Sea; WC : West central; VSCS : Very severe cyclonic storm

Further, the landfall point and time forecast errors as well as track forecast errors have improved during 2011. Quantitative comparison of the 12 and 24 hr track forecast errors during 2003 and 2011 are presented in Figure 9.2. It clearly indicates the gradual improvement in the cyclone forecast over the years, as the error has decreased and the skill has increased. The average landfall error was less than the long period average error for the land-falling cyclones over the north Indian Ocean.

9.4 EARTHQUAKES

9.4.1 Seismic Microzonation

Seismic Microzonation of NCT of Delhi on 1:50,000 scale integrating several thematic maps, viz. geotechnical, geological, seismological and site

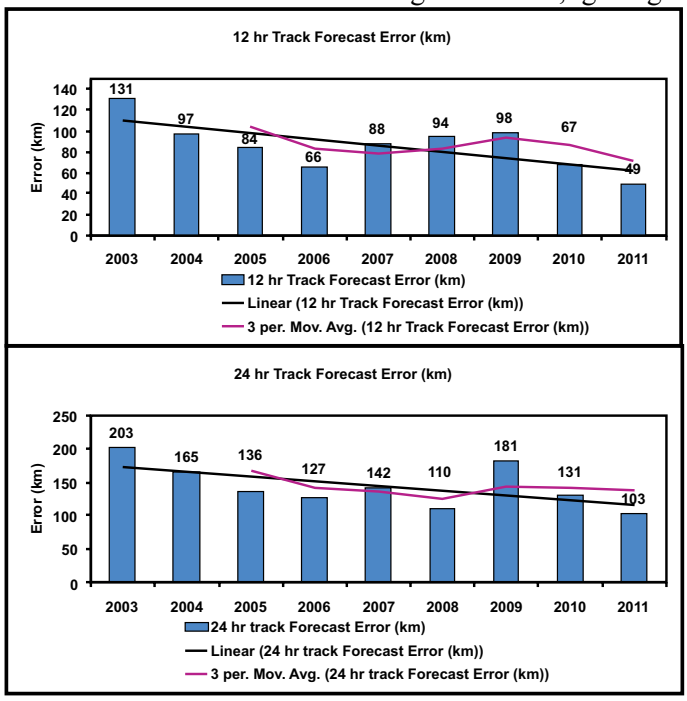


Figure 9.2: 12 hr and 24 hr cyclone track forecast errors of IMD during 2003-2011

response, etc. has been completed. Under the Seismic Microzonation of NCT Delhi on 1:10000 scale, the base and geological map on 1:10000 scale have been generated in collaboration with the Survey of India (SOI) and the Geological Survey of India (GSI) the nodal agencies. The first part of seismic microzonation that is seismic hazard evaluation at engineering bedrock has been completed in collaboration of IIT Roorkee and spectral acceleration maps for different period and different Probability have been generated.

In order to transfer seismic hazard to the surface through ground response analysis as a second part of the study, an intensive programme of geotechnical/geophysical data generation and analysis have been taken up. Geotechnical data generation by drilling boreholes, collecting soil samples at different depth at about 500 sites spread over the NCT of Delhi and laboratory analysis has been taken up and completed at 300 sites. Evaluation of shear wave velocity using geophysical techniques such as Cross Hole Techniques (CHT), Down Hole technique(DHT) and Multichannel Analysis of Surface Wave (MASW) have taken up at 125 sites spread over NCT of Delhi and completed at all sites.

Based on data analysis and interpretation of above generated data at about 125 sites, covering an area of 500 sq km of North Delhi, following thematic maps/products have been generated :

(a) Delineation of engineering bedrock and subsequent preparation of engineering bedrock depth map
(b) Simulation of time history of earthquake at engineering bedrock
(c) Generation of time history surface based on ground response analysis at each borehole location
(d) Peak Ground acceleration(PGA) at surface
(e) Amplification at different locations
(f) Frequency dependent Amplification
(g) Response Spectra at different sites
(h) Liquefaction Analysis at 0-3, 3-6,6-9,9-12 and 12-15 meter depth
(i) Generation of geodatabse of all the attributes for thematic map preparation.

9.4.2 Seismological Service

The National Seismological Network (NSN) consisting of 55 observatories and two V-SAT based telemetry clusters, one each in (i) Delhi and surrounding regions (16 stations) and (ii) Northeast India (20 stations) region for close monitoring of seismic activity in these regions is maintained.

The information on various earthquake parameters is transmitted to various user agencies including public information channels, press, media etc. using different modes of communication, such as SMS, fax, email, IVRS and also posted on IMD's Website (www.imd.gov.in and www. mausam.gov.in).

Major activities and accomplishments

i) A total of 3262 earthquake events have been detected and located during the period January-September, 2011. The events of magnitude 5 and above were 2120.

ii) The seismological data from all the network stations is being compiled, processed, analyzed and archived systematically at the National Seismological Database Centre (NSDC) on a regular basis.

iii) The Centre supplies earthquake data and seismicity reports of specific regions to insurance companies, industrial units, power houses, river valley projects and agencies dealing with relief and rehabilitation measures, earthquake disaster mitigation and management related matters, seismic zoning, etc.

iv) Monthly National Seismological Bulletins containing the phase data and he processed information on source parameters of all earthquakes are prepared regularly and supplied to International Seismological Centre (ISC), UK for incorporation in the ISC's Monthly Seismological Bulletins.

Sikkim Earthquake

An earthquake of magnitude 6.8 on Richter scale occurred on 18th September at 18:11h IST in the Sikkim-Nepal Border region with its epicenter at Latitude 27.7ºN and Longitude 88.2ºE. This event's occurrence was widely felt in Sikkim, Assam, Meghalaya, northern parts of West Bengal, Bihar and parts of other eastern and northern regions of India and caused extensive damage to property and loss of lives. The preliminary information on this earthquake was made available through SMS within about four minutes of the occurrence of the event. Subsequently, the information scrutinized by a seismologist was disseminated to the concerned agencies, through SMS in about 18 minutes of the occur-

rence of the earthquake. The information was also subsequently transmitted to all concerned agencies through FAX and also made available on IMD's website (www.imd.gov.in). The main shock was followed by several minor and a few significant aftershocks located by the national seismological network. So far, there have been 38 aftershocks in the magnitude range of 3.0-5.0 recorded till 23rd January, 2012. The latest aftershock occurred on 18th January, 2012 with a magnitude of 3.4. It is noted that the magnitude and frequency of aftershocks decreased with passage of time.

9.4.3 Seismicity and earthquake precursors

The aim of the programme is to provide added thrust to the earthquake related studies and to generate long-term, comprehensive multi-parametric geophysical database in seismically active areas to help in establishing possible correlation between various earthquake precursors and the earthquake occurrence as well as to understand the source processes.

A number of studies including precursory seismicity changes, seismicity patterns, focal mechanisms and precise focal depths using waveform inversion of earthquakes and also relocation of earthquakes through joint hypocentral determination approach have been carried out in the Koyna Warna region. Following are some significant results:

i) A preliminary three dimensional velocity model has been developed for the region. The network recorded ($0.5<M<4.5$) maximum seismicity concentration in SW of Warna Reservoir. These earthquakes were scattered in the shallow depth ranging from 3.0 - 7.0 km. Spatial and temporal characteristics of seismicity changes were examined. It was observed that the area had shown anomalous seismic activation and quiescence before the main earthquakes of $M \geq 4.8$. The foreshock study of all moderate sized earthquakes of $M \geq 3.5$, revealed that clustering of earthquakes in the magnitude range 1.0 to about 3.4 and presence of nucleation phenomenon was evident prior to all these earthquakes, in the zone near the Warna reservoir. The duration of nucleation varied from about 100 to 400h, whereas the absence of nucleation phenomenon is observed prior to all $M \geq 3.5$ earthquakes that occurred in the zones SW of Warna reservoir and near the Koyna reservoir. This shows that even in a small area like the Koyna-Warna region, earthquake patterns differ spatially and temporally. Two main types of faulting mechanisms govern the Koyna–Warna region are strike-slip and normal faulting. While most earthquakes in Warna have focal mechanism solutions of the normal type, the Koyna region seems to be controlled by the strike-slip mechanism.

ii) GPS measurements in the Indo-Burmese Wedge (IBW) suggest that subduction across this margin is no more active. About 43% of the India-Sunda plate motion is accommodated in the IBW through dextral slip on the Churachandpur Mao fault and does not lead to strain accumulation as it occurs aseismically. This is consistent with a general absence of great and major interplate earthquakes in the region.

iii) The local earthquake tomography and joint inversion of radial receiver functions and surface wave group velocity dispersion data of the Kachch region, suggest a highly altered lower crust (at 14-34 km depth), a 3-7 km Moho updoming, a 6-12 km lithospheric thinning and a thin lithosphere of (62.5±0.6) km thickness below the central Kachhch rift zone relative to the un-rifted surrounding regions (L~73.3±4.7 km).

iv) The analysis of the shield region, indicate low to moderate level seismicity with significant earthquakes are confined to the Godavari Graben, Narmada-Son, Koyna and Aravalli regions.

v) To delineate the offshore extension of Deccan Flood Basalt on the western continental margin of India, a database consisting of structural and tetconic features; P-wave seismic velocity data of western continental margin of India and adjoining onshore areas; bathymetry and satellite altimetry derived free-air gravity anomaly data has been created. Analysis of P-wave velocity datareveals that flood basalts is extended up to the Laxmi Ridge, except some isolated basement high. Thickness of basalt varies from ~0.3 to 2.0 km. The crustal model across the western continental margin of India and adjoing the Arabian Basin obtained from 2-D gravity modeling also corroborates with the above findings.

vi) Crustal model based on Gravity-Magnetic data in the NW part of India traversing the Ganga basin shows variation in Moho depth from 38km in the western part to about 70km beneath the Himalaya. The most significant is the upwarp in Moho and basement in the Ganga basin south of the HFT which represent the outer bulge resulting from flexural bending of the Indian lithosphere due to excess topographic mass of Himalaya. The joint analysis of residual gravity and magnetic anomalies has brought out shallow crustal structures such as the Jaisalmer-Ganganagar ridge coinciding with the Jaisalmer arch that extends to the Himalayan front and the epicentre of the Kangra earthquake of 1905 coincides with their intersection. It shows presence of Aravalli rocks below HFT and MBT at depth.

10 Extramural and Sponsored Research

10.1 Introduction

Research activities have been focused towards improving the various services of the country in earth, science for the societal benefit. A programme on R & D in Earth System Sciences has been launched for granting extramural 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 2011-12:

(i) Climate Change

• "Assessing the Impacts of Climate and Land Cover Changes on Hydrology' to be implemented by the University of Kashmir. The project proposal aims to study the linkages between hydrology, climate change and land cover/ land use for sustainable development of fresh water resources in the region using a coupled regional climate model.

(ii) Geoscience

• Geoscientific studies in parts of West Bengal coast and offshore inundation vulnerability assessment and coastal hazard preparedness funded to the Jadavpur University, Kolkata aims to generate geoscientific data on geological set up, topography, bathymetry, sediment character, tide character, etc. along the coastal belt of the Henry's Island and offshore region of north and east of the Jambudwip Island and the Pitt's creek. The data so collected will be useful in evolving scientific planning for micro level preparedness during and after coastal disasters.

• The proposal on "Petrology, Geochronology and Radiogenic Isotope Systematics of Distinct Proterozoic Mafic Dyke Swarms Emplaced within the Dharwar Craton: Implications for the Recognition of Large Igneous Provinces (LIPs) and Paleocontinental Reconstruction" to be implemented by the Banaras Hindu University aims to study the relationships between different mafic dykes exposed in the Dharwar craton and proposes a viable model for evolution of sub-continental lithosphere of the Dharwar craton.

(iii) Atmospheric Research

• Determination of the impact of the oxidizing capacity of the troposphere on the abundance of carbon monoxide and methane with special reference to India to be implemented by the National Physical Laboratory New Delhi.

• Cosmic Rays-Cloud-Climate Conundrum: Can Ion-Aerosol Near-Cloud Mechanism Explain the Observed Correlations? to be implemented by the IIT Kanpur aims to study the cosmic ray- cloud connection and its impact on climate through development.

(iv) Economic Benefits of Weather and Hazard Services

• Impact Assessment and Economic Benefits of Weather and Marine Services – Phase II" is being carried out by the National Council for Applied Economic Research (NCAER), Delhi. NCAER has carried out the socio-economic benefits of the (a) Aviation Service (b) Desalination (c) Lobster and Crab fattening (d) Ornamental fish. The study proposes to study the impact of these services in economic terms.

10.3 Specialized Labs as National facility

The following two facilities as National Facility for use by various researchers and Institutes have been supported.

• Accelerator Mass Spectrometry (AMS) Measurement facility for 14C at Inter-University Accelerator Centre under UGC. This facility will enable researchers from Indian Universities and research Institutes to study different aspects related to Earth Sciences which includes Paleo-oceanography, Tectonics and Paleo-seismology, Hydrology, Oceanography Glaciology, etc.

• Laser Raman Spectrometer at Center for Earth Sys-

tem Science, Trivandrum. The facility will be used to apply the Fluid Inclusion Technique for oil exploration through study of the palaeo fluids in the sediment fill of the Petroleferous Basins of the Western Offshore and to verify and compare the hydrocarbon potential of the offshore sedimentary formations of Mumbai offshore (proven basin) and the Kerala Offshore (unproven basin).

10.4 Building indigenous capability through Joint Developmental Projects with joint Funding

A joint collaboration between CDAC under DIT and NCMRWF/ESSO with equitable funding. The collaboration is expected to bring out the capability of the high performance computing cluster system developed by C-DAC in real time weather forecasting.

10.5 Human Resource Development & Capacity Building

NIAS, Bangalore: MoES has agreed to support National Institute of Advanced Studies (NIAS) with an annual grant for 5 years for carrying out its various research and development activities including the PhD programme involving interdisciplinary research with a blend of natural science and technology and social science and humanities.

IIT, Kharagpur: MoES has supported IIT, Kharagpur in establishment of a "Samudragupta MoES Chair" in the area of Earth System science and "James Rennell MoES Young Fellow" to encourage young faculty to carry out research in the related field. For this an MoU has been signed between MoES and IIT Kharagpur for a one-time grant as endowment fund for carrying out the activities of the Chair.

10.6 Progress of ongoing projects

(i) Text Book Series for graduate students in Earth Sciences: The proposal to be implemented by IIT Roorkee, aims to publish 14 text books on different aspects of Earth Sciences which are India – centric. Book writing of four out of the 14 text books have been written and will be published by the Geological Survey of India.

(ii) 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. Real Time Kinetic (RTK) Global Navigation Satellite System (GNSS) data was collected from near the 2008 breach site in February 2011 to quantify both the upstream and downstream topography around the breach site to investigate the threat. About 50% of the data collection has been completed using RTK GNSS on land and water and is being analysed to understand the avulsions in the river. Flood inundation map has been prepared using a numerical model. Analysis of structural and hydrological connectivity in the avulsion belt reveals four different types of connectivity in avulsion belt. Fifty percent data collection completed using RTK GNSS (Real time Kinetic Global Navigation Satellite System) on land and water.

(iii) Monsoon driven changes as preserved in marine sediments off the Gujarat and the Konkan coasts during the past 20K years being implemented by the IIT Kahragpur and the NCAOR, Goa is based on foraminiferal and geochemical proxies from deep-sea samples from the study area. 873 samples have been procured from NCAOR and processing of over 500 samples is complete and benthis foraminiferal data from 100 samples has been generated.

(iv) Development of a framework for systematic model diagnostics being implemented by the IIT Delhi. Under this a diagnostic framework is proposed to be built using modern programming tools such as CDAT based on Python programming language and implementing it in R & D Institutes of ESSO, NCMRWF and IMD. As a first step, the a matrix of code has been generated for producing the diagnostics of monsoon 2010 and this is being verified against the diagnostics produced by NCMRWF during the same season.

(v) "Research, Education & Manpower Development in the Discipline of Earth Processes" being implemented at the 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. Five labs have been established and 3 research projects have been undertaken using these facilities. Preparation for initiation of the MTech course in Earth Sciences has started.

(vi) The project on "Mesoscale modelling for monsoon related weather predictions -Phase II" under NIMTLI jointly funded by ESSO and CSIR has been completed. A 10 teraflop machine along with reconfigurable FPGA based FloSwitch has been commissioned in September 2011. Endurance test on 1024 Processors System has been carried out and the output of Varsha GCM is being sent to various Government agencies.

11 Awareness and Outreach Programmes

The participation in National and International exhibition by sponsoring grants to Seminars, Symposia, Workshop, various National Science Centers, National Council for Science Museum and State Council for Science and Technology to propagate and bring awareness about the programmes and achievements among the public, student and user communities are carried out."Earth Day" was also celebrated with the participation of school children, College and University students.

11.1 Exhibitions

ESSO participated in the following exhibitions:

1. **International Exhibitions:** "INMEX INDIA 2011" at Mumbai, International Conclave on "Climate Change (ICCC-1)2011" at Hyderabad, "7th International Conference on Asian Marine Geology (ICAMG-7)' at NIO, Goa.

2. **Indian Exhibitions:** "9th Infra Educa 2011" at Patna, Bihar, New Delhi and Agra ,"Science and Technology Expo-2010" at Dharmshala, HP in June 2011 (Fig 11.1), "Bharat Utsav", at Hyderabad (Fig 11.2), "17th All India National Expo-2011" at Kalyani West Bengal, "15th National Science Exhibition" on the theme of "Evolution of India as a Great Nation in the Twenty first Century" at Kolkata, "India R & D 2011" at New Delhi, "MTNL Health Mela" at New Delhi, Exhibition during Ministry's Foundation Day at Vigyan Bhawan, New Delhi.

Fig 11.1 "Science and Technology Expo -2010" at Dharmshala, HP

3. **Rural Exhibitions:** 6th Agro-Tech India-O-Gramin Shipa Mela 2011" at Sonar Pur Maidan, Kolkata, "2nd Vision Uttrakhand 2011" at Dehradun , "Yigyan Saksharata Utsav-2011" at Hisar, Haryana,. "Krishi Fair 2011" (A National Level Agricultural Exhibition) at Puri, Orissa in May 2011.

11. 2 Earth Day Celebration-2011

Earth Day is the largest, most widely celebrated international event. "Earth Day" was celebrated across the country on 22nd April 2011 and the event was organized at 32 locations across the country including schools, college and universities. The theme was Green Earth". The organizers were encouraged to arrange various competitions like drawing and painting, debate, essay, cycle rally amongst various age groups and cash prizes were offered to the students (Fig 11.3). Popular lectures by eminent scientists/local scholars on Earth Science related topics. A special issue on occasion of Earth Day 2011 covering Ministry's activities and popular articles by eminent scientists was published in a dedicated magazine "Geography & You" (in English) and Bhugol Aur Aap.

Fig 11.2 "Bharat Utsav", at Hyderabad

1st Prize winner in level I

1st Prize winner in level II

1st prize winner in level III

Fig 11.3 Prize winners for Earth Day Competitions

11. 3 Participation in International Earth Science Olympiad

An entrance test was conduct on January 23, 2011 to select 20 candidates for a training camp. A training camp on Earth Sciences held at the Centre for Earth Sciences, University of Hyderabad, Hyderabad, during May 5-24, 2011 and four students were selected to represent India at the International Earth Science Olympiad, Modena, Italy held on September 5-14, 2011.

11.4 Popularization on Television and Print Media

(a) 10 parts of series: Science Mein Twist in Science Safari juniors on the National Geographic Channel was screened.

(b) Production of Multimedia campaign on the following features on i) Agromet Advisory and district level forecasting, ii) Tsunami warning System, iii) Fishery Advisory, iv) Seismic Micronisation of select cities, v) Climate change models.

(c) Production of 48 minutes film on Climate change (Cutting carbon foot print) in the National Geographic Channel.

(d) A special issue on occasion of Earth Day 2011 covering ESSO activities and popular articles by eminent scientists was published in a dedicated magazine "Geography & You" (in English) and Bhugol Aur Aap

(e) Feature on the ESSO activities of the Ministry published in The Outlook, The Week & Geography & you, Bhugol aur app magazines and newspapers like Business standard, Sahafat, Awam-E-Hind etc.

11.5 Seminar, Symposia, Conference and Workshop

About 248 events were supported in area of Earth system science to provide platform to scientists, engineers, technologists. Experts, social scientists and user communities. The beneficiaries are Indian Institute of Technology/ Indian Institutes of Management, CSIR labs, universities, non governmental organizations, government bodies, etc.

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

ESSO activities are not confined to any specific area or region. Scientific community, throughout the world, is constantly putting efforts for the development of new analytical models and accumulation of scientific data. Accordingly international cooperation in this field needs to be developed so as to take advantage of the scientific research already accomplished and to get better results form the research models.

12.1 Cooperation with NOAA,USA

Following projects have been undertaken and the progress is given below.

South Asian Regional Reanalysis(SARR)

Pilot-phase experiments have been completed using conventional data for five years (1999-2003). Two parallel streams of assimilation experiments were carried out, one starting from 1999 and other from 2001 with an objective to estimate overlapping period. Assimilation runs are being extended further to accurately determine the required overlapping period. Systematic bias of the WRF modeling and assimilation system was evaluated and impact of satellite data (SSM/I retrievals) has been estimated. A research work on the impact of background error statistics on analysis and forecast in the context of SARR has been carried out.

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

A new moored buoy array in the historically data-sparse Indian Ocean provides measurements to advance monsoon research and forecasting. 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. Four research cruises were organized to deploy RAMA moorings in the Indian Ocean covering 65% of the RAMA array. 30 out of the 46 sites are operational and data from these is being regularly assimilated. The sub-surface profile is being assimilated into the Global Ocean Data Assimilation System (GODAS) at INCOIS and the initial conditions from the ocean model are provided to IITM to run their coupled ocean model. The Surface data is being assimilated at NCMRWF for use in the atmospheric General Circulation Model(AGCM).

Climate Modelling 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.

Climate Monitoring and Prediction System for South Asian Region

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

Tropical Cyclone Research

This involves development and implementation of a state-of-the-art NWP modelling system for accurate tropical cyclone track and intensity prediction for the Bay of Bengal and the Arabian Sea. The basic version of the model HWRFV (3.2+) operational at NCEP has been ported with nested domain of 27 km and 9 km horizontal resolution and 42 vertical levels with outer domain covering the area of 800x800 and inner domain 60x60. HWRF model was tested to run the model in cyclic mode. The model is presently being tested for experimental implementation during the post-monsoon cyclone season 2011.

INSAT 3D

This involves development and evaluation of algorithms and techniques for satellite-based precipitation

estimates, sea surface temperature, humidity and temperature profiles, ozone etc. using INSAT-3D satellite data over India.

Tsunami Science, Detection, Analysis, Modeling & Forecasting

This involves joint working towards improved capability to develop and sustain tsunami detection and analysis systems, and other early warning capabilities in meteorological, hydrological, oceanographic aspects that will assist in effective warnings and disaster mitigation.

Dynamical Seasonal Prediction of the Indian Summer Monsoon Rainfall (Establishment of Monsoon desk)

Indian and US scientists have been jointly working for improved monsoon prediction. To accomplish the same, a "Monsoon Desk" has been established. The Global Forecast System T574L64 model with a resolution of 22kms has been tested and implemented successfully. Validation studies are under way to see its capability under Indian conditions. The Climate Forecast System Version 2 has been ported and implemented at IITM.

12.2 Cooperation with UKMO, UK

The Global Unified Model (UM) N512L70 with a resolution of 25 km has been successfully implemented at NCMRWF and includes aerosol climatology. The regional version of the Unified model with upgraded physics was run during monsoon season and validation studies are being carried out. The U.K. Met Office (UKMO) 4D-VAR data assimilation scheme with Unified Model is being run along with assimilation of the Indian surface observations. The performance of the trial runs are being carried out.

12.3 India-US Cooperation on Weather and Climate Forecasting and Agriculture

Agro-Climatological and Water Resource Availability Modelling for Agricultural Management : A workshop on Agro-Climatological and Water Resource Availability Modelling for Agricultural Management, was held on March 22-23, 2011, at New Delhi to present and discuss state-of-the-art agro-climatology and water resources simulation. Based on the discussion, three demonstration projects namely (a) Agricultural cropland monitoring and determination of crop water productivity in India; (b) Applying satellite observations for current season agro-climatological monitoring: Predicting the impact of weather on food production; and (c) Modelling groundwater and surface water availability in an agricultural area, were finalized to be taken up under this cooperation.

12.4 Cooperation with NERC (Natural Environmental Regional Council)

Specific collaborative projects for the changing water cycle have been undertaken to achieve the various goals like (a) to develop an integrated, quantitative understanding of the changes taking place in the global water cycle, (b) to improve predictions for the next few decades of regional precipitation, evapo-transpiration, soil moisture, hydrological storage and fluxes, (c) to understand how local to regional scale hydrological and biogeochemical processes are responding and will respond to changing climate and land use (d) to understand the consequences of the changing water cycle for water-related natural hazards, including floods and droughts.

12.5 Cooperation with Badan Meteorologi Klimatologi Dan Geofisika (BMKG)

The identified areas of technical cooperation with BMKG are (i) Agromet advisory Service; (ii) Fishery Service (iii) Observing Systems (iv) Climate Change and (v) Tsunami Operations (v) Geophysics (vi) Instrumentation. A team of scientists from BMKG visited IITM Pune for training on the couple ocean model system.

12.6 Cooperation with Korea Meteorological Administration

ESSO-MoES and Korea Meteorological Administration during the period have worked for the joint development of skilful forecasting capabilities of various weather and climate related phenomenon as per the Agreement of Cooperation (MOU) signed on September 29, 2010.

12.7 Regional Integrated Multi-Hazard Early Warning System (RIMES) for Afro-Asian Region

India joined the Regional Integrated Multi-Hazard Early Warning System for Afro-Asian Region (RIMES) technical cooperation platform in its meeting held on 7th December, 2010. RIMES is a multi-lateral regional technical cooperation platform of 26 countries that came into existence formally on 30th April 2009 with the first

batch of 5 countries signed the Cooperation Agreement on the RIMES for Africa and Asia in consonance with Articles 5 and 25 of the United Nations. RIMES Secretariat is established by the Republic of Maldives at Maldives Meteorological Services, Ministry of Environment and Transport, Male. The RIMES Programme Unit and the RIMES Regional Facility are located at the Asian Institute of Technology Campus in Pathumthani, Thailand.

India has taken over the Chair of the RIMES Executive Council during March 2011. India has already attained regional leadership role in respect of providing Regional Tsunami Watch Provider (RTWP) status for the Indian Ocean since October 2011 by the IOC and our technical leadership shall expand to other multi-hazards (cyclones; floods; Tsunami and various coastal hazards etc.) as well in the region under the RIMES platform.

12.8 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 has been extended upto 2013. IOGOOS 8th annual meeting was held in Iran. Dr. T. Srinivasa Kumar has been nominated for the position of the chairman of IOGOOS. Mr. M. Nagaraja Kumar has been functioning as the Secretary of IOGOOS.

12.9 German Research Centre for Geoscience (GF2)

A Memorandum of Understanding (MoU) has been signed in January 2011with the German Research Centre for Geosciences (GFZ), on behalf of the International Continental Scientific Drilling Programme (ICDP) members, for taking the membership of ICDP.

As a preparatory study for drilling a deep borehole in Koyna region, an international workshop was held during 21-25th March 2011 at NGRI and Karad, where 26 international delegates from the USA, Japan, Germany, France, Italy, Poland, Taiwan, Canada and New Zealand, and 50 national delegates representing major earth science organizations participated for discussing and developing a full proposal for deep scientific drilling. A few key areas have been identified for detailed preparatory studies which would be critical in determining the accurate location for the deep borehole observatory in the region.

12.10 SIBER-IPO (International Programme Office for Sustained Indian Ocean Biogeochemical and Ecological Research)

SIBER is a basin-scale international programme to develop an enhanced understanding of the Indian-Ocean and its role in the global biogeochemical cycle. This programme is intended to provide scientific guidance and potential research focus to many countries, including Indian Ocean rim countries, interested in pursuing research activities in the Indian Ocean. To facilitate information sharing among various international programmes and to co-ordinate the activities pertaining to SIBER in the Indian-Ocean rim countries, an International Programme Office (IPO) has been established in December, 2010 at the Indian National Centre for Ocean Information Services (INCOIS) in Hyderabad, India as a part of the IOGOOS secretariat on the advice and guidance of the SIBER Science Steering Committee (SSC).

During the past one year the SIBER-IPO has made significant contributions to the SIBER community. It coordinated the 2nd SIBER SSC (SIBER-2) annual meeting, concurrent with the Indian Ocean Panel (IOP-8) and the INDoos Resource Forum (IRF-2) meetings during 25-29 July 2011 at Chennai. A new SIBER website (http://www.incois.gov.in/Incois/siber/siber.jsp) was also launched in June 2011.

13 Official Language Implementation

The Ministry is constantly working for promotion and propagation of the official Language. During 2011-12, efforts were made to promote the progressive use of Hindi.

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.

A Hindi fortnight was organized from 12th to 26th September, 2011. During the period, various competitions including Hindi essay writing, noting, drafting, debate, typing, quiz, Administrative Terminology and Hindi Knowledge and recitation were held.

20th National Scientific Hindi Seminar on the topic "Samudri Sampada Ki Khoj" was organized on 20th December, 2011 in New Delhi. Professor Samir K. Brahmachari, Director General, Centre for Scientific and Industrial Research (CSIR) was the Chief Guest. On this occasion, a Hindi book titled "Mausam Aur Jalvayu Ka Krishi Par Prabhav" was released.

Under the Prithvi Vigyan Mantralay Maulik Pustak Lekhan Yojana-2011 second prize worth ` 40,000 was given to the book titled 'Tsunami Leharon Ka Kahar' by Dr. Amit Garg.

GROUP	Representation of SCs/STs/OBCs (as on 1.1.2011)				Number of appointment made during the calendar year 2011											
					By Direct Recruitment				By Promotion				By Deputation			
	Total No. of employees	SCs	STs	OBCs	Total	SCs	STs	OBCs	Total	SCs	STs	OBCs	Total	SCs	STs	OBCs
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Group A	27	06	01	-	1	-	-	-	-	-	-	-	-	-	-	-
Group B	34	08	02	-	-	-	-	-	-	-	-	-	-	-	-	-
Group C (Including MTS)	50	13	02	07	-	-	-	-	3	1	1	-	-	-	-	-
TOTAL	111	27	05	07	1	-	-	-	3	1	1	-	-	-	-	-

GROUP	DIRECT RECRUITMENT								PROMOTION							
	No. of Vacancies reserved				No. of Appointments made				No. of Vacancies reserved				No. of Appointments made			
	VH	HH	OH	Total	In Identified Post	VH	HH	OH	VH	HH	OH	Total	In Identified Post	VH	HH	OH
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Group A	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Group B	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Group C Including MTS	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil

Note:-

(i) VH stands for visually Handicapped (Persons suffering from blindness or low vision)
(ii) HH stands for Hearing Handicapped (Persons suffering from hearing impairment)
(iii) OH stands for Orthopedically Handicapped (persons suffering from locomotor disabilities or cerebral palsy)

16 Citizen's Charter

The Citizen's Charter was reviewed by the Ad-hoc Task Force (ATF) set up by the Cabinet Secretariat. The charter has been fine-tuned as per suggestion and is given below.

The potential areas of services of the Ministry are :-

(i) Improve dissemination of weather forecast to various sectors like Agriculture, Aviation, Sports, Metro cities, defence, etc. Provide wide-range ocean information services for sectors like fisheries, shipping, navy, coast guard etc..

(ii) Develop technology for harnessing marine resources in a sustainable way.

(iii) Provide early warning on natural disasters like cyclone storm surge and Tsunami.

(iv) Assess the coastal and ocean marine living resources.

(v) To tune system with a view to encourage formulation of research and development schemes in the earth system science, create capacity building and promote human resource development by encouraging research.

(vi) To extend support to seminars, symposia, conferences etc. and process application for grants to organize seminars/symposium/conference.

(vii) To create awareness about earth system science sector by participation in educational programmes, exhibitions and trade fairs and through partnership with NGOs.

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 cast marine resource for the socio-economic benefit of the society. All the centres of ESSO have been directed to adopt the Citizen Charter in toto.

The total budget allocation for the Ministry of Earth sciences for the year 2011-12 was ₹1567 crore which includes ₹1220.00 crore for Plan Schemes and ₹347 crore for Non-Plan Schemes. The details of budget estimates and actual expenditure are given in the following table.

(₹. in crore)

Sl. No.	Major Head of Account	2009-10 Actual			2010-11 Actual			2011-12 Budget			Expenditure 2011-12 (upto December, 2011)		
	Revenue Section	Plan	Non-Plan	Total	Plan	Non-Plan	Total	Plan	Non-Plan	Total	Plan	Non-Plan	Total
1	3403- Oceanographic Reasearch	454.14	36.31	490.45	515.25	39.65	554.9	799.00	39.88	838.88	425.36	37.85	463.21
2	3425- Other Scientific Research	66.97	19.02	85.99	73.37	21.04	94.41	49.10	26.28	75.38	30.25	16.14	46.39
3	3451- Secetariate Expenditure	0.00	17.35	17.35	0.00	20.83	20.83	0.00	24	24.00	0.00	12.87	12.87
4	3455- Meteorology	36.30	251.81	288.11	51.06	245.01	296.07	88.8	255.74	344.54	45.97	202.33	248.30
	Capital Section												
1	5403 Capital outlay on Oceanograpic Research	26.53	0.00	26.53	13.16	0.00	13.16	16.50	0.00	16.50	1.97	0.00	1.97
2	5425- Capital outlay on Other Scientific & enviromental Research	0.00	0.00	0	0.00	0.00	0.00	3.40	0.00	3.40	0.00	0.00	0.00
3	5455- Capital Outlay on Meteorology	170.43	0.98	171.4	114.97	0.19	115.16	263.20	1.10	264.30	38.17	0.04	38.21
Grand Total		754.37	325.46	1079.83	767.81	326.72	1094.53	1220.00	347.00	1567.00	541.72	269.23	810.95

The number of Action Taken Notes (ATN's) pending for Ministry of Earth Sciences taken from various C&AG reports are given in the Table 18.1.

Table 18.1 ATN pending for MoES

Sl No.	Year	No. of Paras/ PAC reports on which ATNs have been submitted to Monitoring Cell after vetting by Audit	Details of the C&AG paras/PAC reports on which ATNs are pending			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	
1	1997	Para 3.1 CA 5 of 1997 "Infractuous expenditure on procurement of Polar Bear II"	NIL	NIL	NIL	NIL
2	2002	NIL	NIL	NIL	NIL	Para 6.2 CA 5 of 2002 "Avoidable Expenditure of Water Charges"
3	2007	NIL	NIL	NIL	NIL	Para 5.1 Report no. 2 of 2007 "Wasteful Expenditure"
4	2008	NIL	NIL	NIL	NIL	Para 7.1 Report no, CA 3 of 2008 "Non-achievement of the objectives of Modernizing the Accounting & Personnel Management Functions"
5	2008	NIL	NIL	NIL	NIL	Para 7.3 Report no. CA 3 of 2008 "Unfruitful Expenditure on in -house Projects in NIOT"
6	2008-09	NIL	NIL	NIL	NIL	Para 7.1 Report no. CA 16 of 2008-09 "Construction of Residential Quarters and Hostel Units without demand"

The Summary of the most recent and important audit observations; as made available by o/o C&AG; is given at Annexure -I to this chapter.

CHAPTER V : MINISTRY OF EARTH SCIENCES

5.1 Wasteful expenditure on refurbishment of a vessel

National Centre for Antarctic and Ocean Research did not effectively plan its requirements for hiring of a ship for its Antarctica expedition. As a result, it spent ₹43.68 lakh for refurbishment of a vessel which was ultimately not hired, rendering the entire expenditure wasteful. Ineffective planning also resulted in curtailment of objectives envisaged for the 27th Antarctica expedition.

National Centre for Antarctic and Ocean Research Goa (NCAOR), an autonomous unit under Ministry of Earth Sciences (MoES), had hired a vessel 'MV Emerald Sea' in October 2006 for Antarctica expeditions in 2006-07 and 2007-08. In June 2007, NCAOR decided to charter another vessel called 'MV Ivan Papanin' through Norwegian Polar Institute (NPI) from 20 January 2008 for another expedition to Antarctica. MV Ivan Papanin was to travel from Cape Town to Maitri (27th expedition) and was thus, in addition to MV Emerald which was hired exclusively for travel from Goa to Larsemann Hill[1] and back. The National Committee for Antarctic Programme (NCAP) for the 27th Indian Scientific Expedition to Antarctica, while according approval to the programmes in its meeting held in July 2007, also decided that the expedition to Maitri be totally delinked with the expedition planned to Larsemann Hills in order to provide sufficient working time to the members of both expeditions. The envisaged objective of expedition to Maitri was to continue important scientific assignments at Maitri, undertake glaciological research that has direct bearing on global warming and climate change studies as well as carry out ongoing scientific programs related to atmospheric science, meteorology and mapping biological diversity etc.

It was observed in audit that:

(i) NCAOR went ahead and hired MV Ivan Papanin without ensuring that adequate budgetary provision was available with it.

(ii) NCAOR directed NPI in August 2007 to execute refurbishing work on MV Ivan Papanin related to modification of seven additional cabins, upgradation for helicopter operations, etc., at an estimated cost of US $

[1] The Larsemann Hills is an ice-free area of 40 square km, located approximately halfway between the Vestfold Hills and the Amery Ice Shelf on the south-eastern coast of Prydz Bay, Princess Elizabeth Land, East Antarctica.

1.45 lakh[2]. Subsequently, in October 2007, NCAOR intimated NPI that as MV Ivan Papanin was capable of providing only limited helicopter operations from the deck, the expedition objectives would not be met and as such, it had decided not to hire MV Ivan Papanin. NCAOR, however, released payment of ₹43.68 lakh in December 2007 towards expenditure on refurbishing of the vessel.

(iii) Though NCAOR cited the limited operations of helicopters from the deck of the vessel as a reason for not hiring MV Ivan Papanin, the reason cited in the records of NCAOR was 'budgetary constraints'.

NCAOR, thus spent ₹43.68 lakh without ascertaining whether MV Ivan Papanin matched its requirement and also whether it had sufficient funds at its disposal for undertaking this expedition. This pointed to failure on part of NCAOR to plan its expedition effectively and its failure in ensuring adequacy of funds before undertaking the expedition. Ineffective planning also resulted in curtailment of objectives envisaged for the 27th Antarctica expedition.

NCAOR stated in May 2009 that MV Ivan Papanin vessel was engaged only to avoid hardships of the kind experienced during the earlier charter season for 2006-07, when MV Emerald reported outside of laycan[3] period and was also unprepared for the Antarctic voyage. NCAOR also stated that if the response from MV Emerald had been negative at the last moment, NCAOR would have been left with no time for arranging an alternative means of transporting the life sustaining cargo to Antarctica and consequences would have been disastrous and far-reaching, compromising the survival of men at Maitri. NCAOR further stated in June 2009 that by not going ahead with engaging MV Ivan Papanin, it saved an amount of ₹9.45 crore on charter fees.

The reply of NCAOR that MV Ivan Papanin vessel was engaged only to avoid hardships of the kind experienced during the earlier charter season for 2006-07 was incorrect. The scrutiny of documents relating to hiring of MV Ivan Papanin indicated that in case MV Emerald did not respond positively, another vessel i.e. Boris Petrav was to be kept as the standby vessel and not MV Ivan Papanin.

MoES stated in November 2009 that as the required funds were made available on earlier occasions at revised estimate stage, it planned to arrange

[2] ₹57.56 lakh at the conversion rate of ₹39.695 for 1 USD.
[3] An abbreviation of "layday cancelling date" and is used in a voyage charter party, referring to a designated period of time, or window, reserved for the execution of a specific operation.

another suitable expedition vessel to save time. It also agreed that as fund arrangements and planning did not match properly, it had to incur ₹43.68 lakh for refurbishing of the vessel and agreed that no savings of ₹9.45 crore was made by not hiring M V Ivan Papanin, as claimed by NCAOR earlier. It, however, assured that the corrective measures had already been taken to improve planning with regard to launching of various scientific expeditions to southern high latitude regions including Antarctica, to avoid any repetition of such situation in future.

19 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 adequate representation of minority communities while making recruitment or forming selection Committee set up for filling up of vacancies in Group A, B, and C has been ensured.

19.2 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, several national-level training courses training courses have been conducted.

19.3 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 for a within the stipulated period of time.

19.4 Vigilance Activities and Achievements

Shri D.P.Singh, Additional Secretary had been declared as Chief Vigilance Officer (CVO) of MoES in consultations with the Central Vigilance Commission. After his transfer, Dr S.K.Das (Scientist G) has been declared as CVO for MoES. 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 Officer and Vigilance Officers.

19.5 Grievance redressal of Public and Staff

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 redressal 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.

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.

19.6 Right to Information Act, 2005

Information about the activities of the Ministry and staff have been put on website. Central Public Information Officer has been nominated in respect of the Ministry and its attached/subordinate officers and autonomous institutes. Applications received under RTI Act 2005 are being promptly addressed to by the CPIO and information arranged / provided accordingly.

19.7 Parliamentary Matters

Between April and December 2011, the Ministry replied to Parliament Questions in Lok Sabha (38 questions) and Rajya Sabha (15 questions).

Strength of all groups of Ministry of Earth Sciences including all the constituents of Earth System Organisation is as below:-

Sl. No.	Groups of Post	MOES	NCMRWF	CMLRE	ICMAM	IMD	NIOT	NCAOR	INCOIS	IITM	TOTAL
1	Group A	79	46	10	11	460	36	87	37	141	907
2	Group B	47	21	04	05	4452	13	51	26	74	4693
3	Group C (Including MTS)	64	23	15	06	3501	23	26	-	136	3794
	Total	190	90	29	22	8413	72	164	63	351	9394

MOES	=	MINISTRY OF EARTH SCIENCES
NCMRWF	=	NATIONAL CENTRE FOR MEDIUM RANGE WEATHER FORECASTING
CMLRE	=	CENTRE FOR MARINE LIVING RESOURCES AND ECOLOGY
ICMAM	=	INTEGRATED COASTAL MARINE AREA MANAGEMENT
IMD	=	INDIA METEROLOGICAL DEPARTMENT
NIOT	=	NATIONAL INSTITUTE OF OCEAN TECHNOLOLGY
NCAOR	=	NATIONAL CENTRAL FOR ANTARCTIC AND OCEAN RESEARCH
INCOIS	=	INDIAN NATIONAL CENTRE FOR OCEAN INFORMATION SERVICES
IITM	=	INDIAN INSTITUTE OF TROPICAL METEOROLOGY

21 Awards and Honours

21.1 Awards

1. Vikram Sarabhai Memorial Award, Indian Science Congress : Dr.Shailesh Naik, Secretary (MoES); 'Remote sensing, geodata bases and digital mapping-2011-12'; Bhubaneshwar, 2012.

2. National Geo-science Award 2010, Ministry of Mines, Government of India :

   a. Dr. S. Rajan, Dr. D. K. Pandey and Dr. John Kurian, NCAOR; Ocean Development Field; Feb 2012.

   b. Dr. M. A. Atmanand, Dr. G.A. Ramadass, Dr. Sethuraman Ramesh, Shri Joseph Manecius Selvakumar, Shri Annamalai Subramanian, Dr. Dharmaraj Sathianarayanan, Shri Raju Ramesh, Shri Gopalkrishnan Harikrishnan, NIOT; 'Remotely operable submersible programme'; Oil & Natural Gas Exploration Field; Feb 2012.

   c. Mr. T. Srinivasa Kumar(INCOIS), Mr B.V.Satyanarayana (INCOIS), Dr. M. V. Ramanamurthy(NIOT), Mr. Tata Sudhakar(NIOT), Dr. G.Suresh (IMD), Mr. Ch. Patanjali Kumar (INCOIS), Ms.M.V.Sunanada (INCOIS), Mr.B. Ajay Kumar (INCOIS); for 'Setting up of National Tsunami Early Warning Centre'; Disaster Management Field; Feb 2012.

3. ISRO Team Award, 2008 : Dr. Shailesh Naik, Secretary (MoES); 'Snow and Glacier project'; December 2011.

4. Prof. C. Naganna Gold Medal, Mineralogical Society of India : Dr. Rahul Mohan, Scientist D, NCAOR; for contribution to 'Ecology of coccoilthophores in the Indian sector of the southern Ocean'; 2011.

5. 25th Biennial Mausam award (2008-09), IMD : Dr M. Mohapatra, H. R. Biswas and G.K. Sawaisarje, IMD; for their research paper entitled, "Daily summer monsoon rainfall over northeast India due to synoptic scale systems"; 2011.

21.2 Memorial Lectures

1. Pisharoty Memorial Lecture : Dr. Shailesh Naik, Secretary (MoES); 'Earth System Science: perspective'; Kerala Congress; January 29, 2012.

2. 2nd Prof. R. Vaidyanathan Lecture, Geological Society of India : Dr.Shailesh Naik, Secretary (MoES); 'Remote Sensing for Coastal Geomorphology'; Andhra University, Visakhapatnam; September 26, 2011.

3. 5th Prof. Prem Bahadur Verma Memorial Lecture, Indian Geological Congress : Shri Rasik Ravindra, Director, NCAOR; Panjab University; 3rd February 2012.

4. Dr. H.N. Siddiquie Memorial Lecture–2011, Indian Geophysical Union: Dr.S.S.C. Shenoi, Director, INCOIS; citation and gold medal; 2011.

21.3 Fellowships

1. Indian Society of Remote Sensing : Dr. Shailesh Naik, Secretary (MoES); elected Fellow; 2011

2. Academy of Science, Engineering and Technology : Dr. V.N.Sanjeevan, Director, CMLRE ; awarded Fellow; 2011.

21.4 Convocation address and others

1. Andhara University, Visakhapatnam : Dr. Shailesh Naik, Secretary (MoES); received degree 'Doctor of Science'; June, 2011.

2. 48th Convocation, Shivaji University, Kolhapur : Dr. Shailesh Naik, Secretary (MoES); addressed convocation; January 25, 2012.

3. 79th Convocation, Annamalai University, Tamil Nadu : Dr. Shailesh Naik, Secretary (MoES); addressed convocation; 'Climate Change and Humanity'; November 9, 2011.

21.5 Exhibitions

1. Swasraya Bharat - 2011 Exhibition : INCOIS, Hyderabad; 2nd position; at Kochi; December 15-20, 2011.

2. Exhibition at 26th Indian Engineering congress: NIOT, Chennai; Best exhibitor award; at Bangalore; December 2011.

Atmospheric Science

1) Acharya N., Kar S.C., Mohanty U.C., Kulkarni M.A. & Dash S.K. (2011) Performance of GCMs for seasonal prediction over India- a case study for 2009 monsoon. Theor. Appl. Climatol, DOI 10.1007/s00704-010-0396-2

2) Balakrishna G., Pervez S., Bisht D.S., Source apportionment of arsenic in atmospheric dust fall out in an urban residential area, Raipur, Central India, Atmospheric Chemistry and Physics, 11, June 2011, 5141–5151 (Impact Factor 4.881)

3) Bhowmik S. K. Roy, Kumar Anupam and Das Ananda K., "Real-time mesoscale modeling for short range prediction of weather over Maitri region in Antarctica", MAUSAM, 62, 4, 535-546.

4) Borgaonkar H.P., Sikder A.B., Somaru Ram, High altitude forest sensitivity to the recent warming: A tree-ring analysis of conifers from Western Himalaya, India, Quaternary International, 236, April 2011, 158-166 (Impact Factor 1.601)

5) Budhavant K.B., Rao P.S.P., Safai P.D., Ali K., Influence of local sources on rainwater chemistry over Pune region, India, Atmospheric Research, 100, March 2011, 121-131 (Impact Factor 1.811)

6) C. S. Patil, "A study on water consumption, water use efficiency and crop coefficient of groundnut", MAUSAM, 62, 1, 73-76.

7) Chakravarty K., Mukhopadhyay P., Taraphdar S., Cloud microphysical properties as revealed by the CAIPEEX and satellite observations and evaluation of a cloud system resolving model simulation of contrasting large scale environments, Journal of Atmospheric and Solar Terrestrial Physics, 73, August 2011, 1790-1797 (Impact Factor 1.643)

8) Chate D.M., Below-thunderstorm rain scavenging of urban aerosols in the health hazardous modes, Natural Hazards, 56, January 2011, 81-91 (Impact Factor 1.217)

9) Chate D.M., Murugavel P., Ali K., Tiwari S., Beig G., Below-cloud rain scavenging of atmospheric aerosols for aerosol deposition models, Atmospheric Research, 99, March 2011, 528-536 (Impact Factor 1.811)

10) Debaje S., Jeyakumar S.J., High ozone at coastal sites in India, International Journal of Remote Sensing, 32, February 2011, 993-1015 (Impact Factor 1.089)

11) Deo A.A., Ganer D. W., Nair G., Tropical cyclone activity in global warming scenario, Natural Hazards, online, April 2011, DOI 10.1007/s11069-011-9794-8, 1-16 (Impact Factor 1.217)

12) Deshpande N.R., Kulkarni A., Krishna Kumar K., Characteristic features of hourly rainfall in India, International Journal of Climatology, online, July 2011, 1-15 (Impact Factor 2.347)

13) Devappa V. M., Khageshan P. and Mise S. R., "Long term assessment of southwest monsoon drought events at Taluka levels in Gulbarga district of Karnataka, India", MAUSAM, 62, 3, 449-456.

14) Devara P.C.S., Sonbawne S.M., Dani K.K., Saha S.K., Raj P.E., Characterization of aerosols and pre-cursor gases over Maitri during 24th Indian Antarctica Expedition, International Journal of Remote Sensing, online, July 2011, DOI:10.1080/01431161.2010.507681, 1-13 (Impact Factor 1.089)

15) Dugam S.S., Bansod S.D., Role of mid-latitude westerly trough index at 500 h Pa and its association with rainfall in summer monsoon over Indian region, Earth Science India, 4, April 2011, 49-56 (Impact Factor 0.000)

16) Duraisamy M., Bhowmik S. K. Roy and Bandyopadhyay B. K. , "An objective method for predicting occurrence of pre-monsoon (March- May) thunderstorm events over Delhi using stability indices", MAUSAM, 62, 3, 329-338.

17) Dutta S., Narkhedkar S.G., Sikka D.R., Sunitha Devi, Dynamical comparison between two recent drought southwest monsoon seasons 2002 and 2009 over India, Mausam, 62, April 2011, 133-144 (Impact Factor 0.203)

18) Dutta, Surya K., V. S. Prasad, 2011: 'Impact of Gridpoint Statistical Interpolation Scheme over Indian Region'; In Press Journal of Earth System Sciences.

19) Fadnavis S., Beig G., Buchunde P., Ghude S.D., Krishnamurti T.N., Vertical transport of ozone and CO during super cyclones in the Bay of Bengal as detected by Tropospheric Emission Spectrometer, Environmental Science and Pollution Research, 18, February 2011, 301-315 (Impact Factor 2.411)

20) Fadnavis S., Buchunde P., Ghude S.D., Kulkarni S.H., Beig G., Evidence of seasonal enhancement of CO in the upper troposphere over India, International Journal of Remote Sensing, online, August 2011, DOI: 10.1080/01431161.2010.523733, 1-12 (Impact Factor 1.089)

21) Fadnavis S., Chakraborty T., Ghude S.D., Beig G., Raj P.E., Modulation of Cyclone tracks in the Bay of Bengal by QBO, Journal of Atmospheric and Solar Terrestrial Physics, 73, August 2011, 1868-1875 (Impact Factor 1.643)

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23 Abbreviations

AVHRR	Advanced Very High Resolution Radiometer
BoB	Bay of Bengal
CAS	Centre for Atmospheric Sciences
CCM-3	AGCM Atmospheric General Circulation Model
CMAP	CPC (Climate Prediction Centre) Merged Analysis of Precipitation
C-MMACS	Centre for Mathematical Modeling 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
HC	Heat Content
HLL	Hindustan Lever Limited
IAST	International Argo Steering Team
IISc	Indian Institute of Science
IIT	Indian Institute of Technology
IITM	Indian Institute of Tropical Meteorology
IMD	India Meteorological Department
INDOMOD	Indian Ocean Modelling and Dynamics
IO	Indian Ocean
IOC	Intergovernmental Oceanographic Commission
IOD	Indian Ocean Dipole
IODE	International Oceanographic Data Exchange
IOGOOS	Indian Ocean Global Ocean Observing System
IOM	Indian Ocean Model
IOP	Indian Ocean Panel
ISRO	Indian Space Research Organisation
IRS	Indian Remote Sensing Satellite
ITWC	Interim Tsunami Warning Centre

KPP	K-Profile Parameterisation
LTTD	Low Thermal Temperature Desalination
MDT	Mean Dynamic Topography
MLD	Mixed Layer Depth
MODIS	Moderate Resolution Imaging Spectroradiometer
MOM	Modular Ocean Model
NCEP	National Centre for Environmental Prediction
NCMRWF	National Centre for Medium Range Weather Forecasting
NIO	North Indian Ocean
NIO,Goa	National Institute of Oceanography, Goa
NIOT	National Institute of Ocean Technology
NOAA	National Oceanic and Atmospheric Administration
NODC	National Oceanographic Data Centre
NPOL	Naval Physical Oceanographic Laboratory
NRSA	National Remote Sensing Agency
NW	North West
OCM	Ocean Color Monitor
OGCM	Oceanographic General Circulation Model
OOIS	Ocean Observations and Information System
PBL	Planetary Boundary Layer
PFZ	Potential Fishing Zone
PO	Pacific Ocean
POGO	Partnership for Observation of Global Ocean
POM	Princeton Ocean Model
PWD	Persons with Disabilities
RDBMS	Relational Data Base Management System
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 Organization