Annual Report
2013-2014

Earth System Science Organization
Ministry of Earth Sciences
Government of India

Contents

OVERVIEW

1.1 INTRODUCTION

The Earth behaves as a single, interlinked and self-regulating system. Its components, viz. atmosphere, oceans, cryosphere, geosphere and biosphere, function together and their interactions are complex and significant. The earth system science is a science of national importance. The scientific understanding of the earth system helps to improve prediction of climate, weather and natural hazards as well as explore the polar regions and sea bed and afford sustainable use of resources. The agenda for the earth system science in the country includes promotion of discovery to provide new perspective on earth systems, better understanding of earth processes and apply this knowledge for sustainability of the Earth and develop services for the societal benefits.

The Earth System Science Organization (ESSO) was established in October 2007 with the objective to provide the nation with the best possible services for monsoons, weather, climate, oceans and natural hazards. A framework has been created for understanding the complex interactions among the key elements of the Earth system, namely ocean, atmosphere, cryosphere and solid earth. The weather and climate services cater to a variety of sectors like agriculture, aviation, water resources, shipping, sports, etc; 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, climate change and underwater technology. The policies and programmes of the ESSO

are largely being pursued through its centres, viz. India Meteorological Department (IMD), Indian Institute of Tropical Meteorology (IITM), National Centre for Medium Range Weather Forecasting (NCMRWF), National Centre for Antarctica and Ocean Research (NCAOR), National Institute of Ocean Technology (NIOT), Indian National Centre for Ocean Information Services (INCOIS), Centre for Marine Living Resources (CMLRE) and Integrated Coastal and Marine Area Management (ICMAM).

This year, the Centre for Earth Science Studies (CESS), an Institute under the Kerala State Government, Council of Science & Technology and Education (KSCSTE) has been taken over by ESSO-MoES to strengthen solid earth component. The National Centre for Seismology has been formed to focus on earthquake research.

By all measures, the year, 2013-14 has been the most challenging, eventful and productive year for various endeavors of the ESSO-MoES. During the year, the country witnessed a number of natural disasters such as tropical cyclones like the *Phailin,* the *Helen,* the *Lehar,* the *Mahasen, the Madi* and extreme weather events like heavy rainfall over Uttarakhand and Gujarat. The challenging task of issuing weather forecasts and advisories has received an overwhelming appreciation (**See the BOX-1**). The general improvement in weather and climate services in the country has been achieved through augmentation of observational network, improvements in data assimilation methods, weather and climate models and forecasting.

BOX-1

On the success of weather services provided by the ESSO-MoES

"Our advances in meteorology were evident during the recent cyclone in Odisha, when we received accurate forecasts of the landfall point that were more accurate than the forecasts of well known international bodies. Our decision to set up a new Ministry of Earth Sciences following the Indian Ocean Tsunami in 2004 and to invest in world-class tsunami forewarning systems in 2007 has been amply rewarded. We now have the ability to issue alerts within 13 minutes of a tsunami-genic event. This has established India's scientific leadership in the Indian Ocean region.

I would also like to see continuous improvement in our monsoon prediction capability through the recently launched Monsoon Mission so that we avert the kind of calamities that we saw in Uttarakhand last year. "

Dr Manmohan Singh

Hon'ble Prime Minister

At the Indian Science Congress, Jammu, 2014

The details of various programs are elucidated below:

1.2 ATMOSPHERIC SCIENCE AND SERVICES

Global Modelling:

The data assimilation scheme of the Global Forecast System (GFS) has been upgraded to include a new version of the Community Radiative Transfer Model (CRTM). The data assimilation capacity has been increased from 2 GB to 20 GB during the year. It is now capable of assimilating new satellite datasets such as Metop-B, GEOS-14, GEOS-15 and GPS refractivity. Probabilistic forecasts of quantitative precipitation from the 21 member Global Ensemble Forecast System (GEFS; T190L28) have been made operational and are available on www.ncmrwf.gov.in. Thus, quantitative estimates of the reliability of forecasts in various precipitation ranges are generated. The track and intensity forecasts for Tropical Cyclone "Mahasen" based on GEFS were generated. The 72 hour forecast track errors by the probabilistic forecasts showed about 30% improved skill over the deterministic forecast.

In a pilot study, 72-hour forecasts of wind at 50 and 100 m have been generated. Preliminary results show that for a wind farm located in Tamil Nadu, the actual power generation lies within 30% of the wind power generation forecast schedule. One of the important milestones has been the implementation of high-resolution meso-scale data assimilation for improved operational weather forecast services such as agro-meteorological, aviation, location specific/city forecasts and hydrological for high-impact localized weather phenomena. Operational dynamical prediction system was used to provide global monthly and seasonal forecasts for rainfall and temperatures.

Augmentation of meteorological services:

Currently, atmospheric observations such as maximum and minimum air temperature, wind speed and direction, humidity, rainfall, cloud cover, etc. are

available through weather radars, automatic weather stations, automatic rain gauges (1600 platforms), etc. and satellite and aircraft based platforms. High quality GPS based upper air systems have been installed at 11 stations namely Chennai, Hyderabad, Vishakhapatnam, Goa, Amini, Thiruvananthapuram, Minicoy, Patna, Mohanbari, Portblair, Srinagar. A roadmap was finalized for implementation of the Integrated Himalayan Meteorology Programme to improve mountain weather and climate monitoring and forecast services over the Himalayan region. The data from the new INSAT-3D, launched on 26 July, 2013 are being used to generate various new satellite products with improved resolution. Atmospheric profiles of temperature and humidity are derived from the INSAT-3D sounder data.

The Ensemble based Meteograms (EPSgram), which are a probabilistic interpretation of the forecasts were generated for 33 major cities of India. The ten day EPSgrams display the time evolution of the distribution of several atmospheric parameters, viz. temperature and relative humidity, winds, and six hourly accumulated rainfall.

Cyclone Forecast: Remarkable improvement has been achieved in the skill of forecasts for cyclone track and landfall for Tropical Cyclones over the north Indian Ocean. The genesis, forecast for intensity, track and landfall and heavy rainfall, gale wind and storm surge associated with the tropical cyclone PHAILIN were predicted with great accuracy (See Box 2). These accurate predictions helped the state governments to plan mitigation efforts to save human life and to minimize the losses to properties.

BOX-2

On Successful Prediction of Tropical Cyclone Phailin

"Warm Congratulations on the way that the recent cyclone was handled by MoES and IMD. TV and other media could be a powerful platform for keeping in touch with the people whenever such events are likely to occur. So, I was very happy to see that has now happened. I must particularly congratulate all ESSO-MoES scientists on the very professional way in which the predictions were made and constantly updated, on the quality of graphics and on the apparently effective way in which coordination with the local administrations managed."

Prof. Roddam Narasimha, F.R.S

Hon Professor,

Jawaharlal Nehru Centre for Advanced Scientific Research

Bangalore

Monsoon Mission:

The Monsoon Mission is aimed to improve the monsoon weather and climate forecasts in the country. The Mission's goal is to improve the skill of (i) Seasonal and Extended Range

Monsoon: The monsoon variability is quite complex both spatially and temporally. Seasonal forecasts for monsoon rainfall are provided with fairly good accuracy. The prediction skill of active and break cycles has been improved. Monsoon mission has been launched to further

improve, short-term, medium-range, extended range and seasonal scale prediction of rainfall. Under the monsoon mission, the NCEP CFSv2.0 model was adopted for extended to seasonal forecasts and the UK Met office Unified model was adopted for short to medium range forecasts. Efforts are to identify strength and weakness of these models and incorporate new physics/parameterization schemes to improve the simulations/prediction skill of the monsoon rainfall. The ultimate goal of the mission is to develop improved models, which will have the capability to better simulate and predict the monsoon rainfall in all time scales. On an experimental basis, the coupled dynamical model (CFS V2.0) was run on real-time basis for the operational forecast for the 2013 monsoon rainfall, which was proved to be accurate. The model forecast indicated 104% of its long period average while the observed monsoon seasonal rainfall was 106% of its long period average.

Quantitative Precipitation Forecast (QPF) is provided for flood forecasting for different river basins. Customised forecasts for expeditions, adventure sports, pilgrimage, etc. are generated. Aviation services are provided for Delhi, Mumbai, Kolkatta and Chennai as well as 70 other airports in the country. The Air Pollution Monitoring and Forecasting System has been taken up to provide base line air quality and pollution forecasting in Delhi. Such a system has been recently installed and commissioned in Pune on 1 May 2013. Severe weather events such as dust storms, extremely heavy rainfall, cloud burst, fog, Nor'westers, etc. affect different parts of the country regularly. Efforts have been initiated to develop forecasting system for such extreme weather events.

Agro Advisory and other Services: The district-level Agromet Advisory Bulletins, being issued in 12 languages have been extended to 600 districts covering a five day weather forecast along with crop-specific advisories for carrying out agricultural practices is being provided to 5 million farmers. The impact of this service on GDP is ₹ 50,000 crores. Under the Gramin Krishi Mausam Sewa, agromet advisory services are generated at block level on a pilot mode.

1.3. CLIMATE CHANGE RESEARCH

The increased trend of global temperatures in the recent decades has focused attention of the scientific community on the specific aspect of global climate and regional monsoon variability in a changing climate. Addressing this issue involves research and development of an Earth System Model (ESM), together with comprehensive assessment of various interactions among different Earth System components. The first version of the Earth System Model consists of T126L69 atmospheric model coming from the NCEP GFS coupled to the MOM4P1 Ocean Model. It also contains an active sea-ice model. More than 100 years free integration has been already done using the model. The model has shown a good representation of the present global climate and short term variability. Using this model, the high resolution climate change scenarios have been developed for the 21st century.

The High-Altitude Cloud Physics Laboratory (HACPL), Mahabaleshwar has completed one year of observations of cloud physics and aerosol. X-Band and Ka-Band Radars have been deployed at Mandhardev in co-location with each other for spatial/ temporal distributions of precipitation and clouds respectively.

1.4. OCEAN OBSERVATIONS

Ocean observations, viz. temperature and salinity profiles, currents as well as marine meteorology parameters, are accomplished through moored and drifting buoys, HF radars, current meter moorings, automatic weather stations on ships, autonomous vehicles, remotely operable vehicles, etc. Physical and bio-geo-chemical time-series measurements at the existing stations (Goa, Mangalore, Kochi,

Parangipettai, Visakhapatnam and Gopalpur) were continued and three more stations (Veraval, Chennai and Sundarban) were added to the network. The total number of active Agro floats in the Indian Ocean has gone up to 700 in the Indian Ocean. Totally, 30278 temperature and salinity profiles pertaining to the Indian Ocean were archived in the past one year. All the data related to ocean have been organized and can be accessed through web. INSAT based communication for transmission of oceanographic data was established for some of the ocean observing systems. Project specific data centres for CTCZ and Geotraces-India were hosted.

1. 5.   OCEAN SCIENCE AND SERVICES

A new data service was launched for dissemination of products on global ocean analysis in near real time using Near Real Time (NRIG) from April 2013 onwards. The NRIG service is based on the improved version of the Global Ocean Data Assimilation System (GODAS). In GODAS, in-situ temperature and salinity profiles obtained from GTS are assimilated in the ocean general circulation model (Modular Ocean Model, MoM4p0d) to generate the analysed fields of temperature, salinity and circulation on a daily basis. At present, the analysis results are available with a delay of 2 days.

Information and Advisory Services (O-IAS): Daily issue of PFZ advisory services was initiated and recorded a phenomenal growth in the dissemination to increased number of landing centres. Sea state forecasts were provided to the users during the passage of the very severe cyclone, Phailin. Ocean State Forecast is now being provided in Malayalam in Kerala as well using various modes such as SMS, Village Resource Centres (VRCs) and the Public Address System. The redesigned web pages have been updated which allow the users to generate desired maps of OSF products using 'Web Map Services'. The bi-lingual Content Management System for ocean

data and information system was launched to ensure the uniformity in the web pages, system compatibility and is now available in bilingual pages (English and Hindi).

Indian Tsunami Early Warning Centre:

A state-of-the-art tsunami warning system was set up in October 2007. The system is capable of providing advisories about travel time, and run up height at 1800 coastal forecast points within 10 minutes to all concerned within India and the Indian Ocean Rim countries. The ITEWC had monitored 65 earthquakes of magnitude   6.0 Mw during the period April 2013- March 2014.

Ocean Modelling: A finite element based ADCIRC model has been successfully installed on HPC and conFig.d for the east coast of India for prediction of storm surges. The storm surge model was run on real time for the Mahasen and the Phailin cyclonic storms and the results were in good agreement with ground observations. As a pilot project, a high resolution coastal model, the Regional Ocean Modelling System (ROMS) was setup for the eastern Arabian Sea, which extends from 64.0^0 E to 74.0^0 E in the east-west direction and 8.0^0 N to 25.0^0 N in the north-south direction.

Coastal and Marine Ecosystems:

Marine and coastal ecosystems are most productive areas. Physical, chemical and biological data are collected to understand seasonal and inter annual variability, sensitivity to global change and model ecosystems in terms of productivity to assess their health. Coral reef maps for all regions have been prepared on 1:25,000 scale. Coral health bulletins are issued bi-weekly. An atlas on the environment and productivity pattern of the Indian EEZ has been prepared. Harmful algal blooms are being monitored. Marine pollution is monitored along 21 locations to assess health of seas around the Indian coast. Open cage culture and ornamental fishery have been developed for augmenting livelihood of Island communities.

Seabass seeds (0.22 g mean weight) obtained from the Central Institute of Brackishwater Aquaculture, Chennai, has been reared to an average size of 342 g bodyweight in 290 days in open sea cages at the North Bay, Port Blair.

1.6.   OCEAN TECHNOLOGY

The technology for autonomous vehicles, remotely operable vehicles, mining equipments, drilling equipments, testing equipment for harnessing these resources is under development. Remotely Operable Vehicle and Soil Tester has been deployed and successfully tested to assess environment and sea bed properties at 6000 m in the central Indian Ocean. Both the equipments have been successfully tested in the Central Indian Ocean. The seabed images and sensor data were recorded and transmitted in real time using the web cast facility installed on board Oceanographic Research Vessel (ORV) Sagar Nidhi. The first Autonomous Underwater Profiling Drifter (AUPD) was deployed off Kochi in the Arabian Sea and 3 deep profiles up to 1600 m were obtained. AUPD is programmed to dive to sea depths of 2000 m where it drifts with the current and after a defined time period, it rises to the sea surface, measuring temperature and salinity with respect to depth. At the surface, it relays this information via satellite and sinks again to begin the next cycle. Low temperature thermal desalination plants have been commissioned in the Lakshadweep Islands to provide fresh water from sea. These plants provide 100,000 lpd for drinking purpose. The operating cost of these plants is about 19 paise per litre.

The demonstration of shore protection measures has been successfully carried out and the solution of artificial beach nourishment is being implemented by the Puducherry Government and a beach width 30m was formed. The bathymetry survey and field observations of the Kalpasar project were completed. The development of Buried Object Scanning Sonar (BOSS), fabrication of the new stream lined tow body has been completed and has been successfully tested.

The autonomous ambient noise system has been successfully deployed and made operational with GPRS communication off Chennai. A state-of-the-art of low frequency calibration set up has been implemented and the existing ATF has been enhanced for the frequency range from 3 kHz to 500 kHz.

1.7   OCEAN RESOURCES

The basic survey of the Exclusive Economic Zone (EEZ) for mineral resources, exploration for polymettalic nodules, gas hydrates, hydrothermal sulphides, etc, have been undertaken.

Hydrothermal Sulfides: A series of 7 research cruises, ranging 30-35 days each were conducted near the central Indian Ocean Ridge for collecting marine geophysical parameters towards identification of Hydrothermal sulfide minerals. Quantum of data collected to date, in CIR and SWIR include MBES surveys of ~65,000 km^2 (area)**,** Magnetic surveys of~17,000 km (line) **and** Gravity surveys ~9,115 km (line)**.** Hydrothermal circulation of hot sea water at Mid-Oceanic Ridges penetrates deep into the oceanic crust, mediating substantial chemical exchange with basalts. It is necessary to model the thermodynamic environment and evolution of hydrothermal vent systems to understand ore distribution of precious and strategic metal content of hydrothermal sulphides. India filed the application for allotment of a site for exploration of Polymetallic Sulphides in the Indian Ocean during the meeting of the International Seabed Authority, Kingston, Jamaica, held from 8-19 July 2013.

1.8   POLAR SCIENCE

Changes in snow and ice can impact global climate through changing albedo, thawing of permafrost and attendant release of greenhouse gases, changes in sea level, etc. Hence investigations are carried out in the

Arctic and Antarctica including the Southern Ocean and Himalayas. The major focus is to answer questions related to climate pattern of last few thousand years, ice dynamics and modelling, and mass balance of glaciers and ice sheets.

The processing of snow/ice samples and measurements of stable isotopes, major ionic composition, trace element chemistry, dust particulates and organic composition as well as microbiological studies on snow / ice samples from the Antarctica were taken up. One of the important milestones accomplished during the year is the commencement of full-fledged operations at the 3rd Antarctic Station "Bharati" at the Larsemann Hills. A Digital Elevation Model (DEM) for the Larsemann hills was constructed using WorldView-2 (WV) satellite stereopair. In order to reconstruct the recent Antarctic climate change during the past centuries with annual to seasonal resolution, two well-dated ice cores from the coastal Dronning Maud Land region of the East Antarctica were studied for stable oxygen and hydrogen isotope ratio variabilities. An expedition to the Batal and adjoining Sutri Dhaka Glaciers was undertaken in August-September 2013 to initiate geomorphologic mapping of the area adjoining the glacier and collection of sediment samples to establish chronology of the history of glaciations of the area.

1.9. SEISMOLOGY

Earthquake is one of the hazards, which is still not understood. A national seismological network of seismometers, accelerometers, and GPS has been built for monitoring earthquakes, studying crustal dynamics, seismological research, active fault monitoring, etc on 24x7 basis. The location, magnitude and depth of an earthquake are provided within 10 minutes. A database has also been created for operational as well as research purpose. The relationship between earthquake pre-cursors and earth generation processes is explored through long-term, multi-parametric observations. Equipments related to multi parametric geophysical investigation have been installed in Imphal. Preparatory activities have been initiated to undertake suite of observations in a borehole in the Koyna region to study the stress regime, pore fluid pressure and it's variations, heat flow and it's variation, orientation of faults, study of physical properties, etc. As a preparatory study for Scientific Deep Drilling Investigation in Koyna region, two shallow boreholes have been drilled, to a depth to 1522 m and 1196 m, respectively. The cores recovered from the bore-hole were exposed to the geo-scientific community and scientific proposals have been evolved around these core samples. Also, air-borne gravity and MT surveys have been completed. A report on Seismic Hazard Microzonation of NCT Delhi 1:10000 scale has been prepared. A pilot study for Earthquake Early Warning (EEW) in the Central Himalayan region has been initiated. Under this study, 100 P- alert systems are being deployed in the identified spatial window.

1.10. HIGH PERFORMANCE COMPUTING SYSTEM

The High Performance Computer (HPC) System of 1.20 Petflop with 9 Petabytes of storage has been acquired for the ESSO-MoES. The present HPC System will boost research in weather and climate forecasting and will help the research initiatives undertaken under the monsoon mission.

1.11. RESEARCH EDUCATION AND TRAINING AND OUTREACH

The second batch of training on climate science, consisting of 19 trainee scientists, has been completed. The third batch of 25 trainee scientists for the climate science course was selected in August 2013. The International Training Centre for Operational Oceanography (ITCOO) conducted two training programmes. Two training programmes on Ecosystem Modelling and RS applications to CZM were

conducted. About 40 scientists/officials from the coastal states and Universities were trained. The Earth Science Olympiad was held in September 2013 in Mysore.

1.12. SCIENTIFIC PUBLICATIONS

The number of publications and its impact factor during the current year are 372 and 527 respectively. The quality of the publications has improved considerably over a period.
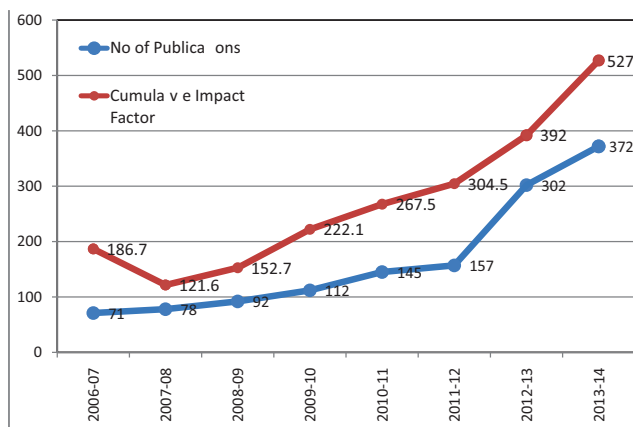

Fig.1.1 Yearly variation of number of peer-reviewed research publications and cumulative impact factors of the journals in which these papers are published

1.13. RESULTS FRAMEWORK DOCUMENT

The performance was evaluated as a part of Results Framework Document (RFD) and it consistently rated well. A score of 94% was achieved during the year 2013-14.

1.14. BUDGET AND EXPENDITURE

The plan and non-plan outlays for current year 2013-14 were Rs. 1281 crores and Rs. 409.00 crores, respectively. The major scheme-wise allocation for the current financial Year (2013-14) (Rs. in crores) is shown (Fig.1.2 and 1.3).
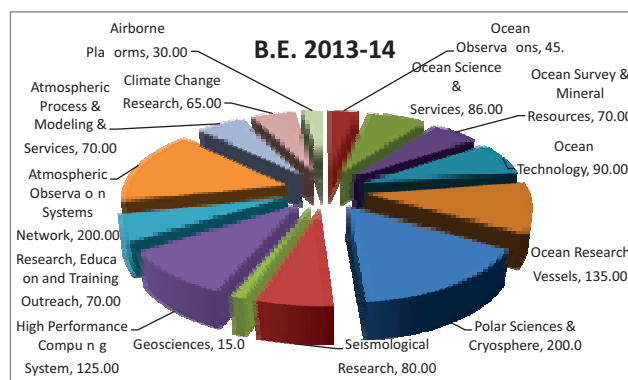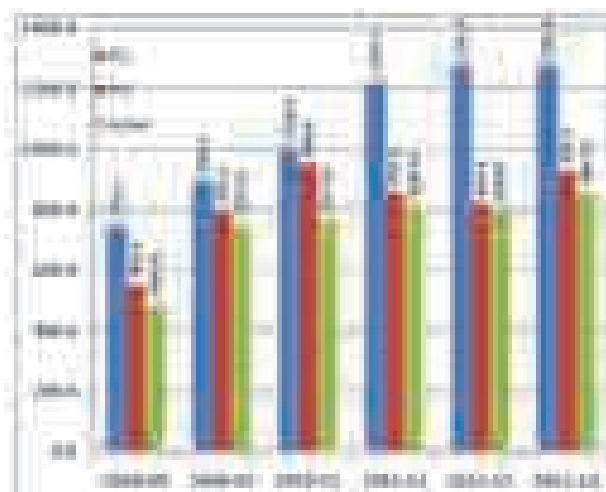

Fig.1.2 Budget details for each of the plan programmes

Fig.1.3. Annual budget (BE, RE and actual) year wise (in crores)

ATMOSPHERIC OBSERVATIONS AND SERVICES

Atmospheric observations are vital for quality of weather and climate services. In order to provide weather services the atmospheric observational network has been significantly enhanced. Installation of the state-of-the-art automatic weather station (AWS) and automatic rain gauge (ARG) systems, commissioning of Doppler Weather Radars, GPS RS/RW and a network of radiation instruments in various parts of the country have contributed towards augmentation of its observational networks. AWS located at remote places collects data from various meteorological sensors, validates, processes and disseminates automatically. The meteorological observations from space through meteorological satellites, INSAT-3D and OCEANSAT-II, have further added its potential in weather prediction. The Doppler weather radar and satellite observations have a significant contribution in nowcasting. The district level agro-meteorological advisory service is providing a 5-day district level weather forecast for farmers in the country. The overall improvement contributed towards providing better weather and climate services through continuous endeavors of upgrading/ augmenting observing, analysis implementing a suite of global and regional forecasts systems and product dissemination. Details of major accomplishments are presented below:

2.1. ATMOSPHERIC OBSERVATIONS AND NETWORKING

2.1.1. Satellite Observations

The new generation advanced dedicated meteorological satellite INSAT-3D was launched on 26 July, 2013. The INSAT 3-D satellite carries six channel imager for imaging the earth in visible (0.55-0.75μm), SWIR (1.55-1.70μm) of resolution of 1 km, MIR (3.80-4.00μm), TIR-1 (10.30-11.30μm), TIR-2 (11.50-12.50μm) of resolution 4 km and WV (6.50-7.10μm) of resolution 8 km. INSAT-3D is also carrying 19 channel sounder consisting of 7 channels of LWIR (14.71-12.02μm), 5 channels of MWIR (11.03-6.51μm), 6 channels of SWIR (4.572-3.74μm) and one channel of visible (0.695μm), each of resolution 10 km, scan the atmosphere for derivation of vertical profiles of meteorological parameters. From the sounder data, atmospheric profiles are derived at 40 vertical pressure levels from surface to about 70 km and for water vapour in 21 levels from surface to about 15 km along with several new products. Availability of INSAT-3D images and products will enhance the forecasting capabilities in the country. The data reception and processing of INSAT-3D satellite has been already operationalized.

The following products are generated using the INSAT-3D data: Multi-channel Sea surface temperature (MCSST), Brightness Temperature, Snow cover, Snow depth point, Fire, Smoke, Aerosol, Cloud motion vector winds, Water Vapor Winds, Visible Winds, Fog, Wind Index, Outgoing Long wave Radiation (OLR), Quantitative Precipitation Index, Quantitative Precipitation Estimate, Cloud Mask, Rainfall using Hydro Estimator, Humidity profile, Total Ozone, Surface Skin Temperature, Geo-Potential height, Total precipitable Water, Lifted Index, Dry microburst Index and Maximum vertical equivalent potential temperature differential. Data from NOAA/METOP and MODIS Polar orbiting satellites are received at New Delhi, Chennai and Guwahati.

2.1.2. Augmentation of observational network

To facilitate ultraviolet observations, 23 UV-B radiometers have been installed. Three AWS were installed at Pahalgam, Chandanwadi and Baltal enroute Shri Amarnathji Yatra during April 2013. Aviation Weather Observation System (AWOS) has been installed at the Juhu heliport for helicopter operations. With commissioning of Doppler Weather Radar (DWR) at Bhopal and at Cherrapunjee, the net work of DWR is now expanded to 15. Details of the observational system installed/commissioned are given below:
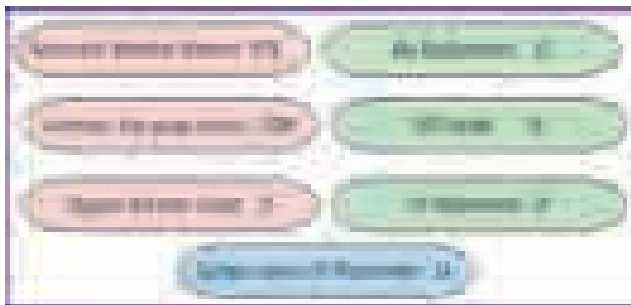
2.1.3. Environment Monitoring Network

A surface ozone monitoring network has been established by installing surface UV absorption ozone photometers at New Delhi, Ranichauri, Varanasi, Nagpur, Pune, Kodaikanal, Thiruvananthapuram, Port Blair, Guwahati and Maitri (Antarctica). Monitoring of columnar Ozone and vertical distribution of ozone is continued. Aerosol Monitoring Network has been established by installing sky radiometers at 12 locations to measure optical properties of aerosols such as aerosol optical depth, single scattering albedo, size distribution and phase function.

2.2. Operational Weather Services

2.2.1. Operational Numerical Weather Prediction System

The National Centre for Environmental Prediction (NCEP) based Global Forecast System (GFS T574/L64) is being used for preparing forecasts up to 7 days. Currently, the model is run twice in a day (0000 UTC and 1200 UTC). In addition to this, the meso-scale forecast system WRF (ARW) with 3DVAR data assimilation is also run daily twice, at 27 km, 9 km and 3 km horizontal resolutions for the forecast up to 3 days. At ten other regional centers, very high resolution mesoscale models (WRF at 3 km resolution) are now made operational and the forecasts are generated. Doppler weather and mesoscale dynamical model based nowcast system was made operational for the national capital of Delhi. The polar WRF model was implemented to provide day to day short range (48 hours) weather forecasts for the Maitri region over Antarctica.

2.2.2. Agrometeorological Advisory Services (AAS)

AAS bulletins are being issued for districts (598), state composite bulletins (23) and national AAS bulletins based on medium range weather forecasts. On a pilot mode, block level weather forecasts are issued for the parameters like rainfall, maximum and minimum temperatures, cloud amount, maximum and minimum relative humidity, wind speed and wind direction for 342 blocks covering 37 selected districts. Verification of the block level forecast issued for all the parameters with the realized weather data is being carried out to compute the accuracy of forecasts. An experimental National Agromet Advisory bulletin based on the extended range weather forecasts has been initiated during 2013. These agro meteorological advisories are disseminated to the farmers in collaboration with NIC/ATMA/KVK/NABARD/Internet in both regional and English languages through "Kisan SMS", a portal (http://farmer.gov.in). At present 4.7 million farmers are benefitted by this service. These advisories are used for scheduling irrigation and application of fertilizers and pesticides. Normalized Difference Vegetation Index (NDVI) maps

derived from INSAT 3A CCD data are used for assessment of crop conditions. Maps for Standardized Precipitation Index (SPI) on weekly, bi weekly and seasonal basis are being used for agromet advisories, in addition to aridity anomaly on weekly basis.

Crop yield forecasting models were developed based on statistical techniques using long-term weather parameters (Temperature, Rainfall, Relative Humidity and Bright hours of sunshine) and Crop yield data. The crop yield forecasts are being generated at different stages of the growth period, viz., mid-season (F2) and pre harvest (F3) stages. Crop yield forecasts for (i) wheat for Madhya Pradesh, Rajasthan, Punjab, Haryana, Bihar and Uttar Pradesh, (ii) rabi rice for West Bengal, Odisha, Karnataka and Andhra Pradesh, (iii) Jute for Assam, Bihar and West Bengal, (iv) kharif rice for Andhra Pradesh, Assam, Bihar, Chattisgarh, Jharkhand, Karnataka, Madhya Pradesh, Odisha, Uttar Pradesh, West Bengal, Punjab, Haryana have been generated. The yield forecast issued by the ESSO-IMD is being used by the Ministry of Agriculture for estimating production of major crops in the country.

2.2.3. Aviation Services

Meteorological information for the use of aviation activities in the form of current weather observations, forecasts, advisories and climatology were provided to all national and international airports across the country. The Tropical Cyclone Advisory Centre (TCAC) provided advisory on tropical cyclones to the Meteorological Watch Offices (MWO) in India and the neighboring countries.

The meteorological information and briefing documentation for flights are provided manually as well as through a web based system. The old on-line Briefing System (OLBS) has been replaced by a fully automated and versatile system for product dissemination and documentation, maintained at New Delhi and Chennai. All meteorological information that are needed for various stages of a flight, such as METAR/SPECI, take-off forecast, TREND forecast, area/local forecasts, upper air wind and temperature forecast, significant weather charts, aerodrome warnings, SIGMET warnings, Tropical Cyclone Advisories and Volcanic Ash Advisories, satellite pictures and radar pictures are uploaded in the system. Technical assistance and consultation were provided to upcoming Durgapur Airport in West Bengal and Sindhudurg Airport in Maharashtra for setting up the aviation meteorological facilities.

2.2.4. Hydrometeorological Services

Quantitative Precipitation Forecasts (QPF) were issued for sub-basin-wise for day-1, day-2 and day-3 using NWP model, WRF (ARW) (9 km) and Multi-model Ensemble (27 km) forecasts. The lead time of QPF has been extended from 24 h to 48 h and also the outlook has been extended from 48 h to 72 h. This information is provided to various Central/State Govt. organizations and other agencies in the field of Hydromet design, flood forecasting, rainfall monitoring for water management and agricultural planning purposes.

2.2.5 Cyclone Monitoring and Prediction Services

Three hourly cyclone warning/advisory bulletins were issued to national agencies including National Disaster Management Authority (NDMA), Ministry of Home Affairs (MHA), concerned state governments and other users as well as to Bangladesh, Myanmar, Thailand, Pakistan, Oman, Sri Lanka and Maldives. The Hurricane-WRF model for Tropical Cyclone track and intensity forecast for North Indian Ocean (NIO) region has been adopted for operational requirements. The forecast model products include: Deterministic and Ensemble TC track forecasts, Strike Probability Maps, Strike probability of cities within the range of 120 km 4 days in advance.

During the year 2013, 9 cyclonic disturbances developed over the north Indian Ocean including one deep depression over the Arabian Sea, one land depression and 7 cyclonic disturbances over the Bay of Bengal. The cyclone, Mahasen formed during the pre monsoon season and other four cyclones formed during the post monsoon season. The cyclone Phailin crossed the coast as very severe cyclonic storm (VSCS) and other two (Mahasen and Helen) as cyclonic storms whereas other two cyclones (Lehar and Madi) crossed the coast as depressions (Fig 2.1).

However, the cyclone Lehar crossed the Andaman and Nicobar Islands as a severe cyclonic storm. Such a severe cyclonic storm crossed the Andaman and Nicobar Islands for the first time since November 1989. While the Phailin cyclone recurved after landfall, the cyclone Mahasen recurved northeastwards over the sea, the cyclone Helen recurved west-southwestwards just before landfall and the cyclone Madi recurved southwestwards over the sea. The observed and forecast tracks of VSCS PHAILIN based on 1200 UTC of 9th October are given in Fig.2.2. Comparing the tracks, the track of Madi was most unique in nature and had a rare analogue with past records.

Fig. 2.2 Storm Surge guidance based on 0000 UTC of 12 October Initial Conditions

Cyclone track and intensity forecast valid for 120 h have been introduced in 2013 from the Cyclonic Storm 'MAHASEN'. Coastal inundation advisories have been introduced experimentally based on the coastal inundation model ADCIRC being run at ESSO-INCOIS, Hyderabad with the input central pressure, maximum wind intensity forecast and distribution of wind in four quadrants of the cyclone up to 120 km, provided by ESSO-IMD. The inundation map was provided to Government of Odisha well in advance indicating the extension of coastal inundation up to 600 m to 1 km along Ganjam district coast. An example of the coastal inundation model output is shown in the Fig. 2.3
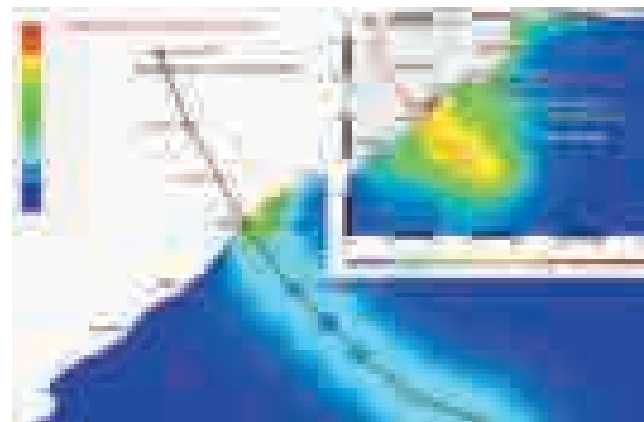

Fig.2.1. Observed tropical cyclone tracks during the post monsoon season, 2013

Fig. 2.3. Observed & forecast track of VSCS, PHAILIN. Forecast time: 1200 UTC, 9th October

Details of forecast errors in case of Tropical Cyclone Phailin are given in Table 2.1.

TABLE 2.1

Track Landfall and Intensity Forecast Error and Skill of the Cyclone, 'Phailin'

Lead Time (h)	Landfall Point Error (km)	Landfall Time Error (h)	Track forecast error (km)	Track forecast skill (%)	Long period skill (%) (2008-12)	Absolute Error (kts)	Skill with respect to Absolute Error (%)	Long period Average of Absolute Error (kts)
12	3	3h delay	62.6	25.7	23.1	9.1	44.3	7.3
24	13	3 h delay	98.4	25.7	34.8	14.9	62.1	10.4
36	5	3 h delay	90.6	52.3	35.1	17.4	70.9	12.7
48	11	3 h delay	91.0	65.4	41.8	18.7	77.9	13.4
60	2	3 h delay	90.0	73.1	47.4	17.7	75.3	13.4
72	6	1 h early	76.7	81.4	50.0	11.1	91.7	19.0
84	41	1 h early	94.8	79.8		19.7	80.4	
96	------	----	135.8	75.1		10.5	87.3	
108	------	---	112.4	77.7		1.8	97.0	
120	----	-----	77.8	71.4		5.4	89.6	

Trend in Forecast Performance of Cyclones

The tropical cyclone forecasts have been verified for the period 2003-2013 following the Standard Operation Procedure as adopted over other Ocean basins. It is observed that the tropical cyclone track forecast errors have decreased significantly in the recent years. The average 48 and 72h track forecast errors over the north Indian Ocean during 2009-2013 have decreased more significantly during the same period, Fig. 2.4(a). The landfall point forecast error has reduced significantly in recent years. The rate of decrease is higher in case of 48 and 72h forecast (Fig. 2.4(b)).

The tropical cyclone intensity (maximum sustained surface wind) forecast has improved significantly with decrease in intensity forecast error during 2005-2013 [Figs. 2.5(a & b)].
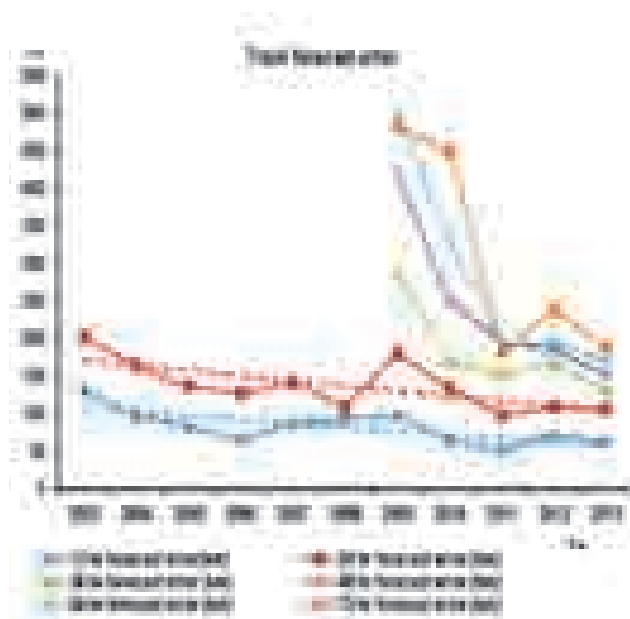

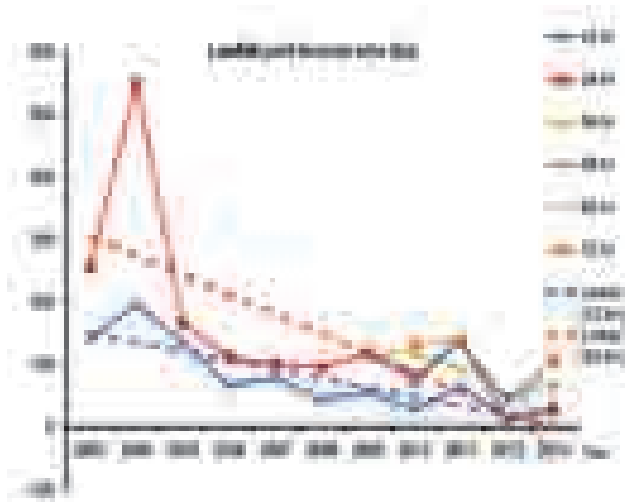Fig.2.4(a) Cyclone Track Forecast Error 2003-2013

Fig.2.4(b) **Cyclone Landfall Point Forecast Error 2003-2013**

Fig.2.5 (a&b). Tropical Cyclone Absolute and Root Mean Square Intensity Forecast Error during 2005-2013

The reason for improvement in cyclone forecast may be attributed mainly to augmentation of oceanic observational network, numerical weather prediction products and capacity building through training of forecasters.

2.2.6. Severe Weather Forecasting Systems

As nowcasting scheme for thunderstorms, squalls and hailstorms has been implemented and are provided every 3 hourly interval utilizing synoptic data, model outputs, satellite products and radar outputs for 120 cities. Various statistical parameters like Probability of Detection (POD), False-Alarm Ratio (FAR) Critical Success Index (CSI) and Equitable Threat Score (ETS) were evaluated for each DWR station. Monthly average statistical scores for India as a whole for the month from March to September are given in Table 2.2. A significant improvement in skill scores is observed in the recent years in various types of forecasts and warnings for extreme weather events. Skill scores of heavy rainfall events over India as a whole in the recent years indicate that critical success index (CSI), False Alarm Rate (FAR) and Heidke Skill Score (HSS) have improved by 42%, 52% and 43% from their respective mean between 2002 and 2013. Trends of FAR and CSI for the period 2002-2013 are given in the Fig.2.6.

TABLE: 2.2

Monthly average statistical scores for India as a whole

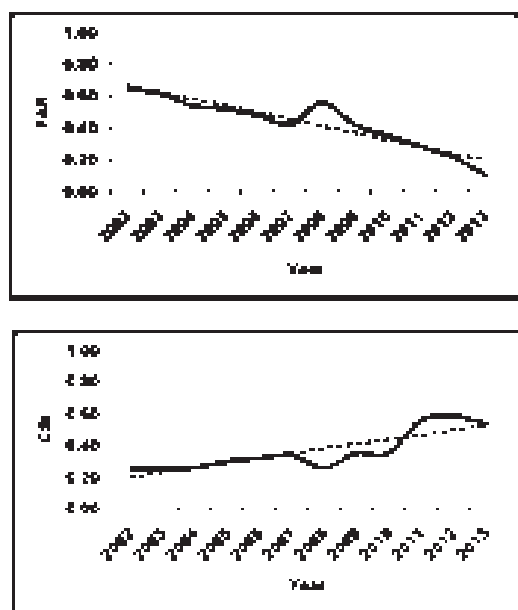| Month	RATIO SCORE	POD	FAR	ETS	CSI
March	1.0	0.8	0.2	0.8	0.7
April	1.0	0.7	0.4	0.6	0.6
May	1.0	0.6	0.3	0.5	0.5
June	0.9	0.7	0.5	0.6	0.6
July	0.9	0.7	0.5	0.5	0.6
Aug.	0.9	0.8	0.4	0.6	0.6
Sept.	0.9	0.7	0.4	0.5	0.6

Fig.2.6.**Trends of FAR and CSI of heavy rainfall forecasts for the period between 2002 and 2013**

2.3.   Climate Services

The development of climate services is going to be a major challenge for the next few years, particularly in response to the needs of mitigation and adaptation policies. This service will cover a wide spectrum, from diagnostics to projections.

The total holding of meteorological data at the data centre as on date is 215.7 billion records and about 2.4 billion records are added to the archives in the current year. Under the Data Rescue Scheme, Monthly Meteorological Registers (MMR) data and old analysed weather charts were rescued and archived (Table 2.3).

TABLE 2.3

Progress of archival and digitization of Surface Data and Analyzed Charts

Type of Product	Volume	Digitized up to 2013	Digitization to be taken up in 2014	Total
Observational Data (MMR)	28 million records (under Phase-I) From 1969	Data sheets scanned and archived : **4.4 million** Data records keyed / digitized : 28 million	(Under Phase - II) Scanning of about 14 million data sheets (Period starting from 1889) Data entry work of about 32 million records	60 million records
Digitization of Analyzed Weather Charts	7.5 lakh charts	5 lakh charts	2.5 lakh charts	7.5 lakh charts

Climate monitoring and forecast products for South Asia are being generated since March 2013. A model climatology of Seasonal Forecast Model (SFM) was prepared for all the 12 months for monthly and seasonal forecast in respect of temperature and precipitation. Monthly rainfall data series for districts, states, Met sub-divisions and India as whole based on data from 1901 onwards have been computed. Climate data products viz., daily gridded rainfall and temperature CDs were supplied to different national and international institutes. CDs of daily district wise normal of meteorological parameters were supplied.

Following new climate monitoring products were introduced since January 2013:

> ➢ **Monthly area-average of total precipitation anomalies expressed as percentages**

➢ **Monthly area-averaged Percent of Time Tmax> 90th Percentile of Daily Maximum Temperature (1971-2000 period for standardisation) (Fig.2.7)**

➢ **Monthly Standardised Precipitation Index (SPI) for each station (Fig.2.8)**

➢ **Monthly area-averaged Percent of Time Tmin < 10th Percentile of Daily Minimum Temperature (1971-2000 period for standardisation)**

➢ **Significant climate and weather events relevant to the area or region**

➢ **Monthly area-average mean temperature time series (Fig.2.9)**

Fig 2.9 Monthly area-average mean temperature time series (%)

Fig.2.7.**Monthly area-averaged Percent of Time Tmax > 90th Percentile of** Daily Maximum Temperature ,1971- 2000 period for standardisation.
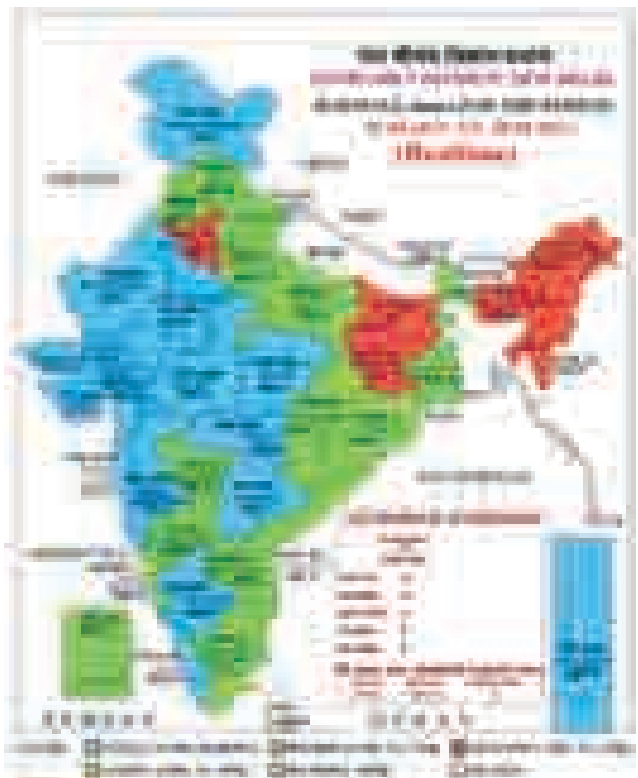
Fig.2.10 Seasonal monsoon rainfall during southwest monsoon season (June to September)

2.4. Monsoon Monitoring

The 2013 southwest monsoon seasonal rainfall over the country as a whole was above normal (93.7 cm against 88.7 cm Long Period Average (LPA). However, there was a marked spatial and temporal variability as shown in Fig 2.10.

2.5. Monsoon Forecasting

The long range forecast for the onset date of monsoon 'June 3' over Kerala was issued on 15th May 2013. The Southwest
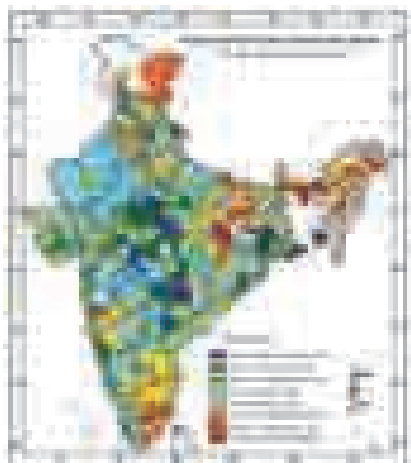
Fig 2.8. Standardized Precipitation Index (SPI) Jan-Dec 2013

monsoon current advanced over the Andaman Sea three days earlier than its normal date of 20th May and set in over Kerala on 1st June. The southwest monsoon covered the entire country by 16th June, about one month earlier than its normal date of 15th July. The forecast for the onset of monsoon over Kerala was proved correct consecutively for ninth time.

The first stage monsoon forecast was issued on the basis of 5-parameter statistical ensemble forecasting system requiring data up to March on 26 April. The model forecast error of the April forecasting system is ±5%.This system was also used to prepare probability forecasts for five pre-defined rainfall categories, viz., deficient (less than 90% of LPA), below normal (90-96% of LPA), normal (96-104% of LPA), above normal (104-110% of LPA) and excess (above 110% of LPA). The climatological probabilities for the above categories are 16%, 17%, 33%, 16% and 17%, respectively. For the 2013 southwest monsoon season, the predicted probabilities for these five categories were 10%, 27 %, 46%, 14% and 3% respectively. Thus the all India monsoon season rainfall was given as normal.

A 6-parameter statistical ensemble forecasting system for the southwest monsoon requiring data up to May was used to issue second stage forecast update on 14th June, 2013. The details of long range forecasts and realized rainfall for southwest monsoon season are given in Table 2.4.

TABLE 2.4

Details of long range forecasts and realized rainfall

| Region	Period	Date of Issue	Forecast (% of LPA)	Actual Rainfall (% of LPA)
All India	June to September	26th April	98 ± 5	106
All India	June to September	22st June	98 ± 4	
Northwest India	June to September		94%± 8	109
Central India	June to September		98%± 8	123
Northeast India	June to September		98%± 8	72
South Peninsula	June to September		103%± 8	115
All India	July		101%± 9	106
All India	August		96%± 9	98
All India	August to September	2nd August	96%± 8	94
All India	September	1stSeptember	96%± 13	86

ATMOSPHERIC AND CLIMATE PROCESSES AND MODELING

The meteorological and climate services have significant impact on society in general. Public, private and government sectors demand for accurate weather and climate forecasts at various spatial and temporal scales. Improved and reliable forecast of weather and climate requires high-resolution dynamical models. Thus, a combined approach involving land, ocean and atmospheric processes hold the key to improve the forecasts of various temporal and spatial ranges. On the other hand, intensive monitoring of various weather systems through different platform based observing systems including satellites provide not only the necessary information about current weather systems, their effective assimilation in numerical models provide important guidance for accurate forecasts.

3.1 PHYSICS AND DYNAMICS OF TROPICAL CLOUDS

Natural Aerosols and Cloud Microphysics

Atmospheric aerosols alter the radiation balance by absorption/scattering of solar radiation, and indirectly by modifying the cloud microphysical properties. It is observed that aerosol loading increased prior to the onset of southwest monsoon over the central Indian region mainly in the 2.5 km level above surface in spite of the increase in rainfall. Natural dust emission from the Thar desert may introduce elevated aerosol layers and warming, which can influence the cloud microphysics of propagating systems from the Bay of Bengal (BoB). Enhanced dust emissions by a factor of 1.25 over the Thar desert can result in an increased radiative heating due to

elevated aerosol layers (Fig.3.1), which leads to an increase in the ice mixing ratio and ice water content in the regions of dry to wet transition. It is shown that even natural dust emissions (without changes in anthropogenic emissions) may feedback through dynamics interactions during the pre-monsoon to monsoon transitions.
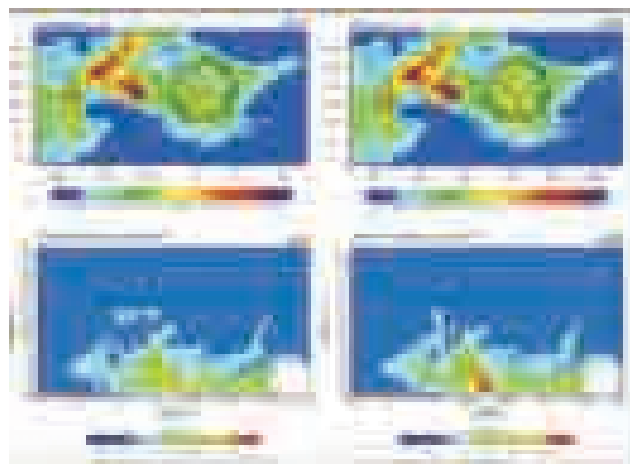
Fig 3.1: Spatial distribution of vertically averaged shortwave heating rate (K/sec) without (a) and with (b) additional natural emissions of dust particles from Thar desert, (c) and (d) show vertical distribution of shortwave heating rate (K/Sec) across 73°E.

Raindrops in monsoon clouds

The formation of first raindrops in deep convective clouds during the monsoon season was investigated through the Clouds and Aerosol Interaction and Precipitation Enhancement Experiment (CAIPEEX) observational data and 2-D and 3-D numerical cloud microphysical model simulations. Both the model results and CAIPEEX observations suggest that the first raindrops form at the top of undiluted or slightly diluted cores. The droplet size distributions in these regions are wider and contain more large droplets than in diluted volumes. The initial

raindrop formation is determined by the basic microphysical processes within ascending adiabatic volumes. The height of the formation of first raindrops can be predicted considering the processes of cloud condensation nuclei activation, droplet diffusion growth, and coalescence growth. The present study provides a physical basis for retrieval algorithms of cloud microphysical properties and aerosol properties using satellites as well as in the formulation of the auto-conversion parameterization in numerical models.

Mechanism of high rainfall over the Indian West Coast region

The mechanism responsible for high rainfall over the Indian west coast region (IWC) has been investigated. The moist adiabatic and multi-level inversion stratifications are found to exist during the high and low rainfall spells, respectively. In the moist adiabatic stratification regime, shallow and deep convective clouds are found coexisting. The CAIPEEX aircraft data showed cloud updraft spectrum ranging from 1-10 m/s having modal speed 1- 2.5 m/s. The low updraft rates provide sufficient time required for warm rain processes to produce rainfall from shallow clouds. The updrafts at the high spectrum end go above freezing level to generate ice particles produced due to mixed-phase rainfall process from deep convective clouds. With aging, deep convection gets transformed into stratiform type. The stratiform heating, high latent heat flux, strong wind shear in the lower and middle tropospheric levels and low level convergence support the sustenance of convection for longer time to produce high rainfall spell. The advection of warm dry air in the middle tropospheric regions inhibits the convection and produce low rainfall spell.

High Altitude Cloud Physics Laboratory (HAPCL), Mahabaleshwar

The High-Altitude Cloud Physics Laboratory (HACPL) established at Mahabaleshwar has completed one year of observations. Level-0 data from HACPL instruments (Cloud Combination Probe, Scanning Mobility Particle Sizer, Aethalometer, Optical/impact/video disdrometers, Nephelometer, Radiosonde, Radiometric profiler, Automatic weather station) until April 2013 after initial quality check were released to research community.

A Ka-Band Scanning Polarimetric Radar has been deployed at Mandhardev (near Mahabaleshwar) in collocation with the existing X-band radar for the Monsoon-2013 observational campaign.

Thunderstorm Dynamics

Observational facilities have been developed for thunderstorm monitoring and conducting mission-oriented experiments in different parts of India to understand the dynamical, thermo-dynamical structure and rain formation processes in thunderstorms. Lightning Location Network has been installed to study the fine structure of lightning and its climatology. Observations of lightning using Lightning Location Network and satellite data would help in the understanding of not only the spatio-temporal distribution of thunderstorms, but also their role and cause in different environments.

Lightning Location Network (LLN)

A lightning location network was implemented in the state of Maharashtra for a detailed study of thunder clouds, the processes responsible for various types of lightning, factors responsible for initiation and possible aspects for nowcasting. LLN Sensors are installed at 17 locations (Fig. 9.3.2 a and b) spread all over Maharashtra as per the plan. The sensor data are sent through internet (TCP/IP connection) and the data is being processed and archived in Lightning Information and Prediction System (LIPS) server at IITM. The system is fully operational since their installation. Internet Link for viewing online lightning information is being

given to Disaster Management Department, Govt. of Maharashtra through which the active and warning regions of lightning activity can be immediately informed to the general public.
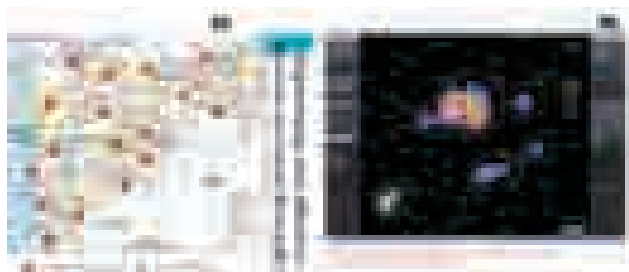

Fig 3.2. Lightning location network stations over Maharashtra (a) and the LLN display (b) showing the direction of storm movement, which could be used to alert public about the severe weather conditions

3.2   CLIMATE PROCESSES STUDIES

3.2.1. Indian Ocean Warming and Weakening of the Indian Monsoon

Recent studies have drawn attention to the steady warming of the tropical Indian Ocean (IO) which is accompanied by a weakening of boreal summer monsoon circulation. The results from this analysis show that the weakening trend of the summer monsoon cross-equatorial flow has favored a preferential orientation of surface westerlies along the equatorial IO during the recent decades, which significantly accelerated the SST warming in the equatorial Indian Ocean. On the one hand, the trend in the equatorial westerlies has promoted downwelling and thermocline deepening in the eastern equatorial IO. In addition, the SST warming trend in the central equatorial IO around the Seychelles region is found to be related to reduced upwelling by the summer monsoon cross-equatorial winds and enhanced equatorial convergence. The results suggest that the weakening of the summer monsoon circulation has accelerated the warming of the equatorial IO and the warming, in turn, has contributed to a further weakening of the monsoon.

3.3   MODELLING

3.3.1. Numerical Weather Prediction

The mission is to continuously improve numerical weather prediction (NWP) systems in a seamless manner entailing all spatial and temporal scales with special emphasis over India and neighbouring regions. The following four-fold approach is taken to improve numerical weather prediction system.

(i)   Enhancement of data for assimilation in the Analysis and Forecast System

The processing and assimilating many new types of satellite observations has been taken up. The new satellite data include radiance and winds from METOP-B, OSCAT-25 km resolution winds, Meteosat-10 AMVS, CrIS and ATMS radiance, GEOS clear sky radiance, polar AMVs, GOES Imager (BT). This has resulted in the manifold increase of the observations received and the total volume of data being now being received is around 20GB/day. Although the overall quantity of data received is comparatively less, enough global coverage of data is ensured for sustained global forecast performance. Availability of METEOSAT-10 AMVs from EUMETCAST broadcast (through ISRO) from November, 2013 has resulted in full disc coverage of data reception. This wind data over Africa and Europe was otherwise not available through GTS within the assimilation cut-off time (~3 hrs).

Efforts are being made to assimilate atmospheric motion vector (AMV) winds derived from the recently launched INSAT-3D satellite. This is in addition to the AMVs derived from other satellites including Kalpana. The data from SAPHIR radiance (from MeghaTropique) are also being assimilated experimentally into weather prediction model for improving the initial conditions. For this purpose, procedures for cloud screening have been developed in-house, based on the theory behind cloud and rain screening processes.

The ESSO-NCMRWF Unified Model (NCUM) with horizontal resolution of 25km and 70 levels in the vertical along with associated 4D-VAR is being used for generating real time forecasts. In-house data pre-processing tools have been developed for the

data assimilation in the NCUM. The horizontal wind data derived from the Indian DWRs at low elevation angles are compared against other radar observations at co-located points (where two radar scans overlap over a common region) as well as against "radiosonde"/"pilot balloon" observations. The inter-comparison results indicate that over co-located regions, the observations from two different radars are matching well, in general. The biases of radar horizontal wind components against the "radiosonde"/"pilot balloon" observations are within reasonable range (+/- 2 m/s). Efforts are being made to assimilate DWR wind data in the regional data assimilations system.

An inter-comparison study of Indian DWR reflectivity observations at radar co-located points is carried out. The DWR reflectivity is found to have some noises which get improved by applying a filtering scheme developed. There is reasonably good comparison of DWR observations with TRMM satellite Precipitation Radar (PR) reflectivity observation as shown in Fig 3.3.
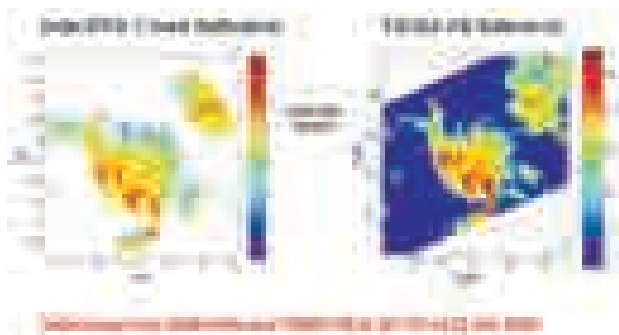

Fig 3.3 Reflectivity from DWR Delhi and TRMM-PR at 2000 UTC of 15 February, 2013

(ii)   Providing   Probabilistic   Forecasts through quantified uncertainty

The 20 member Global Ensemble Forecast System (GEFS) (T190L28 model) is further improved to provide more real time forecast products. During 2013, three new forecast products were generated. These include (i) High resolution (0.5 degree grid) rainfall forecast based on the ensemble mean along with Probabilistic Quantitative Precipitation Forecast (PQPF) over the meteorological sub-divisions, (ii) The forecast meteograms (EPSGrams) showing the 2m Temperature (C), 2m Relative Humidity (%), 10 m wind (m/s) and Rainfall (mm) for 33 cities all over India and (iii) Forecast of wind speed probabilities, during the periods of tropical cyclones. These operational forecasts were provided to ESSO-IMD on regular basis.

Evaluation of forecasts of Tropical Cyclone tracks is also carried out for the tropical cyclones cases during 2012 and 2013. In the case of the TC Phailin (Fig 3.4), the ensemble mean track has shown lower error compared to that of GFS by about 15% in the 72 hour forecast. The strike probability based on 00UTC of 9th October could predict the track and landfall position of Cyclone Phailin with 70% confidence.
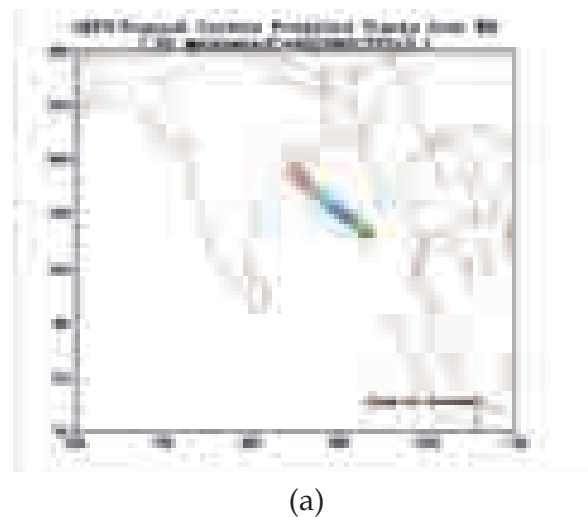
(a)
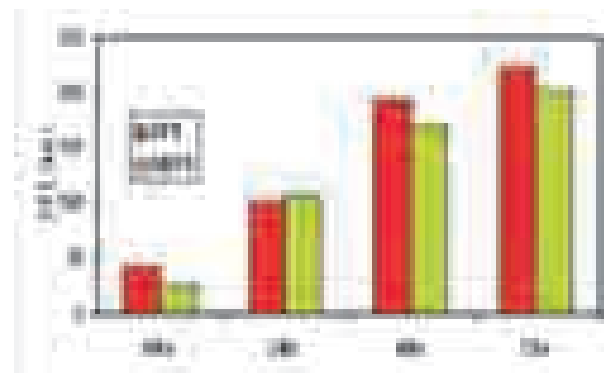
(b)

Fig 3.4. a) Track forecasts of Tropical Cyclone Phailin by GEFS, b) Track forecast error (in km) of Tropical cyclone Phailin by GFS and GEFS for different lead times.

(iii) **Generation of new model products and development of high resolution nested model for severe weather systems**

Efforts were made to generate new model products and also to develop a high-resolution model for severe weather systems.
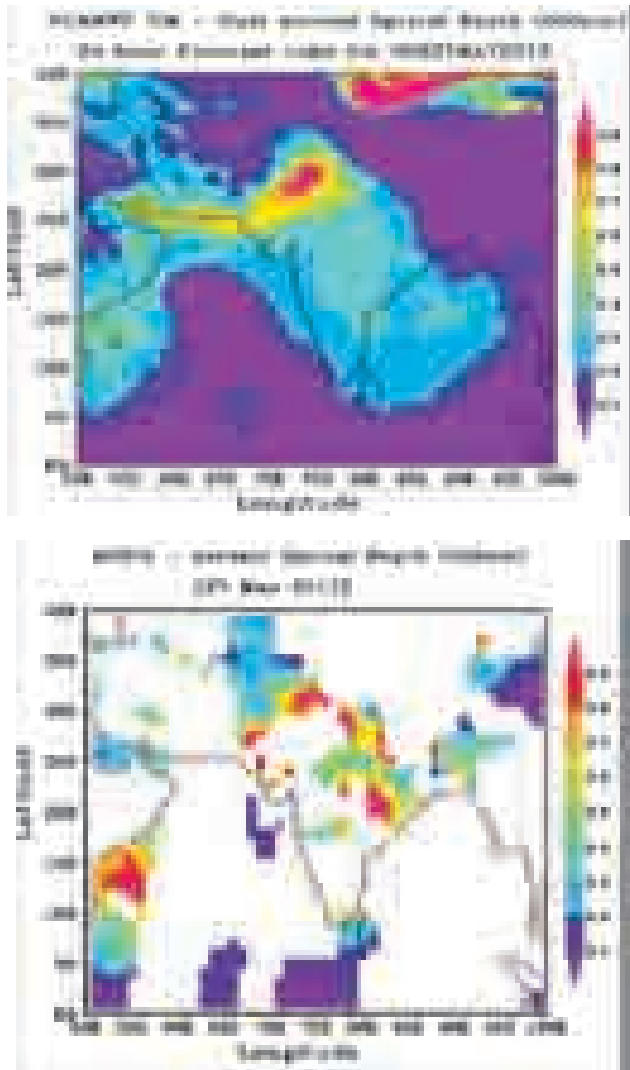
Fig 3.5 a) The day-1 forecast dust optical depth valid for 27th May 2013, b) Aerosol Optical Depth (550nm) derived from MODIS.

The dust optical depth from NCUM model forecasts (by prognostic dust scheme) are verified against various satellite and ground based observations (MODIS, Aeronet, IMD sky radiometer). The case studies of dust storm events over the Indian region suggest that the model has the capability to predict the

dust load 3-4 days in advance. More detailed verification studies are being taken up with satellite and ground based observations over the Indian region. A typical day-1 forecast dust optical depth as against MODIS observation for 27th May 2013 is shown in the Fig. 3.5. As a part of strategy of developing a seamless prediction system for all temporal and spatial scales, regional configurations of NCUM at 12-km and 4-km have been implemented.

iv) **Development of the Unified Coupled Model**

The Indian monsoon is a fully coupled system, where ocean, atmosphere and land-surface interact and play dominant roles simultaneously**.** For extending the temporal range of weather forecasts beyond seven days, a coupled ocean atmosphere model based on UM at a coarse resolution (atmosphere 1.875^0 x 1.125^0 L85, ocean 1.0^0 x 1.0^0 L75) has been implemented. This model has NCUM as the atmosphere component, NEMO as the ocean component and CICE as the sea-ice component.

Fig 3. 6. Observed and coupled model simulated SST and SSS

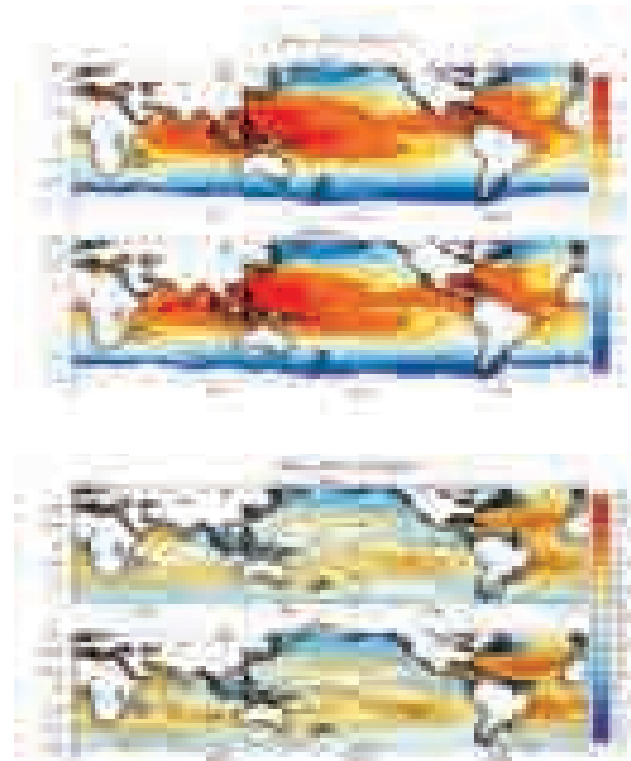The quality of ocean simulation in a coupled system is very important since it generates an important feedback via air-sea interaction. Studies from hind-cast data of ESSO-NCMRWF runs show that the NEMO ocean component in coupled model produces very realistic Sea Surface Temperature (SST) and Sea Surface Salinity (SSS). Fig 3.6 shows mean model and corresponding SST and SSS for July a representative month of monsoon. Work on implementing an ocean initialisation scheme with NEMO-Var was continued. Work on implementing the source codes, scripts and test data have been completed.

3.3.2 Evaluation of Model Forecasts

Verification of the model forecasts is a continuous process for development of next generation numerical weather prediction systems with increased reliability through research and development. A set of diagnostics, which include forecast systematic errors and standard verification scores suggested by WMO/CBS are generated every month. During the recent years several changes have been implemented in the ESSO-NCMRWF analysis-forecast system and the model performance over India has been evaluated. The root mean square error (RMSE) of the magnitude of the wind vector (RMSEV) for the ESSO-NCMRWF GFS T574L64 operational model (blue line) day 03 forecasts at 850 hPa level against the radiosonde observations over India since January 2005 is shown in Fig 3.7. The overall decrease in the RMSEV can be attributed to the increase in the

Fig 3. 7. Monthly average root mean square vector wind errors at 850 hPa for day-3 forecasts against observations over India.

resolution of the model, increase in the amount of data being assimilated and improvements in data assimilation techniques. The scores from NCUM forecasts (red line) since April 2013 show that the NCUM forecasts are marginally better compared to GFS.

New tools for Forecast Verification and Diagnostics:

Spatial verification of rainfall forecasts using advanced verification technique based on Contiguous Rain Areas (CRAs) is adopted. The CRA method is an object oriented verification procedure suitable for gridded forecasts that was developed for estimating the systematic errors in forecasts for rain. It is one of the first methods to measure errors and to segregate the total error into different
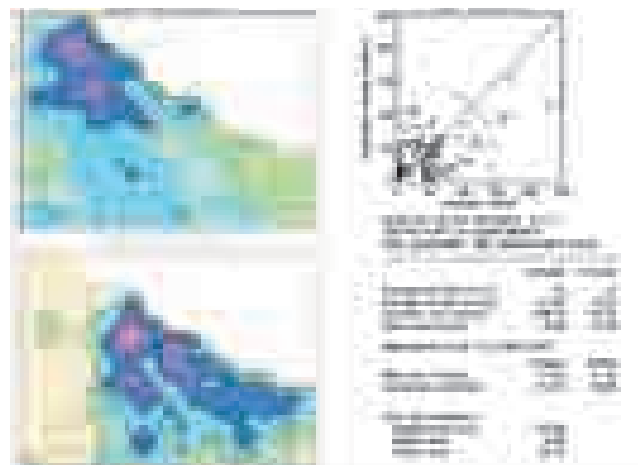
Fig 3. 8. CRA verification of day-5 rainfall forecasts from NCUM valid for 17th June 2013

components like location, volume and pattern. Verification of categorical rainfall forecasts is carried out for five rainfall thresholds (1, 10, 20, 40 and 80 mm/day) and the results indicate higher skill score for NCUM as shown in the Fig 3.8 for the Uttarakhand rain during 16-18 June 2013.

Model Evaluation Tools (MET):

The development and improvement of NWP models are possible only in conjunction with the development of advanced special

diagnostics tools and utilities. These are specific to generate not only the traditional diagnostics but also to provide additional and meaningful insight into the model weaknesses and strengths in terms of underlying physical processes especially for very high resolution models and observations. MET is a state-of-the art verification package which incorporates both the traditional and many of the special diagnostics (like Method of Object-based Diagnostics Evaluation - MODE and wavelet analysis). MET tool was implemented and customized for WRF, GFS and UM outputs. Utilities were developed to compare the routine model forecast products with conventional GTS and AWS observations and also for evaluating all important parameters from model output.

3.3.3 Application of NWP forecasts for various sectors

The NWP forecasts were provided to various sectors for different applications. The details are given below:

Satellite Launching: 7-days forecasts of wind and geopotential height to ISRO-SHAR during the launch of (1) PSLV- C221 IRNSS-1A Mission Launch date 07 Feb 2013 (2) GSAT-14 D5 Mission Launch date 14 Aug 2013 (3) PLSV-C25 Mars Orbiter Mission Launch date 05 Nov 2013 were provided.

Wind Energy: A large number of wind energy farms are operational in India and at present the total installed capacity is about 19000 MW. It is expected that an additional capacity of 2000 MW will be added every year. It has become mandatory for all wind power generators to provide generation schedules in advance. It necessitates accurate high-resolution gridded data of observed and short-term forecasts of wind speed and direction at surface and lower levels (up to 100 metres) for wind power forecasting and scheduling. In a pilot study, 72-hour forecasts of zonal wind (u) and meridional wind (v) is provided. The winds are provided at the levels of 50 and 100 m at every 1 hour interval

based on the initial conditions of 00 and 12 UTC respectively. Preliminary results have shown that for a wind farm located in Tamil Nadu, the actual power generation lies within 30% of the wind power generation forecast schedule based on the ESSO-NCMRWF wind inputs. Analyses and 120 hour forecasts of surface and near surface parameters for the period Jun 2011-Dec 2012 to the Centre for Wind Energy Technology (C-WET) for comparison with the observation over a wind farm in Maharashtra were provided.

Nuclear Emergency Warning System: The Bhabha Atomic Research Centre (BARC) has put in place a real time online nuclear emergency response system, with 72 hours meteorological and radiological forecasts, for off-site nuclear emergency (Indian Real time Online Decision Support System "IRODOS"). IRODOS has been designed and developed, to take care of the predictive requirement for emergency planning. High resolution (3km) hourly forecasts up to 72 hours for 4 sites (namely, Kaiga, Trombay, Narora and Kalpakkam) which is used in dispersion modelling to get the radiological forecast are provided.

Ocean & Wave Model Inputs: Real-time atmospheric forecasts of specific parameters were provided to ESSO-INCOIS to initialize their ocean models such as WAVEWATCH-III, Regional Ocean Modelling System (ROMS) and HYbrid Coordinate Ocean Model (HYCOM).

Snow and Avalanche Study Estt (SASE): A support to SASE's regional atmospheric modelling efforts by providing forecast outputs from global model in real-time has been continued. The regional model products are further used for snow and avalanche prediction.

3.3.4. Forecast Generation for Neighbouring Regions

The Regional Integrated Multi-Hazard Early Warning System for Africa

and Asia (RIMES) is an international and intergovernmental institution, owned and managed by its Member States, for the generation and application of early warning information.

The 12 Member States are: Bangladesh, Cambodia, Comoros, India, Lao PDR, Maldives, Mongolia, Papua New Guinea, Philippines, Seychelles, Sri Lanka and Timor-Leste. The 19 Collaborating Countries are: Afghanistan, Armenia, Bhutan, China, Indonesia, Kenya, Madagascar, Mauritius, Mozambique, Myanmar, Nepal, Pakistan, Russian Federation, Somalia, Tanzania, Thailand, Uzbekistan, Vietnam, and Yemen. Customised forecasts for each country is generated at daily and provided through RIMES website/e-mail.

BIMSTEC Centre for Weather and Climate (BCWC)

BIMSTEC (Bangladesh, Bhutan, India, Myanmar, Nepal, Srilanka) Centre for Weather and Climate has been established at ESSO-NCMRWF. Preliminary analysis of GPCP monthly precipitation over the BIMSTEC countries for July rainfall anomalies from 1979 to 2010 for each of the BIMSTEC member countries indicates that mechanisms of precipitation variability over the countries in the BIMSTEC region are different. An analysis of cyclogenesis over the Bay of Bengal (using IMD e-atlas of tropical cyclones) suggests that strong interannual variability exists on the locations of cyclogenesis. Mechanism of such interannual variability and long-term trend, if any, are being investigated.

India-Africa Centre:

An India-Africa Centre for Medium Range Weather Forecasting (IAC-MRF) has been planned to fulfil India's commitments made at the second Africa-India Forum Summit in the area of capacity building in Africa. ESSO-NCMRWF has been entrusted with the responsibility of establishing such centre in Mauritius, Africa. The regular monitoring of the reception of observations from African SYNOP and upper air stations through GTS has been initiated. It has been seen that though the density of real time observations received is very low, the volume and distribution of observations received at are comparable to that of other leading NWP centres (UKMO, ECMWF). This shows that either many of the African stations are not reporting the data through GTS or not taking observations. It is planned to set up few upper-air and surface observing system over Africa under this project.The evaluation of global model predictions over the African region has been initiated. Meteograms for 52 capital cities of the African Union countries showing 7-days prediction of surface temperature, humidity, pressure, wind and rainfall are being generated regularly and posted in ESSO-NCMRWF's web site. The analysis of global model prediction skill for different meteorological parameters over the African region is in progress.

3.4   CLIMATE PREDICTION MODELLING

(i)   Completion of a 100-year run with the ESSO-IITM Earth System Model

A 100-year run with the ESSO-IITM Earth System Model Version 1 (ESM v1) has been successfully completed. Results indicate that the cold bias that was endemic to the long runs of CFS v2, the original model from which the ESM was developed through modification of the ocean component, has been substantially reduced, and is realistic. Due to this, the simulated SST variability in the tropical pacific has also been improved. The preliminary analysis indicates that the improvement may be associated with the improved mixing process. Further, the ESM sub-group working on preparation of an interactive aerosol model (Hamburg Aerosol Model, HAM) has successfully set up a CFS base version.

(ii)   ENSO-Monsoon links in the IPCC AR4 models

Study on the ENSO-Monsoon links in the IPCC AR4 twentieth century (20C3M) simulations shows that a majority of the AR4 vintage climate models are unable to reproduce the principal modes of climate variability in the tropical Pacific. Results indicate that only a quarter of the twenty odd models examined from 20C3M capture either of the ENSO or ENSO Modoki patterns during boreal summer. Of these "better" models, only two models simulate both ENSO and ENSO Modoki as important modes. Again, out of these two, only a single model simulates both ENSO and ENSO Modoki as important modes during both summer and winter. Further, while these two models represent the links of the ISMR with ENSO reasonably in 20C3M simulations, but indicate opposite type of impacts in the future climate projections. This study brings out the limitations of the models in reproducing the variability of the ENSO types, and reveals the challenges in understanding the changing teleconnections due to global warming.

(iii) Simulations using variable resolution global general circulation model

Feasibility of using a variable resolution global general circulation model (GCM), with telescopic zooming and enhanced resolution (~35 km) over the South Asia has been studied to better understand regional aspects of the South Asian monsoon rainfall distribution and the interactions between monsoon circulation and precipitation. For this purpose, two sets of ten member realizations are produced with and without zooming using the LMDZ (Laboratoire Meteorologie Dynamique and Z stands for zoom) GCM. The simulations without zoom correspond to a uniform 1 x 1 grid with the same total number of grid points as in the zoom version. So the grid of the zoomed simulations is finer inside the region of interest but coarser outside. It

is found that the monsoon simulation with high-resolution zooming greatly improves the representation of the southwesterly monsoon flow and the heavy precipitation along the narrow orography of the western Ghats, the north-eastern mountain slopes and northern Bay of Bengal. A realistic Monsoon Trough (MT) is also noticed in the zoomed simulation, together with remarkable improvements in representing the associated precipitation and circulation features, as well as the large-scale organization of meso-scale convective systems over the MT region. Additionally, a more reasonable simulation of the monsoon synoptic disturbances along the MT is noted in the high-resolution zoomed simulation. On the other hand, the no-zoom version has limitations in capturing the depressions and their movement, so that the MT zone is relatively dry in this case.

3.5   REGIONAL CLIMATE CHANGE PROJECTION

3.5.1 Co-ordinated Regional Downscaling Experiment (CORDEX) South Asia

CORDEX is a major international project of the World Climate Research Programme (WCRP), on regional climate projection experiments to (i) better understand regional climate processes and improve climate models, (ii) evaluate high-resolution regional climate change scenarios and quantify uncertainties in regional climate projections, (iii) link climate modelling better with regional impact, adaptation and vulnerability assessment and develop regional capacity for assessment of regional climate change. The Centre for Climate Change Research (CCCR), ESSO-IITM has been designated as the official nodal agency for leading and coordinating the CORDEX program over the South Asian region. As part of this activity, CCCR and several partner institutions are involved in the generation, analysis and verification of high-resolution regional climate simulations

over the South Asian region required for assessment of climate change impacts. Regional downscaling of outputs from multiple models will allow estimation of uncertainties in the regional climate projections. With regard to CORDEX South Asia, regional climate change simulations from multiple models have been completed and are being analyzed. Efforts are underway towards development of a data portal for archival and sharing of CORDEX data required by regional impact assessment groups.

3.6 MONSOON MISSION

(i) Dynamical Seasonal Prediction for 2013 Indian Summer Monsoon Rainfall (ISMR)

Dynamical Seasonal prediction for the 2013 Indian Summer Monsoon rainfall (ISMR), using CFS v2, was prepared and provided to the ESSO-IMD for the national forecast of monsoon using the February initial conditions. The forecast was issued on 26th April, 2013 and was as follows:
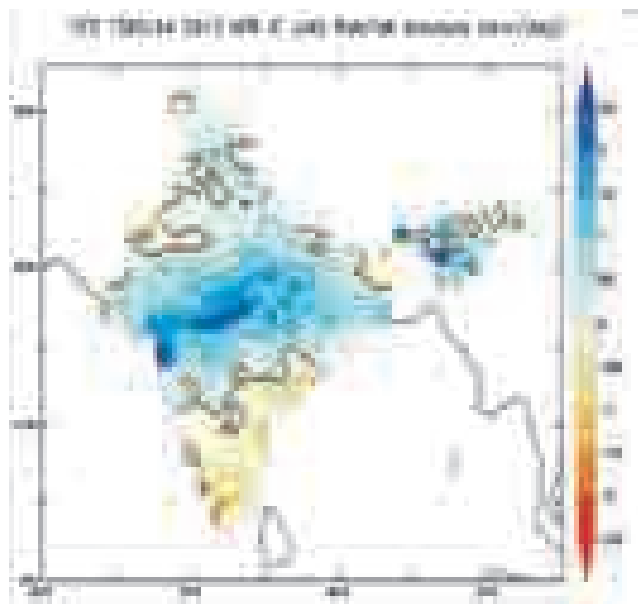
Fig.3.9: Rainfall prediction over Indian region during the 2013 monsoon season using high resolution T382L64 CFS v2 model with April Initial Conditions. The Fig. shows the JJAS (June to September) rainfall anomaly (in mm/day) over the Indian region.

The experimental five category probability forecasts for the 2013 monsoon season rainfall over the country as a whole using the experimental dynamical prediction system are 19% (deficient), 10% (below normal), 33% (normal), 19% (above normal) and 19% (excess). The quantitative forecast indicates that the rainfall during the 2013 monsoon season (June to September) averaged over the country as a whole is likely to be 104% ±5% of long period model average (LPMA).

The experimental dynamical forecast for the 2013 SW Monsoon season rainfall (over the Indian region) (using the latest high resolution research version of the Experimental Coupled Dynamical Modeling System CFS v2) issued on 14 June 2013 using the April initial conditions indicated that the rainfall during the 2013 monsoon season (June to September) averaged over the country as a whole is likely to be 108% ± 4% of long period model average (LPMA). The actual monsoon rainfall during the 2013 season was 106% of its long period average.

(ii) Extended Range Prediction of Active/ Break Spells of ISMR

Experimental real-time forecast of the active-break spells of ISMR since 2011 up to 4 pentad (i.e., 20 days) lead using an indigenously developed Ensemble Prediction System (EPS) based on the Climate Forecast System Version 2 (CFSv2) model has been provided. The EPS generates a large number of forecasts from different initial conditions so that the expected forecast and also the expected spreads or uncertainties in terms of probability from this forecast can be informed.

The real time operational forecasts are issued from 16 May to 28 September at 5-day interval. For the current season, the forecasts are issued from CFSv2 as well as from the Global Forecast System atmospheric model (GFSv2) forced with bias corrected SST from CFSv2 (GFSbc), at T126 resolution. In addition to this, some aspects of large-scale Monsoon
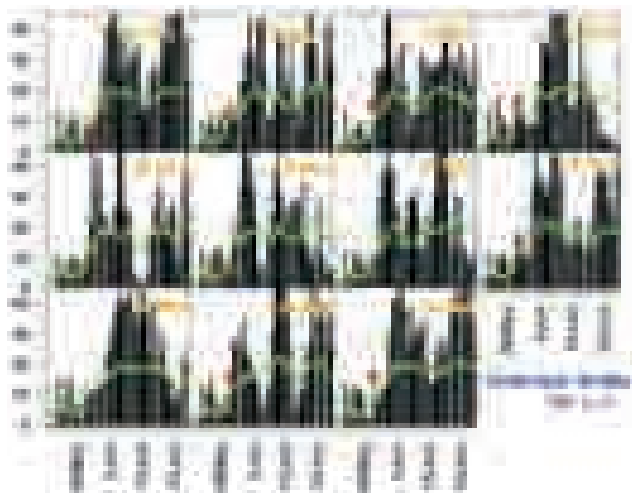
Fig.3. 10: Forecast of Monsoon Onset over Kerala (MOK) based on 16 May 2013 initial condition. Onset date forecasts are obtained from each 11 member of CFS v2 45 day forecast. Then ensemble mean is given as the final forecasted onset date. Red circle is the onset date and also written at the top of each panel

Intraseasonal Oscillations (MISO) are also provided. Predictions and verification have been done over 4 different homogeneous regions of India where ISMR is more or less homogeneous. Forecasts are issued over five homogeneous regions, viz., Central India (CEI), North-East India (NEI), North-West India (NWI), South peninsula (SPI) and a broader region, monsoon core zone of India (MZI).

Prediction of Monsoon onset over Kerala (MOK) was issued from CFSv2 alone based on 16 May initial condition. MOK was forecasted to be 29 May, whereas the actual MOK declared by IMD was on 01 June (3 days later than the forecasted onset). The forecasts from both CFS v2 and bias corrected GFS v2 indicated that monsoon will cover entire country by around 15-20 June, which was experienced in reality.

COASTAL AND OCEAN OBSERVATION SYSTEMS, SCIENCE AND SERVICES

In order to provide reliable, timely and accurate ocean information and advisory services, it is important to sustain an ocean observation system in the seas around India. The ocean observation system has been designed to acquire real-time data on surface meteorological and upper oceanographic parameters from the Indian Ocean region. The primary purpose of acquiring a suite of accurate measurements of ocean parameters is to cater to needs of research and a wide range of operational services including issue of early warning to tsunami and storm surges. Besides, the information from the seas around India is extremely useful of ocean-atmospheric modelling purposes and validation of satellite data.

4.1   OCEAN OBSERVATIONS

4.1.1. MOORED PLATFORMS

The moored platforms are primarily moored data buoys, current meter arrays, RAMA morrings, ADCP, tide gauges, which are deployed at selected locations for continuous reception of time series data.

Buoy network

Ocean Moored buoy Network (17) for the Northern Indian Ocean (OMNI) systems have unique features for measurements of sub-surface parameters in addition to the standard meteorological and ocean parameters in conventional buoy systems. This buoy system transmits more than 66 met-ocean parameters in real time apart from buoy health monitoring parameters.

Fig 4.1 Location of Data Buoys and Tsunami Buoys

The Moored Buoy Network is performing successfully and providing valuable data despite many challenges faced. During this period, 70 deployments/retrievals were completed through 11 cruises of 145 ship-days covering 17021nm (nautical miles) with 2200 man-days. These buoy systems captured the Thane, Jal, Mahasen cyclones and also provided the valuable database for scientific and oceanographic community. These observations also helped to validate the predicted track of "Phailin" cyclone.
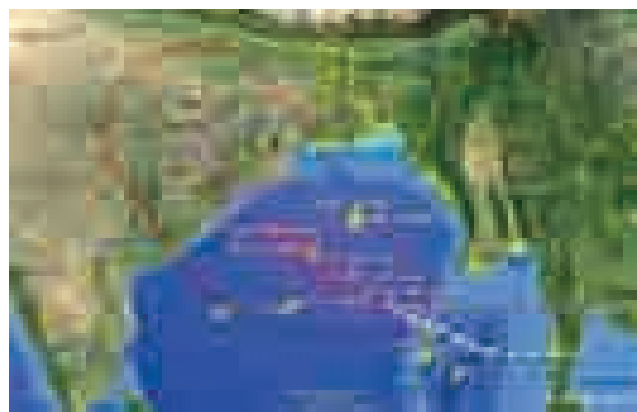
(a)

(b)
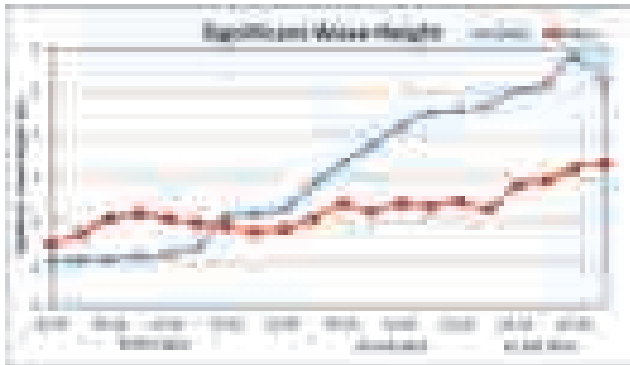
(c)

(d)

Fig. 4.2. The Phailin cyclone was tracked by OMNI buoy BD10 in the Bay of Bengal during 08-12 Oct 2013 a) Track of the cyclone b) Surface air pressure c) Significant wave height and d) wind speed

Four coastal buoy systems are also installed in locations such as Agatti, Port Blair, Goa, Krishnapattinam and also off the Gujarat coast. A new buoy system is being designed with extended life time for tsunami buoy application. This will also include development of water level recorder for tsunami buoy applications. Tsunami buoy at TB12 in the Arabian Sea

is providing continuous data and captured the change in water level on 16th April 2013, following an earthquake event which occurred at South Western Pakistan (Lat:28.107 N, Long:62.053 E) with a magnitude of 7.9.Mw (mB).

The **Advanced Data REception and analysiS System** (ADDRESS) software has been upgraded with BPR, Buoy watching circle and Wind pattern animation analysis, for continuous monitoring of buoy system.

Wave Rider Buoys

With the deployment of two more wave rider buoys off Kozhikode and Gopalpur, the wave rider buoy network expanded to 10 buoys network. All wave rider buoys are integrated with INSAT communications.

Ship/Platform mounted AWS

The Automated Weather Station network installed onboard ships has been increased to 18. A new suite of water quality sensors FLNTUS-ECO Chlorophyll fluorometer, Turbidity meter with SST sensor and Bio-wiper are integrated with the AWS on board Sagar Nidhi. They provide real time data through INSAT communications.

Tide gauge network

21 tide gauges along the west and east coasts as well as over the Andaman and Nicobar islands have been installed.

RAMA Observational Network

Currently, 31 out of 46 (67%) planned moorings have been established and are being maintained by USA and India. Time series measurements of temperature, salinity and surface meteorological parameters recorded at 8 N, 90 E in the southern central Bay of Bengal (Fig.4.3) recorded temperature inversions and their influence on the mixed layer heat budget during the winter (October to March). The analysis showed that intraseasonal and

interannual variability in the thermocline significantly influences the frequency and magnitude of temperature inversions and thickness of barrier layer. The heat budget estimates showed at intraseasonal and interannual time scales, the variability in temperature inversions significantly influenced the SST by modulating the vertical heat flux at the base of mixed layer.

Fig 4.3. Temporal evolution of temperature (C) obtained from (a, b) daily RAMA buoy data at 8 N,90 E during winter (a) 2006-07 and winter (b) 2007-08. In the Fig., thick, dashed and thin lines indicate MLD, ILD, and D23, respectively. Pink contours indicate temperature inversions of magnitude 0.1 C or greater.

HF Radars

Five pairs of HF Radar Remote Stations and two Central Stations (ESSO-NIOT and INCOIS) are being maintained. The surface current flow prior, during and after the Phailin cyclone crossing, near the radar coverage area shows very interesting effect of flows on the ocean surface. The current speed is in the range 60 – 80 cm/s during the normal weather and during cyclone it reaches up to 100 cm/s. A cross meridional flow between the Islands is observed daily which makes an outflow of water from the western part of the islands to the eastern part. However, during the cyclonic event (October 8th), the velocity of the currents increased, as it was pushed by the cyclonic winds, southward. The changed pattern continued throughout the day after which the cyclone crossed the eastern part of the island. This provides us with an excellent opportunity to study the pattern of the surface currents during a cyclonic event.

4.1.2 PROFILING FLOATS

The profiling floats are primarily drifters, argo floats, gliders, etc for collection of limited parameters covering over a large area, which are also capable of transmitting real time data.

Argo Profiling Floats

India continued to contribute to the global efforts on the Argo floats programme. The number of floats deployed by India till September 2013 stands at 304. About 25000-30000 temperature-salinity profiles are measured by these Argo floats in the Indian Ocean.

Drifters

To collect surface meteorological and oceanographic data using the satellite tracked drifting buoys for providing near-real time operational data on SST, sea level pressure and surface winds through GTS for weather prediction, about 37 Met Ocean drifters are being deployed in the Bay of Bengal and the Arabian Sea. The work on development of data transmitter compatible with INSAT is under progress.

4.2. OCEAN INFORMATION ADVISORY SERVICES (O-IAS)

The ocean information and advisory services being rendered to various stakeholders in India and countries of the Indian Ocean Region, include (i) Tsunami Advisories, (ii) Ocean State Forecast (iii) Potential Fishing Zone Information (iv) Ocean Data Dissemination (v) Capacity Building. These services of immense economic benefit are catered to needs of over 12 sectors of both private and public enterprises, which have been contributing substantially to the Gross Domestic Product (GDP) of the nation. The details of major accomplishments under various areas are as follows:

4.2.1.Tsunami Advisories

Indian Tsunami Early Warning Centre (ITEWC) had monitored 65 earthquakes of magnitude 6.0 Mw during the period April 2013 to March 2014 and issued the necessary

bulletins/advisories. Being the Regional Tsunami advisory Service Provider (RTSP), the earthquake/tsunami bulletins have also been issued to the Indian Ocean Rim Countries, Pacific Tsunami Warning Centre (PTWC), Japan Meteorological Agency (JMA) and International Oceanographic Commission (IOC) through email, GTS, FAX and SMS.

Pakistan earthquake on 24 September 2013 with magnitude 7.6 Mw

An earthquake of magnitude 7.6 Mw(mB) occurred in Pakistan on 24 September 2013 at 1659 IST, (24 September 2013, 1129 UTC). The earthquake happened about 180 km away from the nearest coast (epicenter at 26.99^0 N and 65.52^0 E at a focal depth of 10 km). ITEWC issued two bulletins for the event indicating that tsunami threat does not exist for India and the Indian Ocean rim countries. Indian tsunami buoys (STB02 and TB12) and about 8 sea level gauges on the coast of India, Iran and Oman (Fig. 4.4) showed an open ocean tsunami wave of 9 mm and 11 mm and coastal tsunami of 2 cm to 55 cm perhaps due to the motions/landslide in the sea caused following the large earthquake on the land. Further analysis is required to identify the actual reason for the occurrence of this low magnitude tsunami.
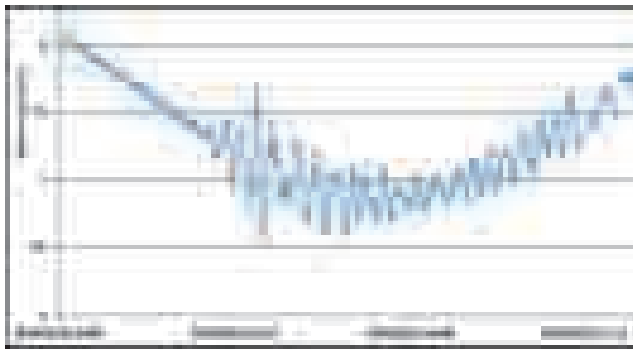
Fig.4.4. Tide gauge from Qurayat Oman, depicting the Tsunami due to Pakistan earth quake

4.2.2. Ocean State Forecast

An improved ocean state forecast was provided to a wide spectrum of users. The sea state forecast was also generated and disseminated during the passage of very severe cyclone Phailin that struck the Odisha coast at 09:00 pm on 12th October 2013. The predicted wave heights (Fig.4.5) matched well with the wave heights reported by the wave rider buoys deployed off the Gopalpur coast.

Fig.4.5. Real time validation of the predicted wave height off Gopalpur during the passage of very severe cyclone 'Phailin'.

Special ocean state forecasts were generated and provided along the ship-routes. The predicted wave heights were compared (Fig.4.6) with the Wave Height Meter (WHM), which is based on a microwave Doppler radar sensor, on board ORV Sagar Nidhi and the wave heights estimated from the satellite based altimeters on board Cryosat 2, Jason-1 and Jason-2 satellites.
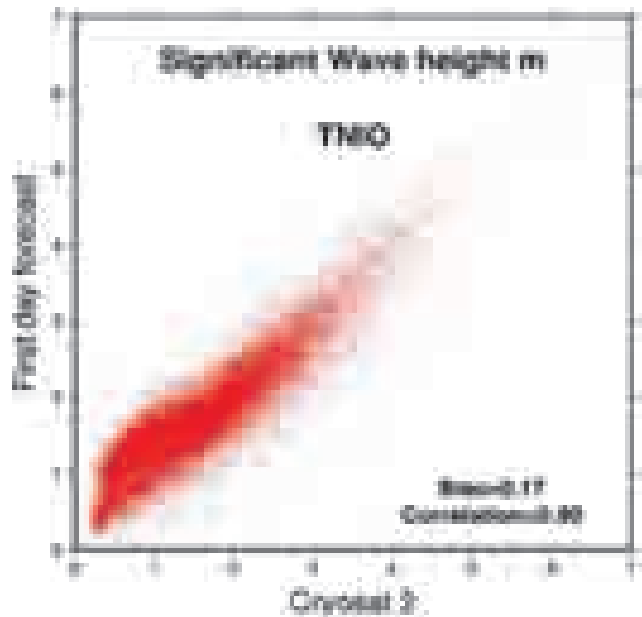
Fig.4.6. Scatter plot showing the comparison between the predicted significant wave height along the ship routes and the significant wave heights estimated from Cryosat-2, Jason 1 and Jason 2 satellites passes over the Tropical northern Indian Ocean.

4.2.2. Ocean State Forecast Service for the Maldives Islands

A customized ocean state forecast on waves, surface currents, Sea Surface Temperature (SST), Mixed Layer Depth (MLD) and ILD has been established on a daily basis for the waters around the Maldives Islands. A dedicated webpage (http://www.incois.gov.in/Incois/osf_rimes/index.jsp) has also been setup for the dissemination of forecasts directly as well as through Regional Integrated Multi-Hazard Early Warning System for Africa and Asia (RIMES). Location specific information/forecasts on ocean state at 21 locations around the Maldives islands are being provided on a regular basis.

4.2.3. Global Ocean Analysis products

A new service was launched on generation and dissemination of the Near-Real Time GODAS (N-RIG), using global ocean analysis on a daily basis. This was made operational which is an improved version of NOAA/NCEP-GODAS. The new system is capable of providing ocean analysis (Fig.4.7), based on the Modular Ocean Model (MoM) that assimilates *in-situ* temperature and salinity profiles available on GTS. Atmospheric analysis generated by ESSO-NCMRWF is used to force the ocean model. Compared to the earlier version of INCOIS-GODAS that was providing the ocean analysis with a delay of 30-days the new N-RIG produces daily 3-dimentional analysis of global ocean with a delay of two days. The outputs from N-RIG are shared with public through ESSO-INCOIS.
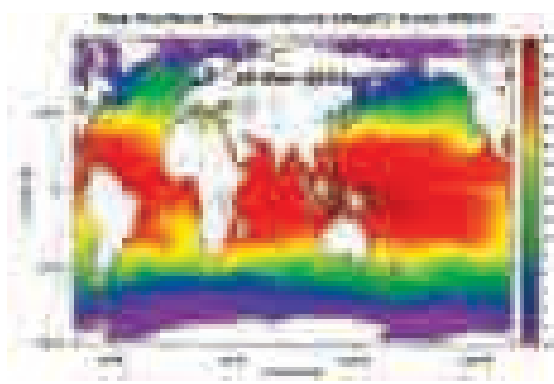
Fig 4.7. A snapshot of near-real time INCOIS-GODAS ocean analysis on ESSO-INCOIS live access server.

4.2.4. Potential Fishing Zone Information

Multi-lingual Potential Fishing Zone (PFZ) advisories to the fishing community on a daily basis were provided to the concerned stakeholders using the SST and Chlorophyll available for the day from all satellites passed over the region (including the night passes; from NOAA-18, NOAA-19, METOP 1 & 2, MODIS Aqua and OceanSat-2), acquired by the ground stations at ESSO-INCOIS. The number of fish landing centers to which the PFZ advisories provided has been increased to 586 from earlier 267 with the inclusion of 319 minor fish-landing centres. Sixteen Yellow Fin Tunas have been tagged so far using satellite telemetry pop-up tags under a collaborative programme between ESSO-INCOIS, CMFRI, ESSO-CMLRE and FSI.

4. 3. OCEAN MODELING

The ocean modelling activity entails implementation of a suite of ocean models of different special scales, viz., Global, regional and Local models required for generation of wide ranging ocean information services. The details of modelling activity which include assimilation of ocean data are as follows:

4.3.1 Storm Surges

A storm surge model based on ADCIRC has been successfully conFig.d for the east coast of India for the prediction of storm surges that may occur during the landfall of cyclones. Triangular gridded meshes are developed for the entire east coast of India to compute cyclone induced surges and associated inland inundation. Model is tested with some past cyclones and the simulations are in good agreement with available observations. Experimental forecast of the storm surge and associated inundation were issued in real time during the severe cyclone PHAILIN that had a landfall near Gopalpur on 12 October 2013 (Fig.4.8).

4.3.2. HYCOM

Hybrid Coordinate Model (HYCOM) has been equipped with a data assimilation scheme (based on multivariate linear statistical estimation using Best Linear Unbiased Estimate (BLUE)) to assimilate sea level anomalies and SST. The system takes boundary conditions from Global HYCOM and issues 5 day daily updated forecasts of oceanic parameters. Cross-verification of the model free-run and forecast runs were carried out and it was found that there is no considerable deterioration of skill from forecast day 1 to 5 (Fig. 4.9).
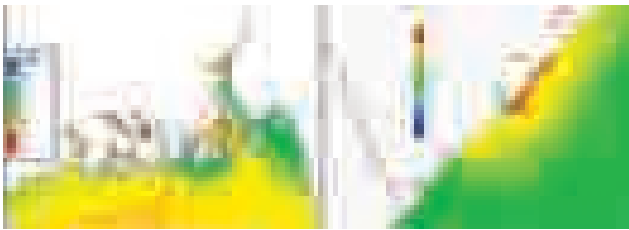
Fig.4.8. Simulated water level and associated inundation due to cyclone a) Sidar (left) and b) Phailin (right).

Fig.4.9. RMSD-SLA (cm) HYCOM vs altimeter, Top Left- NO Data assimilation shows error build-up during 2 years free run and other panels show DAY-1-5 Forecasts with Data assimilation with reduced errors.

4.3.3. High-resolution Regional Ocean Modeling System (ROMS) for coastal ocean forecasts

The first in the proposed series of very high resolution Regional Ocean Modeling System (ROMS) setups for the coastal waters of India has been set up for the northwestern coast of India (64.0° E to 74.0° E; 8.0° N to 25.0° N). Currently, this model set-up takes boundary condition from the basin-scale set up of ROMS with a horizontal resolution of 12.5 km (Fig.4.10).

Fig 4.10.Comparison between the observed (top) and model simulated (bottom) along-shore currents (in cm s-1) at 72.7° E, 15.1° N (left) and 69.2° E, 20° N (right).

4.3.4. Wave Modeling

The first in the series of high resolution wave forecast models for the Indian coasts, SWAN (Simulating WAves Nearshore) has been set up for the coast Puducherry on the east coast of India. The boundary conditions for SWAN taken from the global WW3 run (Fig.4.11)
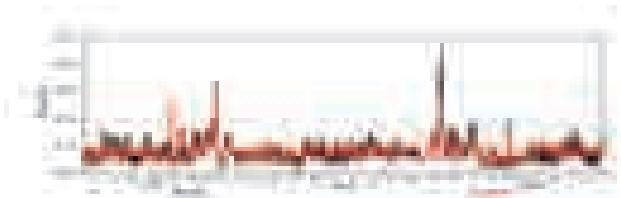
Fig 4.11. Validation of simulation of significant wave height at Pondicherry for the period from June 2007 to July 2009.

4.4. OCEAN COLOUR RESEARCH

The time-series stations established in Indian coastal waters, as a part of Ocean Colour Research programme are being continued with the addition of stations off Veraval, Chennai and Sundarbans.

4.4.1. Chlorophyll dynamics in near coastal waters of the western Bay of Bengal using in situ and long-term satellite data

The temporal distribution of Chla, TSM and $a_{CDOM}440$ showed one common peak during southwest monsoon season (August-October). Chla also showed a prominent peak during pre-southwest monsoon (March-April) (Fig. 4.12).

Fig 4.12. Spatially and monthly averaged a) Chla, b) TSM, c) a_{CDOM}440 and d) spectral slope of CDOM off the coast of Odisha. The vertical bars indicate the standard deviation.

The Chla, retrieved from Moderate Resolution Imaging Spectroradiometer onboard the Aqua satellite (MODISA), Ocean Colour Monitor onboard Oceansat-2 (OCM-2) and Visible Infrared Imager Radiometer Suit (VIIRS) onboard Soumi National Polar-orbiting Partnership (NPP), showed (Fig.4.13) overestimation in the nearshore waters (depth < 30m). The error in satellite estimation of Chla was in the range of 33 to 51% and the overestimation was predominantly due to the covariance of TSM with Chla. The Chla retrieved from MODISA using OC3M algorithm was better compared to other retrievals.

Fig.4.13. Scatter plot showing the relation between in situ measured Chla and that derived from a) MODISA using OC3M algorithm, b) VIIRS using OC3V algorithm and c) OCM-2 using OC4-O2 algorithm. The dotted line indicates 1:1, solid straight line shows the regression and solid curved lined shows the 95% confidence limit.

4.5. COASTAL RESEARCH

4.5.1. Coastal Water Quality Monitoring:

Recognising the importance of monitoring the quality of coastal waters to fisheries and other human related uses, the data on 25 environmental parameters including physical, chemical, biological and microbiological characteristics of water and sediment at selected locations are being collected in the 0 – 5 km sector of the coastline of the country, covering the maritime states and UTs. The achievements made during 2013 pertaining to water quality monitoring are as given below:

Karnataka: Monitoring was carried out at Mangalore. The dissolved oxygen (DO) (3–5 mg/l) and levels of nutrients (nitrate: 5-12 µmol/l) were in normal range. Higher incidence of pathogenic bacteria (SFLO: NG-5100 CFU/ml) indicates contamination due to domestic sewage and riverine discharge.

Lakshadweep: At Kavaratti (May'13), DO (3–7 mg/l) and nutrients were in normal range. However, high levels of pathogenic bacteria (SFLO: 420-13600 CFU/ml) indicate contamination due to domestic wastes.

West Bengal: At Sandheads (Aug'13), high levels of DO (7-9 mg/l) and moderate levels of nutrients (nitrate: 1-5 µmol/l) indicate good water quality. However, high levels of pathogenic bacteria (SFLO: 250–15000 CFU/ml) indicate contamination due to domestic sewage.

Orissa: At Paradip (Apr'13, Jul'13), DO (6–8 mg/l) and nutrients were in normal range. However, moderate levels of pathogenic bacteria (SFLO: 25-4000 CFU/ml) indicate contamination due to domestic sewage.

Andaman and Nicobar Islands: Coastal water quality at Port Blair and Wandoor during May and Aug'13, is observed to be good with normal levels of DO (5–7mg/L) and nutrients. Low levels of pathogenic bacteria was observed (SFLO: NG-120 CFU/ml).

The data collected under COMAPS programme over the years have been compiled and organized into databases and hosted in the ESSO-INCOIS website for dissemination.

4.5.2. Prediction of water quality

In order to understand coastal water quality e.g., DO, BOD, nutrient and bacteria, their dispersion and transport in the near shore waters and likely changes of the water quality in future; a program is initiated with an objective to simulate real time scenarios and predict the health of the coastal waters. Monthly field observations are being carried out at 36 coastal

and offshore for physico-chemical, biological and microbiological parameters of water and sediment. Long term COMAPS (2001- 2010) data infer average DO levels fall below 5 mg/l and a slight improvement is noticed since 2007; the real time observed DO data are in the order of 5 ~ 8 mg/l. Phytoplankton blooms extending over the surf zone occurred on 8 Feb (Asterionella japonica) and 27 March (Phaeocystis sp.). This is mainly due to dredging of the Adyar and Coovum river mouths which bring high nutrient load in to the coastal water and altering the nearshore water quality and triggering such blooms. The longshore current distributes and disperses the bloom within surf zone and contaminates the coastal environment and the public utility beaches (Fig 4.14).
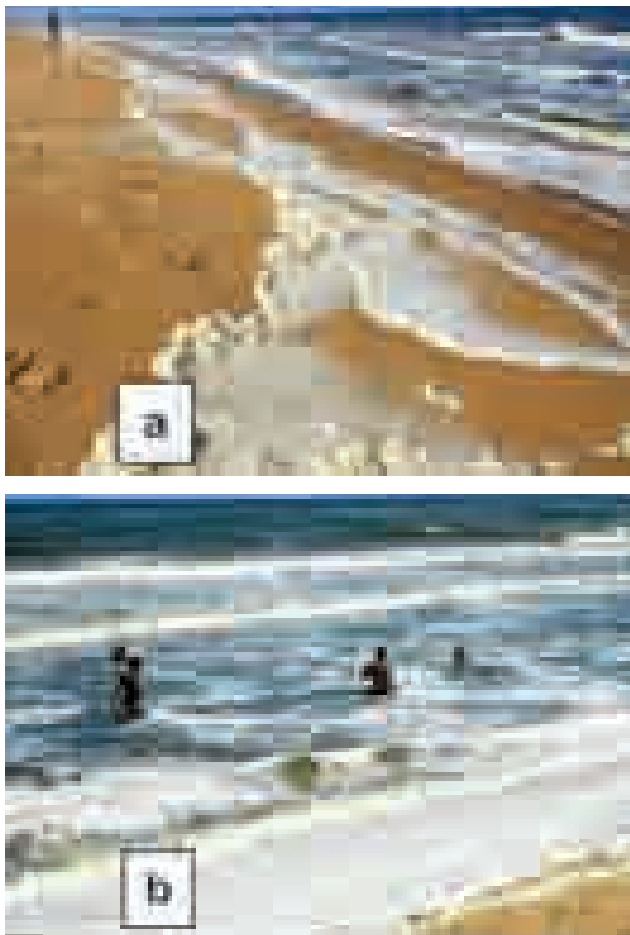
Fig. 4.14: (a) Occurrences of Phaeocystis sp. (Toxic algae) and (b) Chaetoceros sp. bloom.

The Adyar and Cooum Rivers record high nutrient loads (ammonia, sulfide, phosphate, silicate) and lesser aerobic aquatic life due to increased inputs of domestic and industrial wastes. Shannon and Wiener species diversity (Phytoplankton) index (H) categorises Chennai coastal water quality under 'Poor' (H=<2.0). The Cooum and Adyar rivers were least diverse in terms of species richness (Shannon-Wiener index, H' and Margalef, d') while the evenness (J') was least in the beach stations suggesting overwhelming dominance of certain species (e.g., Asterionella japonica, Chaetoceros sp. and Phaeocystis sp.) in the population.

The water quality model is set up for 30X6 km domain to predict the water quality i.e., DO-BOD-Bacteria. Models such as DHI-MIKE ECOLAB, River and Water Quality Model (QUAL2E, Environmental Fluid Dynamics Code (EFDC) are being initiated.

4.5.2. Marine Ecotoxicology

Seawater Quality Criteria (SWQC) for heavy metals like Cadmium, Copper, Mercury, Zinc, Lead, Arsenic, Chromium and Monocrotophos for the Ennore and adjacent coastal waters of Chennai was derived and a revised report is under preparation (after incorporating the Expert's Committee review) for evaluation by the Central Pollution Control Board (CPCB) for consideration to notify as Primary Water Quality Criteria for coastal uses. Toxicity experiments for other metals like Nickel are under progress. Considering such criteria for ecologically sensitive area for e.g. Coral reef ecosystem of Gulf of Mannar, the ecotoxicology studies for 5 chemicals viz., Cadmium, Copper, Mercury, Zinc and Lead were completed and the samples are under process to derive the safe limits of the chemicals. Similarly toxicity studies for the Kochi backwaters for heavy metals to determine such criteria are initiated with participation of the Cochin University of Science and Technology, Kochi.

4.5.3. Ecosystem Modelling

The study area includes coastal waters (within 50m depth contour from the shoreline) from Goa to Kanyakumari including estuarine, inlet, backwaters. The main objective of the programme is to hindcast and forecast the ecosystem response in SW coast/ marine environment to anthropogenic /natural inputs and also impacts of climate change. Estimation of C, N and P fluxes and also prediction and validation of primary productivity are being carried out. Three season data (Jan, Feb and Aug 2013) on various physical and biogeochemical parameters have been collected along the coastal waters from Goa to Kanyakumari. A physical and biogeochemical coupled model is being used and the necessary model input on hydrodynamics is obtained from ESSO-INCOIS ROMS model. The satellite data such as OCM and MODIS are used to derive the chlorophyll and compare the same with the insitu estimated one as well as with the model predicted one (Fig.4.15).
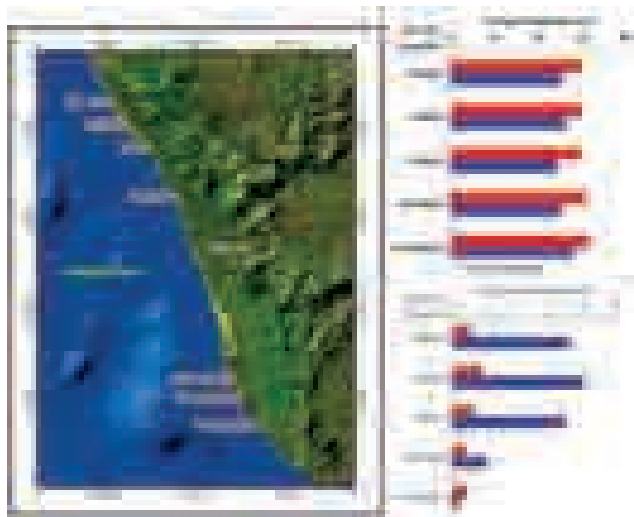
Fig 4.15. Comparison of water temperature and phosphate for different inlet locations along SW coast of India during NE monsoon (Dec 2012) and SW monsoon (August 2013)

4.5.4. Shoreline Mapping

It is planned to map the status of shoreline changes i.e. erosion and accretion on 1:25000 scale for entire coastline along with rate of changes and update annually the status for high priority areas. The Shoreline change maps is indexed as per SoI standard. During current year, the shoreline changes along the Tamil Nadu coast have been computed from 1990 to 2012 using satellite images. 5 Nos of Multi-resolution satellite data Landsat TM(1990), Landsat ETM+(2000), IRS- P5 (Cartosat-1) (2006), IRS-P6 Resourcesat-1(LISS-III)(2008) and Resourcesat-2 (LISS-IV) for 2012 were used to analyse the shoreline changes. Verification of results is being carried out at various locations all along the Tamilnadu coast. The preliminary results indicate that 6% Tamilnadu coast is having moderate to high erosion, 6% moderate to high accretion, 29% minor erosion, 29% minor accretion and 30% coast is relatively stable. A typical map of shoreline changes along the Chennai coast and consolidated view of Tamilnadu coast is given in Fig. 4.16.

Fig 4.16. Shoreline changes for 22 years (1990-2012) along the Tamail Nadu coast.

4.5.5. Tsunami Hazard Mapping

Constructing the tsunami hazard maps is the key step in tsunami risk assessment and forms the basis for evacuation and future landuse planning along coastal areas. Tsunami hazard maps on 1:25000 scale have been prepared for the coastal states of Tamil Nadu, Andhra Pradesh, Orissa, West Bengal, Kerala, Karnataka, Goa, parts of Lakshadweep. Maps for Maharashtra and Gujarat are in progress. All maps have been prepared as per 1:25000 scale, standardized with uniform legend and accuracy assessment of these maps have also been carried out . For the first time in the country elevation data derived from CARTOSAT satellite data has been used to prepare tsunami hazard maps for the entire Indian coastline (Fig. 4.17).
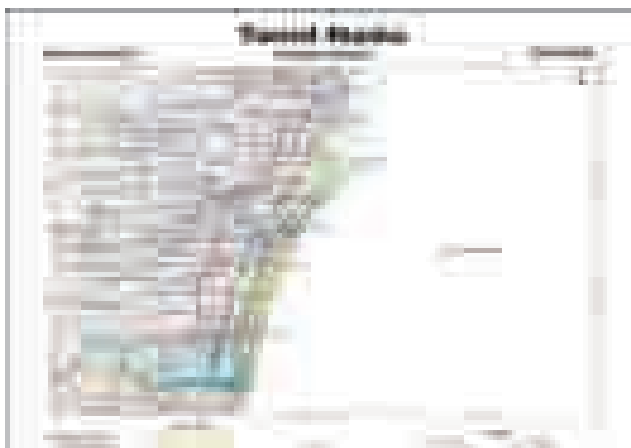
Fig.4.17. Tsunami hazard Map for Tamil Nadu

4.6. Sustained Indian Ocean Biogeochemistry (SIBER)

Trace elements and isotopes (TEIs) and micronutrients play important role in the ocean of the contemporary and the past processes, as they regulate ocean processes, such as marine ecosystem dynamics and carbon cycling. Towards studying of the carbon and nitrogen biogeochemical processes and associated trace elements in the seas around India, for understanding of climate change and marine biogeochemistry, two programs viz., Sustained Indian Ocean Biogeochemistry (SIBER) and GEOTRACES were launched.

4.6.1. Sustained Indian Ocean Biogeochemistry (SIBER)

Long-term observation platforms - one each in the Arabian Sea (Lat. 17^0 N, Long. 68^0 E) and at the site of Bay of Bengal Observatory (Lat. 18^0 N, Long. 89^0 E) - for regular visits by research ships and deployment of sediment traps and other moorings have been established. The aim is to carry out multi-disciplinary research at fixed sites covering, core physical, chemical and biological parameters including currents and particle sedimentation. Both the Arabian Sea Time Series (ASTS) and the Bay of Bengal Time Series (BOBTS) are located in the core of oxygen minimum zones (OMZ) of the Arabian Sea and the Bay of Bengal, respectively. In addition to open ocean time series sites, sampling was also done along the coastal transect, off Goa named as the Candolim Time Series (CaTS) station on a monthly basis. The Arabian Sea (AS) surface chlorophyll concentration found to be approximately two fold higher than that of the Bay of Bengal (BOB). Both regions showed a build-up of distinct subsurface chlorophyll maximum (SCM). Though SCMs were build-up at nearly the same depth, the Arabian sea was roughly holding 1.5 times more biomass than the Bay of Bengal. This might be due to the stratified conditions resulting from the low saline waters (and sediments) coming from the Ganges and the Brahmaputra and several peninsular Indian rivers thereby limiting exchange processes between deep waters and the surface waters. Microbial components, heterotrophic bacteria (TBC) and nano-flagellates (HNF), latter in particular showed decreased population despite increased bacterial counts (data not shown at ASTS station). This possibly be due to the high abundance and biomass of zooplankton in the upper layer strongly influencing community grazing rates on HNF. Abundance of bacteria fluctuated from 0.25 to 0.41 in BOB. While, abundance of bacterivorous microbes in the AS and BOB did not show much variations. However, below the euphotic zone both these microbes showed decreasing trend with depth.

4.6.2. Marine biogeochemical cycles of Trace Elements and their isotopes: GEOTRACES (India)

Many of the stable and radiogenic isotopes in oceans serve as tracers to tag and time various oceanic processes and reconstruct paleo- climate / oceanographic records stored in sediments. Recently, some of these TEIs are also introduced into the oceans via anthropogenic processes and their distributions also provide information as environmental contamination. GEOTRACES (India) programme was started to map the distribution of trace elements and isotopes in the Indian Ocean and to identify the factors influencing these distributions. One of the major accomplishments of the GEOTRACES programme was establishment of clean sampling facility on board ORV Sagar Kanya. This was the first clean GEOTRACES cruise in the Indian Ocean during March-May2013 (Fig.4.18). The samples collected during this cruise are being analysed in the shore-based laboratory. Biogeochemical studies of selected trace elements and their isotopes in the estuaries and in the Indian ocean were continued last year. Basic hydrographic parameters were measured onboard during the cruise. Relatively cooler waters were found off Indonesia with high salinity and shallow mixed layer depth. Shallow nitracline was found in the northern Indian Ocean than South.

As a part of GEOTRACES activities, the Hooghly and the Mahanadi estuaries were sampled onboard Sagar Manjusha during peak monsoon, July 2013. Water and particulate matters were collected from the Hooghly river at salinitites ranging from 0.1 to 32. However, very few samples were collected in Mahanadi due to steep salinity variation. The Ganga-Brahmaputra river supply large amount of Ba to the surface layer of the Bay of Bengal which is transported to the intermediate depth through particulates where it gets remineralised and are transported to the equatorial Indian Ocean. Open ocean water profiles of Mo isotope composition in the Arabian Sea and the Bay of Bengal is conservative at value of 2.41±0.05 and is similar to that of other ocean basins. It is independent of oxygen content of water column. OMZ prevailing in intermediate depth water column of the Arabian Sea displays similar □98Mo. In the Bay of Bengal near the mouth of the Ganga river □98Mo, however, is significantly different compared to open ocean value which seems to be influenced by particle desorption.

Meetings of International GEOTRACES Scientific Steering Committee and Data Management Committee were organized in Goa during October 27 -31, 2012. Members from all the participating nations were present in this meeting.

Fig.4.18: Cruise track of GI03 and sampling stations conducted during March – May 2013.

4.7. Marine Living Resources

The Marine Living Resources Program (MLRP) is primarily focused on Monitoring and Modelling of Marine Ecosystems (MMME), Microbial Oceanography (MO), Deep sea and Distant Water Fisheries (DSDWF), Integrated Taxonomic Information System (ITIS), Southern Ocean MLR (SO-MLR) and Technology Development on MLR (MLR-TD). As part of the MMME programme, seven cruises were undertaken on-board FORV Sagar Sampada, of which two cruises for winter bloom monitoring at the North Easter Arabian Sea and associate biogeochemistry; and the

remaining five cruises for ecological modelling studies of South Eastern Arabian Sea (SEAS).

4.7.1 Harmful Algal Blooms:

Four algal blooms were observed along the Indian EEZ, viz. red Noctiluca scintillans blooms off Thrissur (July 2013) (Fig.4.19); Pseudo-nitzschia spp. bloom off Kochi (July-Sept. 2013); Gonyaulax polygramma bloom off Kollam (September 2013) and Karenia mikimotoi bloom off Kochi (September 2013). The Pseudo-nitzschia bloom was dominated by P. pungens and P. seriata; these are the toxic species among the genus Pseudo-nitzschia and are capable of producing neurotoxin Domoic acid (DA), which causes Amnesic Shellfish Poisoning (ASP).
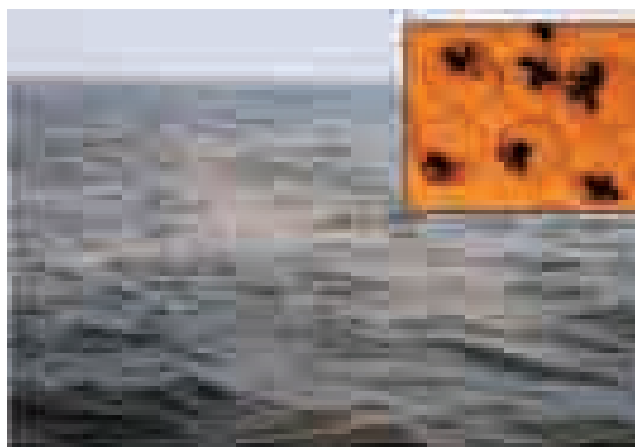
Fig 4.19. Noctiluca red tide (Inset Noctiluca scintillans x 40)

During the summer monsoon (June-Sept) of 2013, Noctiluca cells were observed in higher abundance along the coastal waters of SEAS from Cape Camorin to Mangalore and its bloom was recorded from off Thrissur with red surface water discolouration (cell density 2.5x 104 cells/ L). One of the Noctiluca scintillans (syn. N. miliaris suriray) bloom area recorded off Chavakkad (Lat.10° 23.67° N; Long. 76° 01.295 E) was observed to have depleted oxygen level in the intermediate depths during its crashing stage which in turn is suspected to have driven the bottom fauna comprising primarily of flat fishes and crabs towards the shore. This phenomenon is called as "Crab

Jubilee". Only few reports are available on jubilee phenomenon from the world oceans such as Mobile Bay- Gulf of Mexico, Walvis Bay- Southwest Africa and from Florida coast. There is no published report on the Jubilee from the Indian EEZ so far.

An Algorithm for discriminating diatom and Noctiluca blooms from Ocean Color data has been developed and validated. Modified version of this algorithm can provide approximate cell densities in bloom areas.

4.7.2. Cold Core eddy in NEAS

Cold-core eddies contribute substantially to the open ocean production of the North Eastern Arabian Sea (NEAS) during the fag end of the winter monsoon and early phase of spring inter-monsoon. A prominent cyclonic eddy was observed at 21 20.38′N; 66 30.68′E in the North Eastern Arabian Sea (NEAS) during March 2013. Through in situ observation and satellite data, it is proved that this cyclonic eddy is triggered by baroclinic instability due to weak stratification and strong vertical shear in the horizontal flow as evidenced with low (<0.0001) Richardson Number (Ri).
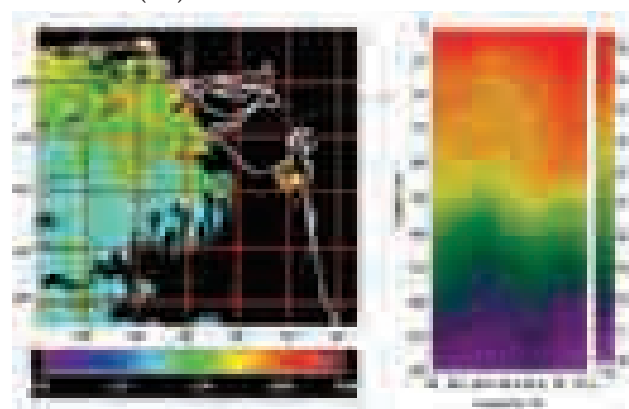
Fig 4.20 Chl imagery (MODIS AQUA) for March 9, 2013 showing the eddy (marked area) and upsloping of cold nutrient –rich waters

4.7.3. Upwelling and Coastal pelagic fishery

Upwelling along the South Eastern Arabian Sea (SEAS) was comparatively

stronger during the year with strong offshore transport of upwelled waters. Breeding aggregation of oil sardines, mackerels and anchovies were relatively weak during the month of June, July and August. Continuous monitoring of brood-stock was undertaken all along the SEAS including using the Vertical Egg and Larvae Net (VELNet). High densities of Oil Sardine larvae were recorded from off Goa during Aug 2013.

4.7.4. Marine Benthos

Macrofaunal polychaete communities (>500μ) along the continental margin (200-1000m) were described for the first time based on three systematic surveys covering 27 sites along 9 transects in the South Eastern Arabian Sea (SEAS). Multivariate analysis revealed the existence of three distinct polychaete assemblages at the shelf edge (200m), intermediate depth (500m) and deep-water (1000m). Latitudinal differences were also observed in species composition.

4.7.5. Deep-Sea and Distant Water Fishery (DSDWF)

Six fishery cruises were conducted along the continental slope of SEAS. The Terrace off Thiruvananthapuram (TOT) was observed to support a unique deep sea biodiversity in terms of mega-fauna. A total of 80 species were recorded from the bathyal region of the TOT. Among teleost Lamprogammus niger, L. brunswigi (ophidiformes) and Coryphaenoides hexti (Gadiform) were recorded to be dominant whereas among crustaceans, Aristeopsis edwardsiana and Acanthepyra fimbriata were dominant. Large bodied holothurians (Benthodytis sp.) and deep sea star fishes were also recorded.

Myctophid fishery survey in SEAS were conducted using 3 newly designed MLR-Mid water Trawls (MLR-MWT) and the Cosmos trawl. Myctophid catches were dominated by

Diaphus spp. and Benthosema sp. Extensive infestation of myctophid species by Copepods was observed.

In an effort to estimate the age of deep sea fishes sections of otoliths were taken using saw microtome and analysed for annual growth rings (Fig. 4.21). The technique was perfected using various combinations of epoxy resins and hardeners in varying proportions.

Fig. 4.21. Saw microtome sections showing annual growth rings

4.7.6. Indian Ocean Biogeographic Information System (IndOBIS)

The International Oceanographic data and Information Exchange (IODE) recognized Regional Node of OBIS for the Northern Indian Ocean. An on-line web-based portal – Indian Ocean Biogeographic Information System (IndOBIS) was established to archive all biodiversity information being collected through MLR program. The primary and secondary data being collected through MLRP is made use to update constantly the IndOBIS website. At present the database has about 72,000 records of species occurrence from the Indian Ocean. Towards the development of barcodes for marine organisms under Census of Marine Life (CoML) program, totally six DNA barcodes were developed for species of Lyphira perplexa, Cryptopodia angulata, Charybdis natator, Dorippoides nudipes, Priacanthus hamrur, Sardinella longiceps. The barcodes were deposited with National Centre for Biotechnology Information (NCBI).
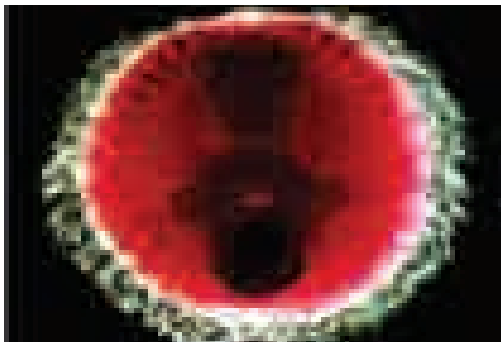
Fig. 4.22. Palmyreuphrosine n sp. from the Nicobar Islands

Fig.4.23. Halieutoposis stellifera (Smith and Radcliffe, in Radcliffe 1912)

4.8.Marine Ornamental fish production

Breeding and rearing of clownfish such as A. nigripes, A. clarkii and other indigenous species such as A. percula, A. ocellaris & Premnas biaculateus has been perfected in the hatchery set-up at Agatti, Lakshadweep. Several brood stocks are also maintained for experimental purpose. Techniques for breeding and rearing of 2 species of damsels fishes were perfected during the current year.

A training workshop on Ornamental fish culture was conducted in Agatti Island during March 2013 involving 15 islanders. The trainees were encouraged to form a society and undertake ornamental fish culture to generate income and employment to them. The society successfully grew 5000 clown fishes to the juvenile stage (90 days) which were sold to the Tata Aquaventure Ltd at the rate of Rs. 90/juveniles.

OCEAN TECHNOLOGY

Ocean Technology program aims at developing reliable indigenous technology to address the issues associated with harvesting of non-living and living resources from Ocean, as well as protection of coast, construction of offshore structures etc. The details are given below:

5.1   COASTAL ENGINEERING

5.1.1   Engineering Investigations for the 'Kalpasar' Project

The Kalpasar project envisages installation of a dam across the Gulf of Khambhat (GoK). The engineering investigation related to dam site selection and the after-effects of the dam on sedimentation pattern in the Gulf, was carried out. The bathymetry survey has been completed and the Digital Terrain Map (DTM) of the Gulf of Khambhat from various surveys has been prepared (Fig 5.1). The river bathymetry survey and intertidal topography survey have been completed (Mahi, Narmada & Tapi). Tide and current observations in three rivers along the Gulf of Khambhat has been completed. Nine tidal and nine meteorological stations continue to operate on long term basis on permanent structures. This project involved a survey of 24000 line km to cover whole of GoK.

5.1.2   Demonstration of Shore Protection Measures

The coastline of Puducherry and the neighbouring Tamil Nadu is affected by severe erosion due to natural and anthropogenic activities. The local governments have resorted
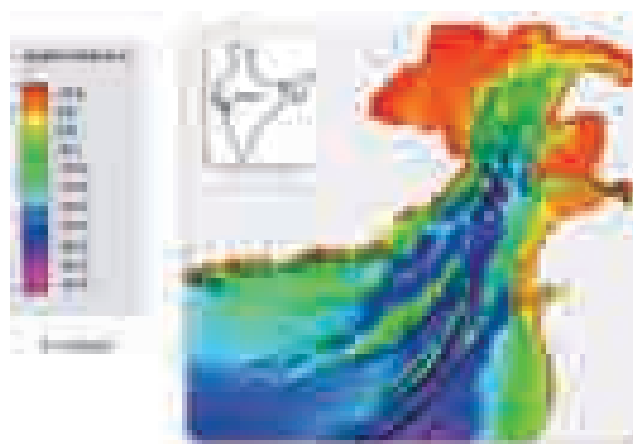
Fig. 5.1.Digital terrain model of Gulf of Khambhat

to short term protection measures like seawalls and groins. These actions protected the coast under the threat but shifted the problem towards North. A study was undertaken to assess causes of coastal erosion through shoreline change data and coastal process measurements. Probable solutions for shoreline management were worked out and report was submitted to the Puducherry and Tamil Nadu governments. As an initial attempt, beach nourishment at the North of Puducherry harbour was carried out (Fig. 5.2) during July 2013 (SW Monsoon), which resulted in a gain of 60m wide beach towards the north of the harbour. Offshore reef with beach nourishment has been proposed for the restoration of the beach.

5.1.3   Sustainable Shoreline Management

The project aims to develop options for sustainable management of coastlines with potential stakeholder interests like industry, fishing, tourism, etc. Variable solutions like groins, seawalls, shore parallel submerged dyke, etc. for providing a sustainable coastal
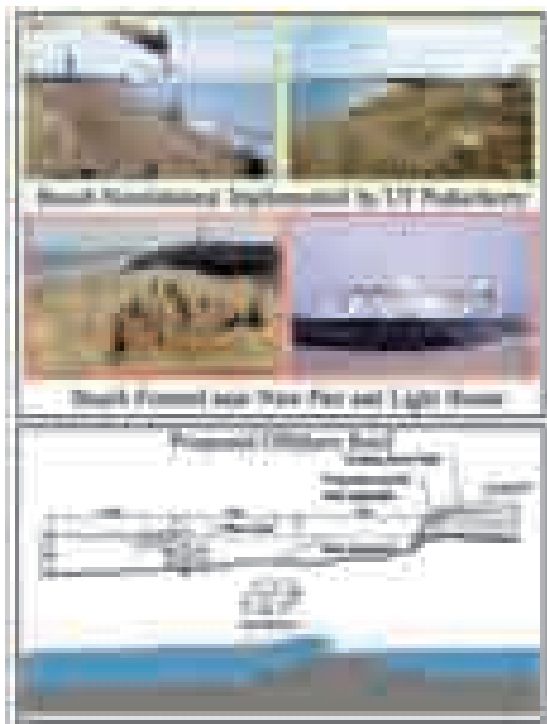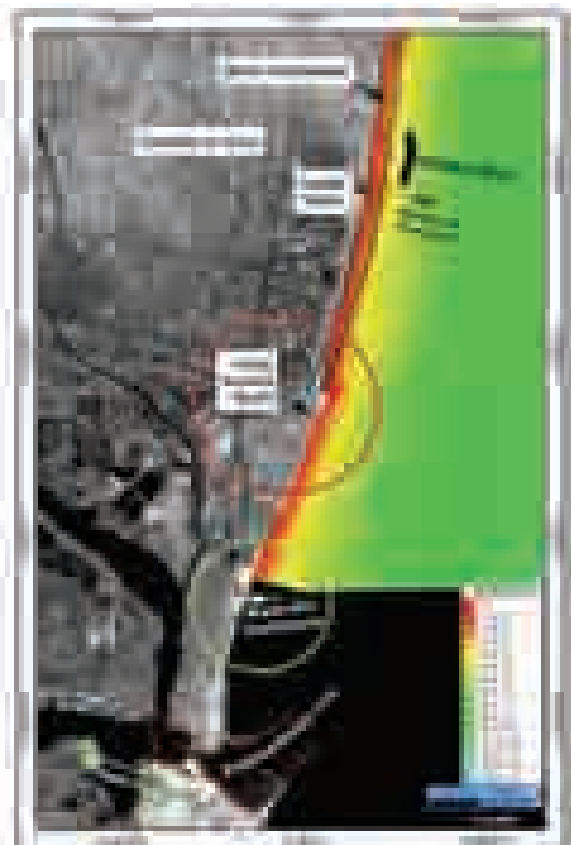
Fig.5.2 A layout of Puducherry coastline with the views of the beach nourishment activities, the formed beach and a location of the proposed offshore reef.

stabilization measure have been under evaluation in the coastal stretch of the Kadalur Periyakupam (KPK), Tamil Nadu. One of the options is to provide a submerged shore parallel offshore dyke over a length of 1.5 km so that wave forces are absorbed and loss of material is prevented. Numerical modelling was carried out for various combinations of segmented submerged dyke for determination of the best combination of dyke segment and gap. The final configuration consisted of a segmented submerged dyke consisting of 200m long segments with gaps of 60m in between them. A total of 7 segments covering a length of 1.7 Km including gaps covering all the fishing villages is proposed.

5.2 DEEP SEA TECHNOLOGY AND OFFSHORE STRUCTURES

5.2.1 Remotely Operable Submersible (ROSUB 6000)

ROSUB 6000, a Remotely Operable Submersible with a depth rating of 6000m is a technological tool for assisting in the mining of Polymetallic nodules, Gas hydrates and Hydro thermal sulphides exploration. An exploration using ROSUB 6000 at the Rodriguez Triple junction at 26 South was performed and executed during April- May 2013. The submersible was successfully launched and retrieved near the Rodriguez Triple junction site at SONNE field in South Central Indian Ridge at water depths 200, 1200, 1512, 2750 and 2812 m, and videography, oceanographic measurements, still photography (Fig.5.3) and system performance feedback were successfully carried out. Video imaging done by ROV cameras was successfully live telecasted to ESSO-NIOT, Chennai.

Fig 5.3 Pictures of the SONNE Field at 2812 m water depth

The ROV-500 developed by the Central Mechanical Engineering Research Institute (CMERI) was deployed and tested by the ESSO-NIOT along with CMERI team, for its envisaged functionality up to 505m depth off Chennai during August 2013 (Fig. 5.4 and 5.5). This ROV is meant for underwater exploration and inspection of underwater objects, seabed, and installations such as well heads, etc. The design qualification test of ROV 500 has been successfully completed in the open ocean. During the sea trials, data on temperature, videography and vehicle parameters were collected and found to be satisfactory.

Fig 5.4 ROV being assembled on board Sagar Nidhi
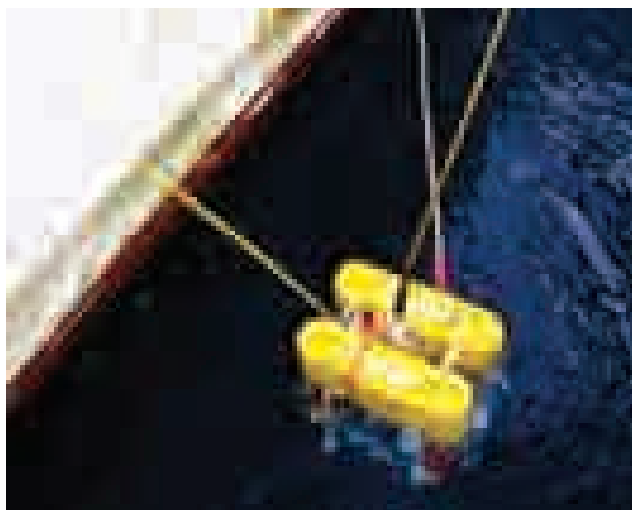
Fig. 5.5 ROV being deployed from Sagar Nidhi

5.2.2 Integrated Mining System

As a part of development of new crawler based mining machine, the assembly, Integration and performance testing of hydraulic power unit for pickup and collection was completed. The solids handling pump is proposed to be a positive displacement piston pump. The pressure and flow rate of the pump have been calculated for a hose size of 90-mm internal diameter and an approximate velocity of 2 m/s. The new crawler for 5000-m application has been designed with a load distribution area of 8.28 m2. Collection of Environmental data in the Central Indian Ocean Basin for dynamic analysis of Flexible Riser System has been completed.

5.2.3 Feasibility Studies on Platform for Fixed and Offshore Wind Turbines

The importance of harvesting the potential offshore wind farms is being realized worldwide with the near exhaustion of the onshore sites. The key aspects in setting up of offshore wind farm are identification of potential sites and development of viable offshore structures. Wind resource assessment carried out using satellite data indicated that 3 MW turbine is optimum at the potential sites of Kanyakumari, Rameshwaram and Jakhau. Commercial viability studies carried out based on wind potential indicated good Internal Rate of Return (IRR) for the above sites. A complete static and earthquake analysis was performed for 3 MW Wind Turbine for monopole and jacket substructure concepts for coupled aerodynamic and hydrodynamic loads. Activities to setup a LIDAR based offshore platform (Fig. 5.6) to collect wind profile along with met-ocean data at one of the potential locations have been initiated.

Fig. 5.6 Layout of the proposed LIDAR based offshore data collection platform

5.3 FRESH WATER FROM SEA

In-order to meet the ever growing demand for freshwater, utilization of Low Thermal Temperature Desalination (LTTD) technology in the coastal power plants by using waste heat recovery, has been experimentally carried out. To produce high quality freshwater, the following studies have been taken up.

5.3.1 Theoretical and Experimental studies on Components like Heat Exchangers, Demisters for Desalination and Energy Conversion

The objective is to develop demisters for getting ultralow Total Dissolved Solids (TDS) water through LTTD plant. Installation of an experimental LTTD plant using waste heat recovery at the North Chennai Thermal Power Station – Ennore has been completed and experiments are being carried out. Numerical Computations were carried out using Computational Fluid Dynamics (CFD) code FLUENT to predict the performance of demisters or mist-eliminators. Two phase flow through the demister consisting of water vapour and sea water droplets was modeled using Discrete Phase Model (DPM). The flow

was simulated for non-uniform distribution of droplet diameters as well.

5.4 OCEAN ENERGY

One of the significant resources from the oceans is renewable energy and ocean currents serve as one of the tools to harness power from the oceans. The development of ocean current turbines to suit low current speeds prevailing in Indian waters has been taken up under this programme.

5.4.1 Current turbines

A straight bladed cross flow current turbine, capable of producing more than 120 W of electricity, has been developed and tested successfully in the laboratory. Current data at a few locations in the Gulf of Khambhat, the Sunderbans and the Andaman Islands are being studied for exploring the possibility of carrying out open sea trials.

5. 5. MARINE BIOTECHNOLOGY

Development of indigenous technologies for marine micro algal culture and open sea cage culture has been carried out to enhance production.

5.5.1. Marine Algal Biotechnology

Technology development for marine micro algal culture involves enhancement of biomass production by optimizing various culture parameters for the chosen strains, development of custom designed media that gives optimal biomass production and maximal nutraceutical production. Isolation and screening of high biomass, lipid, nutraceuticals yielding marine microalgae from Indian waters; design, development and testing of photobioreactors and pond based mass culture systems; optimization of physicochemical variables, mass scale harvesting, dewatering and extraction techniques are the important targets under this activity. So far more than 200 marine microalgal

strains isolated from the coastal and oceanic waters of the Indian main land, the Andaman & Nicobar Islands and the Lakshadweep were screened for biomass, lipid and other nutracuetical production. A pilot scale electroflocculation experiment in one tonne capacity tank was attempted using aluminium electrode. The efficiency of electroflocculation of Neochloris aquatica culture was tested for two durations (7 &15 min). The effect of electro flocculation on biomass, lipid and lutein content was analysed. Lipid content of the algal biomass was not affected by both durations of electroflocculation. This technique is optimized to harvest biomass and extract lipid and nutracueticals from marine microalgae.

Supercritical Fluid Extraction (SFE) technique was employed for solvent free extraction of algal oil and lutein from dry algal biomass. Algal oil was extracted using SFE with CO_2 (flow rate of 20 g/min) methanol as a cosolvent (flow rate of 0.5 g/ min) pressure of 200 bar and temperature of 60 C which yielded 10% of algal oil.

5.5.2. Open Sea Cage Culture

Development of a suitable offshore culture system with proper mooring accessories is a prerequisite for large scale marine fish farming. Design and development of sea cages with mooring systems suitable for the Indian seas, have been carried out, for the demonstration of open sea cage culture of commercially important marine finfishes. A successful demonstration was made by developing and deploying 9m dia. HDPE cages with multipoint mooring at Kothachathram (Andhra Pradesh), Olaikuda (Tamil Nadu) and the North Bay (Andaman Islands) representing open sea, semi-protected and fully protected environments, respectively. Seabass seeds (0.22g mean weight) obtained from the Central Institute of Brackishwater Aquaculture , Chennai, has been reared to an average size of 342 g body weight in 290 days in open sea cages at North Bay, Port Blair (Fig. 5.7).
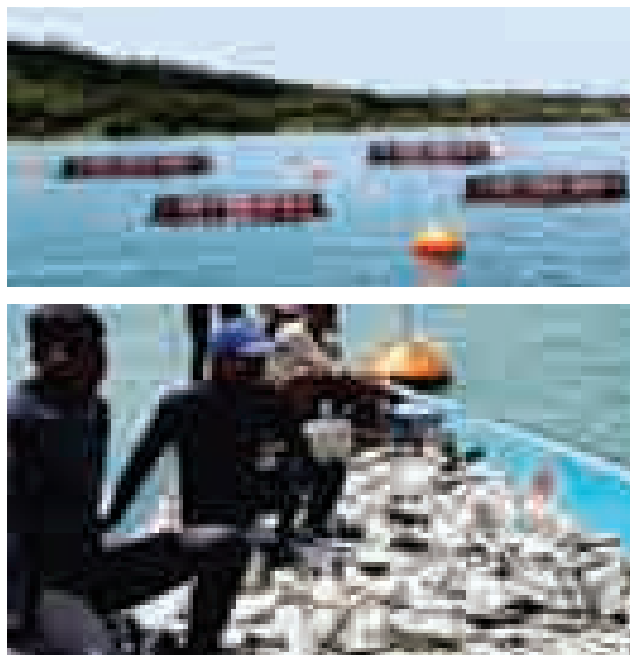
Fig. 5.7. Open sea cages (North Bay- Port Blair) & harvested seabass fish

5.6 MARINE SENSORS, ELECTRONICS AND OCEAN ACOUSTICS

Development of sensor technologies to detect buried object under seabed using acoustic and magnetic detection techniques, indigenization of ocean observation systems such as underwater profilers and autonomous underwater noise measurement systems have been taken up, for shallow as well as deep water applications.

5.6.1 Buried Object Scanning Sonar (BOSS)

Buried Object Scanning Sonar (BOSS) consists of subsystems such as a tow body, hydrophone array, data acquisition system etc and as part of the development of BOSS, the design and development of prototype tow body has been completed. The algorithm developed for BOSS has been completed and tested in Acoustic Test Facility (ATF). The field trials of BOSS hardware and software have been carried out in shallow waters off Kochi at 6m depth and layered demarcation of the seafloor has been captured (Fig. 5.8).

Fig. 5.8 Visible layer demarcation with receiver sensitivity adjustment and calculation of coherence factor at 12m deep water column

5.6.2 Autonomous Underwater Profiling Drifter (AUPD)

The AUPD after extensive testing and ballasting, was deployed in the sea off the Lakshadweep Islands. The float is programmed to perform one profile every 48 hours and it is working satisfactorily (Fig. 5.9). The float is diving upto a depth of 1629m and measuring conductivity and temperature with reference to depth.
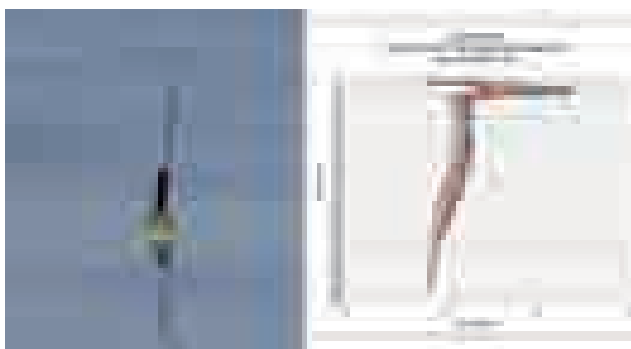
Fig. 5.9 Autonomous Underwater Profiling Drifter (AUPD)

5.6.3 Establishment of Ocean Ambient Noise System with Real Time Communication In Shallow Waters

Measurement and characterization of ocean ambient noise in shallow waters has been a significant area of ocean acoustics and a totally indigenous autonomous noise measurement system with real time data reception has been developed and successfully tested in the sea. In order to enhance the ocean ambient noise measurement system, as an alternative to RF communication for real time reception, GPRS (General Packet Radio Service) based communication has been developed and tested with the subsurface noise measurement system. A few systems are being made to serve for naval applications.

5.6.4 Establishment of Low Frequency Calibration Setup

The state of the art Acoustic Test Facility (ATF), has been enhanced with a low frequency calibration setup. The vibrating water column based method for low frequency calibration of acoustic sensors has been established at ATF (Fig. 5.10).

Fig. 5.10. Low Frequency Calibration Setup

POLAR SCIENCE AND CRYOSPHERE

Cryosphere plays an important role in modulating the Earth's climate system and acts as an indicator and integrator of climate variability and change. Ice sheets continuously record the chemical and physical nature of the Earth's atmosphere and often provide climate records at various temporal resolutions. Considering the multiple processes influencing the cryospheric system on an inter-annual, decadal, centennial and millennial time scale, it is crucial to undertake an integrated study on glaciology, biogeochemical processes and ice core records to understand the role and response of cryosphere within the climate system in polar regions and their global linkages.

Against the above background, a series of field studies were carried out in the Arctic, Antarctic and the Himalaya during 2013-2014. On the laboratory front, processing of snow/ice samples and measurements of stable isotopes, major ionic composition, trace element chemistry, dust particulates and organic composition as well as microbiological studies on snow / ice samples from the Antarctica were taken up.

6.1   SCIENTIFIC STUDIES IN ANTARCTICA

6.1.1   Glaciochemical and biogeochemical studies on snow cores from the Antarctica

A Study of the annual records of sea spray ionic components from snow cores along a 180 km coast to inland transect in the Princess Elizabeth Land (East Antarctica) revealed exceptionally high Na+ concentrations and large variations in Cl-/Na+ ratios up to a distance of 50 km (~1100 m elevation) along the transect. The steepest slope in the entire transect (49.3 m km^{-1}) was between 20 and 30 km and the sea-salt records in snow from this area revealed extensive modifications, with Cl-/Na+ ratios as low as 0.2 (Fig 6.1). Statistical analysis show a strong association between the slope aspect and the variation in Cl-/Na+ ratios along the transect. However, altitude does not appear to have any significant control over the sea-salt ion variability. The results thus highlight the more dominant role of steep slopes than altitude in modulating the deposition of sea-salt aerosols in the Antarctic snow.
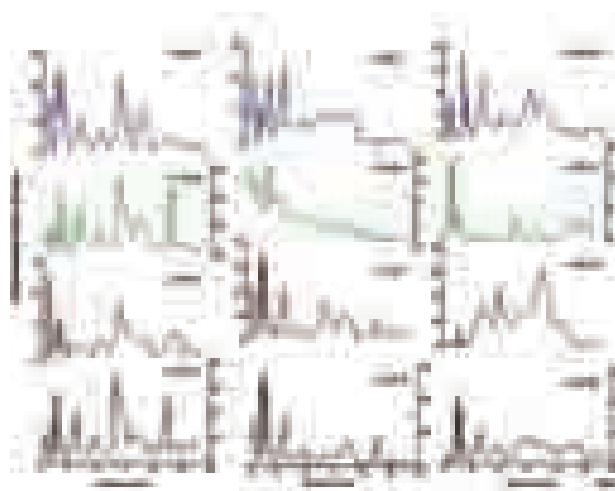
Fig. 6.1. Seasonal variability in Cl-/Na+ ratios in Antarctic snow reveal a strong Cl- depletion in the coastal sites.

Bacterial abundance, diversity and glaciochemical composition from three depths of an ice core (IND-25/B5) from the coastal Dronning Maud Land revealed that higher bacterial abundance corresponding with high in situ sea-salt Na and dust concentrations, suggesting that bacteria

might have been transported and deposited in ice along with dust and marine aerosols. Fourteen bacterial isolates belonging to the genera Methylobacterium,Brevundimonas, Paenibacillus, Bacillus and Micrococcus were retrieved. Some of the isolated bacteria were found to respire and grow using methanesulfonate, suggesting that they may utilize this substrate to sustain growth in ice. In addition, NO_3 (2.93–3.69 µM), NH_{4+} (1.45–3.90 µM) and $PO4_3$ (0.01–0.75 µM) present in the ice could be potential sources fueling bacterial metabolism in this environment.

6.1.2 Climate reconstruction using ice cores

In order to reconstruct the recent Antarctic climate change during the past centuries with annual to seasonal resolution, two well-dated ice cores (IND-22/B4 – 62m and IND-25/B5 - 65 m) from the coastal Dronning Maud Land region of the East Antarctica were studied for stable oxygen and hydrogen isotope ratio variabilities. Proxy-based surface air temperatures using the d18O profiles of two ice cores reveal a significant warming with greatly enhanced warming during the past several decades (~0.4° C per decade) (Fig. 6.2). Complimentary to the recent findings, it is proposed that the coastal areas of the Dronning Maud Land are experiencing significant warming in the recent centuries and further support for a detailed evaluation on actual rates of the Antarctic warming through a combination of instrumental and proxy records.

6.1.3 Monitoring Antarctic Ice Topography using satellite data

A Digital Elevation Model (DEM) for the Larsemann hills was constructed using WorldView-2 (WV) satellite stereopair (Fig. 6.3). The vertical accuracy of the DEM is 16.5 cm. The DEM generated was utilized for cast-shadow modeling for multispectral satellite, to identify various land covers. This is important for studying the spatial changes in the study area. A novel method based on a customized set of normalized difference Spectral Index Ratios (SIRs), incorporating multiple bands, was utilized to improve the accuracy of land-cover mapping. Most recently available WV-2 data were classified into land-cover surfaces such as snow/ice, water bodies, and landmass using the customized normalized difference SIRs. A multi-fold methodology was used to evaluate the effect of pan-sharpening algorithms on spectral characteristics of satellite data, and on subsequent land-cover mapping using an array of SIRs. The final accuracy of the land-cover map is found to be more than 98%, which is considered as an excellent in remote sensing applications. The results indicate that the use of 8-band WV-2, customized SIRs, and appropriate pan-sharpening can greatly improve the extraction of land-cover information.

Fig. 6.2. Oxygen isotope and reconstructed temperature records of IND-22/B4 core along with South Pole 10Be proxy data of solar variability

Fig. 6.3. DEM of the Larsemann Hills using WorldView-2 (50 cm) stereo pair

6.1.4. Paleoenvironmental reconstruction from the Lake Sediments of the Antarctica

The Schirmacher Oasis and the Larsemann Hills (East Antarctica) are bestowed with hundreds of lakes which record the signals of past climate variability. A few sediment cores from the lakes of the Schirmacher Oasis (Sandy Lake and L-49) were analysed for rock magnetics, sedimentology and organic geochemistry. The geochronology for these cores is supported by a few AMS 14C dates from different depth intervals. The age-depth model (Fig 6.4) was used to calculate the sedimentation rate and the sediment core dates back to 43,000 cal. years B.P. The dates were calibrated and different calibration curves were used for calibrating the dates.
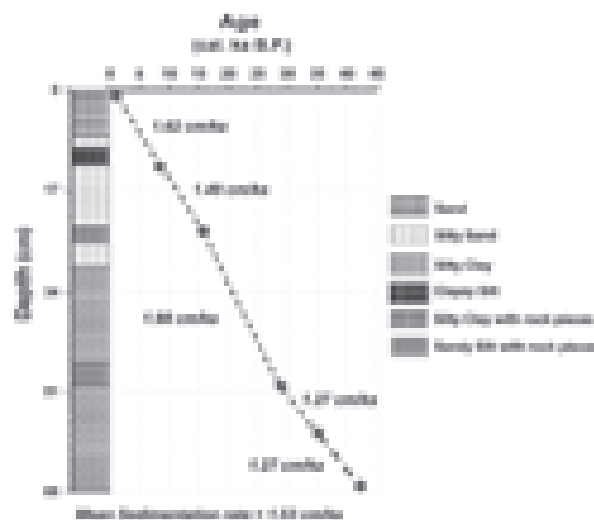
Fig. 6.4 Age-Depth model constructed on the basis of 6 AMS 14C dates for Sandy Lake sediments. The sediment core is predominantly made up of silty clay texture interspersed with sandy silt and silty sand texture. The core-top is rich in sand sized particles.

6.1.5 32nd Indian Scientific Expedition to Antarctica

Shri. P.S. Negi (SASE) and Dr Aditi Krishnamurthy (Medical Doctor-NCAOR) were selected as Leaders of the 32nd Indian Scientific Expedition to Antarctica at Maitri and Bharati, respectively, with Shri Ajay Dhar, (IIG) as the voyage Leader. The expedition members proceeded to Antarctica in eight different batches between 17 November 2012 and 06 February 2013. The Expedition was successfully completed on the 3rd April 2013.

The details of the scientific projects taken up during the Expeditions are as below:

No.	Project	Institution	New/ Continuing
[1]	Atmospheric Science & Meteorology		
1	Temporal and Spatial Variations of Meteorological Parameters and Energy Budget of Different Snow-Ice Media in Antarctica Using Remote Weather Station and Satellite Remote Sensing data	SASE/DRDO	Continuing
2	Observation of meteorological parameter and ozone observation	ESSO-IMD	Continuing
3	Geophysical Studies at Antarctica	IIG/DST	Continuing
4	Climate Change Research and Low Latitude High Latitude Coupling	SPL/ISRO	Continuing
5	Assessment of Polar ice dynamics using remote sensing and in-situ observations.	SAC/ISRO	New
6	Investigation of solar wind – thermospheric - magnetospheric-ionospheric coupling over polar region during high solar activity period with special emphasis on adverse space weather conditions	NPL/CSIR	Continuing

[2] Biology & Environmental Sciences			
1	Environmental Monitoring and Health of Indian Antarctic Station in Pursuit of Antarctica- Treaty-System and its Governance	ESSO-NCAOR	Continuing
2	Taxonomic and ecological studies on nematodes of Schirmacher Oasis, East Antarctica	ZSI/MoEF	New
3	Effect of human intervention on Antarctic Microflora	CSIR-NEERI	New
4	Cosmic ray Dosimetry	BARC/DAE	New
[3] Earth Science, Glaciology & Global Change			
1	Studies on Seismotectonics and Geodynamical Processes between Antarctica and Southern Indian Peninsula: Continuous GPS monitoring between India and Antarctica	CSIR-NGRI	Continuing
2	Studies on Seismotectonics wnd southern Indian Peninsula: Continuous Operation of Permanent Seismological Observatory at Maitri	CSIR-NGRI	Continuing
3	Hydrodynamics of the Indian sector of coastal Antarctica	ESSO-NCAOR	Continuing
4	Paleoenvironmental reconstruction from lake sediments of Larsemann Hills and marine sediments of Prydz Bay: a multi-proxy approach	ESSO-NCAOR	Continuing
5	Large Scale Topographical Mapping and Geophysical Studies for Neo-tectonics & Monitoring Inter-plate movement of Antarctica plate w.r.t. Indian plate	SOI/DST	Continuing
6	Hydrographic Survey – Off Princess Astrid Coast and Larseman Hills	NHO/MOD	Continuing
7	Detailed Geological Investigations of the Larsemann Hills (including all the islands and Peninsulas), East Antarctica to evaluate the tectono-metamorphic evolutionary history of Larsemann Hills in the context of reconstruction of the Gondwana tectonic frame work	GSI	Continuing
8	Glaciological Studies in Central Dronning Maud Land, East Antarctica	GSI/MOM	Continuing
9	Geological studies in nunataks between Schirmacher Oasis and Wohlthat Mountains to establish the continuation of East African Orogen (EAO) in cDML	GSI/MOM	Continuing

10	Meteorite search in Antarctica	GSI/MOM	New
11	Bathymetric Survey of Lake Untersee, Dronning Maud Land, in collaboration with Carl Sagan Centre, NASA (TAWANI Expedition)	GSI/MOM	Continuing
12	Paleoclimatic Studies from Antarctic Coastal Areas with special reference to Larsemann Hills based on terrestrial and marine records	BSIP/DST	Continuing

The two teams of the earlier 31st Expedition winterers led by Shri Uttam Chand at Maitri and by Dr Rupesh Das at Bharati, together with the summer team of the 32nd Expedition led by Shri Ajay Dhar were felicitated by the Secretary, Ministry of Earth Sciences at a debriefing function at ESSO-NCAOR on 3rd June 2013. A book entitled Studies in Biological Sciences and Human Physiology – Three Decades of Indian Scientific Activities in Antarctica [ISBN No. 978-81-906526-8-1] was also released on the occasion.

6.1.6 Logistics accomplishments of the XXXII Expedition

The most notable accomplishment of the 32nd Indian Scientific Expedition to the Antarctica was the completion and commissioning of India's Third research base "Bharati" in the Larsemann Hills. Although the construction activities related to Phase II of the station building were initiated during the austral summer of 2011 (31st Expedition), due to severe sea ice conditions, the Expedition Ship carrying construction material and workers could not reach the construction site as scheduled and was delayed by 18 days which adversely affected the completion of the station. Despite this difficulty, about 92% of the planned work could be completed by March 2012. Subsequently, during the 32nd Expedition, the construction activities at the Larsemann Hills commenced in November 2012, and the remaining construction work related to Phase II was completed (Fig. 6.5).

Fig. 6.3. DEM of the Larsemann Hills using WorldView-2 (50 cm) stereo pair

Besides completing the construction and furbishing of the state-of-the-art building, the other significant logistics achievements of the 32nd expedition have been:

Establishment of Sea Water Intake Facility at Bharati: Bharati has been built with a sophisticated water treatment system, recycling facilities and with insulated pipelines for fresh and grey water running between station and seafront. However, the sea water intake facility – [the pipe going down to the sea bed], the structure to support the pipes + pump house and the control systems -could not come up in the first phase because of the unforeseen problems in near shore topography. The above work was successfully completed between November 2012 and January 2013.

Data and communication facilities at Bharati: About 10 to 12 satellite passes of the Indian Remote Sensing Satellites at polar

Fig. 6.6. Sketch showing the data communication between India and Bharati

orbits per day of each mission are visible at the Larsemann Hills. Considering this unique location of Bharati, a Remote Sensing Ground Station to receive the satellite data in S/X-Band was conceived by the Department of Space and the Ministry of Earth Sciences (Fig. 6.6). As planned, the link would also support 2-way communication services between India (NRSC/ISRO, Shadnagar and ESSO-NCAOR).

The above work of establishing a ground station was taken up and operationalised by the NRSC-ISRO during the 32nd Expedition.

6.2 INDIAN SCIENTIFIC EXPEDITIONS TO THE SOUTHERN OCEAN

Some of the salient results of the studies carried out during 2012-13 on the data collected during the previous two Expeditions to the Indian Ocean Sector of the Southern Ocean are described below:

6.2.1 Southward transport of water masses by eddies in the Indian sector of the Southern Ocean

The study illustrates the influence of eddies on the southward transport of Subtropical Surface (Fig. 6.7). Three large eddies in the Indian sector of Southern Ocean is compared for the same period during the years 2011 and 2010. During 2011, 3 eddies were present in the hydrographic structure along 57.30 E, whereas, during 2010, the eddies were

absent. Satellite sea level anomaly showed that the eddies were mostly stationary, but influenced the transport of subtropical surface water. The southward extent of Subtropical Surface Water was at 450S during 2011 but restricted to 420S during 2010 suggesting the role of eddies in its southward transport.
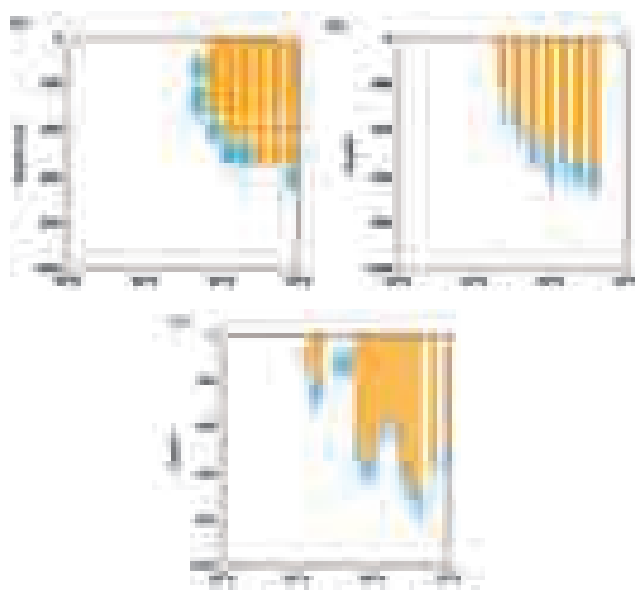
Fig. 6.7. Location of Subtropical surface water (yellow) and Subtropical mode water (STMW, blue) in (a) climatology (b) 2010 and (c) 2011

6.2.2 Influence of an eddy on productivity, plankton community and inorganic carbon along the Sub-Tropical Frontal waters during the austral summer of 2012

During the austral summer of 2012, a cold-core eddy was encountered at 56.5^o E, 40° S. The eddy was three months old, stable, and was active as observed from the nutrient and DNCc profiles. The overall productivity (chl a) across the three stations did not differ much and the phytoplankton community based on pigment composition indicated dominance of flagellates over diatoms at all stations. Increased surface Dissolved Inorganic Carbon (DIC) concentrations, higher zooplankton biomass and low diatom contribution may influence the sea-air carbon exchanges.

6.2.3 Indian Scientific Expedition to the Southern Ocean

The Eighth Indian Scientific Expedition to the Southern Ocean is proposed to be taken up during December 2013-February 2014 on board ORV Sagar Nidhi. Following 10 proposals as detailed below, have been recommended:

No.	Project	Institution	New/ Continuing
1	Physical and chemical characterisation of aerosol and aeorosol radiative forcing over regions of different optical domain.	Department of Marine Sciences, Goa University	Continuing
2	Understanding sources of sediments and processes through the Study of suspended particulate matter and surface & sub-surface of southern ocean	Dept. of Marine Sciences, Goa University	New
3	Photosynthetic efficiency of phytoplankton in the India sector of southern ocean during austral summer.	NIO/CSIR, Kochi	Continuing
4	Oceanic volatiles and their impact on atmospheric halogens and cloud forming aerosols in the Southern Ocean.	ESSO-IITM Pune	New
5	Investigations on the bio-optical characteristics of Southern Ocean Coastal waters using absorption spectra of phytoplankton sizefractions.	Central Institute of Fisheries Technology, Kochi/ Kerala Government	Continuing
6	Understanding the impact of global warming on surface and Bottom water of Antarctic coastline using sediment core study.	Indian Institute of Science, Bangalore	Continuing
7	Ecology, diversity and molecular phylogeny of marine actinobacteria from STF, PF and AZ of the Indian sector of the southern ocean.	Annamalai University, Tamil Nadu	Continuing
8	Hydrodynamics & biogeochemistry of the Indian Ocean sector of Southern Ocean	ESSO-National Centre for Antarctic and Ocean Research	Continuing
9	Biodiversity studies along Indian sector of Southern Ocean	ESSO-Centre for Marine Living Resources and Ecology, Kochi	New
10	Remotely sensed Biogeochemical cycle in the Ocean: Bio-Agro float deployment as part of Indian expedition to Southern Ocean 2013-14	Laboratoire d'Océanographie De Villefranche, France	New

6.3 SCIENTIFIC STUDIES IN THE ARCTIC

6.3.1 The Kongsfjorden fjord Monitoring Program

The Kongsfjorden fjord in Ny-Ålesund is an established reference site for the Arctic marine studies, and in many regards it functions as a natural laboratory in the Arctic. Considering the uniqueness of the fjord and its proximity to the Arctic and the Atlantic water masses, a comprehensive long-term physical, chemical, biological and atmospheric measurement programme was initiated during the summer of 2010. This programme seeks to address (a) the variability in the Arctic/Atlantic climate signal by understanding the interaction between the freshwater from the glacial run-off and the Atlantic water from the west Spitsbergen current (b) the effect of interaction between the warm Atlantic water and the cold glacial-melt fresh water on the biological productivity and phytoplankton species composition and diversity within the fjord (c) the winter convection and its role in the biogeochemical cycling and (d) the production and export of organic carbon in the fjord with a view to quantify the CO_2 flux.

Hydrographic observations and water sampling which were initiated during 2010 were continued during 2012-13 as well at the pre-fixed sixteen stations along the major fjord axis (Fig. 6.8). Sampling was carried out at almost 15 day intervals from June to mid October, 2012. A Conductivity-Temperature-Depth (CTD) profiler equipped with a fluorescence sensor was used to obtain information about the hydrographic features and fluorescence profile. The water samples collected from the fjord were analyzed for dissolved oxygen content, nutrients such as nitrate, silicate and phosphate, phytoplankton and zooplankton abundance, total heterotrophic bacterial count and total cell count, particulate carbon and nitrogen content. Water samples brought to India were analyzed for pigment signature of phytoplankton groups as well as for their oxygen isotopic composition.

Fig. 6.8. Map of Spitsbergen Island showing the locations of Ny-Alesund, the Kongsfjord and the 16 observation stations.

Initial results of the oxygen isotopic composition of the water from select stations show that most of the variability is limited to the top 100 m. The spatial variability shows that the effect of freshwater from glacial melting was affecting the station I-9 and I-6 much more that the stations I-1 and I-3. We obtained 18O-Salinity Slopes for both the inner (Stations I-6 and I-9) and the outer (Stations I-1 and I-3) fjord (Fig 6.5). The inner and outer fjords yield a slope of 0.20 and 0.28 based on an r2 value of 0.30 and 0.38, respectively. The correlation coefficient
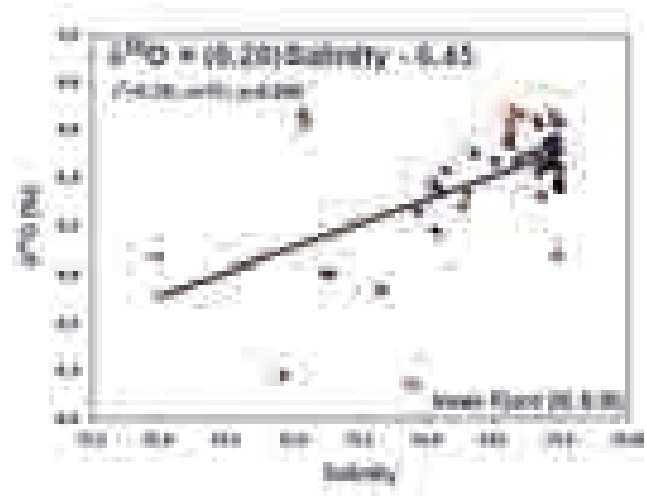
Fig. 6.9. δ^{18}O-salinity relationship of water from the Kongsfjorden.

values are low, which may be because the dataset comprises samples from different depths collected during different periods nevertheless correlation is significant at the 99.5% level as determined by Student's T-Test.

6.3.2 Polar Biodiversity and Microbiology

Bacteriological and mycological studies on the sediments from the Kongsfjorden and the surrounding areas of the fjord at Ny-Ålesund in the Arctic constitute the highlights of the polar biodiversity studies.

Bacteriological studies: The sediment samples collected from the Kongsfjorden and Ny-Ålesund were processed for bacterial isolation on different isolation media viz. Nutrient Agar (NA), 1/10 NA, Antarctic Bacterial medium (ABM), 1/10 ABM, Marine Broth (MB) and 1/10 MB, and incubated at 3 different temperatures (4°, 15° and 25° C). The emerging colonies were isolated, purified and their colony characteristics studied. Bacterial cultures from the Arctic cryoconite and permafrost samples were also examined. All the cultures were subjected to physiological and biochemical tests such as effect of temperature, pH and salinity on the growth of the isolates. The isolates were also tested for carbohydrate utilization ability and antibiotic susceptibility against 45 antibiotics using the disc method. The ability of these isolates to produce enzymes such as catalase, protease, amylase, lipase urease and cellulase was studied.

Mycological studies: For mycological studies, the sediment and water samples from the Arctic were processed through standard procedures, inoculated on various artificial mycological media including Potato Dextrose Agar, Dichloran Glycerol-18 Agar, Czapek Dox Agar, Glucose Peptone Yeast Extract Agar Rose Bengal Agar and Boyd and Kohlmeyer agar, and incubated at 4° and 15° C until the emergence of colonies. Emerging colonies were isolated, purified and stored for future studies. The sediment samples were also processed to measure the total hyphal biomass using fluorescent brightener and epifluorescence microscopic procedure. All the isolated strains were subjected to screening for the production of amylase, cellulase, esterase, pectinase, phosphatase, protease and urease enzymes.

Twelve isolates that showed positive activity for pectinase were further quantified for production of polygalacturonase (pectinase). Two of the best producers were selected for further studies. Effect of temperature, pH and metal ions of the activity of polygalacturonase was determined. Optimization of the media for maximum production of polygalacturonase by these strains was standardized through Plackett-Burman experiments. Thin layer chromatographic analysis of the end product of polygalactouranase activity at various time intervals was conducted to determine the mechanism of hydrolysis. The two isolates produced enzymes that were active between 15° to 30° C. It was also observed that the concentration of pectin was the only significant factor that affected the production the enzyme.

6.3.3 Glaciological studies

The focus of the study has been on monitoring the mass budget, snout and dynamics of the Vestre Broggerbreen glacier at Ny-Ålesund. The monitoring was carried out during September- October 2012 and again during March-April 2013. The previously installed stakes on the Vestre Broggerbreen were traced and re-measured to know ablation while snow depth, stratigraphy and density were measured to know accumulation. A temporary reference point (coordinate) was established below the snout of the Vestre Broggerbreen glacier by using the Ny-Ålesund control point. This temporary reference point was used to survey the glacier for different purposes. The accurate coordinates of all installed stakes were surveyed by differential GPS (Leica 1200 series) to know the surface ice velocity.

6.3.4 Arctic Expeditions

During the year 2012-13, the Indian station "Himadri" was manned for 185 days and a total of 25 scientists visited Ny-Ålesund under 12 different projects. Taking into consideration the ongoing long term programs and the collaborative studies planned to be initiated between India and Norway, the call for proposals for the year were restricted to the following focus areas:

a.   Atmospheric Science with special reference to study of aerosols and precipitation measurements over the Arctic

b.   Biogeochemical studies in the Kongsfjorden

c.   Glacier-Mass balance studies and snow-air flux measurements

The details of the various projects initiated during the year in the Arctic are as below:

Sl. No.	Name of the scientific project	Institution	New/Continuing
1	Long term monitoring of Kongsfjorden system of Arctic region for climate change studies	ESSO - NCAOR	Continuing
2	Role of Aerosols and precursor gases in direct radiative forcing over Arctic region at Ny-Ålesund	ESSO-IITM	Continuing
3	Investigations of atmospheric aerosols and there characterization over the Arctic during summer season	SPL/ISRO	Continuing
4	Crustal Deformation studies in the Arctic	Manipur University	Continuing
5	Mercury geochemistry in the sediments of Kongsfjorden, Ny-Ålesund, Arctic	Kerala University	New
6	Monitoring of Arctic precipitation	ESSO- NCAOR	Continuing
7	Quantifying variability in freshwater influx to the Kongsfjorden system using oxygen isotopes of seawater: Implications to the ice melting	ESSO- NCAOR	Continuing
8	Study of snow –air fluxes of ionic compounds and trace gasses at Ny-Ålesund	ESSO- NCAOR	Continuing
9	Study of macro and micro-structures in the ductile shear zones of the west Spitsbergen fold thrust belt with implications on the tectonic evolution of the Svalbard area of Arctic region	GSI/MOM	New

10	Integrated monitoring of the Vestre Broggerbreen Glacier, Syalbard, Arctic	ESSO- NCAOR	Continuing
11	Parameterization of Glaciers in Northern hemisphere to variations of climate- inter annual and intra annual	GSI/MOM	Continuing
12	Study of the mass balance and dynamics of the Austre Broggerbreen, Vestre Broggerbreen and Midtre Lovenbreen Glaciers of, Svalbard archipelago, Arctic using Global Positioning System (GPS0 and interferometric Synthetic Aperture Radar (InSAR), techniques	IIG/DST	New

6.4   GLACIOLOGCIAL STUDIES IN THE HIMALAYAS

In the Himalayas, a pilot expedition to the Batal and the Sutri Dhaka glaciers in Himachal Pradesh was undertaken by a five-member team during August –September 2013, as a prelude to the initiation of a major long-term program of cryosphere studies in the Himalaya. The team, during its month-long expedition, established a network of stakes on the glaciers to collect data for mass balance studies.

GEOSCIENCES AND OCEAN MINERAL RESOURCES

The survey and exploration constitutes one of the important components of geoscientific studies and harnessing the marine resources. The comprehensive understanding of various processes coupled with various exploratory tools such as ocean drilling is expected to facilitate sustainable harnessing of ocean resources for the benefit of mankind. The comprehensive legal framework in the form of UN Convention on Law of the Sea provides an opportunity to delineate continental shelf beyond the Exclusive Economic Zone (EEZ) and to explore various deep sea mineral resources viz. polymetallic nodules, polymetallic/ hydrothermal sulfides and cobalt crusts. In addition, another promising resource, viz. gas hydrates is attracting the attention of scientists. An earthquake is the result of a sudden release of energy in the Earth's crust that creates seismic waves. The seismicity, seismism or seismic activity of an area refers to the frequency, type and size of earthquakes experienced over a period of time. Tectonic earthquakes occur anywhere in the earth where there is sufficient stored elastic strain energy to drive fracture propagation along a fault plane, an another area of investigation.

7.1 EXCLUSIVE ECONOMIC ZONE

India has an Exclusive Economic Zone (EEZ) of around 2.02 million km^2 in the western and eastern offshore domains, which is nearly two-third in area of the landmass of the country (Fig. 7.1). The primary objective of the programme is to prepare a comprehensive high resolution seabed bathymetric map for the entire Indian EEZ using the state-of-the-art technologies of multi-beam swath bathymetric

echo-sounder systems. It is also planned to carryout systematic sediment sampling and analysis to understand the sediment characteristics and dynamics, and possibly assess the potential of seabed resources.
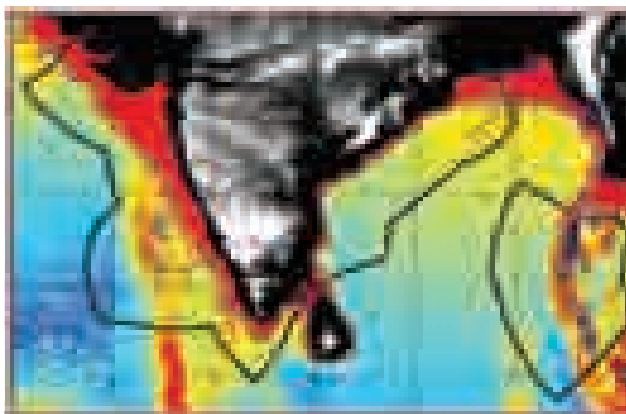
Fig.7.1: The Exclusive Economic Zone of India

The total area covered so far under the EEZ Mapping programme are 8,35,404 km^2 of deep-water and 16,262 km^2 of shallow waters. During the year 2013-14, six cruises were undertaken and a total area of ~2,05,860 km2 of deep-water area in the Arabian sea off the Mumbai-Ratnagiri and the Saurashtra and off the Laccadive Region have been covered. Until now, 60 sediment core samples have been collected from the surveyed area. Analysis and interpretation of the parametric and swath bathymetric data suggested the presence of a prominent channel-levee characterized by highly variable sinuosity in the lower fan region in the proximity of the 90° E ridge in the Bay of Bengal. The channel-levee system and morphology reported for the first time in the distal Bengal Fan.

7.2 Delineation of India's Continental shelf

The Indian Continental Shelf Programme is a multi-institutional and multi-crore national mission that seeks to gather, analyse and document the requisite scientific and technical information that would help define and delineate the country's continental shelf boundaries beyond 200 nautical miles under the provisions of the United Nations Convention on the Law of the Sea (UNCLOS).

The activities during the year have been largely confined to provide additional information/clarifications sought by the UN on the Submission, preparation of of first draft of the second partial submission for an extended shelf and providing technical inputs to prepare a counter-memorial in respect of the arbitration between Indian and Bangladesh.

7.3 Indian Ocean Deep-Drilling Programme (IODP)

The scientific proposal entitled "Deep sea drilling in the Arabian Sea: Discovering the tectono-climatic unknowns" a Complimentary Project Proposal (IODP-793_CPP) has recently been recommended by IODP for initiation during early 2015. As a prelude to the proposed drilling, detailed multibeam bathymetric surveys have already been initiated in the drilling area.

The Indian scientific participation onboard IODP platforms has been one of the most significant activity as scientists from various disciplines and expertise have been able to get hands-on experience of scientific drilling in the ocean. Indian scientists from a host of national institutions and universities have been participating in various IODP expeditions around the world, as given below

No.	IODP Expedition*/Period	Name & Affiliation of the Indian participant
1	IODP-346 (Asian Monsoon) July-August 2013	Dr. Raj. K. Singh,IIT-Bhubaneswar
2	IODP-338 (Nankai Trough) Oct. 1, 2012-Jan. 13, 2013	Dr. Ravi Mishra, ESSO-NCAOR, Goa
3	IODP-345 (Hess Deep) Dec. 11, 2012-Feb. 12, 2013	Dr. Abhishek Saha, Calcutta University, Kolkata
4	IODP-343 (JFAST, Japan) April 01-May 24, 2012	Dr. Santanu Bose, Calcutta University, Kolkata
5	IODP-342 (Newfoundland) June 02-August 01, 2012	Dr. Amit Kumar Ghosh, BSIP-DST, Lucknow
6	IODP-340 (Lesser Antilles) March 03-April 17, 2012	Mr. K.S.V.Subramanyam, CSIR-NGRI, Hyderabad

A meeting of the Indian IODP participants since 2008 was organised on 14-15 January 2013 at ESSO-NCAOR, Goa to facilitate scientific interaction among the participants. The meeting was focussed on evolving future strategy to utilise expertise of Indian participants for the Indian proposal. About 30 delegates from various parts of the country attended the two-day programme and presented the scientific work carried out by them based on their expeditions.

7.4 Gas Hydrates Exploration

Scientific interest in gas hydrates increased tremendously in the last few decades mainly by interest in the potential future role of gas hydrates as an energy resource, and by the role of methane as a strong greenhouse gas and contributor to global climate change. Further interest is linked to the geo-hazard aspect of gas hydrate occurrences (especially in the marine environment) related to seafloor subsidence, slumps and slides. Large data sets were acquired from the selected blocks (namely- the Krishna – Godhavari and the Mahanadi basins) in the Indian waters for understanding the gas hydrate formation and their occurrence. The data collected was analysed and the preliminary results are given below:

The processing of large volume of multi-channel seismic (MCS) data, acquired in the Krishna-Godavari (KG) and the Mahanadi basins, has brought out very good seismic image of shallow sediments showing wide-spread occurrences of Bottom Simulating Reflectors (BSRs)(marker for gas-hydrates) over a large area in both the basins (Fig. 7.2). Fig.7.3 exhibits BSRs on two representative seismic sections.
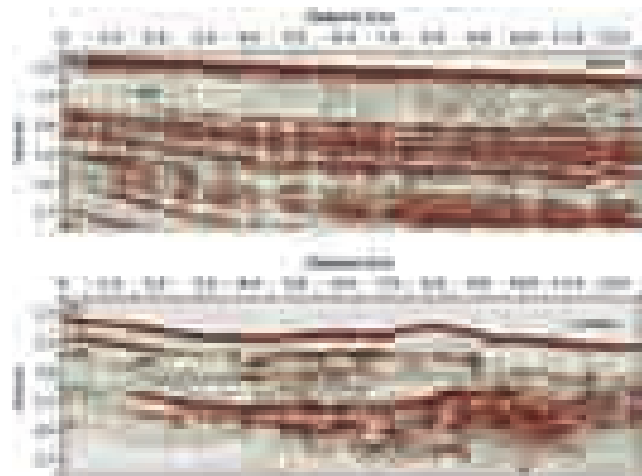
Fig.7.3: Specimen seismic sections in (a) the Mahanadi and (b) the KG basins with distinct BSRs.

Significant patterns of shear wave (S-wave) splitting in the azimuthal gathers of ocean bottom seismic (OBS) data acquired in the Mahanadi offshore, exhibits the fast (S1) and slow (S2) axes of propagation in the radial azimuthal gathers, and amplitude nulls and amplitude highs in the transverse azimuthal gathers (Fig. 7.4). These two features are diagnostic of anisotropy due to the presence of fractures, which is linked to the near vertical faulting in gas hydrate layers. The strike of this fracture set is inferred to be ~130 from the variation in the P-wave amplitude with azimuth. The density of fracture set and the orientation are delineated by full wave modeling of the OBS data. A good match between the synthetic and observed data is observed for a near vertical fracture (angle of about 85). The seismic image obtained from the high resolution MCS data correlate well with the OBS results.
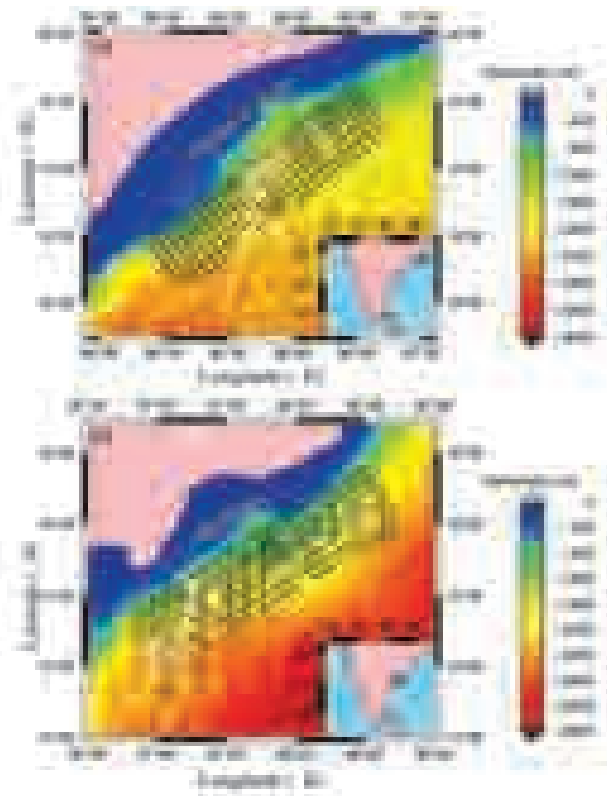

Fig.7.2: Locations of seismic profiles (black lines) along which MCS data were acquired along the eastern Indian margin. The BSRs, identified on seismic lines, have been marked by white.
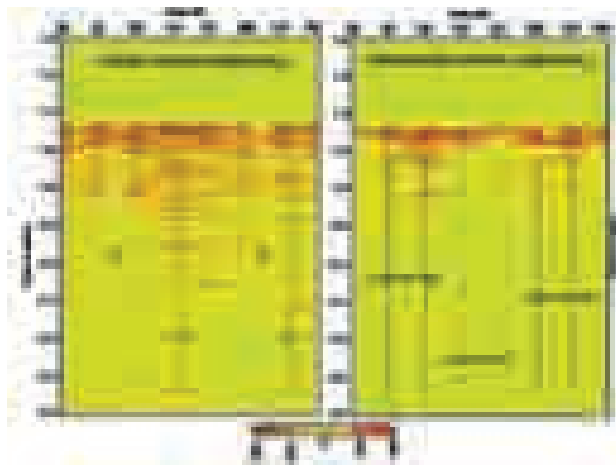
Fig.7.4: Fixed-offset azimuthal radial and transverse gathers for an OBS. The fast and slow axes, S1 and S2, are clearly noticed on the radial gather while the amplitude null and amplitude highs can be identified on the transverse gathers, indicative of anisotropy.

Presences of gas hydrates in sediments above the bottom simulating reflector (BSR) is associated with low seismic attenuation or high quality factor (Q), whereas free gas bearing sediments below BSR exhibit high attenuation or low Q. The logarithm spectral ratio (LSR) method was applied to marine seismic reflection data along two cross line in the Krishna-Godavari (KG) basin to calculate the interval Qs for three sedimentary layers bounded by the seafloor, BSR, one reflector above and another reflector below the BSR to study the attenuation characteristics of sediments. The interval Qs for hydrate-bearing sediments above the BSR are estimated to be higher than the interval Qs for the gas-bearing sediments below the BSR. This demonstrates that the gas hydrates bearing sediments exhibit low attenuation (Q), and underlying gas bearing sediments are associated with high attenuation. Thus seismic Q can be considered as a marker for gas hydrates particularly at places where BSR (main marker) is not so prominent.

The concept of storage and transportation of fuel gas as gas hydrates (clathrates) is attractive if their stable pressure and temperature conditions are in the vicinity of ambient or in easily manageable conditions.

The Tetrahydrofuran (THF) and tert – Butylamine (t-BuNH2) are the thermodynamic promoters for the methane hydrates. The mixed hydrates formed with methane and THF/t-BuNH2 in sII stoichiometry dissociates at much higher temperatures (THF - 18 and t-BuNH2 - 12) compared to pure methane hydrate. At intermediate mole fractions (x = 0.033 for THF & for t-BuNH2) a two stage hydrate formation in both sII & sI structures are prominently observed. However, at much lower mole fractions (x = 0.0056 for THF and t-BuNH2) methane hydrates are dominated by sI structure. Noticeably the dissociation curve gets shifted to the right of pure methane hydrate phase boundary curve by around 2 indicating the hydrate promotion affect. However, the mixed hydrates with THF (x = 0.0056) are dominated by sII. In summary the dissociation behavior of methane hydrates is essentially controlled by sII forming component (THF/ t-BuNH2).

7.5 POLYMETALLIC NODULES (PMN):

Nodule exploration in India was initiated in 1981 and has been continuing since then over the last three decades. India undertook extensive investigation and developmental work progressively in all the four major components viz. Survey and Exploration, Environmental Impact Assessment (EIA) Study, Technology Development for Mining and Extractive Metallurgy of the Polymetallic Nodule Programme (PMN).

7.5.1 Survey & Exploration

The task of identifying the Test Mining Site (TMS) within the First Generation Mine site (FGM) is accomplished during the year. Each block of uniform size (0.125 x 0.125) was evaluated against the five parameters (3 relating to bathymetry and one each to nodule abundance and grade) and the best block was identified as TMS.

7.5.2 Environmental Impact Assessment Studies (EIA)

EIA studies for nodule mining in CIOB were initiated for evaluation of environmental data for providing inputs for mining of polymetallic nodules.

Surface sediments from three different physiographic areas in the Indian Ocean were selected for the study. One from the equatorial Indian Ocean and the other two cores were selected from different sediment domains from the CIOB, i.e. siliceous ooze and pelagic red clay areas and analysed as follows:

a. Grain size separation was done on the three samples (<1, 1-2, 2-4, 4-8, 8-16, 16-32, 32-45, 45-63 and >63µm sediment fraction) by sieve and pipette methods.

b. Detailed microscopic, Scanning electron microscopy was performed for textural studies

c. Minor and trace element analysis was carried out by inductively coupled mass spectrometry.

d. Relationship of different size fraction versus metal concentration was studied in the cores.

e. The study of macrofaunal community was conducted to evaluate its distribution and the following results were obtained:

f. In all, 30 taxa belonging to 11 groups from 6 samples were identified, with an average abundance of 316 no./m2 and 148 no./m2.

g. These were dominated by Tanaids (35%), polychaetes (22%), amphipods (20%).

h. Fauna belonging to 10 groups and 4 groups were identified.

7.5.3 Technology Development (Extractive Metallurgy):

The following activities were pursued related to extraction of Cu, Ni, Co and Mn from the polymetallic nodules:

i. Extraction of Cu, Ni, Co and Mn by sulphuric acid leaching, purification / metal separation and electrowinning: pilot scale studies

j. Alternative processing of polymetallic nodules for recovery of Cu, Ni, Co and Mn.

k. Recovery of rare earth elements and other valuable metals such as molybdenum, strontium and zirconium from manganese nodules.

l. Technology development for liquid and solid effluent disposal for polymetallic nodules processing.

m. Rheological studies and hydraulic transportation of seabed mineral resources.

7.6 Studies on Hydrothermal Sulphides

Under the major multi-disciplinary project aimed at exploration for potential sites of hydrothermal multi-metal sulphide mineralization in the Indian Ocean Ridge Areas, ORV Sagar Kanya and a chartered research vessel RV Nikolaj Strakhov were deployed in the Central Indian Ridge (CIR) and Southwest Indian Ridge (SWIR) areas to carry out the preliminary geoscientific survey and exploration. Systematic geophysical surveys including multibeam eco-sounder (MBES) bathymetric mapping, magnetic, gravity and Sub-Bottom Profiler (SBP) surveys for a few selected blocks in the proposed region were carried out, which provided very useful preliminary constraints in selecting the sampling locations from possible zones of mineralization. Sampling carried out along few selected locations using rock-dredging, grabs and gravity corers have recovered altered rocks, mafic-ultramafics rocks comprising of basalts, gabbros, Fe-Mn crusts and metalliferous sediments (Fig. 7.5). Most of the sediment samples collected contains high quantity of metalliferrous minerals, which indicates extensive hydrothermal mineralization in the region. More than 80 CTD observation carried out serves not only as inputs for baseline environmental data but also useful in providing vital clues about possible plume locations.

Fig 7.5: a) Ultramafic b) Basalt c) Fe-Mn crust

Based on the preliminary analysis of the data collected as well as integration of the geoscientific investigations undertaken by several national and international institutions/organizations in the Indian Ocean to date, an area of around 300,000 km² along CIR and SWIR, has been selected for detailed geoscientific studies. An application for approval of a plan of work for exploration for polymetallic sulphides covering an area of 10,000 km² falling within the identified area of 300,000 km² was filled before the International Seabed Authority on 26th March 2013. Major minerals including calcite, chegemite, calcioancylite, chalcocite (sulphide) and connellite (hydrous cupper-chloro-sulphate) were identified by mineralogical studies of deep seabed sediment samples collected from the CIR and SWIR.

7.7 EARTHQUAKE MONITORING

A country-wide seismological network consisting of a total of 82 seismological stations is being monitored. The network is capable of monitoring the local seismicity in Delhi and Northeast India and the regional seismicity within the country. Through integration of global data, the network is also able to provide earthquake source parameters, within ten minutes. f The field stations data are received at Central Receiving Stations (CRSs) at ESSO-IMD, New Delhi and ESSO-INCOIS Hyderabad (Fig.7.6). All (80) standalone broadband seismographs and permanent GPS stations being operated in the country have been connected through V-SAT to the CRSs. As part of an international commitment, continuous real time seismic waveform data of three
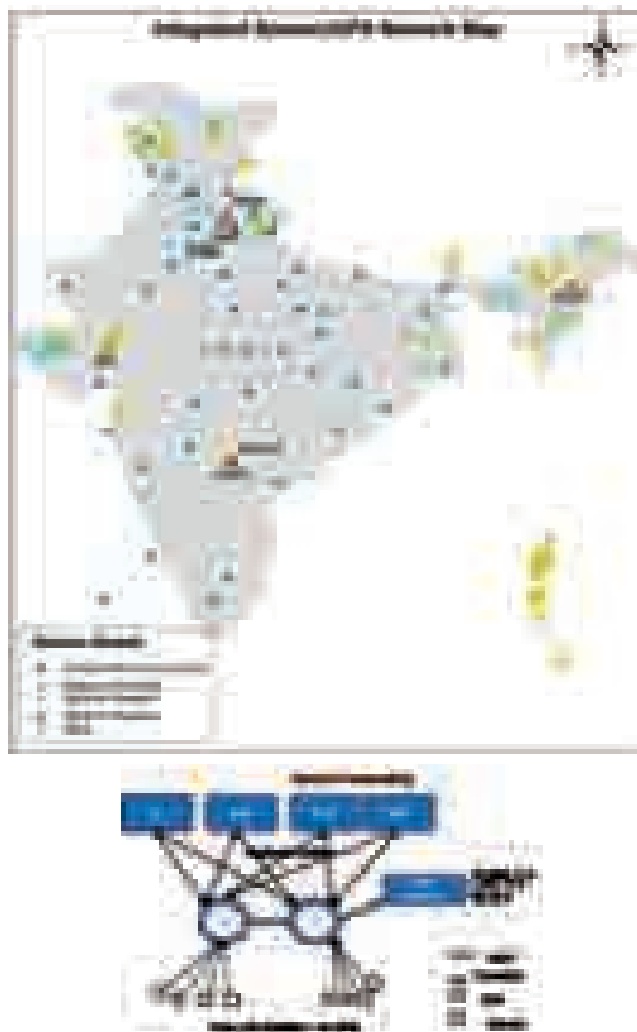
Fig. 7.6 Locations of standalone Broadband seismographs and permanent GPS stations connected through V-SAT and Network connectivity

seismic stations, viz., Portblair, Minicoy and Shillong is being transmitted to Incorporated Research Institutions of Seismology (IRIS), Washington, USA. The earthquake information is transmitted to various user agencies including public information channels, press, media etc. using different modes of communication, such as SMS, fax, email, IVRS and also posted on ESSO-IMD's Website (www.imd.gov.in).

During the period January-September, 2013 a total of 2692 earthquake events were detected and auto-located. These include 1331 events of magnitude 5 and above, whose hypocentral parameters are comparable with those of other global networks and are within the acceptable error bars. Information pertaining to significant events was transmitted to all concerned state and central government agencies dealing with relief and rescue operations in the region within 10 minutes of occurrence of the event. During this period, the Indian subcontinent witnessed a large magnitude earthquake of M:7.4 in Pakistan on 24th September, 2013, which was felt in parts of western India including Delhi. The Doda district of J&K witnessed a moderate earthquake of magnitude 5.8 on 1st May, 2013, followed by intense aftershock activity. In collaboration with Bhaskaracharya Institute of Space Applications and Geoinformatics (BISAG), Gandhinagar, the Center has developed a prototype application for generating dynamic earthquake damage scenarios, depicting the likely expected intensities, ground accelerations, etc. The prototype is under test and shall soon be made operational. Under the project 'Archival and vector digitization of seismic analog charts', a total of one lakh analog seismic charts have been raster scanned and about 4,200 seismograms have been vector digitized. The quality checks of the raster scans and vector digitized seismic events are in process.

Crustal Deformation monitoring across the Karakoram fault in the Ladakh region

Siachen Base Camp

Kuri

Partapur

Saserla road, 32 km milestone

Partapur Siachen Base Camp, and Sasoma are online and data are being received at INCOIS.

Fig.7.7: Location of GPS stations

7.8 EARTHQUAKE PRECURSORS:

A National Program on Earthquake Precursors (NPEP) was initiated by Ministry about 4 year back with a view to generate long-term multi-parametric geophysical observations in seismically active areas, and comprehensive analysis and interpretation of

these multi-parametric observations through a multi-institutional participation.

Various geophysical data sets, viz. seismic, GPS, magnetic, radon and water level, recorded during the period June 2006 to September 2011 at Shillong MPGO have been analysed. 13 events occurred, within their preparatory zone have been examined having M 4.1-5.9. A total 8 earthquakes were found to be preceded few minutes to 3-8 days by magnetic changes, however, a continuous data streams for longer period, as well as from other nearby stations would help in concretizing the hypothesis. No significant changes in water level and Radon have been observed.

Multiparametric geophysical data sets, viz. seismic, GPS, gravity magnetic, radon and water level, recorded during the period January 2007 to September 2013 at Ghuttu MPGO were analysed. A total 11 earthquake events having M 3.2-6.4 show their preparation zone area greater than the epicentral distance from the observatory, were examined. Significant probable precursory changes have been observed only for a moderate earthquake of Mw 5.0 occurred at a distance of 60 km from the MPGO observatory in the early hours of July 23, 2007 (04:32:12 IST). Co-seismic changes in gravity data and anomalous behavior in the second and third eigen values were obtained after principal component analysis of three station total magnetic field data during the Kharsali earthquake of 22 July, 2007. A sudden co-seismic offset of more than 2 µGal occurred in the gravity level measurements at MPGO station due to occurrence of this earthquake. Some abnormalities in radon emanation and other parameters in the borehole have also been observed as precursory changes to this earthquake.

7.9 GPS STUDIES

4 GPS stations (Fig. 7.7) have been established at the Siachen Base Camp, Partapur, Kuri, Saserla road- 32 km milestone for crustal deformation monitoring across the Karakoram fault in the Ladakh region.

7.10. MICROZONATION

Seismic Hazard Microzonation of NCT Delhi on 1:10,000 scale has been completed for (a) 2% probability of exceedence of an earthquake in 50 years (return period 2475 years) based on MCE and (b) 10% probability of exceedence of an earthquake in 50 years (return period 475 years) based on Design Basis Earthquake (DBE) (Fig. 7.8). Output data are to be used by the Bureau of Indian Standards for formulating strategies of implementation of seismic hazard microzonation products in Building codes of NCT Delhi.
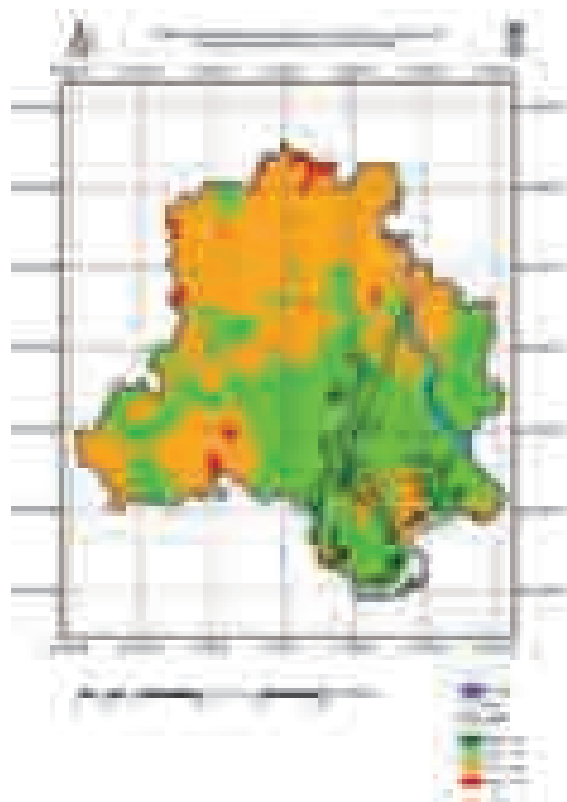
Fig. 7.8 Seismic hazard microzonation map of NCT Delhi

As a part of Microzonation of Kolkata city work on Seismotectonic Map, Geology and Geomorphology Base Map at 1:25,000 scale, Probabilistic Seismic Hazard analysis at bedrock level, site characterization (partially), pre-Monsoon and post-Monsoon water table/ piezometric surface configuration, vulnerability analysis (landuse/landcover, building typology and population density etc) have been completed (Fig. 7.9).
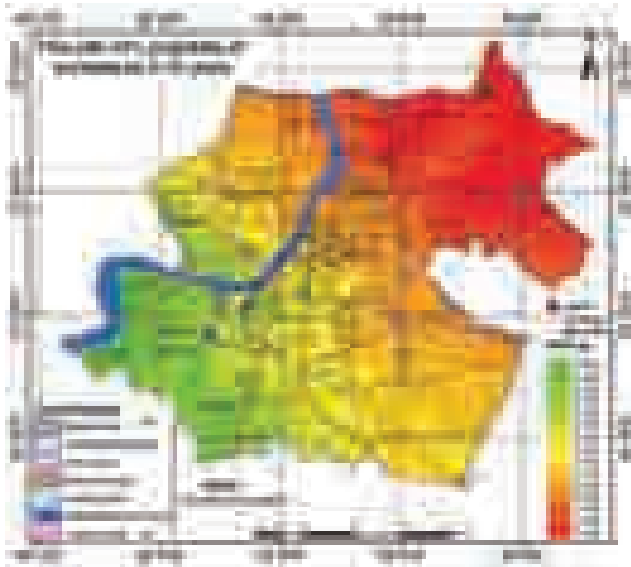
Fig. 7.9 Probabilistic seismic hazard of Kolkata

7.11. GEOPHYSICAL AND SEISMOLOGICAL STUDIES IN THE KOYNA-WARNA REGION:

A scientific deep drilling programme is underway in the Koyna-Warna region to set up a deep borehole observatory to study the earthquakes physical and chemical rock properties before, during and after the earthquake. Towards this goal, geophysical investigations like broadband seismology, broadband magneto-tellurics (MT), controlled source audio-frequency magnetotellurics (CSAMT), land-based gravity-magnetics, airborne gravity-gradiometry and LIDAR surveys are being carried out to precisely delineate the sub-surface structure around the seismic zone. This will help to identify most prospective for scientific deep drilling and fault zone investigations. This is supplemented by exploratory boreholes to ~1.5 km depth, surrounding the seismic zone, including geophysical logging, hydrogeology, borehole Seismology for precise delineation of hypocentral trends and fault plane geometry for taking up the deep drilling experiment. Following are achievements:

n. Drilling of two boreholes, at Rasati, Koyna to a depth of 1522.5 m while the other one at Udgiri, Warna, to a depth of 1196m.

Geological and geophysical logging has been undertaken at both these sites. Interestingly the basalt thickness is 933 m in Koyna and 1185 m in Warna, immediately underlain by the granite gneissic basement with no sediments in between (Fig.7.11).

o. The core retrieved from boreholes revealed a flood basalt pile comprising a number of lava flows, each flow being characterized by a vesicular and /or amygdaloidal layer underlain by fine grained massive basalt. Flow top breccias has been identified in some flows. The vesicles are frequently filled with quartz and calcite crystals, occasional zeolite and other amygdals. Large vugs, either completely or partially filled with amygdales have been observed in a few segments. Often, the basalt changes from grey to chocolate brown, possibly due to the oxidation of ferromagnesium minerals in them. The massive basalt segments are characterized by well developed sets of joints with frequent splitting of the rock along joint planes, showing evidence of fluid movement on the joint surfaces. Occasionally, small vesicular patches have been noted even within the massive basalt layers.

p. Inter-trappean red bole and/or pyroclastic beds, ranging in thickness from a few tens to several tens of centimetres have been observed at m ultiple depths. The thicknesses of individual flows, based on preliminary physical examination, are highly variable with a range from a few meters to a few tens of meters. The transition from basalt to granite is marked by the occurrence of quartz and pink feldspar, followed deeper by typical, coarse grained granite. No infra-trappean sediments have been observed.

q. Airborne Gravity-gradiometry and Magnetic survey on a regional scale in the Koyna-Warna region has been successfully

completed over 5000 line km of flight. Detailed processing and interpretation for regional structures is underway.

r.   Deep resistivity sounding (DRS) data has been acquired at 9 stations in Koyna and Warna. The maximum AB/2 used is 5000m and the inferred basement is below the trap at a depth of around 1200m.

Airborne LIDAR studies are scheduled to be carried out for a detailed delineation of the geomorphology in conjunction with surface geological mapping which will be useful for studying the hydraulic connectivity in the Koyna-Warna region.

a)   Massive basalt

b)   Vesicular and amygdaloidal basalt with large vugs filled with quartz and/or calcite

c)   Flow-top breccia

d)   Red bole and overlying massive basalt

e)   Vuggy basalt filled with zeolite

f)   Basement

g)   granite-gneiss

Fig.7.10 (a) Drilling at Rasati, Koyna

Fig.7.10 (b) Sample cores from KBH-1 (Rasati, Koyna)

EARTH SCIENCE-DATA CENTRES

The data centres play a cardinal role in realizing the aims and objectives of the ESSO, sharing information, knowledge and services. The present priorities of the ESSO in this area are:

a. Substantially strengthening the existing data centres and expanding their activities and establishing new ones.

b. Integrating all the data centres for smooth access and effective use of their data holdings.

c. Enabling the data centres to seamlessly deliver data and information services for the national and international community.

In addition, the ESSO is also an active partner in the national efforts in the field of data and its usage. ESSO is actively engaged in implementing the National Data Sharing and Accessibility Policy (NDSAP 2012) of the Government of India. As part of this activity, ESSO-MoES made available various useful meteorological and oceanographic data through the Data Portal India (data.gov.in) established by the Ministry of Communication and Information Technology.

A brief description of the various data centres under the ESSO and their on-going developmental activities are given below:

8.1   OCEAN DATA AND INFORMATION SYSTEM (ODIS)

The data centre at the ESSO-INCOIS obtained and archived the in-situ data from the ocean observing systems [moored buoys (22), RAMA buoy (22), drifting buoys (51), ship-mounted AWS (17), wave rider buoys (10) and HF Radar (04 pairs)]. The data centre also received data on XBT/XCTD (74 profiles), Met observations (3585 records from NODPAC), RAMA buoys (22 buoys) and water quality from various agencies in delayed mode.

The remote sensing data received at the ESSO-INCOIS ground station include OceanSat-2, NOAA series of satellites, METOP, MODIS Terra and Aqua and Oceansat-1 also have been archived. For easy dissemination of data and data products, a bi-lingual (English and Hindi) content management system is also developed.

Fig.8.1. Ocean Data Information System website

A DVD (version 2.2.) containing over 2,00,000 T-S Profiles collected by the Argo floats during 2002-2012 was released along with gridded data Products. New features of the DVD include a user friendly GUI for easy navigation, browsing and data extraction with user defined spatial and temporal domains.

A new web interface has been developed for the submission of cruise summary reports by the Chief Scientists of cruises undertaken on board the Ocean Research Vessels. Another web-interface has been developed to receive

and archive the data collected under the programme on 'Geotraces-India'.
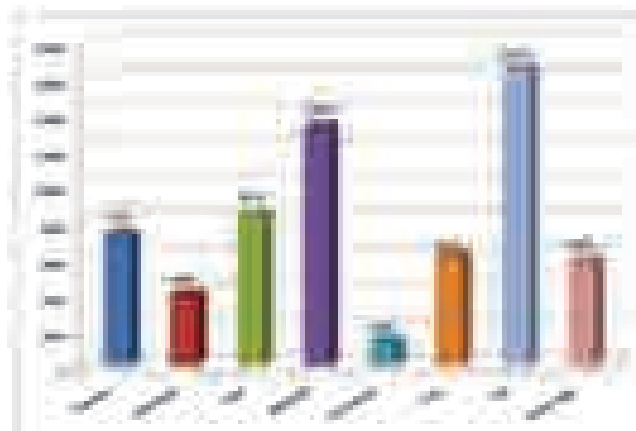
Fig. 8.2 Number of visitiors to ESSO-INCOIS web pages in 2013

8.2. Marine Geophysical Data Centre

The National Marine Geophysical Data Centre was established at the ESSO-NCAOR wherein over 31,000 line km of multichannel seismic reflection, gravity and magnetic data together with bathymetric information were archived (7 TB). The data was used for delineating the outer limits of the country's continental shelf beyond 200 nautical miles under the provisions of the United Nations Convention on the Law of the Sea (UNCLOS). The state-of-the-art archival and retrieval facility of all marine geoscientific data in a structured database has been developed. The metadata functionality of the database describes the primary details in terms of when and how the data was collected, the nature of data, how the data was processed, necessary supporting

information that went in to the processing etc. The database also facilitates customized GIS-based interface for easy retrieval of data from a NAS, queries based on different scientific inputs, and web based input/output interface to facilitate the application to run on internet/intranet with login authentication. The database format is also flexible enough to allow for both vertical and lateral growth.

8.3 SEISMOLOGICAL DATA BASE

The seismological data from the network stations (80 stations) is compiled, processed, analyzed and archived systematically at the Database centre on a regular basis. The Database centre has capabilities for storing of continuous waveform data in standard SEED format, retrieval as per user criteria, SeedLink protocol for connectivity with auto-location software, etc. The Data Centre has a web portal (http://www.isgn.gov.in), which gives access to the registered users for downloading the waveform data for research purposes. The earthquake bulletins are prepared on monthly basis and archived vis-à-vis also sent to the International Seismological Center. On request basis, the earthquake data and site specific seismicity reports are supplied to industrial units, power houses, river valley projects etc. Earthquake data are also being supplied to various scientific, academic and R&D institutions for research purposes. Seismological data and earthquake related information is supplied to various user agencies dealing with relief and rehabilitation measures, earthquake disaster mitigation and management related matters, seismic zoning, etc.

Fig. 8.3: National Geophysical Data Centre at the ESSO-NCAOR

Fig.8.4. The data centre architecture
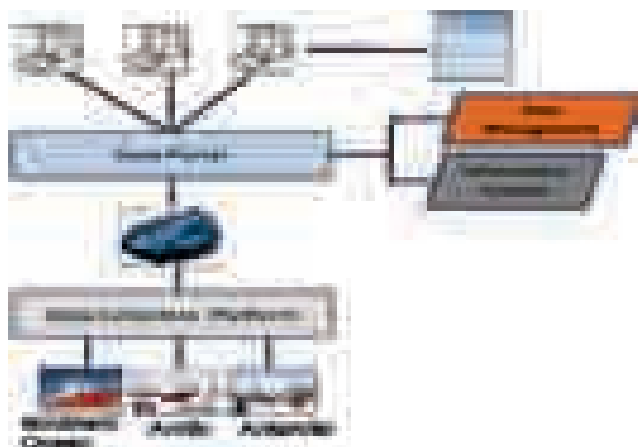
Fig.8.4. Polar Data Centre architecture

8.5. CLIMATE DATA CENTRE

Long term climate observations are very important for monitoring and predicting climate variability and climate change. To support useful climate services, records of climate data should be assembled in standardized formats, archived in accessible electronic formats, subjected to quality management procedures including quality control. At present, the National Data Centre (NDC) of the ESSO-IMD at Pune is the sole custodian of all data being collected from various parts of India. The mandate of this centre is to preserve quality controlled data and supply for Weather Prediction, Aviation, Agriculture, Environmental studies, Oceanography and Shipping and Researchers of various Institutions and Universities. There are about 15 types of meteorological data viz. surface temperature, rainfall, wind, pressure, autographic, upper-air data, radiation data, air-pollution data. Recently, the observational networks were expanded and upgraded with installations of Automatic Weather Stations (AWS), Automatic rain-gauge stations (ARG), and other automatic surface and upper-air atmospheric observations which have further increased the inflow of volumes and variety of data for permanent archival. The data size of about 10 MB or more is expected to flow every day or depending on the observational frequency. These data would help in providing the instantaneous detail of weather and ultimately improve climatological information services. A state-of-the-art National Climate Data Centre (NCDC) is being set up to improve the existing data management system.

This centre will include data acquisition from different media (internet, SMS, VPN, etc.,) and archival, quality checks, retrieval, on-line payment and data supply and web-based climatological information services systems, visualization of data, products and analyses in GIS / Text formats, e-commercialization on all types of meteorological data.

CAPACITY BUILDING AND HUMAN RESOURCE DEVELOPMENT

To gain scientific understanding of the earth system (the atmosphere, ocean, solid earth, biosphere) as well as to study the interactions between its components and their response to the natural and human induced changes, several programmes have been launched. In order to cater to the enormous requirement of skilled manpower in the field of Earth System Sciences three training schools have been established.

There is a need to continuously upgrade knowledge through assimilation of new ideas and application of new knowledge in the field of earth sciences for improvement of weather and climate forecasts. This can be effectively done through adoption of multi-institutional and multi-disciplinary approach involving amalgamation of expertise existing in various research and development (R&D) institutes of the country. Therefore, focused R & D through networked projects involving various institutes within India and abroad, academic programmes, and establishment of Chair Professors, establishment of National Lab facilities and Centers of Excellence at various Universities with state-of the art research facilities are being supported.

9.1. CENTRE FOR ADVANCED TRAINING IN EARTH SYSTEMS SCIENCES AND CLIMATE (CAT ESSC)

The Centre for Advanced Training in Earth System Sciences and Climate (CAT-ESSC) was established in 2011. The main objective was to create a pool of trained and dedicated earth system and climate system scientists with in-depth hands-on expertise on physical processes of the land, ocean, atmosphere, biosphere and cryosphere with special emphasis on modeling. The second batch of 18 trainees inducted in August 2012 has completed their training and are placed at various ESSO units. Third Batch of 25 Trainee Scientists was inducted in August 2013 and is presently undergoing training. CAT-ESSC has been approved by the University of Pune as part of the Ph.D. course work.

9.2 TRAINING IN OPERATIONAL METEOROLOGY

The Training School in Operational Meteorology is being set up at the ESSO-IMD, Pune with an aim to reorganize the existing training with introduction of concepts like continuous learning and self development; e-learning etc. Regular long duration training courses (3-12 months) are conducted of the meteorologists in India and Afro-Asian region (in RA-II region).The following Training Courses were conducted.

i. **Advanced Meteorological Training Course for Naval, Coast Guard and foreign trainees (one year)**

ii. **Forecasters training course for Assistant Meteorologists (6 month)**

iii. **Intermediate training course for Scientific Assistants (4 months)**

iv. **Integrated Meteorological Training Course for newly recruited Scientific Assistants (4 months)**

v. **A customized short term training course for scientists of the ESSO-NCMRWF (2 months)**

9.3 INTERNATIONAL TRAINING CENTRE FOR OPERATIONAL OCEANOGRAPHY

The International Training School for Operational Oceanography (ITCOOcean) has been set up under the ESSO-INCOIS, to enable support for capacity building activities in the field of operational oceanography in the Indian Ocean Rim (IOR) and Islands Region as well as Africa. A Memorandum of Agreement (MoA) between ITCOOcean and International Oceanographic Commission (IOC)/UNESCO was signed on 4th July 2013 during the 27th Assembly of IOC in Paris. Two courses of two weeks duration were conducted in July and August 2013 involving international faculty and were attended by participants from IOR countries.

9.4 ESTABLISHMENT OF THE INDIA AFRICA CENTRE FOR MEDIUM RANGE WEATHER PREDICTION

An India-Africa Centre for Medium Range Weather Forecasting has been planned to fulfill India's commitments made at the second Africa-India Forum Summit in the area of capacity building in Africa. The ESSO-NCMRWF is the nodal agency responsible for generating and establishing a complete end-to-end medium range weather prediction system suitable for Africa. Mauritius has been identified for establishment of the Center. Various meteorological products are being generated for the African region.

9.5 BIMSTEC-CENTER FOR WEATHER AND CLIMATE

The Bay of Bengal Initiative for Multi-Sectoral Technical and Economic Cooperation (BIMSTEC) Member Center for Weather and Climate (BCWC) has been established at the National Center for Medium Range Weather Forecasting (ESSO-NCMRWF). This will enable enhanced regional cooperation on observing systems, forecast information, early warning systems and capacity building. A pilot project has been undertaken for improving probabilistic medium range predictions and to examine the rainfall variability in the BIMSTEC region.

9.6 R & D FUNDING IN EARTH & ATMOSPHERIC SCIENCES

To improve the understanding of the earth system (the atmosphere, ocean, solid earth, biosphere) and their response to the natural and human induced changes, research projects in academic and research institutes are being supported. The following areas of Earth Sciences have been identified for funding.

1. Atmospheric Science including Climate Science

2. Geosciences

3. Ocean Science & Resources

4. Hydrology & Cryosphere

5. Earth System Technology

The R & D activities include supporting

1. Focused research in areas of national importance;

2. Building indigenous development through joint collaborative programs

3. Human resource development through opening of centers of excellence, initiation of academic programmes, establishment of ESSO/MoES Chairs;

4. Setting up of specialized labs as national facilities;

5. National and international collaboration in the field of Earth sciences.

6. National coordinated projects

The programme is monitored by four Project Appraisal and Monitoring Committees (PAMCs) and a Technology Research Board. An Apex committee has also been constituted to consider specific proposals recommended by these committees.

Focused Research Projects

The following research projects in focused research areas were funded in 2013-14:

Atmospheric Research:

- Establishment of Pulsed Laser Photolysis-Laser Induced Fluorescene (PLP-LIF) Spectrometer and measurements of atmospheric lifetimes of volatile organic compounds in the Earth's atmosphere - IIT Madras

- Development of a mid-IR Cavity ring-down Spectrometer for high Precision Real-time continuous Monitoring of Multiple Trace Gases and Stable Isotopic species in the atmosphere- S.N. Bose National Centre for Basic Sciences, Kolkata

- Estimation of Carbon Sequestration Potential of Trees in Southern Eastern Ghats of Tamil Nadu, India-Pachaiyappa's College, Chennai

- Monitoring Indoor Air Pollution (IAP) in Urban Agglomeration of Delhi and accessing its Human Health Impacts-Delhi University

- Size-resolved measurements and modeling of cloud condensation nuclei (CCN) in Indian continental and marine air - IIT Madras

Geoscience Research:

- Study of the Sub-Himalayan Lower Cenozoic succession with special reference to the reconstruction of tectono sedimentary history of Subathu basin - Presidency University, Kolkata

- Mineral Mapping in Kajali Dongari of Dist. Jhabua using Hyperspectral data analysis & filed verifications by ASD spectro-Radiomometers- Maulana Azad National Institute of Tech. (MANIT),Bhopal

- Exhumation and Denudation of the Western and Central Himalaya: Low Temperature Thermochronology Investigation- IIT, Bombay

- Metamorphic Trajectory of the granulites from the Jagtiyal Section, Andhra Pradesh : Implication on the crustal evolution – BHU, Varanasi

Technology Development:

- **Development of Ka Band Polarimetric Doppler Radar for cloud profiling** -Society for Applied Microwave Electronics Engineering and Research (SAMEER), Mumbai, a Society under DIT will design, develop and fabricate Ka Band (~ 35 GHz) Polarimetric cloud radar with scanning capability wherein cloud parameters from height of 300 m to 15 km with a minimum height resolution of 50 m can be measured. This would be helpful to study the properties of tropical warm clouds prevailing in India. The study of physical process involving the initial stages of cloud formation, its development and dissipation will help Indian atmospheric scientists to develop better short term weather and climate prediction models. A preliminary design document on overall system was made and preliminary design review (PDR) has been completed. Developments of various hardwares and algorithms are in progress.

- Advancing Integrated Wireless Sensor Networks for Real-time Monitoring and Detection of Disasters" -Amrita Vishwa Vidyapeetham, Kerala aims to develop and deploy an integrated landslide and flood monitoring and detection system using wireless sensor network technology. The system will help to predict rainfall induced landslides in landslide prone area in North East region.

9.7 Human Resource development & Capacity Building

- Supported Human Resource Development through Sponsorship of 5 M.Tech and 5 PhD students in Atmospheric Science, Sponsorship of 10 MTech student in Ocean Technology at IIT Madras, initiation of M Tech course in Earth Sciences at IISc, Bangalore with the induction of five students as 1st batch.

- Two candidates have been selected under the PhD fellowship programme in Glaciology. The students will work on Arctic and Antarctic Glaciology under the joint guidance of ESSO-NCAOR, Norway Polar Institute (NPI), Norway and University of Oslo. This will be done under an MoU between the ESSO-NCAOR and NPI to facilitate modalities of implementation.

- Guidelines for establishing ESSO-Distinguished Professor/Fellows at ESSO units have been formalized. Under this ESSO-MoES proposes to establish ESSO Distinguished Professors, ESSO Professor and ESSO Fellows in the ESSO institutes. In addition it will also establish ESSO Visiting Chair Professor at premiere institutes of the country. The eligibility, tenure, selection procedure and other details have been laid out in the guidelines.

9.8. PROGRESS OF ONGOING PROJECTS

A. Focused research Atmospheric Research including Climate Change

Development of a Framework for Systematic Model Diagnosis IIT Delhi. The proposal is aimed at development and implementation of a diagnostic framework for routine and research diagnostics. Model Diagnostics as per the WMO standards has been completed. MJO diagnostics (variance maps, filtering, power spectra, frequency-wave number plot or Wheeler-Kiladis diagram, etc.) and phase diagram were implemented. These were also tested on ECMWF and ESSO-NCMRWF forecasts for the year 2012 and monsoon season of 2013. Phase plots for displaying MJO phases as a time evolving Fig. are implemented. Graphical User Interface (GUI) has been developed for ingesting data (model and observational) into diagnostic framework.

Fine Particles over an Ecologically Sensitive Zone - Source Apportionment, Visibility and Climate Effects - IISER Bhopal. This project aims to enhance the understanding of the sources of visibility reduction over ecologically sensitive locations in the central India, quantify the radiative forcing (climate effects) of such sources, and thereby provide background information for future sources. The meteorological parameters were correlated with fine PM mass, carbonaceous aerosol components, and optical properties. Additionally wind speed, wind direction, and temperature were significantly correlated with several PM components. It was also found that soil was a major contributor to fine PM, accounting for nearly 30% of the mass on average during the study period. In addition, organic carbon and elemental carbon were also important contributors to fine PM mass accounting for up to 50% of the PM mass on several occasions

Geoscience

River dynamics and Flood Risk evaluation of the Kosi River, North Bihar plains: an integrated approach" - IIT Kanpur. The project with an aim to understand river dynamics and flood risk evaluation of the Kosi River in north Bihar and development of flood management strategies has been completed. This project has focused on identifying the reaches prone to avulsion using an integrated approach of slope ratios and planform

dynamics. A model to predict the pathway of the avulsion channel has been developed. The disconnectivity caused by rail-road network on the fan surface has been identified as one of the important reasons of extensive waterlogging and prolonged inundation in the region. Modern techniques of kinematic GPS, Total Station and echo-sounding have been used to map the channel profile and topography of the adjoining floodplain and demonstrated that several reaches of the Kosi are super-elevated and that this is a major cause of frequent breaches and avulsion of the Kosi including the August 2008 event. A number of thematic data sets including rainfall, topography, geomorphology, population density, rail-road network, and landuse /landcover have been used to produce a flood risk map of the region using a GIS based approach.

Geoscientific studies in parts of West Bengal coast and offshore - inundation vulnerability assessment and coastal hazard preparedness - Jadavpur University.

The programme involves offshore exploration in the inner shelf as well as studies along Henry's Island coast, West Bengal to understand the seabed morphology and sediment character vis-à-vis coastal processes of the area. A cruise was undertaken to collect bathymetry data, seabed samples and other oceanographic parameters using portable echo-sounder, GPS, grab samplers and other portable equipments off Henry's Island and southern part of the Muriganga River and north and east of Jambudwip. Field works were carried out in the coastal belts of Henry's Island to study the geomorphological features, shoreline position, and to collect sediment samples towards understanding of the coastal processes in the area. Topographic surveys were carried out to measure the relief of the area and repeat beach profiling was carried out to measure the micro level changes in geomorphology in 2-3 years. Follow up laboratory studies include sedimentology, grain morphology, mineralogy,

palynology etc. Micropalaeontological studies have also been done for selected samples. Bathymetric data were processed to prepare morphobathymetric map of the seabed. Surficial sediment distribution maps along with bathymetric pattern were prepared. Changes in shoreline position of the area were delineated by studying satellite image in time series for about last 40 years as well as data collected during the present work.

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 Paleoontinental Reconstruction - BHU, Varanasi.

The Dharwar Craton in southern India is a sizeable Archean cratonic fragment with numerous well exposed mafic dykes with different trends throughout the craton. Three field works have been completed. On the basis of observed mineralogy and textures, these dyke rocks may be classified as dolerites and olivine dolerites. Geochemically all these samples are sub-alkaline tholeiitic in nature and their nature vary from picrite to basalt to basaltic andesite. The studied samples are not co-genetic; probably more than one magma batches were responsible for their petrogenesis. They have variation from primitive nature (contain high Mg#; as high as ~75) to evolved (differentiated) nature (with low Mg#).

Ocean Science

- Marine Resources Development and Management (MRDM) – IIT Kharagpur (ii) The Indian Continental Shelf as a potential source of phosphates (Mineral Potential Mapping using satellite image data, GIS and geochemical signals).

- Enhanced production, purification and characterization of marine bacterial lipopeptides as potential broad spectrum antimicrobial and anticancer agents for

breast cancer therapy: Invivo toxicity tests and antitumor activity tests of the compound was conducted. The results are published as three papers in SCI journals and a patent on lipopeptides from marine sources has been filed.

- A study of the behavior of oil Spill on Ocean Surface through Laboratory Experiments, modeling and satellite image was conducted for development of oil spill study model which can be used for studying disasters. The project developed a small scale laboratory set up to study oil spill behavior and a simple model to help in investigations of oil spill spreading. The investigators also have developed a broom to clean the oil spill.

- Under the project "Bioprospecting of the Antarctic Flora: Screening of novel genes, so far one bacterium and one fungus (Thelebolus) isolated from cultures provided by ESSO-NCAOR are being investigated for metabolites. Proactive exopoly polysaccharide molecule isolated from these organisms has been found to have antitumor and antidiabetic properties. One patent has been filed and two reputed industries have shown interest for commercialization.

- Atomistic simulations of Gas hydrates and stabilizers/inhibitors" extensive studies were carried out to determine gas hydrate stability in presence of Na, Ca, K; inhibitors such as methanol, impact of inhibitors in structure etcm, which has resulted in eleven publications, and a few PhD theses, some of which are nearing completion.

- During the year, 32 project proposals from various academia and research organisations dealing with various aspects of Ocean Science and Resources from Ocean modelling to marine microbiology were appraised.

The committee had recommended for financial support to 12 project proposals where are at various stages of implementation.

Hydrology & Cryosphere

- L-moments Based Regional Extreme Rainfall and Flood Frequency Analysis for Hydro- meteorological Sub zones 2 (b) and 2(c) of India by NIT Silchar

- Flood and erosion in North east India is a serious problem. The area under sub zones 2 (b) and 2 (c) cover entire south Assam and parts of the state Manipur. Most of the catchments in the area are ungauged mainly because of remote locality and financial constraints. Reliable flood estimates for different return period is required for planning and designing projects. To achieve the objectives, required data like annual maximum daily rainfall for 40 gauging stations for the period from 1990 to 2010 and annual peak discharge / peak level from 37 gauging stations for the period from 1996 to 2010 has been collected. In Sub Zone 2(c) two homogeneous regions have been identified and 10, 20, 30, 40, 50, 75 and 100-year rainfall magnitude for Region I and II has been obtained by using selected best fit distributions. The work is in progress on developing regional flood frequency relationship for sub zones 2(b) and 2 (c).

- Assessing the Impacts of Climate and Land Cover Changes on Hydrology by University of Kashmir, Srinagar.

- Modifications in the land use and land cover changes significantly affect the hydrological processes. However, the long-term climate changes are also major contributing factors to hydrological variability. Statistical analysis of hydrological and climatic data on precipitation, temperature, discharge,

wind, humidity, etc procured for 12 watersheds of the Jhelum basin has been completed. For land use and land cover characterization and change detection of the Jhelum basin, time series of historical satellite data (Corona, LANDSAT and IRS satellite data series from 1962 up to present) have been processed to generate LULC maps.

Changing Water Cycle Program

- The following five projects are running under the Changing Water Cycle Program jointly funded by the ESSO-MoES and Natural Environment Research Council (NERC), UK.

  ➢ Hydro-meteorological feedbacks and changes in water storage and fluxes in Northern India.

  ➢ South Asian Precipitation: A seamless assessment: SAPRISE.

  ➢ Hydro-meteorological feedbacks and changes in water storage and fluxes in Northern India.

  ➢ Mitigating climate change impacts on India agriculture through improved irrigation water management.

  ➢ The structure and dynamics of groundwater systems in northwestern India under past, present and future climates.

B. Collaborative Research

- **Biofuel from marine microalgae under NMITLI with joint funding between CSIR and ESSO** has been completed in June 2013. The project, initiated in April 2010 was aimed towards development of a viable and scalable process for the generation of biofuel from Indian marine algae. Microalgal samples collected from select coastal pockets were characterized with respect to oil content and suitability of oil for biodiesel production as per standards. Promising microalgal biomass from about 20 species was taken forward for cultivation in open pond as well as lab-scale photobioreactor. Through up scaling, 100 kg scale biomass production has been achieved at two partnering centres. The oil extracted from dried biomass has been transesterified to produce biodiesel. The road worthiness of biodiesel from marine microalgal source was established when a regular diesel vehicle under full load condition was test driven on B100 microalgal biodiesel in March 2012.

- The projected cost for a 1 kilolitre/day B100 microalgal biodiesel plant backward integrated to cultivation was Rs 125/litre. 200 km test-run of a regular vehicle on neat (B100) biodiesel from marine microalgal source was carried out.

- **Computational Aspects of Numerical Weather Prediction - C-DAC, Pune.** The project is aimed at implementation of global weather model codes on open source Linux Cluster, Integrating weather applications with indigenously developed C-DAC HPC Resource Management Engine (CHReME) and exploring HPC for weather models with General-Purpose computation on Graphics Processing Units (GPGPUs). Porting and Execution of three CUDA enabled modules of WRF Model on GPGPU platform, Porting and Benchmarking of Unified Model on x86_64 based Linux Cluster, Development of scripts to automate disk management, System utilization and Security of HPC system and System Administration for existing PARAM PADMA Storage, PARAM VAYU HPC Facility & Storage have been completed.

C. Continental Tropical Convergence Zone (CTCZ)

- CTCZ is a National coordinated program and aims to understand the variability of convection/rainfall over the Indian monsoon through various field observations and modeling studies during monsoon. In all 18 projects have been funded and they are as follows:

- Cloud Microphysics characteristics and modelling over the Indian Region using a cloud resolving model- IISC, Bangalore

- Understanding microphysical evolution of clouds in the Indian CTCZ: varibility and impacts of aerosols – IIT, Delhi

- Investigations of Aerosol-Cloud-Environment Interactions using Combined Aerosol, CCN and Rain Measurements during CTCZ Field Campaigns – IITM, Pune

- Surface layer characteristics and moisture budget of the monsoon boundary layer-A study using micrometeorological measurements and Large-eddy simulation - University of Pune

- Regional assimilation of land surface parameters over Indian Landmass for providing surface boundary condition to numerical models for simulation of monsoon – IIT, Kharagpur

- Surface process observational studies coupled with atmospheric transfer interaction along eastern end of monsoon trough –BIT, Ranchi

- Boundary layer characteristics over surface representative of CTCZ region in India – IIT, Delhi

- Near simultaneous measurements of Aerosols, cloud and turbulence as the Maximum Cloud Zone (MCZ) moves northward -coordinated airborne, shipborne/ground-based and space-borne measurements – IIST,

Trivandram

- Observational and modeling of Atmospheric Boundary Layer over Different Land Surface Conditions in the CTCZ domain during different epochs of Indian Summer Monsoon – IIT, Kharagpur

- Modelling Hydrology of Mahanadi River Basin considering Changes in Land-Use/Land-Cover – IISC, Bangalore

- Surface energy balance and Atmospheric structure over the CTCZ Area: An observational study – IISC, Bangalore

- Oceanographic observation component during CTCZ 2011-12 – NIO, GOA

- Underwater radiation & chlorophyll measurements during CTCZ(2011-12) – IISc, Bangalore and NIO, Kochi

- Air-sea flux observations from research vessel during CTCZ –NIO, Goa

- Development of a Prognostic cloud scheme for Global Climate models –IISC, Bangalore

- Role of High Frequency Oscillations on the predictability of Monsoon Transients over the continental tropical convergence zone through nonlinear error energetics of prognostic model – IITM, Pune

- Impact of Bay of Bengal Cold pool on the seasonal and intra-seasonal pattern of Rainfall – IISc, Bangalore

- Simulation and prediction of intense convective systems associated with Indian Summer Monsoon: Role of Land surface Processes – IISc, Bangalore

- Some of the findings from the projects are:

- A summer monsoon salt Pump was discovered in the southern Bay of Bengal during CTCZ field experiment using Oceanographic Observations in the southern Bay of Bengal during July - August, 2009. This helps maintain the

salt balance in the Bay through upward mixing of the saltier, subsurface water and thereby prevents the Bay from freshening.

- Inter comparison between the datasets from Multiple Imaging SpectroRadiometer, GCM Oriented CALIPSO cloud product (GOCCP) and the International Satellite Cloud Climatology Project has been done to study the climatology of cloud vertical distribution over the oceanic regions (Arabian Sea, Bay of Bengal and south Indian Ocean) and the study reveals a multilayer cloud structure through out the year that must be accounted for in the climate models to improve the estimates of cloud radiative feed back.

- Some monsoon features were studied from the large volume of data set collected during the CTCZ cruises during the July -August 2012 which includes surface meteorological parameters, fast response sensor data for computing surface fluxes using eddy covariance method, upper air data, rain drop size distribution etc. ORV Sagar Kanya and RV Sagar Nidhi occupied northern and southern Bay, respectively. The analysis showed the temporal variation of temperature, pressure, daily rainfall and wind speed. It reveals a cold lower troposphere during the rainy days and a stable layer above 900 hpa on a non rainy day. A large contrast is observed in the vertical structure between southern and northern Bay.

D. Human Resource Development

- Text-Book Series for the Graduate Students in Earth Sciences: To encourage research in Earth Sciences and also to augment capacity building in the field of Earth Sciences, financial support was given to the Indian Institute of Technology- Roorkee (IIT, Roorkee) for writing of " Text-Book Series for the Graduate Students in Earth Science". The proposal aims to fill in knowledge gaps for the Earth Science Graduate Students by providing a set of 14 affordable and illustrative text books with examples that are India-centric. The writing of the books will also help to overcome the acute shortage of text books in Earth Sciences for undergraduate students. The books proposed to be written in a phased manner by experienced scholars in the field, will be published by the Geological Society of India (GSI), Bangalore a premiere society of the country established to promote the cause of advanced studies and research in all branches of Earth Systems Science. Towards this direction, two books published by GSI and titled "Crystallography and Minerology" co-authored by Prof Ram. S Sharma and Prof Anurag Sharma and "Elements of Palaeontology" by Prof S.K.Shah were released by Dr Shailesh Nayak, Secretary, Ministry of Earth Science on 7th January 2014. The books priced at Rs 700 and Rs 350 respectively, are being initially offered by IIT Roorkee to over 22 colleges free of cost to be used for their undergraduate courses in BSc Geology and BSc (Hons) in Geology.

- Indian Centre for Space Physics (ICSP), Kolkata: has been given recurring grants for 5 years to support manpower for carrying out research in areas of direct relevance to the ESSO-MoES activities. ICSP has recruited 12 scientific personnel to carry out research in Ionospheric activities, propagation of radio waves in Earth-ionosphere wave guide and Earthquake prediction.

- Under Himalayan Cryosphere Program of ESSO-NCAOR, MoES Panikkar Chair Professor, Sh. Rasik Ravindra has led a 5 member team for field investigation on the Sutri Dhaka & Batal Glaciers in Chandra Basin, H.P.

E. National facility

- Laser Raman Spectrometer: Center for Earth Science Studies (CESS), Trivandrum: The facility is being used to study the application of fluid inclusion technique for oil exploration by using the drill core/cutting samples from ONGC. The fluid inclusions observed in a sample from Panna Formation off shore to Ratnagiri were primary as well as secondary inclusions. Hydrocarbon Fluid inclusions (HCFI) showed good fluorescence. Microthermometric studies performed on both the non- HCFIs as well as HCFIs confirmed the presence of the carbonic inclusions, aqueous inclusions as well as hydrocarbon inclusions.

- Laser Diamond Anvil Cell - IISER Kolkata

- The main objectives of this project are to develop a laser-heated diamond anvil cell (LHDAC) laboratory as a national facility. This LHDAC facility will be capable of generating and maintaining states of matter at high pressures (ranging above 150 GPa) and temperatures (more than 30000 K) to enable measurements of material properties at these extreme. Using the diamond anvil cells, a pressure of about 80 GPa has been achieved at ambient temperatures and some important physical changes in the systems $BaRuO_3$ and $(Bi,Eu)FeO_3$ perovskite systems have been studied. . The above facility in combination with in situ characterization methods, like Raman spectroscopy and ab-initio electronic structural calculations will be a valuable tool to investigate physical and chemical processes taking place under extreme conditions of pressure and temperature.

- Accelerator Mass Spectrometry (AMS) Measurement Facility for 14C at IUAC), New Delhi. The dedicated AMS facility will be used for the measurement of 14Carbon and to measure ultra-low concentrations of the isotopes of carbon-14 for applications in radiocarbon dating and earth sciences. 500 kV based Ion accelerator based AMS system has been installed. IUAC has entered into an MoU with ETH Zurich for development of an automated graphitization system.

9.9. Earth System Science & Technology Cells

- Earth System Science & Technology Cells (ESTCs) are aimed towards capacity building in various disciplines of Earth System Science. Apart from Ph.D. degrees and research publications in reviewed journals, some of the recent major outputs are:

i. Bose Institute, Kolkata DNA markers for diseases free aquaculture industry were found which could be used to identify disease resistant shrimps. This technology based invention is likely to be patented for commercialization.

ii. IIT, Kharagpur Sea trial of the indigenously developed Autonomous Underwater Vehicle was carried. This vehicle can autonomously operate under water up to a depth of 150m and perform specific designated tasks like sea-bed mapping, collection of oceanographic data, etc.

iii. Andhra University: The antagonistic bacteria identified as Messococcus strain was found to be safe and could be mass cultured. This was a significant finding in controlling pathogenic Vibrios in Shrimp hatchery.

iv. Cochin University of Science and Technology: Novel drugs and immune - stimulants were developed from marine actinomycetes and yeast for disease management in aquaculture. Study showed that the protection imparted by these beneficial microbes would be highly helpful to farming industry.

INFRASTRUCTURE DEVELOPMENT

To improve the quality of atmospheric, oceanic, polar and geosciences services, it is essential to develop infrastructure like high performance computers, ocean research vessels and aircraft facility. Significant efforts were made to improve the infrastructure capability which will ultimately improve the quality of services rendered. The details of infrastructure development made during the year are given below:

10.1. High Performance computing

The primary mandate is to provide the nation with best possible services in forecasting the monsoons and other weather/climate parameters, ocean state, earthquakes, tsunamis and other phenomena related to earth systems. The existing computing resources of 112 TF commissioned in 2009 has already shown improvement in the short- medium range scale with usage of high resolution models

For further improving weather and climate prediction, high resolution dynamical models with high complexity (e.g. coupled ocean-atmosphere-biosphere-cryosphere models) and advanced data assimilation techniques (e.g. 4D-VAR/Hybrid 4D-VAR EnKF) are required which are highly computationally intensive. Rigorous developmental work has been undertaken including enhancing of model resolution, sensitivity studies of observations and physical processes, numerical technique development, development of atmosphere-ocean coupled model, along with probabilistic forecasts with quantified uncertainty, etc. In addition, there is requirement of adequate computational facilities for the training programs to cater to the enormous requirement of skilled manpower in the field of Earth System Sciences. In addition, real-time weather and climate related information and services are provided for the societal benefit to countries under the South Asian Association for Regional Cooperation (SAARC), Indian Ocean Rim Association for Regional Cooperation (IOR-ARC), the Regional Integrated Multi-Hazard Early Warning System (RIMES), and Association of Southeast Asian Nations (ASEAN). The Indo Africa Centre for Medium Range Weather Prediction in Mauritius; hosting and establishing the Bay of Bengal Initiative for Multi-Sectoral Technical and Economic Cooperation (BIMSTEC) Centre for Weather & Climate have been undertaken. The state-of-the-art National Tsunami Early Warning Centre, is regularly providing early warnings to India and Indian Ocean Rim Countries. Dedicated computational facilities are required to carry out all activities related to these flagship programs.

Considering the urgent need to augment HPC facility to implement the various flagship programmes, the High Powered Committee drew a Strategic Plan and recommended enhancement of the computing capacity in phased manner. As a result, the present computational infrastructure has been

enhanced by additional 1.1 petaflop capacity bringing the total computational capacity to about 1.3 peta flop. The entire computational facility has been established at ESSO-IITM and ESSO-NCMRWF with access to other ESSO units through dedicated NKN linkage.

10.2 Ocean Research Vessels

Ocean research vessels are essential for carrying out oceanic observations in a campaign mode. A fleet of six scientific research vessels are under operation for undertaking oceanographic research activities.

Table 10.1

Utilization of Research Vessels

Vessel	Total no. of days=365				
	Days of Utilization/ Cruising	Days for Maintenance & Logistics	Days for Cruise preparation	Days for Port stay / Statutory survey	No. of Cruises Undertaken
ORV Sagar Kanya	212	103	30	20	09
FORV Sagar Sampada	125	185	10	45	11
TDV Sagar Nidhi	286	14	50	15	14
BTV Sagar Manjusha	267	66 (32 Days Major Overhauling of Engines)	32	-	27
CRV Sagar Purvi	141	176*	27	21 (Bad weather)	22
CRV Sagar Paschimi	195	103**	38	29 (Bad weather)	28

*Sagar Purvi: Engine and CPP repair, Anchor and Anchor winch repair, Maintenance of Scientific equipments viz., Millipore, Dosimat, Spectrophotometer, Microscope, Sampling gears etc., testing and troubleshooting, Installation of Multibeam Echosounder, Pole fabrication, arrangement for probe, Rack arrangement inside the lab etc.,

**Sagar Paschimi: Engine and Gear box repair

Oceanography Research Vessel (ORV) Sagar Kanya is a multidisciplinary ship. The vessel is a versatile ocean observing platform equipped with technologically advanced scientific equipment and related facilities. The vessel is capable of carrying out geoscientific, meteorological, biological, physical and chemical oceanographic research as major disciplines. The vessel has completed more than 300 cruises so far and had been the flagship of the country in all ocean related activities for nearly 3 decades. The vessel was also deployed for Ocean Observation Systems; Sustained Indian Biogeochemistry and Ecosystem Research (SIBER), tsunami buoys, The Continental Tropical Convergence Zone (CTCZ); the Research Moored Array for African-Asian-Australian Monsoon Analysis and Prediction (RAMA) moorings; Hydrothermal Mineralisation in Indian Ocean; Current measurements and Geotracers.

FORV Sagar Sampada undertook scientific cruises within the Indian EEZ towards undertaking environment and productivity

studies, harmful algal blooms, myctophid fishery survey, fish egg and larvae studies, studies on marine mammals, upwelling studies, benthic productivity studies, Indo BIS, ITIS, SIBER and Argo float deployment.

Sagar Nidhi is a Technology Demonstration Vessel (TDV) India's most sophisticated ice class multi-disciplinary vessel having a fully automatic diesel-electric propulsion with azimuth and bow thrusters, Dynamic Positioning (DP) class II system, is being used mainly for ocean technology demonstration, viz., deployment and retrieval of tsunami, meteorological and OMNI buoys, RAMA Moorings, ROSUB Sea trials were carried out at Indian Ocean basin, ROV Sea trials.

Buoy Tender Vessel (BTV) Sagar Manjusha is actively involved in providing platform for deployment and retrieval of data buoys, Fish Aggregating Devices (FAD) AUPD deployment, Current meter deployment, CTD deployment and water sampling etc. Major overhauling of engines was completed during August 2013.

Coastal Research Vessels (CRVs) Sagar Purvi and Sagar Paschimi mainly are used for the implementation of Coastal Ocean Monitoring and Prediction System (COMAPS). In addition, Sagar Purvi was used for swath bathymetry survey of the Indian EEZ and Sagar
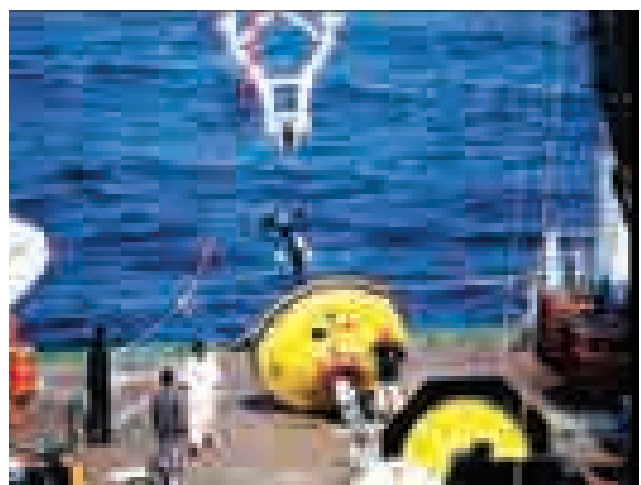
Fig.10.1 Buoy deployment and retrieval operations
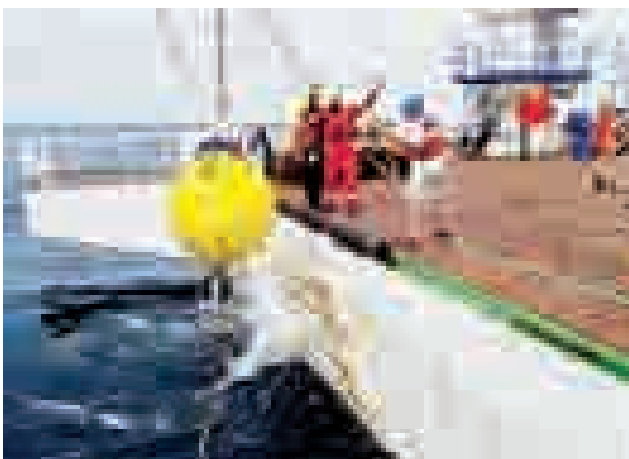
Fig 10.2 a) Drifter deployment (left) and RAMA Mooring Operation (right)

Paschimi was used for ocean colour research. Various maintenance activities viz., Engine, Gear box, CPP and other maintenances were carried-out for both Sagar Purvi and Sagar Paschimi to keep the vessels ready for scientific research.

10.3. Airborne Platforms

Atmospheric observations are required for better understanding of the complex atmospheric process involving aerosols, clouds and their interaction, for their accurate representation in weather and climate models. Ground based and satellite observations have some limitations in making targeted atmospheric observations and thus highlight the need for airborne measurements. With this motivation, a programme for the National Facility for Airborne Research (NFAR) has been initiated. It is proposed to procure a twin Turbo-Prop Engine aircraft along with a host of observational sensors for measurements of atmospheric processes including weather parameters, aerosol, trace gases, radiation, atmospheric electricity and microphysics of clouds. The proposed aircraft also will be equipped with a weather radar and atmospheric LIDAR.

AWARENESS AND OUTREACH PROGRAMMES

Outreach programmes are being carried out to bring awareness about the programmmes and achievements of ESSO-MoES among the public, academic and user communities. Outreach programmes include participation in national and international exhibitions, sponsoring grants to Seminars, Symposia, Workshop and various National Science Centers of National Council for Science Museum and State Council for Science and Technology, Universities, NGOs, CSIR labs, etc.. The "Earth Day" is celebrated with the participation of School, College and University students. National and International Earth Science Olympiad are also sponsored.

11.1 EXHIBITIONS

International Exhibition: Participated in the following International Exhibitions a) "Geospatial World Forum 2013" 13-16 May, 2013, Beurs World Trade Centre, Rotterdam, The Netherlands, b) "Waterex-2013" 10-12 October 2013, Chennai, c) "Global R & D Summit-2013", 25-26 June 2013, New Delhi and d) "Indian International Trade Fair 2013" 14-29 November 2013, Pragati Maidan, New Delhi and e) "International Agricultural Trade Fair & Conference- Krishi-2014", 15-19 November, 2013 at Nashik,

Fig. 11.1. Dr Shailesh Nayak, Secretary, ESSO-MoES inaugurating the pavilion of ESSO-MoES during the India International Trade Fair 2013

Fig.11.2. The pavilion at the International Exhibition "Geospatial World Forum 2013" at Rotterdam, The Netherlands.

Fig.11.3 a. Pavilion at Waterex-2013 at Chennai, 10-12 October 2013

Fig.11.3. b. Pavilion at Global R&D Summit-2013, New Delhi

Fig.11.3. c. Foundation Day at Vigyan Bhawan, 27 July 2013 at New Delhi

11.2 National exhibitions

ESSO-MoES participated in the exhibition "Pride of India Expo-2014" during the 101st Indian Science Congress from 3-7 February, 2013 at Jammu University, Jammu, J&K.

An exhibition was organized on the Foundation Day of ESSO-MoES on 27th July 2013 at Vigyan Bhawan, New Delhi. The other national exhibitions organized include a) the "11th Infa Educa 2013", 3-4 July, 2013 –Srinagar b) "7th Science and Technology EXPO-2013" 6-8 June, 2013, Bhimtal (Nainital),

Uttarakhand, c) "IInd Science Expo-2013" 28-30 September d) Science & Technology, Research and Development & Earth Sciences in September, 2013, Goa e) "MTNL Health Mela 2013", 23-27 October, 2013, New Delhi, and f) "AGROVISION 2013-14", 26-29 December, 2013, Nagpur, Maharashtra,

Rural Exhibition

ESSO-MoES participated in the "17th National Science Exhibition 2013" on 06-10 September, 2013 at Belur Math, Howrah, WB, 17th Sundarban Kristi Mela O Loko Sanskriti Utsab 2012" and "9th Jatiya Sanhati Utsav-O-Bharat Mela-2012" December, 2012 at 24 North parganas, West Bengal.

Exhibition on Wheels

Mobile Exhibitions to display activities on Earth, Atmosphere and Ocean Sciences and Technologies including earth processes to create awareness amongst students and general public in rural areas. The 'Exhibition on Wheels' was launched in 2012 to criss-cross eight states of the country which covered 29 locations including mofussil towns in the state of Gujarat, 37 locations in Maharashtra, 14 locations in the state of Goa and cover 21 locations in Karnataka.

Fig.11.4. Exhibition on Wheels in Maharastra, Goa & Karnataka

Earth Day Celebration-2013

Earth Day is the largest and most widely celebrated international event. The "Earth Day" was celebrated across the country on 22nd April 2013 and the event was organized at 65 locations across the country including schools, college and universities. The theme of the Earth Day was "Future Earth". Various competitions like drawing and painting, debate, essay, cycle rally were arranged amongst various age groups and cash prizes were offered to the students. Popular lectures by eminent scientists/ local scholars on Earth Science related topics were also organized. About 4500 children participated in the painting competition and prizes at the National level were distributed on the ESSO-MoES foundation day, 27th July.

Various competitions like drawing and painting, debate, essay, cycle rally were organized amongst various age groups and cash prizes were given to the students. About 2000 children participated in the Ozone Day celebrations.

Fig.11.5. Earth Day Celebration Brochure

Ozone Day Celebration-2013

The "Ozone Day" was celebrated across the country on 16 September 2013.
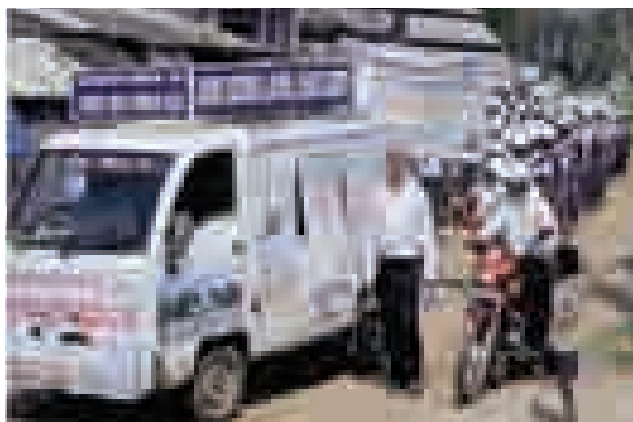
Fig.11.6. Ozone Day Celebrations

Painting Competition, Tree plantation, lectures, debate competitions, street play etc. were organized in different parts of the country.

Fig.11.7. Distributing awards for painting Competitions of Earth day 2013 at Vigyan Bhawan

Participation in International Earth Science Olympiad

The 7th International Earth Science Olympiad 2013 was held at Mysore, from 12-19 Sept 2013. School children from 27 countries participated in the event with 90 students, 11 guest-students. The Indian team won 3 silver medals and one bronze medal.

Fig.11.8.International Earth Science Olympiad 2013 at Mysore, India.
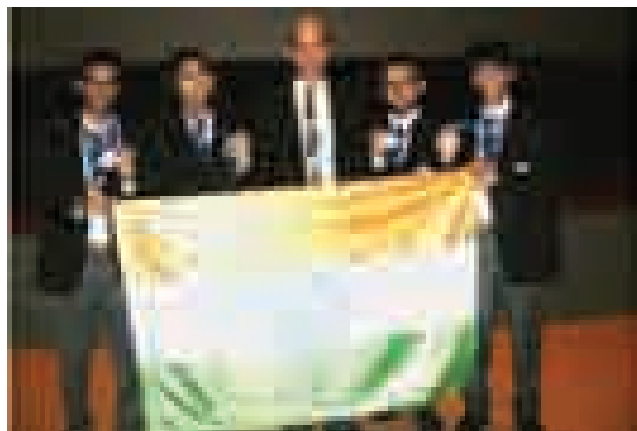
Fig.11. 9. Prize winning Indian students-IESO 2013 Mysore

Seminar, Symposia, Conference and Workshop

250 events were supported in the area of Earth System Science to provide platform to scientists, engineers, technologists, experts, social scientists and user communities. The beneficiaries of this support are Indian Institute of Technology/ Indian Institutes of Management, CSIR labs, Universities, Non-Governmental organizations, government bodies, etc.

Major areas 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 modelling and simulation; fish development etc.

Geological Society of India (GSI):

ESSO-MoES has been providing annual financial support to the Geological Society of India (GSI) for printing of journals, memoir, books, maps and required stationary etc. since 2008. GSI is playing a very important role in popularization of earth sciences. It is a premier organization in the country and strives to promote holistic activities in the cause of earth science by publishing monthly journal of JGSI and the quarterly journal Episode, besides text books, field guides and popularization of earth science books such as on Oceans, Tsunami, Earthquakes, Glaciers, Rivers, Groundwater, etc. In addition to these regular activities, it organizes national and international Earth Science Olympiad, Earth Day celebration and several national and international conferences regularly. GSI has brought out large number of special publications on different aspect of earth sciences.

World Meteorological Day

The World Meteorological Day 2013 was celebrated on 23rd March, 2013 at all the offices of ESSO-IMD. The theme for the WMO day -2013 was "Watching the weather to protect life and property- Celebrating 50 years of World Weather Watch". Meteorological Observatories were kept open for general public and school children. On this occasion, tele-talk, live program were also organized.

INTERNATIONAL COOPERATION

The primary mandate is to provide the nation with best possible services in providing skilful weather forecast and climate information, ocean state, earthquakes, tsunamis and other phenomena related to earth systems. These services are becoming increasingly important for well being of the society. In order to provide better services, various programs are undertaken by ESSO through continuous "research", "discovery" and exploration" of new phenomena and "development of techniques" for safety and betterment of the well being of the mankind.

Research and development is an international endeavour and is an important aspect of building understanding about earth system. This is facilitated by bringing together the best researchers and facilities wherever they are placed in the world. This in turn helps in not only to share the cost of expensive facilities and manage large volumes of data; it also enhances the impact of research through lessons learnt from each other's experience. With human society facing a number of wide-ranging and interlinked 'global challenges' such as climate change, food security, energy and water security , international scientific collaboration has become pertinent in today's scenario for addressing the causes, dealing with the impacts of these problems for the benefit of the society.

12.1 COOPERATION WITH NOAA,USA

Recognizing the importance of scientific and technical cooperation in Earth Observations and Sciences, a MoU was signed on the Earth sciences and Observations by MoES (on behalf of Govt. of India), and NOAA (on behalf of US Government)

on 16th April 2008. For overall monitoring and integration of the various activities, a mechanism, is being put in place in the form of *Joint Committee (JC) having members from both the countries*. Following IAs have een signed so far. Good progress is seen in these agreements.

i. **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 was 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 collaboration has resulted in fundamental understanding of Indian Ocean dynamics and ocean-atmosphere interactions that affect the weather and climate. Till date, the data from *RAMA moorings have been used in 49 articles published in international journals.* In addition to the usage of data in scientific publications, India is also using RAMA data to generate ocean analysis products through the assimilation of data in an ocean model.

ii. **Dynamical Seasonal Prediction of Indian Summer Monsoon Rainfall (Establishment of Monsoon desk)**

A "Monsoon Desk" along with a dedicated scientist has been established in NOAA to interact with ESSO-MoES scientists. The state-of-art model has been tested and transferred to ESSO for its subsequent operational use. *Detailed evaluation of the model performance showed positive results (with practically 1 day gain in the performance of the flow pattern).*

iii. Climate Modelling and Ocean Data Assimilation Analysis

This involved work on statistical downscaling using GFDL coupled model analysis towards development of prediction of monthly rainfall for the Indian region using different GFDL model outputs. Impact of parameters like 200 hPa height, sea level pressure and 850 hPa relative humidity are being carried out. Future work will include nonlinear technique like neural network in order to improve the performance of the forecast.

iv. 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 renalysis; outgoing longwave radiation; sea surface temperatures, estimate of soil moisture, surface temperature and rainfall etc.

v. 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 region.

vi. South Asian Regional Reanalysis(SARR)

Sensitivity experiments with data and physics options (convection, PBL and land surface) have been carried out. It is seen that just downscaling of coarse resolution global reanalysis is not sufficient for accurate representation of the Indian monsoon hydro climate which is possible with regional high-resolution assimilations. This project has resulted in capacity building of the Indian scientists in the area of reanalysis work.

vii. 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.

viii. 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.

ix. Development of Predictive Capabilities on Marine Fisheries and Harmful Algal Blooms of the Indian Seas

A research project to study marine fisheries and harmful algal blooms leading to improvements in forecast systems has been initiated. A Training Workshop was conducted at Kochi from 23-27 September 2013, to provide hands on training to the scientists and scholars on field data collection, identification and enumeration of fish eggs and larvae and the general concept of Daily Egg Production Model (DEPM).

Fig.12.1. Participation in International seminar and meeting on Marine Fisheries and Harmful Algal Blooms of the Indian Seas

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

Agro - Climatological and Water Resource Availability Modeling for Agricultural Management

Three demonstration projects were identified (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) Modeling groundwater and surface water availability in an agricultural area, were finalized to be taken up under this cooperation. During the recent Joint Committee meeting during June in USA, USGS and MoES agreed to work in the ground water as well as drilling program.

12.3 Cooperation with UKMO, UK

The unified model with 4D-VAR data assimilation scheme with a resolution of 25 km is being run along with assimilation of the Indian surface observations. The UM is based on the emerging paradigm of seamless prediction of weather and climate, wherein the same modelling system is used across a range of spatial and temporal scales. The unified coupled ocean atmosphere model has also been implemented at ESSO-NCMRWF in which the ocean model is the Nucleus for European Modelling of the Ocean (NEMO). Hindcast runs show that the NEMO ocean component in coupled model produces very realistic Sea Surface Temperature (SST) and Sea Surface Salinity (SSS).

12.4 Cooperation with the NERC (Natural Environmental Regional Council)

The ESSO-MoES and the Natural Environment Research Council (NERC), UK are jointly supporting research in the area of changing water cycle. Five collaborative research programmes have been selected for funding and they are progressing well.

Another joint work on monsoon variability has been undertaken. The following three major research proposals have been finalized for funding:

1. Bay of Bengal Boundary Layer Experiment.

2. Interaction of convective organizations and monsoon precipitation, atmosphere, surface and seas.

3. Southwest Asian Aerosol Monsoon Interactions

For these three research projects, it is proposed to bring the NERC, UK research aircraft for airborne measurements simultaneously with surface observations.

12.5. Cooperation with the Badan Meteorologi Klimatologi Dan Geofisika (BMKG)

The identified areas of technical cooperation 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 ESSO-IITM Pune for training on the coupled ocean model system.

12.6. Cooperation with Regional Integrated Multi-Hazard Early Warning System (RIMES)

India has been leading in enhancing technical capabilities of the RIMES Member and Coordinating states in dealing with multi-hazards. Under this cooperation, tsunami advisory and ocean state forecasting and improved high resolution weather forecasts are provided for the RIMES member countries.

12.7. Cooperation with Belmont Forum Countries

The Belmont Forum, created in 2009, is a high level group of the world's major and emerging funders of global environmental change research and international science councils. Under the Coastal Vulnerability CRA, four proposals with participation of Indian scientists have been accepted. Under the CRA on Food Security six proposals with Indian Investigators have been selected. A CRA on Artctic, Antactica and Monoons teleconnection

to be taken up during 2014-15, has been proposed.

12.8. Cooperation with the Bay of Bengal Initiative for Multi-Sectoral Technical and Economic Cooperation (BIMSTEC) countries

BIMSTEC Member Countries are Bangladesh, Bhutan, India, Myanmar, Nepal, Sri Lanka and Thailand. A BIMSTEC Centre for Weather & Climate (BCWC) for enhanced regional cooperation on forecast information, early warning systems, capacity building and observing systems has been set up.

12.9 Cooperation with the Korea Meteorological Administration (KMA)

A 4-member delegation visited KMA to attend the 2nd bilateral meeting and identified three broad areas of collaboration, viz. (i) Climate Data rescue and Climate Data Management System (ii) Data assimilation and Global forecast system (iii) Regional Climate Downscaling under the Coordinated Regional Downscaling Experiment (CORDEX) programme.

Participation in International Events/meetings Atmospheric Science and Climate Sciences

- ESSO scientists have participated in the meetings and programmes of the World Meteorological Organization (WMO) viz., National Drought Policy Meeting, Executive Council meeting and the Inter-Governmental Board for Global Framework for Climate Services.

Oceanic Science and Technology

- ESSO scientists have participated in the meetings of the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR), Belmont forum Biodiversity workshop, Ad Hoc Informal working group to study conservation and sustainable use of marine biological diversity.

Geosciences and Seismology

- ESSO Scientists have participated in the meeting of the Executive Committee of International Seismological Centre and Joint Assemble Sessions of the International Association of Seismology and Physics of the Earth's interior (IASPEI), Joint workshop on Earthquake Disaster Mitigation and international workshop for regional cooperation in Seismology and Earthquake Engineering in South and Central Asia.

Polar Science and Cryosphere

- ESSO scientists have participated in the 36th Antarctica Treaty Consulative Meeting and 15th meeting of the committee on Environmental Protection, meeting of the Council Managers of the National Antarctic Programme, meeting of the Arctic Council, International Arctic Science Committee, meeting of the Scientific Steering Committee and the First SOOS Asian workshop and the Asian Forum for Polar Science.

Visit of the Hon. Minister for External Affairs to Himadri

The Hon. External Affairs Minister of India, Shri Salman Kurshid made a visit to Ny-Ålesund, Svalbard on 12th June 2013. He was accompanied by the Hon. External Affairs Minister of Norway, Mr. Espen Barth Eide and 14 other distinguished delegates from the both the countries. The delegation visited Himadri in Svalbard and was received by the Indian team. The team also made a detailed presentation of the various scientific activities being carried out by India in the Arctic to the Delegation.

PAGES 2013

The 4th Open Science Meeting of PAGES-Past Global Changes- was organised by ESSO-NCAOR in Goa during 11-16 February 2013. The PAGES, an international effort to coordinate and promote past global change research, and the Open

Science Meetings, which take place once in four years, represent one of the largest congregations of global change researchers who use past climate changes to frame the future climate change. India hosted PAGES for the first time.

The 4th PAGES Open Science Meeting (OSM) was a huge success in terms of the participation (450 delegates), international representation (45 countries), scientific networking as well as new ideas for future research. The associated Young Scientist Meeting (YSM) was attended by internationally
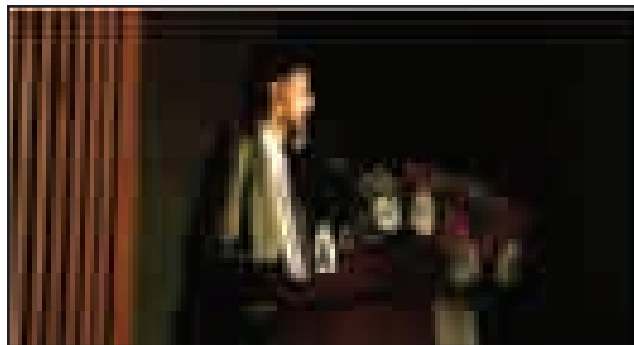
chosen 85 scientists. The PAGES OSM and YSM provided excellent opportunities for Indian scientists for networking and interactions. The event was inaugurated by Dr. Shailesh Nayak, Secretary to Government of India, Ministry of Earth Sciences and was attended by well known scientists and dignitaries from India and abroad.

The PAGES meeting was also marked by a Public Lecture entitled, "Climate change and implications for Global Society" by renowned climate scientist and Chair of the IPPC, Dr. R. K. Pachauri.

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AWARDS AND HONOURS

1. Dr Shailesh Nayak, Chairman, ESSO and Secretary, MoES has been elected as a Fellow of the Indian Academy of Sciences.

2. Dr S.S.C. Shenoi has been elected as a Fellow of the Andhra Pradesh Academy of Sciences (AP Akademy).

3. ESSO-IMD and ESSO- INCOIS received the Award for Excellence in Humanitarian Action in the category of Early Warning and Dissemination for 2013 in the field of Humanitarian Logistics and Disaster Management in India given by Indian Institute of Management (IIM), Raipur.

4. Dr. Thamban Meloth, Scientist E was conferred with the National Geoscience Award for 2011-12 by the Ministry of Mines in recognition of his significant contributions in the field of glaciology and Antarctic research.

5. ESSO-NIOT was awarded the FICCI water award for the innovation category for solar desalination.

6. Dr R. Venkatesan, Scientist, ESSO-NIOT was awarded the NIGIS Meritorious Corrosion Award for the year 2013 by NACE USA-India section.

ADMINISTRATIVE SUPPORT

14.1. CITIZEN'S CHARTER

The Charter is given below. The potential areas of services are:-

i. To improve dissemination of weather forecast to various sectors like agriculture, aviation, sports, urban areas, defence, etc.

ii. To provide wide-range ocean information services for sectors like fisheries, shipping, navy, coast guard, etc.

iii. To develop technology for exploring and harnessing marine resources in a sustainable way. To undertake and support cryospheric research in the Antartica, Arctic and Himalayas.

iv. To monitor earthquakes, conduct seismological and geosciences research.

v. To provide early warning on natural disasters like cyclone, storm surge and tsunami etc..

vi. To assess the coastal and ocean marine living resources.

vii. To encourage formulation of research and development schemes in the earth system science, create capacity building and promote human resource development.

viii. To extend support to seminars, symposia, conferences, exhibitions, etc. and process applications

ix. for grants to organize seminars/symposia/conferences.

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

xi. 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 centers of ESSO have been directed to adopt the Citizen **Charter in toto.**

14.2. 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 community while making recruitment of forming Selection Committee set up for filling up of vacancies in Group A, B,C including MTS has been ensured.

14.3 BUDGET AND ACCOUNTS

Budget and Accounts

(₹. in crore)

Sl. No.	Major Head of Account	2011-12 Actual			2012-13 Actual			2013-14 Budget Estimates			Expenditure 2013-14 up to 31.03.2014 (Provisional)		
		Plan	Non-Plan	Total	Plan	Non-Plan	Total	Plan	Non-Plan	Total	Plan	Non-Plan	Total
	Revenue Section												
1	3403 Oceanographic Reasearch	615.49	60.14	675.63	467.14	52.41	519.55	621.00	58.66	679.66	438.63	46.70	485.33
2	3425- Other Scientific Research	50.39	25.08	75.47	135.62	28.69	164.31	261.00	29.36	290.36	227.14	22.40	249.54
3	3451- Secetariat Expenditure	0.00	19.38	19.38	0.00	21.71	21.71	0.00	24.54	24.54	0.00	23.52	23.52
4	3455- Meteorology	51.93	246.88	298.81	89.62	258.53	348.15	198.00	296.33	494.33	117.01	275.29	392.30
	Capital Section												
1	5403 Capital outlay on Oceanograpic Research	5.87	0.00	5.87	4.99	0.00	4.99	5.00	0.00	5.00	5.24	0.00	5.24
2	5425- Capital outlay on Other Scientific & enviromental Research	2.10	0.00	2.10	9.03	0.00	9.03	29.00	0.00	29.00	7.76	0.00	7.76
3	5455- Capital Outlay on Meteorology	92.94	0.06	93.00	104.60	0.07	104.67	167.00	0.11	167.11	67.45	0.05	67.50
	Grand Total	818.72	351.54	1170.26	811.00	361.41	1172.41	1281.00	409.00	1690.00	863.23	367.96	1231.19

* Approved Revised Estimates 2013-14 under MH 5403 was Rs. 8.00 Crores and re-appropriation of Rs. 3.00 Crore from MH-5455 was done.

14.4. REPORT OF THE CONTROLLER AND AUDITOR GENERAL OF INDIA

Report of the Comptroller and Auditor General of India

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

SI 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	2007	NIL	NILw	Para 5.1 Report No. CA 2 of 2007 "Wasteful Expenditure of ₹ 33.08 lakh by IMD for procurement of precision Ni-span 'C'- India Meteorological Department (IMD)	NIL	NIL
2	2008	NIL	NIL	Para 7.1 Report No, CA 3 of 2008 "Non-achievement of the objectives of Modernizing the Accounting & Personnel Management Functions"	NIL	NIL
3	2009	NIL	NIL	NIL	NIL	Para 7.1 Report no. CA 16 of 2008-09 "Construction of Residential Quarters and Hostel Units without demand"
4	2013	Para 8.1 Report No. CA 22 of 2013 "Irregular Introducation of pension scheme and diversion of funds at INCOIS, Hyderabad".	ONE	NIL	NIL	Nil

14.5. STAFF Strength

The sanctioned strength of the Ministry of Earth Sciences including attached offices i.e 321 during the year 2012-2013. The detailed break up is given below:

Ministry/ Attached Offices	Scientific/ Technical Posts	Non-Technical Posts	Grand Total
Ministry Headquarters	41	123	164
National Centre for Medium Range Weather Forecasting (NCMRWF), Noida	57	33	90
Centre for Marine Living Resources & Ecology (CMLRE), Kochi	22	9	31
Integrated Coastal and Marine Area Management (ICMAM), Chennai	15	7	22
National Programme on Earthquake Precursors (NPEP)	11	0	11
	146	172	318

14.6. Representation of SCs/ STs/ OBCs in Government Services in respect of Ministry (Proper)

Group	Representation of SCs/ STs/ OBCs as on 1.1.2013				Number of appointments made during the calendar year 2012											
					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	37	9	3	5	0	0	0	0	0	0	0	0	0	0	0	0
Group B	35	8	3	2	1	1	0	0	0	0	0	0	0	0	0	0
Group C including MTS	51	22	4	7	1	1	0	0	0	0	0	0	0	0	0	0
Total	123	39	10	14	2	2	0	0	0	0	0	0	0	0	0	0

14.7. Representation of Persons with Disabilities in Government Services

GROUP	Direct Recruitment								Promotion							
	No. of vacancies reserved				No. of appointments made				No. of vacancies reserved				No. of appointments made			
	VH	HH	OH	Total	Un-identified posts	VH	HH	OH	VH	HH	OH	Total	Un-identified posts	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	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil

14.8. Official Language Implementation

Efforts are made constantly for the promotion of the Official Language. ESSO-MoES has organized the 21st National Scientific Hindi Seminar on the topic "Jalvayu Ke Sambandh Mein Samudro ki Bhoomika " on 22nd March, 2013 at New Delhi. Dr. S.Ayappan, Director General, Indian Council Of Agricultural Research was the chief Guest. On this occasion, a CD titled "Samudri Sampada Ki Khoj" was released.

Under the Prithvi Vigyan Mantralya Maulik Pustak Lekhan Yojana-2012, the Ministry awarded the second (Rs 40,000/-) and consolation prizes(Rs 20,000/-) to the books titled (1) 'Maha Sagar Hamari Bhavi Virasat' by Shri. Navneet Kumar Gupta; (2) 'Namak Aur Samudri Rasayan' by Dr. D.D. Ozha and Dr. V.P Mohandas respectively. The prizes were given during the 21st National Scientific Hindi Seminar.

A Hindi Fortnight was organized from 9th to 23rd September 2013. During this period, various Hindi Competitions were organized to create an atmosphere conducive to use of Hindi in the official work. The Cash Incentive Scheme for original work in Hindi introduced by the Department of Official Language is being implemented in the Ministry. An Incentive Scheme for officers for giving dictation in Hindi is in operation in the Ministry.

Committee of Parliament on Official Language inspected various offices of the Ministry like Centre of Marine Living Resources and Ecology, Kochi, Regional Meteorological office of IMD , Mumbai and National Centre for Antarctic and Ocean Research, Goa on 16.01.2013, 17.01.2013 and 19.01.2013 respectively and also the Meteorological office, Bhuntar on 28.05.2013.

Under the Department of Official Language "Rajiv Gandhi Rashtriya Gyan Vigyan Maulik Pustak Lekhan Puraskar" 2011-12, Shri Neloy Khare, Scientist 'F' of this Ministry has been awarded first prize for his book "Arctic Madhya ratri ke Surya ka kshetra". He received this award from the President of India in a function held in Vigyan Bhawan on the occasion of "Hindi Diwas" on 14th September 2013.

14.9 Capacity Building and Human Resources development

During the year officers/ staff of this Ministry (from the Headquarters) 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 (DoP&T). In this regard, several National-level training courses have been conducted.

14.10. Implementation of the judgements/ orders of the CAT

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

14.11. Parliament Matters

The Ministry has parliament section which caters to the correspondence with the parliament secretariats. Between April 2013 and March 2014, the ministry has replied parliament questions in Lok Sabha (56 questions) and Rajya Sabha (25 questions).

PATENTS AND RESEARCH PAPERS

RESEARCH PAPERS

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PERFOMANCE EVALUATION REPORT

Performance Evaluation Report

Objective	Weight	Action	Success Indicator	Unit	Weight	Excellent 100%	Very Good 90%	Good 80%	Fair 70%	Poor 60%	Achievement	Raw Score	Weighted Score
1 To improve weather forecast and provide advisory to agriculture, aviation, shipping, sports including the extended, Long Range Seasonal Monsoon forecast	21.00	Integrated Agro Advisory Services	Number of Districts covered by Agro Advisory	number	3.15	575	570	560	555	500	585	100.0	3.15
			Grameen Krishi Mausam Seva	Number	2.10	3500000	3400000	3300000	3200000	3100000	3400000	90.0	1.89
		Improve Operational Weather Services	Augmentation of High Performance Computing System as part of Monsoon Mission	number	3.36	160	150	140	130	120	170	100.0	3.36
			Strengthening of Observational Network(AWS, ARGs)	number	4.20	1100	1075	1050	1025	1000	1595	100.0	4.2
			Quality of Research Publications	number	3.15	100	90	80	75	70	157	100.0	3.15
			Application of higher resolution Global Numerical Models	Horizontal resolution (km)	1.26	22	23	24	25	25	22	100.0	1.26
			Completion of Admission process of the first batch of ten students for the advanced training program in Earth System Sciences & Climate	number	1.68	25	20	13	11	9	27	100.0	1.68
			Research Publications for operational forecast	number	2.10	270	265	260	255	250	172	100.0	2.1
2 To provide a wide range of ocean information advisories	10.00	Strengthening of Ocean Observational network	Number of deployments	number	3.00	270	265	260	255	250	324	100.0	3.0

Performance Evaluation Report

Objective	Weight	Action	Success Indicator	Target / Criteria Value		Excellent 100%	Very Good 90%	Good 80%	Fair 70%	Poor 60%	Achievement	Raw Score	Weighted Score
including fishery information		Potential Fishing Zone Advisory & Ocean State Forecast Services	Potential Fishing Zone Advisory	number	3.00	130	120	115	100	90	292	100.0	3.0
		Ocean State Forecast Services	Ocean State Forecast	number	3.00	328	310	300	290	275	365	100.0	3.0
		To acquire Ocean Research Vessels	Preparation of DPR & EFC	Date	1.00	15/02/2013	28/02/2013	10/03/2013	20/03/2013	31/03/2013	15/02/2013	100.0	1.0
3 To improve the understanding of Polar Science and its implications for climate change	12.00	Planning, Coordination and implementation of Indian Antarctic Program	Launching of 32nd Expedition	Date	2.40	20/11/2012	01/12/2012	15/12/2012	31/12/2012	15/01/2013	10/11/2012	100.0	2.4
			Completion of targeted scientific and logistics task	%	1.00	80	70	60	55	50	80	100.0	1.0
			Initiation of PhaseII constructive-stage activities of the 3rd station	Date	1.20	30/11/2012	17/12/2012	18-12-2012	31/12/2012	15/01/2013	30/11/2013	0.0	0.0
		Planning, Coordination and implementation of Scientific Expeditions to the Arctic	Launching of the summer (S) and winter (W) phases of study in the Arctic region	Date	1.20	25/06/2012	10/07/2012	15/07/2012	20/07/2012	25/07/2012	01/06/2012	100.0	1.2
			completion of targeted scientific and logistics activites at Ny-Alesund for the year	Date	1.00	01/03/2013	10/03/2013	15/03/2013	20/03/2013	25/03/2013	15/04/2013	0.0	0.0
		Planning, Coordination and implementation of Scientific studies in the Indian Ocean sector of the Southern Ocean	Launching of Southern Ocean Expedition (201213)	Date	2.00	15/01/2013	25/01/2013	05/02/2013	10/02/2013	15/02/2013	11/01/2013	100.0	2.0
			completion of analytical work of data collected	Date	1.00	31/10/2012	15/11/2012	30/11/2012	15/12/2012	31/12/2012	31/10/2012	100.0	1.0

Performance Evaluation Report

Objective	Weight	Action	Success Indicator	Unit	Weight	Target / Criteria Value						Performance	
						Excellent 100%	Very Good 90%	Good 80%	Fair 70%	Poor 60%	Achievement	Raw Score	Weighted Score
		In-house R&D projects in the fields of cryospheric studies, polar remote sensing, paleoclimatology,polar biology and environmental studies	Completion of targeted field data collection and analytical work and submission of reports during the previous expedition and submission of report.	%	1.20	100	90	80	70	60	100	100.0	1.2
			Publication of Results in peer reviewed journals	Number	1.00	15	12	10	8	5	24	100.0	1.0
4 To develop technology for harnessing marine resources	12.00	Development of Underwater Collector & Crushing Systems for manganese nodule mining and testing in shallow waters	Completion of Deep-sea Trials of Subsystems	Date	4.80	31/01/2013	15/02/2013	28/02/2013	15/03/2013	31/03/2013	14/12/2012	100.0	4.8
		Technology Development for Gas Hydrates	Demonstration of suction pile in field	Date	2.88	16/12/2012	31/12/2012	15/01/2013	31/01/2013	15/02/2013	16/12/2012	100.0	2.88
		-Development of Autonomous coring system and sea trials	Sea trials of Autonomous Coring System (ACS) more than 100 m	Date	4.32	31/08/2012	31/10/2012	31/12/2012	31/01/2013	31/03/2013	17/09/2012	97.21	4.2
5 To conduct survey for assessing non-living resources	6.00	Survey, exploration for Polymetallic Nodules, Cobalt crust, hydrothermal sulphides gas hydrates,and topographic survey of Exclusive Economic Zone	Deployment of Research Vessel	sq. km	3.00	25000	20800	16000	14400	11200	11500	60.94	1.83
		Geological and Tectonic Evolution of the Northern Indian Ocean and activities related to Integrated Ocean Drilling	Completion of Data Analysis pertaing to the Laccadive offsore region: data collection from the forearc region	Date	2.00	30/09/2012	31/10/2012	01/01/2013	01/02/2013	15/02/2013	30/09/2012	100.0	2.0

Performance Evaluation Report

Objective	Weight	Action	Success Indicator	Unit	Weight	Target / Criteria Value					Achievement	Performance	
						Excellent 100%	Very Gooc 90%	Good 80%	Fair 70%	Poor 60%		Raw Score	Weighted Score
		Program (IODP)	of Andamans and field studies of Barren and Narcodam islands:										
		Creation of Marine Geophysical Data Centre at NCAOR - Design of a structured RDBMS capable of archiving & retrieving marine geophysical data	Revision and submission of the Scientific Proposal to IODP based on the comments from the reviewers; Participation of Indian Scientists in IODP cruise	Date	1.00	15/11/2012	30/11/2012	15/12/2012	15/01/2013	31/03/2013	15/11/2012	100.0	1.0
6 To asses coastal marine productivity and Marine Ecosystems	4.00	Integration and analysis of field data, Simulation of models, validation of results and preparation of Shoreline management plan	Finalization of Shoreline Management Plan for Gopalpur coast	Date	2.00	01/01/2013	15/01/2013	01/02/2013	15/02/2013	01/03/2013	01/01/2013	100.0	2.0
		Establishment of Indian Ocean biogeographical Information System (IndOBIS)	No. of records.	number	2.00	6000	4000	3000	2000	1000	5000	95.0	1.9
7 To improve understanding of Climate Change Science	5.00	To set up Centre for Climate Change Research (CCCR) at IITM with dedicated research facilities	Regional Climate Model Projections	number	1.50	2038	2035	2025	2020	2015	2038	100.0	1.5
			Cumulative Impact Factor of the Research Papers	number	2.50	21	20	15	10	10	25	100.0	2.5
		To acquire airborne platforms for studying montoring upper air parameters	Finalisation DPR and circulation of EFC to seek the approval	Date	1.00	15/12/2012	31/12/2012	31/01/2013	28/02/2013	31/03/2013	15/12/2012	100.0	1.0
8 To provide early warning of natural hazards viz. cyclone, tsunami, sea level rise.	5.00	Issues of Earthquake bulletin with minimum time lag after the earth quake on sea-bed	Number of EQ bulletins issued within 12 minutes after the earthquake(%)	percenta ge	2.00	100	98	95	85	75	100	100.0	2.0

Performance Evaluation Report

Objective	Weight	Action	Success Indicator	Unit	Weight	Target / Criteria Value					Achievement	Performance	
						Excellent 100%	Very Good 90%	Good 80%	Fair 70%	Poor 60%		Raw Score	Weighted Score
		Issue of Tsunami Warning with minimum time lag after the earth quake on sea-bed	Number of Tsunami Bulletins issued within 30 minutes after the earthquake(%)	percentage	2.00	100	98	95	85	75	100	100.0	2.0
		Issue of Tsunami warning with minimum time leg after the earth quake on sea-bed	Accuracy of warning(%)	percentage	1.00	77	70	60	55	50	77	100.0	1.0
9 To promote basic research including Capacity building in the Earth System Science	4.00	To strengthen capacity development and promote research outside the ministry	Supporting research and academic programmes in Earth System Science	Number of Projects	4.00	110	100	90	80	70	110	100.0	4.0
		To set training centres in the field of Operational Oceanography, Meteorology	Finalisation of EFC and Circulation for appraisal	Date	0.00	01/11/2012	01/12/2012	01/01/2013	01/02/2013	01/03/2013	01/11/2012	100.0	0.0
10 To promote awareness and educate the public by extending support to seminars, symposia, conferences and conduct workshops with stakeholders	2.00	Conducting user oriented workshops with key stakeholder to promote awareness	Conducting user oriented workshops with key stakeholder to promote awareness	Number	1.00	15	12	10	8	6	55	100.0	1.0
		Support seminar/symposium/conference in the field of earth sciences	Support seminar/symposium/conference in the field of earth sciences	Number	1.00	50	40	30	25	20	100	100.0	1.0
11 To develop a national Geographical Information System	1.00	To establish a centre for development of National GIS	Preparation of DPR and EFC	Date	1.00	01/01/2013	15/01/2013	30/01/2013	15/02/2013	28/02/2013	01/01/2013	100.0	1.0
12 To conduct research in Seismology and Geoscience	3.00	To setup a National Centre for Seismology	Obtain the approval and launch of the programe of NCS	Date	1.50	31/10/2012	30/11/2012	31/12/2012	31/01/2013	28/02/2013	30/11/2012	90.0	1.35
		To conduct front ranking research of solid earth process for understanding seismic	Preparation of DPR and circulation EFC for Deep Sea borewell at Koyana	Date	1.50	15/09/2012	15/11/2012	15/12/2012	15/01/2013	15/02/2013	15/02/2013	60.0	0.9

Performance Evaluation Report

| Objective | Weight | Action | Success Indicator | Unit | Weight | Target / Criteria Value | | | | | Achievement | Performance | |
						Excellent 100%	Very Gooc 90%	Good 80%	Fair 70%	Poor 60%		Raw Score	Weighted Score
*Efficient Functioning of the RFD System	3.00	process											
		Timely submission of Draft for Approval	On-time submission	Date	2.0	05/03/2012	06/03/2012	07/03/2012	08/03/2012	09/03/2012	05/03/2012	100.0	2.0
		Timely submission of Results	On- time submission	Date	1.0	01/05/2012	03/05/2012	04/05/2012	05/05/2012	06/05/2012	24/04/2012	100.0	1.0
*Administrative Reforms	6.00	Implement mitigating strategies for reducing potential risk of corruption	% of implementation	%	2.0	100	95	90	85	80	100	100.0	2.0
		Implement ISO 9001 as per the approved action plan	Area of operations covered	%	2.0	100	95	90	85	80	100	100.0	2.0
		Timely preparation of departmental Innovation Action Plan (IAP)	On-time submission	Date	2.0	01/05/2013	02/05/2013	03/05/2013	06/05/2013	07/05/2013	30/04/2013	100.0	2.0
*Improving Internal Efficiency / responsiveness / service delivery of Ministry / Department	4.00	Implementation of Sevottam	Independent Audit of Implementation of Citizen's Charter	%	2.0	100	90	80	70	60	71	71.0	1.42
			Independent Audit of implementation of public grievance redressal system	%	2.0	100	90	80	70	60	60.20	60.2	1.2
*Ensuring compliance to the Financial Accountability Framework	2.00	Timely submission of ATNs on Audit paras of C&AG	Percentage of ATNs submitted within due date (4 months) from date of presentation of Report to Parliament by CAG during the year.	%	0.5	100	90	80	70	60	100	100.0	0.5
		Timely submission of ATRs to the PAC Sectt. on PAC Reports.	Percentage of ATRS submitted within due date (6 months) from	%	0.5	100	90	80	70	60	100	100.0	0.5

*Mandatory Objective(s)

Performance Evaluation Report

Objective	Weight	Action	Success Indicator	Unit	Weight	Target / Criteria Value					Achievement	Performance	
						Excellent 100%	Very Good 90%	Good 80%	Fair 70%	Poor 60%		Raw Score	Weighted Score
			date of presentation of Report to Parliament by PAC during the year.										
		Early disposal of pending ATNs on Audit Paras of C&AG Reports presented to Parliament before 31.3.2012.	Percentage of outstanding ATNs disposed off during the year.	%	0.5	100	90	80	70	60	100	100.0	0.5
		Early disposal of pending ATRs on PAC Reports presented to Parliament before 31.3.2012	Percentage of outstanding ATRS disposed off during the year.	%	0.5	100	90	80	70	60	100	100.0	0.5

Total Composite Score: 94.07

ACKNOWLEDGEMENTS

During the year, many scientists and academicians from India and abroad actively participated as external experts in the various committees and helped us in the ongoing activities and programmes of the ESSO-MoES. We would like to thank all of them, who worked in the scientific and administrative committees, selection and recruitment boards, and expert panels for reviewing research proposals.

The following committees constituted by the ESSO-MoES participated in the on-going activities and programmes.

1. International Advisory Panel, Chaired by Dr J.Shukla, George Mason University, USA.

2. Program Advisory & Monitoring Committee (PAMC) on Atmospheric Sciences and the Scientific Steering Committee, Monsoon Mission chaired by Prof. J. Srinivasan, IISc Bangalore.

3. PAMC on Hydrology and Cryosphere and the Indian Panel of Changing Water Cycle Programme, Integrated Ocean Drilling Program (IODP) and the NERC-MoES Monsoon Research Panel, chaired by Prof V.K.Gaur, CMMACS, Bangalore.

4. PAMC on Geosciences, chaired by Prof. Ashok Singhvi , PRL, Ahmedabad.

5. PAMC on Ocean Science and Resources, chaired by Prof. S.Krishnaswami, PRL, Ahmedabad.

6. Technology Research Board for Earth System Science Technology, chaired by Dr P.S.Goel, DRDO, Hyderabad.

7. Research Advisory Council of ESSO-IITM and ESSO-NCAOR, chaired by Prof U.R. Rao, ISRO, Bangalore.

8. Scientific Review and Monitoring Committee, Monsoon Mission, Research Advisory Council (RAC) of ESSO-NCMRWF, chaired by Prof. D.R. Sikka, Delhi.

9. Research Advisory Committee to review the Performance of Scientific Activities relating to Integrated Coastal and Marine Area Management Project (ICMAM) – chaired by Dr. M Baba, former Director, Centre for Earth Science Studies (CESS).

10. Research Advisory Committee of the Center for Marine Living Resources & Ecology (CMLRE) – chaired by Dr. Dileep Deobagkar, former VC, Goa University.

11. Scientific Advisory Council of ESSO-NIOT chaired by Dr P.S.Nair, Emeritus Scientist, ISRO, Bangalore.

12. Scientific Program Committee of the International Symposium on Antarctic Earth Science, chaired by Prof S.K. Tandon, University of Delhi.

13. Programme Advisory Committee (PAC) of Seismicity and Earthquake Precursor programme and Scientific Deep Drilling investigations in Koyna intraplate zone and Group Monitoring Committee (GMC) of Seismicity and Earthquake Precursor Programme, chaired by Dr. Harsh K Gupta, Member, NDMA, New Delhi.

14. Scientific Steering Committee, CTCZ Programme, Chaired by Prof. Sulochana Gadgil, IISc Bangalore.

15. Expert Committee for setting up of Geochronology facility, chaired by Prof. V. S. Ramamurthy, NIAS, Bangalore.

16. Expert Committee for exchange of High Resolution Sea Level Data from the Indian Tide Gauges, chaired by Dr S.R.Shetye, Vice Chancellor, Goa University.

17. Expert group on Active Fault Mapping, chaired by Dr. P. Pande, former DDG, GSI, Lucknow.

18. Technical Committee for preparation of RFP for microzonation in 30 cities, chaired by Prof. S. K. Nath, IIT, Kharagpur.