

# Annual Report

2012-2013



सत्यमेव जयते

Earth System Science Organization  
Ministry of Earth Sciences  
Government of India





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## OVERVIEW

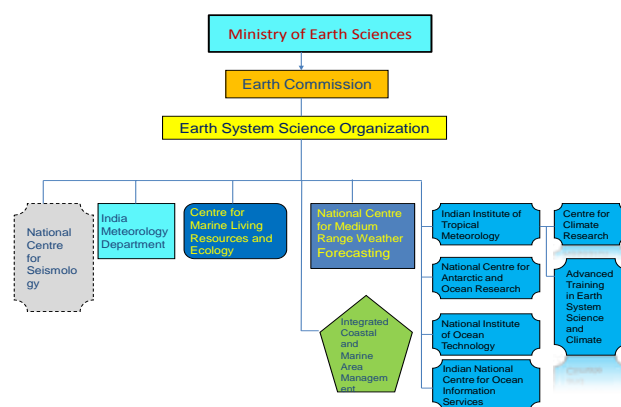
The Earth System Science Organization (ESSO) was established in October 2007 to address holistically various aspects relating to earth processes for understanding the variability of earth system. The overall vision of the ESSO is to excel in knowledge and technology enterprise for the earth system science realm towards socio-economic benefit of the Indian sub-continent and in the Indian Ocean region. It is primarily responsible for developing and improving capability to forecast, weather, climate and hazard related phenomena for societal, economic and environmental benefits including addressing aspects relating to polar and climate change science and climate services. It is carrying out development of technology for the exploration of marine resources.

The services being rendered include weather services for a variety of sectors 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 and climate change and underwater technology. Secondly, the ESSO is also responsible for defining and deploying satellite-based, airborne and in-situ atmospheric, ocean and lithosphere observing systems. These policies/programmes are being pursued through its centres viz. India Meteorological Department (IMD), National Centre for Medium Range Weather Forecasting (NCMRWF), Indian Institute of Tropical Meteorology (IITM), National Centre for Antarctica and Ocean Research (NCAOR), National Institute of Ocean Technology (NIOT), Indian National Centre for Ocean Information Services

(INCOIS), Centre for Marine Living Resources (CMLRE) and Integrated Coastal and Marine Area Management (ICMAM).

Under the framework of ESSO, a well established mechanism has been put in place to review and monitor the various programs on half-yearly basis, which are generally held in the month of April and October. The primary objective of the review mechanism is to formulate proposals for Annual Plan and apply a mid course corrections, if required.

The organizational chart of the ministry is as follows:



The major accomplishments during the year include finalization of 12th Five Year Plan proposals. The exercise has been completed based on zero-based budgeting which includes review of the ongoing schemes and identification of new initiatives proposed for next five years considering the current activities of the ESSO. Besides, selective implementation of important ongoing activities, over twenty new subjects have been proposed for implementation during 12<sup>th</sup> Plan primarily to address the process studies and capacity building activities. A large number of



schemes have been appraised for implementation during the 12<sup>th</sup> Plan.

## 1.1 ATMOSPHERIC SCIENCE AND SERVICES

During the year 2012-13, a paradigm shift in numerical modeling activity for operational weather forecast has been achieved. A number of experiments were carried out using high resolution global circulation models. Some of the major accomplished are described below:

### Global Modelling

The Global Model GFS was set up at a resolution of T764L91 (~18 Km) and tested in both Eulerian and semi\_Lagrangian frameworks on 8 nodes. Verification of high resolution GFS model (T574L64) forecasts are carried out independently by National Centres for Environment Prediction (NCEP)/ National Oceanic and Atmospheric Administration (NOAA), USA along with performance of other major operational centres of the world. The performance of the ESSO-NCMRWF forecasts is found to be at par with the other centers. The Root Mean Square Error (RMSE) of the day-3 forecasts of the vector winds at 850hPa against observations from Indian radiosonde stations for the period (Jan 2005-Oct 2012) is shown in Figure 1.1 The steady decrease in the RMSE (thus increase in skill) can be attributed to the increase in the resolution of the model, increase in the amount of data being assimilated and improvements in data assimilation techniques.

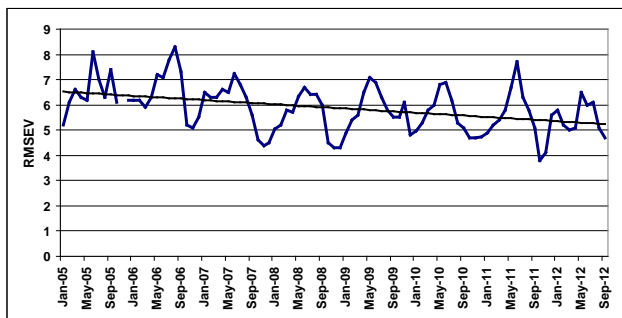


Fig. 1.1 The RMSE (in ms<sup>-1</sup>) of vector winds during the last 8 years.

The Root Mean Square Error (RMSE) of the day-3 forecasts of the vector winds at 850hPa against observations over the Global Tropics (20°S-20°N) for the month of September 2012 from ESSO-NCMRWF, United Kingdom Met Office (UKMO), European Centre for Medium-Range Weather Forecasts (ECMWF) and NCEP models is shown in Figure 1.2 below. The performance of the ESSO-NCMRWF forecasts is found to be at par with the other centres.

The UK Met Office Unified Model (UM) with a horizontal resolution of about 25 km and 70 levels in the vertical and the associated 4D-VAR data assimilation system have been successfully implemented at ESSO-NCMRWF. Experimental real-time forecasts are being generated daily since May 2012. All the available data from both national and international satellites are being assimilated. Procedures for assimilation direct radiance data from satellites of older period (HIRS2 and MSU satellite radiance data) using WRF and WRF-3DVar have been implemented successfully. The pilot-phase assimilation experiments with 6hrly update assimilation cyclic using only conventional observation data through WRF-VAR analysis system were carried out continuously for the period 1999-2003.

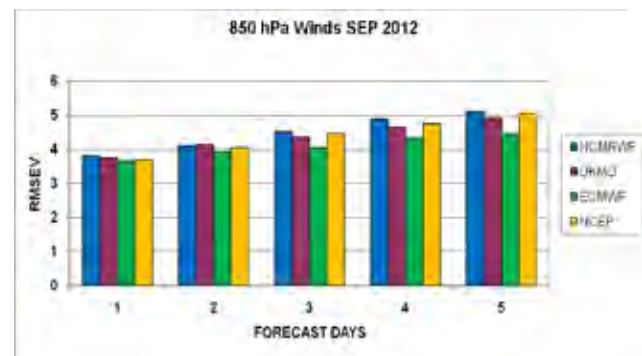


Fig.1.2 Root mean square error (in ms<sup>-1</sup>) in 850 hPa vector winds during September 2012.

Under the framework of Regional Integrated Multi-hazard Early warning System(RIMES), a data-sharing arrangement has been established with the nine countries to provide 24 hour accumulated rainfall forecast for 3 days. The countries include Bangladesh, Bhutan, India, Lao People's Democratic Republic, Maldives,

Mongolia, Myanmar, Nepal, and Sri Lanka. The departments of irrigation, agriculture, and other primary users of weather information also have become major beneficiaries.

One month experiment utilizing Indian Satellite Vegetation Data in model GFS T574 indicated that the Indian vegetation data positively influences land surface parameters as well as the flow pattern at 850 hPa (1.5 km). Further, Oceansat-2 Scatterometer (OSCAT) winds along with polar winds from NOAA and METOP series of satellites were assimilated in the operational model.

**Monsoon Mission:** The monsoon mission is a multi-institutional and inter-agency research mission with the ultimate aim to improve the monsoon prediction over the country on all time scales. The monsoon mission has been supporting national and international participation of academic and research institutions. The mission is being implemented (2012-2017).

**Agro-meteorological advisory service:** The agro advisory service bulletins were issued to 585 Agro Advisory Services units. Weather related information and crop advisory through SMS in Maharashtra has been initiated through Farmers Club which is catering to 50,000 farmers. The

total number of SMS subscribers to the Agro-meteorological advisory service is increased to 34.5 lakh.

**Modernization meteorological Services:** The Atmospheric observation network has been augmented including installation of over 10 Doppler Weather Radars in various cities, viz., Delhi airport, New Delhi, Nagpur, Jaipur, Hyderabad, Lucknow, Patna, Patiala, Agartala, Mohanbari, Bhuj and Mumbai during the period. The installation of DWRs has improved nowcasting in these cities. Besides, installation of over 552 AWS and 955 ARGS in various locations of the country was completed as a part of national network.

**Monsoon Prediction 2012:** In June, 2012, the forecast for the southwest monsoon season rainfall (June to September) for the country as a whole was issued as 96% of the Long Period Average (LPA) with a model error of  $\pm 4\%$ . The actual 2012 seasonal monsoon rainfall was 92% of its LPA. The seasonal rainfall was excess in 1 meteorological sub-division, normal in 22 meteorological sub-divisions and deficient in 13 meteorological sub-divisions. The verification results are given in Table 1.1.

**Table 1.1** Long Range Forecasts and verification with observed data for the 2012 South West monsoon

Region	Period	Forecast issued			Actual Rainfall (1 June to 30 September) Per- cent of Long period average
		1st stage	2nd Stage	3rd stage	
All India	June to September	99 $\pm$ 5	96 $\pm$ 4	-	92
Northwest India	June to September	-	93 $\pm$ 8	-	93
Central India	June to September	-	96 $\pm$ 8	-	96
Northeast India	June to September	-	99 $\pm$ 8	-	89
South Peninsula	June to September	-	95 $\pm$ 8	-	90
All India	July	-	98 $\pm$ 9	-	87
All India	August	-	96 $\pm$ 9	96 $\pm$ 9	101
All India	August + September	-	-	91 $\pm$ 8	104



**Advanced Training School:** An Advanced Training School was established at Pune, to create a large pool of trained and dedicated earth system scientists with the special emphasis on climate modeling. Twenty candidates were selected in 2012 as Trainee scientists for the 2<sup>nd</sup> batch.

**Cyclone Forecast:** Tropical Cyclone Tracker, which tracks and generates the cyclone positions in the forecasts has been implemented in the Global Ensemble Forecast System (GEFS) and the T574L64. This module has been

implemented in India for the first time and is used for tracking the cyclones in the Bay of Bengal, the Arabian Sea, the Indian Ocean. The track and landfall forecast for cyclone "Nilam" occurred in the Bay of Bengal during 28<sup>th</sup> - 30<sup>th</sup> October 2012, was quite accurate. Under its influence gale wind speed reaching 70-80 kmph along with heavy to very heavy rainfall prevailed along and off the north coastal Tamil Nadu, Puducherry and adjoining south Andhra Pradesh coast. The evaluation of cyclone forecast for "NILAM", is given in Table 1.2.

**Table 1.2** Improvement in the Cyclone Landfall errors for "NILAM"

Lead Period (hr)	Landfall Time Forecast Error (h)	Land fall Forecast Error (km)	Average Track Error (km)
12	1.5	16	70
24	2.0	11	114
36	3.0	74	145
48	1.0	45	176
60	3.0	11	172
72	It was predicted that the system would move towards north Sri Lanka and Tamil Nadu Coast.		236

### Forecasts for Pilgrimage

Weather forecast was issued on 3-hourly basis for each of the nine sectors of the Amarnath Yatra route during 21<sup>st</sup> June to 6<sup>th</sup> August 2012. Updated weather forecast and warnings were given through SMS service to the authorities concerned.

## 1.2 OCEAN SCIENCE AND INFORMATION SERVICES

The advisories on Potential Fishing Zone (PFZ) information were issued on daily basis, within 2 hours of satellite pass, an improvement over the last year. Thirty Seven Tuna fishery advisories in the form of maps and text information were generated and disseminated to the registered users through emails and website thrice-a-week. Ocean State Forecasts along ship routes were made operational during this year. The Location Specific Ocean State

Forecasting and Real-Time Information system for the South Tamil Nadu districts also was developed made operational in collaboration with the M.S.Swaminathan Research Foundation (MSSRF), Chennai. Over 60,000 users registered directly to receive the PFZ advisories and Ocean State forecast.

A new service was introduced to provide "first day forecasts of surface currents" to all coast guard centres and to coastal security police in Tamil Nadu, Goa, Karnataka, Lakshadweep and the Andaman and Nicobar Islands.

The 'High Wave Alerts' issued during cyclone Thane (25-29 December 2011) proved to be highly beneficial for the fishermen and civilian authorities in Puducherry. A Coral Bleaching Alert System (CABS), providing bimonthly status on 5 major coral environments of India, viz., Andaman and Nicobar Islands Lakshadweep, Gulf of Mannar, Gulf of Kutch has been set up. This provides early signs on the coral



degradation that undergo thermal stress and possible bleaching.

A climatic atlas of Mixed Layer and Sonic Layer for the Tropical Indian Ocean was prepared comprising approximately 1,11,000 profiles from Argo floats and other sources. A software application also was developed for viewing the Mixed Layer and Sonic Layer Depth Climatology which facilitates visualization and spatio-temporal sub-setting.

As a part of **Ocean Observation Network**, a set of 16 moored buoy network was established for acquisition of realtime data from the seas around India. This has been useful for operational weather forecasting including providing cyclone warning besides validation of satellite data.

### 1.3 DISASTER SUPPORT

The Indian Tsunami Early Warning Centre (ITEWC) has reported 74 earthquakes of magnitude > 6.5 during the period. A major earthquake of initially estimated magnitude 8.7 (later revised to 8.5) on the Richter scale occurred off the West Coast of Northern Sumatra, Indonesia on 11 April 2012 14:08 IST with epicenter at 2.4° N and 93.07° E. The first bulletin was issued in 8 minutes at 1416 h. This was followed by another earthquake of estimated magnitude 8.5 (later revised to 8.2) occurred off the West Coast of Northern Sumatra, Indonesia on 11 April 2012 16:13 IST with epicenter at 0.77 Deg. N and 92.45 Deg. E. Five tsunami bulletins were issued for the event simultaneously with the first event. Regional Tsunami advisories were disseminated to a total of 21 countries in the Indian Ocean region.

The First Ministerial Conference of the Regional Integrated Multi-Hazard Early Warning Systems (RIMES) for Afro-Asian Region was organized on 21<sup>st</sup> June 2012 in Delhi. Both Hon. Minister of Earth Sciences and Hon. Minister of State for Earth Sciences participated along with Ministers, Ambassadors/High Commissioners and Senior Government

officials from Afghanistan, Armenia, Bangladesh, Bhutan, Cambodia, Comoros, Kenya, Lao PDR, Maldives, Mauritius, Mongolia, Mozambique, Myanmar, Nepal, Papua New Guinea, Philippines, Seychelles, Sri Lanka, Tanzania and Uzbekistan met in New Delhi to deliberate on and resolve the issue of organizing resources for implementing RIMES core operations and Master Plan.

The maps of Coastal Vulnerability Index (CVI) for the entire country was prepared using seven basic parameters - Shoreline Change, Geomorphology, Coastal Regional Elevations, Coastal Slope, Sea-level Change Rate, Mean Significant Wave Height and Tidal Range. A CVI atlas comprising 157 maps on 1:100000 scales was prepared for nine coastal states and Islands. The tsunami hazard maps on 1:25000 Scale for Tamil Nadu, Andhra Pradesh, Odisha, West Bengal, Kerala, Karnataka and Goa have been completed.

As a part of setting up of a Deep Borehole (~7 Km) Observatory in the Koyna-Warna region for direct and continuous monitoring of intra-plate seismic zone at depth, leading to a better understanding of the mechanics of faulting, physics of reservoir triggered earthquakes as well as earthquake hazard assessment, Govt. of Maharashtra has provided 125 acres of land in Hazarmachi area in Karad. The preparatory studies have been initiated to carry out scientific investigations and select the suitable site for deep borehole drilling in the Koyna-Warna region. The investigations include seismological, geophysical (seismic, gravity, magnetic), LIDAR, geomorphology and structural geological studies, apart from a few shallow (~ 1 km) exploratory boreholes.

### 1.4 POLAR SCIENCE & CRYOSPHERE

In March 2012, India successfully commenced operations at Bharati, the third permanent station in the Antarctica. The summer complement of the 31<sup>st</sup> Indian Scientific Expedition to Antarctica returned from Antarctica after completion of targeted activities.



During the 6<sup>th</sup> expedition to the Southern Ocean 2011-12, continuous observations were carried out for ocean currents, atmospheric parameters and biogeochemistry by operating various instruments such as Acoustic Doppler Current Profiler, Automatic Weather Station, surface water sample collection and XBT deployments from 7.7°N-78.1°E onwards during the voyage from Goa to Southern Ocean. CTD, XCTD, Micro-profiler Multiple Plankton net and Bongo net were operated between 40°S-57°30'E and 53°S-57°30'E. Time series observations were made over a period of 48 hours (3 hourly intervals) at 40°S-58°30'E.

The summer phase I of the Indian Arctic Programme was completed between June - July 2012. The studies on (i) Long term monitoring of the Kongsfjorden system of the Arctic region for climate change studies and (ii) Quantifying variability in freshwater influx to the Kongsfjorden system using oxygen isotopes of seawater and the implications to the ice melting have been undertaken. India hosted and chaired the meeting Asian Forum for Polar Sciences in New Delhi on 6-7 August 2012. China, Japan, Korea, Malaysia and host India participated in the meeting and exchanged information on the activities carried out in the Antarctic, Arctic and Southern Ocean.

India won the bid for hosting the Scientific Committee on Antarctic Research (SCAR) - XII International Symposium on Antarctic Earth Sciences, in 2015 at Goa.

### 1.5 OCEAN TECHNOLOGY & RESOURCES

The geophysical survey for the revised dam corridor for the Kalpasar project in Gujarat was completed with submission of the draft report. The geotechnical analysis was also completed and the reports of Cone Penetration Testing (CPT) and Vibrocore samples collected along the dam corridor at the Gulf of Khambhat was prepared.

The Two LTDD plants commissioned one each at Minicoy and Agatti of the Lakshadweep Islands during 2011 were made fully

operational. These plants have been contributing significantly to the drinking water needs of the local population of these islands. The capacity of these plants is 1 lakh liter per day.

In order to harness deep sea resources, development of various equipments such as Remotely Operable Submersible (ROSUB) to assess environmental conditions and Remotely Operable Subsea In-situ Soil Tester (ROSI) to test mechanical properties of sea-bed has been undertaken. A Remotely Operable Subsea In-situ Soil Tester (ROSI) has been developed and was tested at a water depth of 5462 m in the Central Indian Ocean Basin (CIOB).

### 1.6 COASTAL MARINE ECOLOGY

R&D efforts over the past 10 years have succeeded in producing black-pearls from the pearl oyster (*Pincta damargratifera*). Two number of high quality black-pearls were obtained from 12 of the black pearl oysters maintained at the Andaman and Nicobar Hatchery Unit. These pearls fetch more than US\$ 50 per pearl in the international market.

Ten Fish Aggregating Devices were deployed successfully off the Andaman & Nicobar Islands.

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

### 1.7 CLIMATE CHANGE SCIENCE

The past variability of Indian Ocean Dipole (IOD) and its relationship with the Indian Summer Monsoon (ISM) over 140 Kyr using a sediment core from the southern Indian Ocean has been computed. Short-term climatological studies based on recorded meteorological data have shown that positive IOD mode events tend to increase the ISM rainfall by strengthening the monsoonal-Hadley circulation on annual to decadal timescales. However, long-term variability (millennial timescale) of IOD mode and its relationship with ISM vis-à-vis changing climate of the earth is largely unknown.

## 1.8 NETWORKING OF CENTRES

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

## 1.9 EXTRAMURAL RESEARCH

Endowment fund has been provided to IIT Kharagpur for the establishment of a “*Samudragupta MoES Chair*” in the area of Earth System science and “*James Rennell MoES Young Fellow*” to encourage young faculty to carry out research in the related field.

## 1.10 OUTREACH & REWARDS

Towards promoting awareness about the programmes and achievements among the public, student and user communities, major National and International exhibitions held in India and Seminars, Symposia, Workshops, have supported. The major ones are as detailed below:

The Earth Day 2011 was celebrated on 22 April, 2012 at 33 locations across the country. Various activities, viz. debate competitions, drawing and painting competition, bicycle rally, cleanliness campaigns, slogan writing, etc. were organised during the occasion.

Earth Sciences Foundation Day function was held on 27<sup>th</sup> July, 2012 at the Vigyan Bhawan, New Delhi. Dr. Ashwini Kumar, Honourable Minister of State for Planning, Science & Technology and Earth Sciences was the Chief Guest with Dr. R.K. Pachauri, Director General, The Energy and Research Institute, as the Guest of Honour. Dr. Pachauri delivered a Foundation Day lecture on this occasion entitled “India and the challenge of climate change - Devising a scientific response strategy”. A coffee-table book on “90 degree south - India’s journey to Antarctica” was released, on the day.

Scientists of Earth System Science Organization (ESSO) received the “National Geoscience Awards for 2010” on 16 February, 2012 at New Delhi, in the field of Oil and Natural Gas Exploration, Disaster Management and Oceanography & Marine Geology.

India was re-elected on the 21 member UN Commission on the Limits of the Continental Shelf (CLCS) for a five year period beginning June 2012.

India was re-elected on the Council of International Seabed Authority in Investors Category (Group B) for the period of 4 years commencing from 1<sup>st</sup> January, 2013. International Seabed Authority is the UN institution governing the resources of high seas outside the national maritime zones, set up under the UN Convention on Law of the Sea.

## 1.11 SCIENTIFIC PUBLICATIONS

There has been a significant growth in research publications in SCI Journals during the last few years. The number of publications and its impact factor during the current year are 310 and 392, respectively. It is important to note that the quality of the publications has been improved considerably over a period.

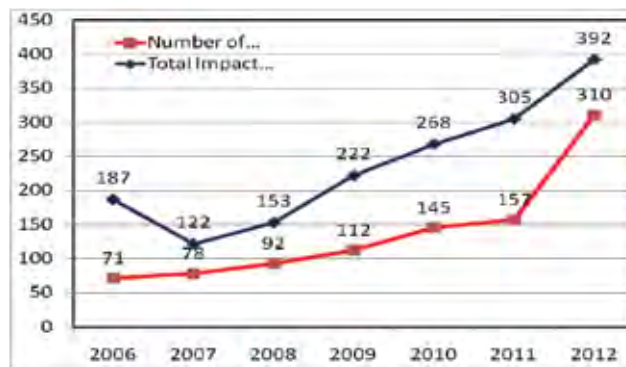


Fig.1.3 Growth of Scientific Publications with impact factor

## 1.12 BUDGET AND EXPENDITURE

The approved outlays for the plan and non-plan for current year 2012-13 were Rs. 1281 crores and Rs. 349.12 crores, respectively. The major priority areas during the year have been



(i) Completion of Third permanent Indian Station at the Larsesman Hills, Antarctica, (ii) Modernization of Phase-1 program of Meteorological Services, and (iii) Setting up Training centre.

Major scheme-wise allocation for the current financial Year (2012-13) (Rs. in crores) is shown in Fig. 1.4.

There has been considerable increase in the budget allocation over the last 5 years for planned activities.

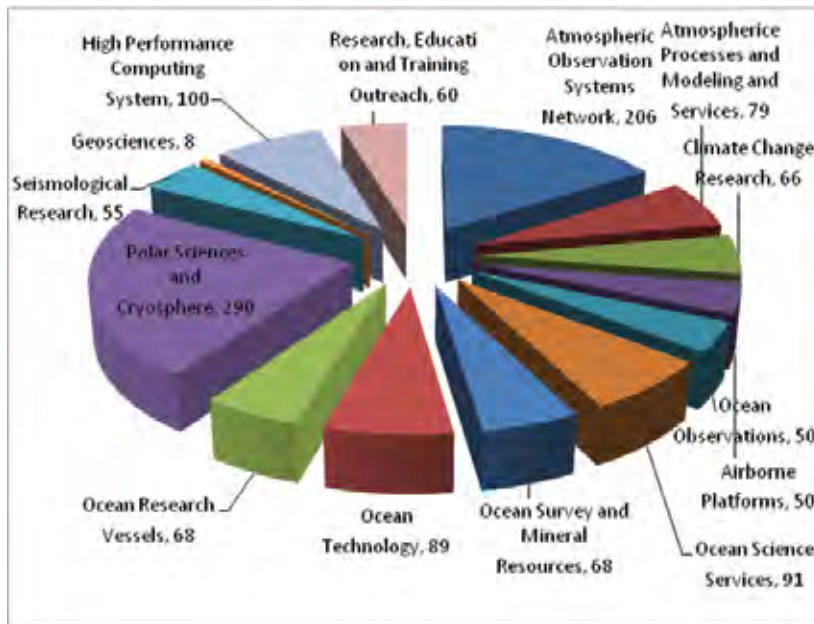


Fig.1.4 Major scheme wise allocation of funds.

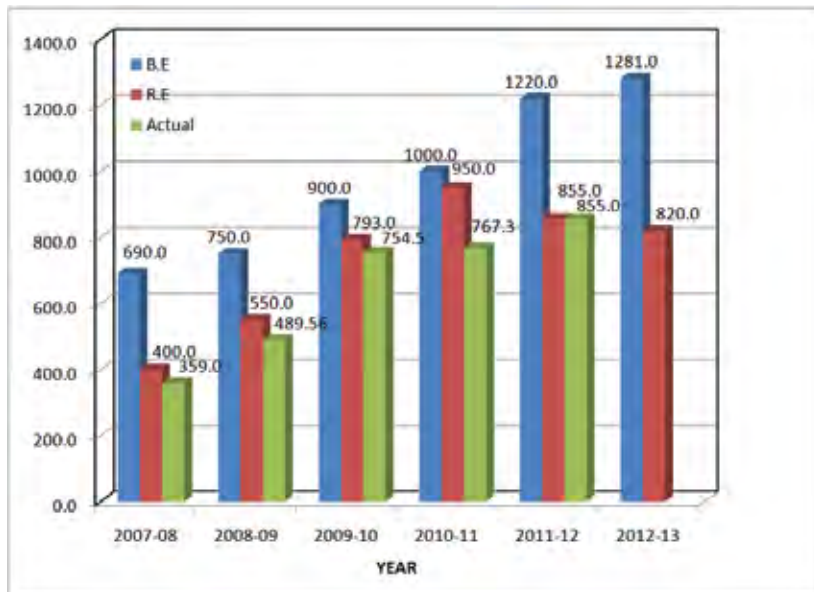


Fig.1.5 Budget Allocation and expenditure of the ministry during the last 5 years.

# ATMOSPHERIC OBSERVATIONS AND SERVICES

Weather and climate services have been improved through continuous endeavors of upgrading/augmenting observing, data reception, auto analysis, forecast assessment product dissemination, computing, network systems and a implementing a suite of global/regional/meso-scale assimilation and forecast systems. Details of major accomplishments are presented below:

## 2.1 OBSERVATIONAL NETWORKS

### 2.1.1 Augmenting Doppler Weather Radars (DWRs) Network

Currently, 20 DWRs have been commissioned and data products are exchanged through VPN for generation and dissemination of forecasts related to severe weather, high intensity rainfall, within the 100 km radial range. Number of products derived from the three base products, viz. reflectivity, velocity and spectrum width were readily used for nowcasting (very short-term up to 6 h), monitoring and timely warnings of severe weather in support of organizing appropriate emergency response actions by the designated disaster management authorities.

### 2.1.2 Automatic Weather Station (AWS) and Automatic Rain Gauge (ARG) Networks

AWS and ARG networks, comprising 675 AWSs and 965 ARGs in remote areas across the country, for monitoring the local weather conditions is currently operated. During the year the network of AWS and ARG are expanded by 9 and 408 systems, respectively. Three AWSs at Sheshnag, Panchtarni and the Holy Cave of Shri

Amarnath have especially been commissioned for providing weather surveillance during annual pilgrimage to the Amarnath Cave during 2012.

### 2.1.3 Agro-meteorological Observation (AgMO) Network

A network of 264 AgMOs across the country are operated in close cooperation with the state agricultural universities/Indian Council of Agriculture Research (ICAR) Institutes. In addition, 42 evapotranspiration (ET) measuring stations, 214 pan evaporation measuring stations, 75 dewfall measuring stations and 43 soil moisture observatories are operated. Under the scheme of desert locust meteorology, 7 micro-meteorology-cum-pilot balloon stations are made functional over north-west India.

### 2.1.4 Surface, Upper Air Radiation Measurement Network

A network of 45 radiation measurement stations having pyrhemeters and pyranometers have been maintained with accuracy levels of 1% and 5%, respectively. Various radiation parameters, viz. Global Solar Irradiance, UV-A radiation and terrestrial radiation (45 stations), direct radiation (13 stations) and diffuse solar radiation are measured (35 stations). The calibration of all radiation sensors was carried out with respect to the World Radiometric Reference (WRR).

The upper-air radiation networks consists of 8 stations, conducting fortnightly ascents for monitoring upper-air radiation data including at the Indian Antarctic station. Surface ozone monitoring network of 5 stations including



fabrication and supply of ozonesondes have been maintained.

### 2.1.5 Network of High Wind Speed Recording Systems

A network of 20 High Wind Speed Recording Systems at various coastal stations is operated.

### 2.1.6 Aviation Meteorological Observation (AMO) Network

AMO network at various airports involving, Transmissometers, Current Weather Instrument Systems (CWIS) and Laser Ceilometer, Distant Indicating Wind Equipment (DIWE) at national and international airports has been operated. Indigenously developed Drishti Transmissometer was commissioned during the winter of 2012-13 at the Delhi International Airport with full stand-by systems, along with digital Current Weather Information System (CWIS) and Ceilometers on all the 3-runways.

### 2.1.7 Satellite Meteorological Products and Dissemination Network

Kalpana-1 and INSAT-3A provide data from the meteorological payloads, viz. Very High Resolution Radiometer (VHRR) for imaging the Earth in Visible (0.55-0.75 $\mu\text{m}$ ), Infra-Red (IR: 10.5-12.5 $\mu\text{m}$ ) and water vapour (WV: 5.7-7.1 $\mu\text{m}$ ) channels having resolution of 2X2 km in visible and 8X8 km in WV and IR channels. In addition the INSAT-3A has a three channel Charge Coupled Device (CCD) payload having spatial resolution of 1 X 1 Km for imaging the earth in Visible (0.62-0.69 $\mu\text{m}$ ), Near Infra Red (0.77-0.86 $\mu\text{m}$ ) and Short Wave Infra Red (1.55-1.77 $\mu\text{m}$ ) bands of Spectrum. Currently, 48 images from Kalpana-1 VHRR and 24 images are taken from INSAT-3A VHRR are taken daily. Imaging from CCD is done 5 times during daytime only. The qualitative products (satellite images) are transmitted to users for use in Weather forecasting. All products namely, satellite images in all channels and various sectors, outgoing longwave radiation, Atmospheric Motion Vectors, Quantitative Precipitation Estimates, Upper Tropospheric

Humidity, Cloud Top Temperatures, Sea Surface Temperatures and Normalized Difference Vegetation Index (NDVI) are displayed on ESSO-IMD website. The daily/weekly/monthly/seasonal averages of various products are also displayed, and archived.

Three Ground receiving and processing systems for NOAA/METOP and MODIS Polar orbiting satellites were installed at New Delhi, Chennai and Guwahati. These satellite data receiving & processing systems have enhanced the capability of weather forecast by direct interpretation of images and products which include vertical profiles of temperature and humidity, cloud properties, fog, sea surface temperature, surface pressure, NDVI, etc. Night time Fog and MODIS RGB composite images are the two most used products for aviation purposes. Microwave channel images and high-resolution images are used in cyclone monitoring.

Five no's GPS stations for measuring integrated precipitable water vapour were installed at New Delhi, Mumbai, Chennai, Kolkata, and Guwahati to collect data every half hour. IPWV is found to be useful in nowcast of thunderstorms over the station.

The DMDD System transmits satellite cloud imagery, GTS Data and analyzed weather charts round the clock in digital mode, from New Delhi using INSAT-3C satellite. DMDD receiving stations are installed at ESSO-IMD forecasting offices all over India. Besides these, there are 3 nos. of DMDD receiving stations, in the neighbouring countries (Nepal, Sri Lanka and Maldives). A cyclone warning dissemination network of 353 stations is in operation for issuing cyclone warning to the coastal stations.

### 2.1.8 Environment Monitoring

Surface Ozone Monitoring Network has been commissioned with surface UV Absorption Ozone Photometers to determine O<sub>3</sub>. Monitoring of Columnar Ozone and vertical distribution is also continued at New Delhi, Ranichauri, Varanasi, Nagpur, Pune, Kodaikanal, Thiruvananthapuram, Port Blair, Guwahati and



Maitri (Antarctica) stations. Each station is also equipped with the standard Ozone calibrator for onsite calibration.

Aerosol Monitoring Network has been set up by installing skyradiometers at twelve locations, viz. New Delhi, Delhi (Reference Standard), Ranichauri, Varanasi, Nagpur, Pune, Port Blair, Visakhapatnam, Guwahati, Kolkatta, Jodhpur, Rohtak, and Thiruvananthapuram Sky Radiometer is used to measure optical properties of aerosols such as Aerosol Optical Depth, Single Scattering Albedo, Size Distribution, Phase Function, etc. Sky radiometers make measurements in eleven narrow wavebands in the ultraviolet, visible and infrared parts of the solar spectrum. The observing scheme takes measurements in the almucantar geometry every ten minutes, while taking direct solar measurements every minute.

## 2.2 OPERATIONAL NUMERICAL WEATHER PREDICTION (NWP)

### 2.2.1 Medium Range Forecast System (4-10 days)

#### *Implementation of Global Forecast System (GFS)*

The Global Forecast System (GFS) at T574L64 resolution has been implemented at ESSO-IMD. In horizontal, it resolves 574 waves ( $\gg$  25 Km in the tropics) in spectral triangular truncation representation (T574). The model has 64 vertical levels (hybrid; sigma and pressure). The horizontal representations of model variables are in spectral form (spherical harmonic basis functions) with transformation to a Gaussian grid for calculation of nonlinear quantities and physics.

In the operational mode, the Global Data Assimilation (GDAS) cycle runs 4 times a day (00 UTC, 06 UTC, 12 UTC and 18 UTC). The assimilation system for GFS T574 is a global 3-dimensional variation technique, based on NCEP Grid Point Statistical Interpolation (GSI) scheme. The major changes incorporated in T574 GDAS include use of variational quality control, flow dependent re-weighting of back ground statistics, use of new version and coefficient for

community radiative transfer model, improved tropical cyclone relocation algorithm, changes in the land, snow and ice skill temperature and use of some new observations in the assimilation cycle. The data presently being pre-processed for Global Forecast System are Upper air sounding - TEMP, GPS & PILOT, Land surface - SYNOP, SYNOP MOBIL & AWS, Marine surface - SHIP, Drifting buoy - BUOY, Sub-surface buoy - BATHY, Aircraft observations - AIREP & AMDAR, Automated Aircraft Observation - BUFR (ACARS), Airport Weather Observations - METAR, Satellite winds - SATOB, High density satellite winds - BUFR (EUMETSAT & Japan), Wind profiler observations - BUFR (US/Europe), Surface pressure Analysis - PAOB (Australia), Radiance (AMSU-A, AMSU-B, HIRS-3 and HIRS-4, MSU, IASI, SSMI, AIRS, AMSRE, GOES, MHS, GPS Radio occultation, Rain Rate (SSMI and TRMM)

### 2.2.2 Short Range Forecasting system (1-3 Days)

#### *Meso-Scale Assimilation-Forecast System - Weather Research and Forecast (WRF) Framework*

The regional mesoscale assimilation-forecast system - WRF (ARW) is implemented with its all components namely, pre-processing programs (WPS and REAL), data assimilation program (WRF-VAR), boundary condition updating and forecasting model (WRF) and NCL for display. The pre-processed observational data from GTS and other sources prepared for the Global Forecast System is used for WRF assimilation.

In the WRF-VAR assimilation system, all conventional observations over a domain (20°S to 45°N; 40°E to 115°E), which covers the designated Regional Specialized Meteorological Centre (RSMC) Delhi region, are considered to update the first guess obtained from the GFS analysis. Assimilation is done with 27 km horizontal resolution and 38 vertical levels. The boundary conditions from GFS forecasts run are updated to get a consistency with improved mesoscale analysis. WRF model is then integrated for 75h



with a nested configuration (27 km outer and 9 km inner domain) with physics including cloud microphysics, cumulus, planetary boundary layer and surface layer parameterization. The post-processing programs ARW post and WPP are also installed to generate graphical plots and sent out for SYNERGIE system at various forecasting offices across India. WRF at 3 km resolution was implemented for the National Capital Region of Delhi Region. High resolution WRF model has been made operational to generate 9 Km grid scale regional forecasts from ten regional offices of ESSO-IMD.

#### *Advanced Regional Prediction System (ARPS) Meso-scale Model Framework*

The ARPS is implemented for the Delhi and Kolkata region at the horizontal resolution of 9 km with the objective of assimilating the Doppler Weather Radar observations.

#### *Nowcast and very short range forecasting systems (0-6 hours)*

For nowcasting purposes, the application software called “Warning Decision Support System Integrated Information (WDSS-II)”, developed by the National Severe Storm Lab, USA has been used in experimental mode. For meso-scale forecasting, radar data has been assimilated into the ARPS mesoscale model. With the ingesting of the Indian DWR observations, the application software is capable of detecting and removing anomalous propagation echoes.

### **2.2.3 Operational Agrometeorology**

Multi Model Ensemble (MME) technique using forecast products available from number of models of India and other countries, viz. T-799 model of European Centre for Medium Range Weather Forecasting (ECMWF), National Centre for Environmental Prediction (NCEP), USA and Japan Meteorological Agency (JMA), Japan and ESSO-IMD and ESSO-NCMRWF models. The products are disseminated to Regional Meteorological Centres and Meteorological Centres of ESSO-IMD located in different states. These

offices undertake value addition to these products and communicate to 130 Agromet Field Units (AMFUs) located at State Agricultural Universities (SAUs), institutes of Indian Council of Agricultural Research (ICAR), IIT, etc.

Crop yield forecasting models based on multiple correlation and regression technique are employed under Forecasting Agricultural output using Space, Agrometeorology and Land based observations (FASAL). Mid-season yield forecast (F2) and pre-harvest yield forecast (F3) using agromet model with crop area estimation are communicated to the Department of Agriculture & Cooperation (DAC) for final forecast of crop yields before harvest. Kharif crop yield forecast assessment for 2012 covering 248 districts in 20 states for seven major crops in the country is also taken up.

### **2.2.4 Operational Models for Cyclone Forecasting**

**2.2.4.1** Three regional models WRF (ARW), WRF (NMM) and Quasi-Lagrangian Model (QLM) for short-range prediction and one Global model (T574L64) for medium range prediction (7 days) are used for this purpose. The WRF-VAR model is run at the horizontal resolution of 27 km and 9 km with 38 levels in the vertical and the integration is carried up to 72h over three domains covering the area between lat. 25°S to 45°N; long 40°E to 120°E. Initial and boundary conditions are obtained from the ESSO-IMD Global Forecast System at the resolution of 25 km. The boundary conditions are updated at every six hours interval. The QLM model (resolution 40 km) is used exclusively for cyclone track prediction in case of cyclone situation in the north Indian Ocean. NWP products prepared by other global operational NWP centres like, ECMWF (European Centre for Medium Range Weather Forecasting), GFS (NCEP), JMA (Japan Meteorological Agency), UKMO, etc. are also assessed. A multimodal ensemble (MME) for predicting the track of tropical cyclones for the Indian Seas is developed by applying multiple linear regression technique using the member

models WRF, QLM, GFS (NCEP), ECMWF and JMA. Six hourly intensity forecasts and genesis potential inputs during cyclone conditions are

also provided. Cyclone track prediction skill of operational NWP models over the Indian region during 2011 are summarized in Table 2.1.

**Table 2.1** Average Track Position Errors (in km)

Models	Lead time →					
	12 hr	24 hr	36 hr	48 hr	60 hr	72 hr
ECMWF	103	77	75	86	116	118
GFS (NCEP)	80	103	77	126	202	114
JMA	119	129	241	179	204	307
QLM(ESSO-IMD)	76	126	174	295	425	515
MME(ESSO-MD)	70	76	95	119	122	164
GFS(ESSO-IMD)	122	169	202	230	276	332
WRF(ESSO-IMD)	147	198	245	278	246	293

#### 2.2.4.2 Hurricane WRF for the Indian Seas

The basic version of the model HWRFV (3.2+) which was operational at EMC, NCEP was ported with nested domain of 27 km and 9 km horizontal resolution and 42 vertical levels with outer domain covering the area of 800x800km and inner domain 60x60km with centre of the system adjusted to the centre of the observed cyclonic storm.

The model has special features such as vortex initialization, coupled with Ocean model to take into account the changes in SST during the model integration, tracker and diagnostic software to provide the graphic and text information on track and intensity prediction for real-time operational requirement. In this run only the atmospheric model (HWRF) was tested. The Ocean Model (POM-TC) and Ocean coupler requires the customization of Ocean Model for the Indian Seas.

## 2.3 OPERATIONAL WEATHER SERVICES

Weather services are provided to different sectors, like agriculture, floods, shipping, aviation, offshore oil explorations, etc. The state-of-the-art observing, monitoring/ early warning and data visualization/information processing and communication technologies are

commissioned. All the scientific and technical staff have been provided due orientation, training and skill development opportunities to attain appropriate operating skills of advanced technological platforms and to contribute efficiently to the quality enhancement.

### 2.3.1 Agrometeorological Advisory Services (AAS)

AAS bulletins are prepared twice weekly and issued at district, state and national levels to cater to the needs of agricultural community at various levels. The district level bulletins have been issued by the Agromet Field Units (AMFUs) located in the State Agricultural Universities, ICAR institutes, IITs, etc who are serving as partners in this integrated service endeavour. The bulletins include realised weather of the previous week and quantitative district level weather forecast for next 5 days in respect of rainfall, maximum temperature, minimum temperature, wind speed, wind direction, relative humidity and clouds as well as weekly cumulative rainfall forecast and crop specific advisories including field crops, horticultural crops and livestock. At present, this service is covering 585 districts of the country.

AAS advisories are disseminated through various modes of communication including mass and electronic media. In addition to multi-mode





dissemination system, advisories are disseminated to the farming community through SMS and IVR (Interactive Voice Response Technology) through regional and state level Public Private Partnership with various service providers. At present, 3.5 million farmers have been benefited directly by SMS service delivery of crop specific advisories.

ESSO-IMD and Watershed organization Trust (WOTR) started collaborative project for the generation of short range weather forecast using the inputs from Automated Weather Stations (AWS) and block level advisories. Initially block level forecast and agromet advisories are issued for 2 specified clusters of 25 villages in the Sangamner and Akole Talukas of the Ahmednagar District, Maharashtra. A pilot project is also initiated jointly by ESSO-IMD and the Consultative Group on International Agricultural Research (CGIAR) to develop block level advisories for the selected districts in Punjab and Bihar.

### 2.3.2 Hydrometeorological Services

The Hydrometeorological support is provided to various Central / State Govt. Organisations and other agencies in the field of design flood forecasting, water management and agricultural irrigation planning purposes. This includes compilation of rainfall statistics, hydrometeorological analysis of different river catchments and meteorological forecast for flood warning and flood control operations to field units of the Central Water Commission.

Rainfall magnitude and time distribution are provided for various river catchments/ projects in the country. Design storm studies of 42 projects were completed; 41 in India and 1 in Nepal. Based on 3748 number of rain gauges operated all over the country in collaboration with other stakeholders (state governments, Central Water Commission etc.), the daily assessment of monsoon season rainfall for the country is carried out and rainfall statistics at district-wise/statewise/meteorological-subdivision-wise/region-wise and for the Country as a whole was prepared.

### 2.3.3 Flood Meteorological Service

Flood Meteorological Service provides inputs on catchment scale rainfall to the Central Water Commission (CWC) through 10 Flood Meteorological Offices (FMOs) established in different part of India. Quantitative Precipitation Forecast (QPF) up to 72h in advance are regularly issued by FMOs and supplied to CWC for flood forecasting over 42 rivers and their 75 sub-basins. During this monsoon year, total number 15495 of QPF were issued by all the FMOs and overall performance of QPF was 70.1%. Sub basin wise Quantitative Precipitation Forecast(QPF) for day-1, day-2, day-3 using NWP model, operational WRF ARW (9 km x 9 km) and Multi-model Ensemble(0.25° X 0.25°), are operationalized during the flood season 2012 .

### 2.3.4 Aviation Meteorological Services

Aviation meteorological support towards the safety, economy, efficiency and regularity of the aviation services through a net work of 4 Meteorological Watch Offices, 18 Aerodrome Meteorological Offices (collocated with the 4 MWOs) and 54 Aviation Meteorological Stations (AMSs). An ICAO designated Tropical Cyclone Advisory Center (TCAC) is also functioning. On an average 260000 scheduled and non-scheduled flights were briefed through On-Line Briefing System and through manual briefing.

Efforts are on to implement Quality Management System (QMS) by obtaining ISO certification. Competency assessment of the Aviation Meteorological Personnel (AMP) and Safety Oversight of aviation meteorological service are two major components of the QMS. Safety audit of all the four MWOs and majority of the meteorological offices at busy airports have been completed.

### 2.3.5 Cyclone warning and advisory services

The Cyclone advisories comprise monitoring and prediction of cyclonic disturbances over the north Indian Ocean during 2012 and issued 3 hourly warning/advisory bulletins to national disaster management agencies including

National Disaster Management (NDM), Ministry of Home Affairs (MHA), concerned state Governments and other users at designated intervals. It also issues advisories to the World Meteorological Organization (WMO)/Economic and Social Cooperation for Asia and the Pacific (ESCAP) Panel member countries including Bangladesh, Myanmar, Thailand, Pakistan, Oman, Srilanka and Maldives during cyclone period.

Global Maritime Distress and Safety System (GMDSS) bulletin contains weather forecast of the elements wind direction, wind speed, weather, visibility and wave height for high seas for the area  $10^{\circ}$  S to  $05^{\circ}$  N and  $60^{\circ}$  E to  $100^{\circ}$  E for the Indian Navy. Two sea weather bulletins daily for the area covering  $50^{\circ}$  S to  $45^{\circ}$  N and  $20^{\circ}$  E to  $155^{\circ}$  E are also provided which are valid for 24 and 48h. In disturbed weather (cyclone etc.) extra bulletins are issued every three hours. These bulletins are issued on Global Channels through Land Earth Station (LES) Arvi via INMARSAT/NAVTEX.

The north Indian Ocean witnessed formation of three cyclonic disturbances during January-October 2012 that are described below:

**i) Deep Depression over the Bay of Bengal (10-11 October, 2012)**

A deep depression formed over the northeast Bay of Bengal in the evening of 10<sup>th</sup> October, 2012. It moved northward and crossed Bangladesh coast near Hatia during 11<sup>th</sup> morning and then moved northeastwards across Bangladesh. It weakened into a well marked low pressure area at 0600 UTC of 11<sup>th</sup> October, 2012 over Tripura and adjoining Bangladesh and Mizoram. It was short-lived with the life period of about 15h.

**ii) Cyclonic Storm, 'MURJAN' over the Arabian Sea (23-26 October, 2012)**

A depression formed over southeast and adjoining the southwest and the central Arabian Sea near lat.  $11.0^{\circ}$  N and long.  $65.0^{\circ}$  E, about 800 km west of Amini Divi in the morning of 23<sup>rd</sup> October, 2012. It moved initially west-northwest wards and then

westwards and intensified into a deep depression in the evening of 23<sup>rd</sup> October. It then moved west-southwest wards and intensified into a cyclonic storm, 'MURJAN' in the evening of 24<sup>th</sup> October. It then continued to move west-southwestwards and crossed the Somalia coast near lat.  $9.5^{\circ}$  N between 2230 and 2330h IST on 25<sup>th</sup> October, 2012. Due to land interaction, it weakened into a deep depression over coastal Somalia at 2330 h IST of 25<sup>th</sup> October. It further weakened into a depression over Somalia in the morning of 26<sup>th</sup> October while moving west-southwest wards. It further weakened into a well marked low pressure area over Somalia and neighbourhood in the evening of 26<sup>th</sup> October, 2012.

**iii) Cyclonic Storm, 'NILAM' over the Bay of Bengal (28 Oct. -1 Nov., 2012)**

A depression formed over southeast and adjoining southwest Bay of Bengal at 1130h IST of 28<sup>th</sup> October 2012 near latitude  $9.5^{\circ}$  N and longitude  $86.0^{\circ}$  E. It moved westwards and intensified into a deep depression in the morning of 29<sup>th</sup> October over the southwest Bay of Bengal near latitude  $9.0^{\circ}$  N and longitude  $83.0^{\circ}$  E, about 550 km South-Southeast of Chennai. It continued to move westwards and intensified into a Cyclonic Storm, **NILAM** in the morning of 30<sup>th</sup> October over the southwest Bay of Bengal off the Sri Lanka coast. It then moved north-northwestwards, crossed the north Tamilnadu coast near Mahabalipuram, south of Chennai between 1600 and 1700h IST of 31<sup>st</sup> October 2012. After the landfall it moved west-northwestwards and weakened gradually into a deep depression and then into a depression over the south Interior Karnataka in the morning of 01<sup>st</sup> November 2012. Over the land surface, the cloud mass was significantly sheared to the northeast of system centre during its dissipation stage leading to rainfall activity over entire Andhra Pradesh and adjoining Odisha. Maximum rainfall occurred over southwest



sector of the system centre and heavy to very heavy rainfall extended up to 300 km.

The forecast skill errors of tropical cyclones during 2012 are shown in Tables 2.2

**Table 2.2** Annual average tropical cyclone track forecast errors

Name of cyclone	Lead period in hours			Error (km)		
	12	24	36	48	60	72
Nilam	70	114	145	176	172	236
Murjan	76	92	112	-	-	-
Average	72	109	168	186	197	240

The tropical cyclone intensity forecast has been verified by calculating the absolute error and the root mean square (RMS) error of

maximum sustained wind forecast. The error is calculated by comparing the forecast wind with the actual wind and given in Table 2.3.

**Table 2.3** Tropical cyclone intensity forecast errors during 2012

Name of cyclone	Lead period	Intensity Error (knots)		No. Observations
		Absolute Error	RMS Error	
Murjan	12	6.9	7.8	5
	24	6	6.4	3
	36	7.4	7.4	1
Nilam	12	5.7	6.9	11
	24	7.8	9.2	10
	36	6.8	8.4	9
	48	8.6	11.7	7
	60	7.9	8.5	5
	72	6.7	7.8	3
Annual	12	6.1	7.2	16
	24	7.4	8.7	13
	36	6.8	8.3	10
	48	8.6	11.7	7
	60	7.9	8.5	5
	72	6.7	7.8	3

At present a common website ([www.imd.gov.in](http://www.imd.gov.in)) exists for both national and international use. However, a dedicated RSMC website with defined static and dynamic pages and link to the websites of WMO ESCAP Panel member countries is under development. Best track data and

figures of cyclones and depressions over north Indian Ocean since 1891-2011 in digital form are available on electronic Atlas. The same has been hosted in IMD's website since 2012. Web e-Atlas is now available online at [www.mcchennai.eat-las.tn.nic.in](http://www.mcchennai.eat-las.tn.nic.in) with free access to users.



### 2.3.5.7 Cyclone Hazard Prone Districts Map of India



Fig. 2.1 Cyclone Hazard Prone Districts Map of India

Cyclone Hazard Prone Districts Map of India has been prepared based on frequency of cyclones affecting the districts, frequency of severe cyclones affecting the districts, probable maximum precipitation over the districts, maximum wind strength over the districts due to the cyclone and probable maximum storm surge over the districts

### 2.3.6 Forecasting for Heat wave and Cold waves

The prediction of heat wave and cold wave is carried out by the analysis of initial condition and forecast fields of temperature, relative humidity and circulation features. The data recorded by the AWS and synoptic observatories and satellite and DWRs also prove to be very useful in issuing operational heat wave and cold wave warning.

### 2.3.8 Weather Services for the Antarctic Region

Polar WRF model for the Maitri and the Bharati regions at the horizontal resolution of 15 km has been implemented. Daily Forecasts for next 48 hours are produced based on available observations, satellite images of NOAA and

synoptic charts provided by the Weather Service of South Africa. (<http://www.imd.gov.in/section/nhac/dynamic/polarwrf.htm>). Systems/storms in the South Indian Ocean are studied as the southern limits extended up to Antarctica and to develop the connectivity of the southern Indian Ocean and the Antarctica region and understanding of continuum.

### 2.3.9 Metropolitan Air Quality and Weather Services

A high resolution emission inventory for Pune Metropolitan Region has been prepared based on activity data from various sectors such as transport (vehicles, paved & unpaved roads), residential, commercial, industrial and agriculture. Data on surface ozone concentration compiled for a ten-year period from 1990 to 1999 for Pune and Delhi were analyzed in terms of its frequency distribution, annual trend, diurnal variation and its relation with various meteorological and chemical parameters. It is found that the surface ozone concentration range showing highest frequency of occurrence at Pune is 0-5 ppb during winter and post-monsoon seasons and 15-20 ppb and 5-10 ppb during summer and monsoon seasons, respectively. It is 0-5 ppb at Delhi during all the seasons. The surface ozone concentration has shown a decreasing trend at Pune during the observational period with an average rate of decrease of 1.54 ppb/year.

## 2.4 MONSOON MONITORING AND PREDICTION

India is predominantly an agricultural country. Success or failure of crops in any year is always crucial and depend on monsoon rain which in turn controls the economy of the country. The salient features of southwest monsoon for the year 2012 are follows:

### 2.4.1 Onset and withdrawal of S-W Monsoon

The arrival of southwest monsoon current over the south Bay of Bengal and south Andaman Sea was delayed by 3 days and it was set in

over the region on 23rd May. With the strengthening of cross equatorial flow over the Arabian Sea from 4th June, the rainfall activity over Kerala increased and the monsoon was set in over Kerala on 5th June. The onset forecast issued on 13<sup>th</sup> May, 2011 suggested that the southwest monsoon over Kerala was likely to be on 31st May with a model error of  $\pm 4$  days issued on 13<sup>th</sup> May 2011. The progress of monsoon in 2012 is given in Fig. 2.2. The southwest monsoon withdrew from extreme parts of west Rajasthan on 24th September with a delay of more than 3 weeks as the normal date of withdrawal from extreme western parts of Rajasthan is 1st September. The withdrawal of monsoon is given in Fig. 2.3.

#### 2.4.2 Low Pressure Areas

Normally 4-6 depressions forms in the monsoon season. In this year, 10 low pressure areas formed during the season. However, none of the low pressure areas intensified into depression. Of the 10 low pressure areas formed during the season, 2 were in July, 5 were in August and 3 were in September.

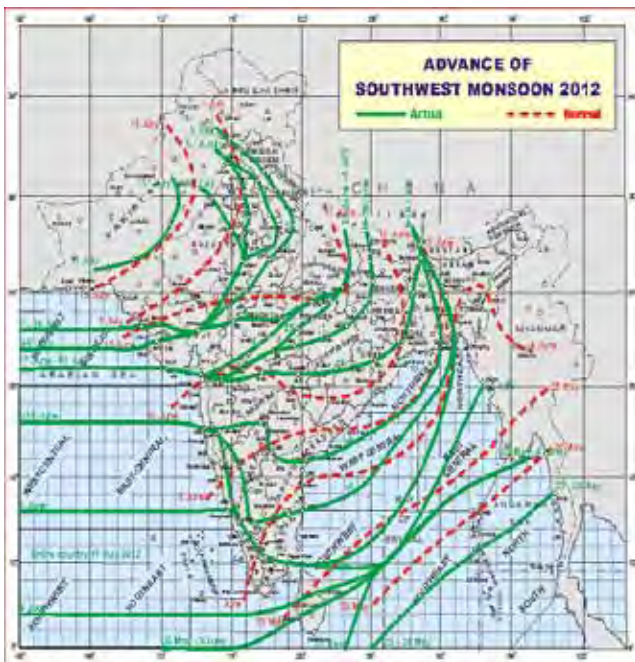


Fig. 2.2 Isochrones of advance of Southwest Monsoon



Fig.2.3 Isochrones of withdrawal of southwest monsoon

#### 2.4.3 Rainfall Distribution

The seasonal rainfall over the country as whole and four geographical regions of the country were less than the respective Long Personal Average (LPA)s. Month wise the rainfall during the first two months (June and July) was below its LPA values. However, monthly rainfall for August and September was higher than its LPA values.

The seasonal rainfall from 1st June to 30 September 2012 was excess only in one subdivision (Andaman & Nicobar Islands) which constitutes 0.3% of the total area of the country, normal in 22 meteorological subdivisions (67% of the total area of the country) and deficient in 13 meteorological subdivisions (32.7% the total area of the country) as shown in Fig. 2.4.

The weekly rainfall anomaly from the first week to the week ending 22nd August was negative. However, the rainfall anomalies from week ending 29th August to week ending 19th September were positive and during the remaining two weeks of the season were again negative (Fig. 2.5). As a result, the all India cumulative weekly rainfall anomalies were negative throughout the season (Fig. 2.6).



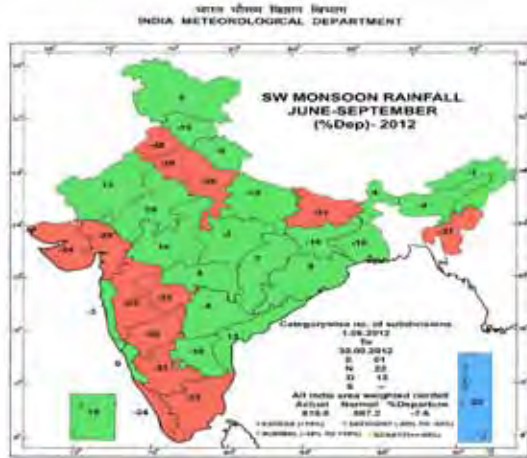


Fig. 2.4 Subdivision wise Seasonal Rainfall. (June to September)

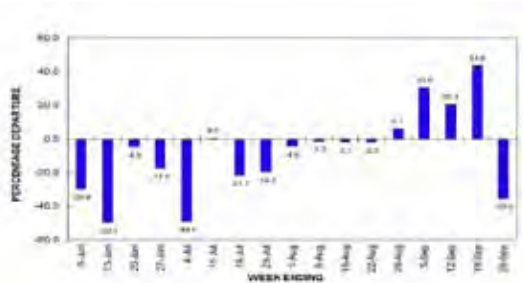


Fig. 2.5 Week - by - Week Progress of the Monsoon Rainfall

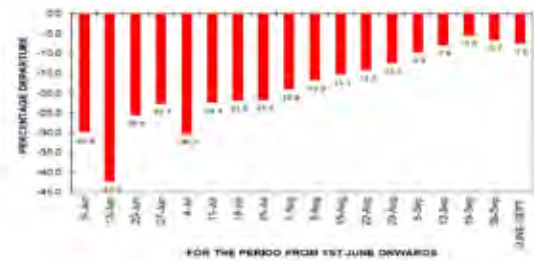


Fig. 2.6 Week - by - Week Progress of the Monsoon Rainfall - 2012(Cumulative)

### 2.4.4 Verification of the Long Range Forecasts

Long range forecasts of monsoon rainfall always have certain degree of uncertainty. ESSO-IMD issued the first long range forecast for the 2012 southwest monsoon seasonal rainfall in April, which was updated in June. Long range forecasts for four homogenous regions and July rainfall were also issued in June. Quantitatively, southwest monsoon season rainfall for the country as a whole was 92% of its long period average (deficit by 8%) as against the forecast of 96% of LPA.

**ESSO-IMD-IITM Experimental Dynamical Model Forecasting System:** The state-of-the-art coupled climate model, the Coupled Forecasting System (CFS) [developed by the National Centers for Environmental Prediction (NCEP), USA] has been implemented at IITM. The seasonal forecast (issued on 26<sup>th</sup> April 2012) was as follows:

“The experimental forecast for the 2012 monsoon season using the IMD-IITM dynamical prediction system using February initial conditions indicates that the rainfall during the 2012 monsoon season (June to September), averaged over the country as a whole, is likely to be 100% of long period model average (LPMA), with a model error of  $\pm 4.5\%$ .”

The long range forecasts issued by ESSO-IMD and the verification of the forecasts are given in the Table-2. 4.

Table 2.4 Long range forecasts and their verification

Region	Period	In % of long period average		
		Issued on 26 <sup>th</sup> April	Issued on 22 <sup>nd</sup> June	Actual Rainfall
All India	June to September	99±5	96 ± 4	92
Northwest India	June to September		93 ± 8	93
Central India	June to September		96 ± 8	96
Northeast India	June to September		99 ± 8	89
South Peninsula	June to September		95 ± 8	90
All India	July		98 ± 9	87
All India	August		96 ± 9	101
All India	August-September		91 ± 8	104



# ATMOSPHERIC AND CLIMATE PROCESSES AND MODELING

The meteorological services have significant impact on society in general. Public/private/government sectors demand for accurate prediction of weather and climate at various temporal and spatial scales is increasing due to possible impacts of global climate variability and change. Improved and reliable forecast of weather and climate requires high-resolution dynamical models (e.g. coupled ocean atmosphere-biosphere-cryosphere 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. ESSO has taken positive steps to implement comprehensive developmental programs in these lines involving all its constituent units.

## 3.1 PHYSICS AND DYNAMICS OF TROPICAL CLOUDS

### 3.1.1 Overview and preliminary results of CAIPEEX

CAIPEEX phase-I aimed at documenting the prevailing microphysical characteristics of aerosols and clouds and associated environmental conditions over different regions of the country and under different monsoon conditions with the help of an instrumented research aircraft. First time simultaneous observations of aerosol, cloud condensation nuclei (CCN) and cloud

droplet number concentration (CDNC) over the Gangetic Valley during monsoon season show very high concentrations ( $> 1000 \text{ cm}^{-3}$ ) of CCN at elevated layers. Observations of elevated layers with high aerosol concentration over the Gangetic Valley extending up to 6 km and relatively less aerosol concentration in the boundary layer are also documented. Evidence of strong cloud-aerosol interaction in the moist environments with an increase in the cloud droplet effective radius is seen. Observations also show that pollution increases CDNC and the warm rain depth, and delays its initiation. The critical effective radius for warm rain initiation is found to be between 10 and 12  $\mu\text{m}$  in the polluted clouds and it is between 12 and 14  $\mu\text{m}$  in cleaner monsoon clouds.

Observations for warm clouds are found useful for verifying and tuning the schemes used in large scale models to parameterize the cloud effective radius (a representative parameter of cloud droplet spectra) using the cloud liquid water content and the cloud droplet number concentration. This analysis used 50-m altitude bin averaged vertical profiles of the microphysical parameters measured in clouds during pre-monsoon, transition to-monsoon, and active monsoon situations sampled at various locations during June to August 2009. These monsoon cumulus clouds are found to be significantly diluted due to entrainment mixing. A linear relationship between the cloud droplet number concentration and adiabatic fraction (a measure of mixing between the cloud and its environment) is found for the each flight averaged data. The least squares best fit of this linear relationship is suggested as a simple formulation that will

be useful for large scale models to predict cloud droplet number concentration, when only cloud liquid water content is diagnosed. The use of this simple formulation is shown to improve the skill of parameterized cloud effective radius for monsoon clouds.

Pre-monsoon aerosols in the northern part of India may play an important role in the advancement of the monsoon. On all the flight days, thick haze was observed, with elevated aerosol layers up to 4 km with varying concentrations. The aerosol size distributions depict increases in both fine and coarse mode aerosols in polluted layers. This indicates that aerosols over this region are well mixed and the vertical distribution is a mixture of both biomass burning and dust aerosols at different altitudes, as also observed by CALIPSO and inferred from Mie calculations. Clouds observed above the elevated aerosol layers showed higher droplet concentrations ( $200\text{--}1400\text{ cm}^{-3}$ ) with small effective radii ( $3.5\text{ to } <6\text{ }\mu\text{m}$ ). Ice phase observed above 6 km at temperatures lower than  $-14^{\circ}\text{C}$  might be due to the presence of dust aerosol acting as potential ice nuclei.

### 3.1.2 High Altitude Cloud Physics Laboratory (HACPL), Mahabaleshwar



Fig. 3.1 A suite of instruments at HACPL, Mahabaleshwar

A Mobile X-Band Dual Polarization Doppler Weather Radar has been installed and commissioned at Mandhardevi village (1300 m AGL) in the month of May 2012. Regular observations of clouds and precipitation by this radar at Mandhardevi have been conducted in coordination with *in-situ* measurements at High Altitude Cloud Physics Laboratory (HACPL) at Mahabaleshwar Fig. 3.1 & 3.2).

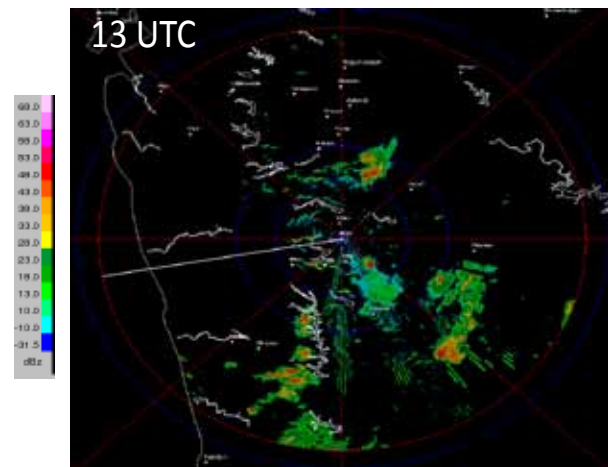


Fig. 3.2 A Mobile X-Band Dual Polarization Doppler Weather Radar installed at the Mandhardevi village and the observations of clouds taken by the Radar

A field observational campaign was conducted during the monsoon season 2012 at Mahabaleshwar. The important equipments include microwave radiometric profiler, micro rain radar, optical and video disdrometers for temperature, humidity profiles and rain drop size distribution.

## 3.2 THUNDERSTORM DYNAMICS

### 3.2.1 Effect of lightning activity on surface $\text{NO}_x$ and $\text{O}_3$ over a tropical station during pre-monsoon and monsoon season

The effect of lightning activity on surface  $\text{NO}_x$  and  $\text{O}_3$  over Pune, India ( $18.54^{\circ}\text{N}$ ,  $73.81^{\circ}\text{E}$ ),



for the years 2005 to 2008 during thunderstorm events in pre-monsoon and monsoon period is studied. Surface concentration of NO<sub>x</sub> is found to be increased significantly at the dissipation stage of thunderstorms. It is observed that increase in NO<sub>x</sub> greater than titration threshold level reduces the surface ozone concentration. However, in some cases when NO<sub>x</sub> increases but it does not reach the titration-threshold limit, it helps in the production of ozone. Thus, results suggest that lightning production of NO<sub>x</sub> inside a thunderstorm can lead to significant impacts on surface ozone concentrations in the tropics. Enhancement in NO<sub>x</sub> at the surface after thunderstorm activity is found to be much greater in pre-monsoon periods compared to the monsoon period.

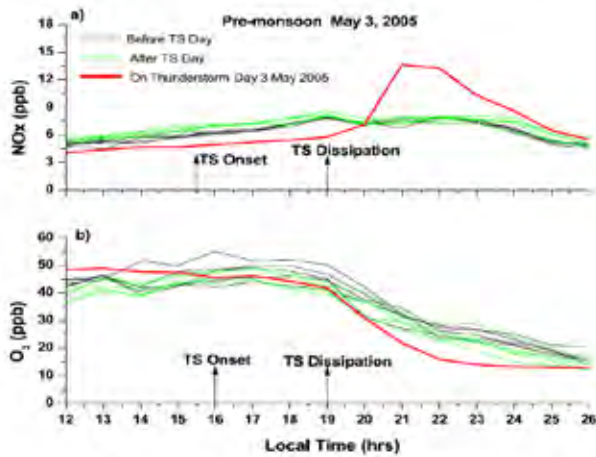


Fig. 3.3 Comparative plot of surface (a) NO<sub>x</sub> and (b) O<sub>3</sub> on thunderstorm day (3 May 2005) (red line) with 5 days (28 April to 2 May 2005) before thunderstorm, fair weather days (black line), and 5 days (4–8 May 2005) after thunderstorm fair weather days (green line)

### 3.2.2 Lightning characteristics over Central India during the Indian summer monsoon

Lightning data of last 12 years (1998 to 2009) measured by the TRMM satellite, over Central India (Lat. 15.5° to 25.5°N and Long. 75° to 85° E) during the Indian summer monsoon (July–September) have been analyzed to study the effect of Convective Available Potential Energy (CAPE) on lightning activity during monsoon and time evolution of lightning over this region. Analysis suggests that CAPE plays important role in

the lightning activity during monsoon over the Central India. The CAPE shows no significant change during transition of monsoon from break to active or from active to break phase. Time evolution of lightning over the Central India, in the last 12 years shows a systematic increase in lightning activity over the Central India and this increase in lightning over this region is attributed to the increase in CAPE. The lightning data show a typical diurnal pattern with a strong peak at 1700 h local time (LT). Such a typical diurnal variation of lightning and its good positive correlation with CAPE suggest that the monsoon convections over the Central India are not purely of oceanic based type but they are combination of oceanic and continental type convections.

## 3.3 CLIMATE PROCESS STUDIES

### 3.3.1 Global warming signal emerging in the tropical Pacific

It is found that a global warming signature, which has been manifesting in the Tropical Pacific (TP) SST with increasing trend in the last three decades, has emerged prominent. The result is a hitherto unforeseen anomalous basin-wide warming in the TP during 2009 from boreal summer through the ensuing fall. The corresponding southern oscillation collapsed, with the magnitude of its index falling below 16% of its standard deviation. Further, model experiments reported in this work show that the unique and serious climate impacts during the summer of 2009 such as the 22% deficit in the Indian summer monsoon, exceptional drought in 17 southern states, heat wave conditions in India in June and July, etc. were associated with the basin-wide warming in the TP. Interestingly, it is also observed that the 2009 boreal summer conditions in the TP were atmosphere-driven, with little presence of the coupled processes that are the signature of its interannual variability. It is demonstrated through an Empirical Orthogonal Function based reconstruction analysis that, without the global warming trend, the TP will have seen a typical El Niño with maximum warming (cooling) in the



east (west), such as in 1997, instead. This indicates that the natural climate evolution in the TP has been disrupted. The implication is that any further increase in global warming may result in more basin wide warm events in place of canonical El Niños, along with the occurrence of more intense La Niñas and El Niño Modokis.

### 3.3.2 Changes in temperature extremes over India

Observational analysis from daily maximum and minimum temperature data at 121 Indian stations for the period 1970-2003 suggests a widespread warming through increase in annual intensity and frequency of hot events, along with decrease in frequency of cold events. More than 75% stations show decreasing trend in number of cold events, and about 70% stations show increasing trend in hot events. Analysis of highest maximum temperature (lowest minimum temperature) indicates that 78% (71%) of the stations show a warming.

### 3.3.3 Impact of altitude and latitude on changes in temperature extremes over South Asia during 1971-2000

South Asia covers more than 30° of latitude with weather observation stations situated from 6°N at Galle, Sri Lanka, to 36°N at Chitral in Pakistan. Moreover, the South Asian station network ranges in altitude from sea level to nearly 4000 m above sea level. Time series of 11 objectively defined indices of daily temperature extremes at 197 stations in Bangladesh, India, Nepal, Pakistan and Sri Lanka are used to examine the possible impacts of elevation and latitude on changes in temperature extremes over the period of 1971-2000. Trends in extreme indices are found to be consistent with general warming only at low altitudes and latitudes. Stations at high altitudes and latitudes show both positive and negative trends in extreme temperature indices. As a notable example, the Diurnal Temperature Range (DTR), which has been known to decrease in most parts of the globe, has increasing trends over many high altitude stations in South Asia.

Trends in extreme temperature indices at stations in South Asia higher than 2000 m above sea level are mostly in disagreement with those reported over the Tibetan Plateau. Observed trends at low altitude locations in South Asia suggest that these sites can generally expect future changes in temperature extremes that are consistent with broad-scale warming. High-elevation sites appear to be more influenced by local factors and, hence, future changes in temperature extremes may be less predictable for these locations.

### 3.3.4 Tropospheric ozone and aerosol long-term trends over the Indo-Gangetic Plain (IGP), India

For the first time, long-term trends in troposphere ozone and its association with the industrial growth in large part of India are investigated. A multifunction regression model has been used to estimate the trends in troposphere ozone between 1979 and 1992 over the Indian region. Increasing trends in tropospheric ozone are observed over most of the regions of India. Recent year's (2005-2010) data also show the similar features. It is quite consistent with the observed trends in coal (9.2%/y) and petroleum (8.3%/y) consumption, and NO<sub>x</sub> and CO emissions in India during the study period. The regressed Tropospheric Ozone Residual (TOR) pattern during the monsoon season shows large trend over the entire Indo-Gangetic region and is largest, 6-7.2 % per decade, over the northeastern Gangetic Plain of India. Annually, trend of about  $0.4 \pm 0.25$  (1 $\sigma$ ) % per year has been seen over the northeastern Gangetic region. Similar positive trend in Aerosol Index (AI) ( $1.7 \pm 1.2$  (1 $\sigma$ ) % per year) is also detected over this region. The quality of correlation between TOR and AI suggested that tropospheric ozone appeared to be influenced by the increased anthropogenic activities in this region.

## 3.4 MODELING

### 3.4.1 Numerical Weather Prediction Modeling

Weather/climate forecasts, including those of extreme weather, are becoming increasingly



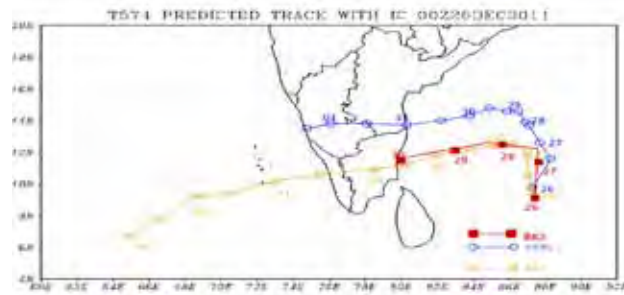
important in various aspects of life, viz. safety of life and property, reduction of the impact of natural disasters, sustainable development, community health, recreation and quality of life, National security, preservation and enhancement of the quality of the environment, efficient planning, management and operation of government and community affairs. These can be achieved through continuous improvement in providing reliable forecasts through routine integrations as well as research & development using very high resolution dynamical models with high complexity (e.g. coupled ocean-atmosphere-biosphere-cryosphere models).

During the year 2012, the global weather modeling is improved by implementing a higher resolution model at 22km as well as introducing procedures for assimilation of new data. There has been one day gain in the high resolution model at 22km resolution compared to previous year which is attained due to augmented data ingestion as well as increase in model resolution from 35 km in 2011 to 22km in 2012. Work is on to operationalise Unified Model in seamless framework so that no artificial boundaries exist between meso-scale, short-range, synoptic scale, medium range and monthly/seasonal prediction.

**i) Data Monitoring and Assimilation**

The data volume through GTS has been augmented by about 7% while ftp enabled data reception has gone up by almost 90% since last year. The data volume now ingested is comparable to the other leading global

Centers except for some additional satellite data for which steps are undertaken to acquire through possible bilateral agreements. Full efforts are undertaken to utilize the Indian satellite data. Ocean scatterometer data are now being assimilated (Fig. 3.4). Initial experiments are being performed for utilization of Indian Land use/Land cover data that results in more realistic regional specific variations in rainfall forecast. The quality of the Kalpana winds are continuously monitored for its possible utilization on operational mode.



**Fig. 3.4** Improved Track prediction of cyclone Thane with the use of OSCAT data

**ii) Model Evaluation**

In order to assess the performance of the present NWP model for weather forecast, continuous evaluation is undertaken vis a vis other global centres over the Indian region. Independent evaluation by NCEP(National Centers for Environmental Prediction) USA on daily basis shows that the performance by India is comparable to any other global

**Table 3.1** Verification of high resolution global forecasts carried out independently by NCEP, for November 2012

Parameters	ECMWF (UK)	NCEP (USA)	NCMRWF (India)	UKMO (UK)
Day 05 500 hPa AC (Anomaly Correlation) of Geopotential Height Northern Hemisphere	0.91	0.89	0.88	0.88
Day 05 500 hPa AC Geopotential Height Southern Hemisphere	0.90	0.86	0.83	0.86
Day 03 850 hPa Wind RMSE (m/s) Global Tropics	2.8	2.75	3.0	2.9
Day 03 200 hPa Wind RMSE (m/s) Global Tropics	6.4	7.25	7.5	7.1



leaders. The marginal under performance by India is attributed to comparatively low data volume and the technique of data assimilation which are at present compromised due to lack of required computational facilities. The current trend is on the usage of ensemble-based data assimilation techniques for further improving the initial conditions. This utilizes an ensemble of parallel data assimilation and forecast cycles and caters to the flow dependent nature of background error covariances, thus representing more realistically the uncertainties associated with the initial conditions. These are highly computationally extensive and studies have shown their definite improvements over the existing 4D VAR assimilation technique.

### iii) Merged Satellite Gauge Gridded Daily Rainfall Data Preparation

In order to validate model and study the various monsoon processes in terms of interseasonal and intra-seasonal variability, it is very important to have a good analysed data set of rainfall. A merged satellite gauge gridded daily rainfall data set at  $0.5^\circ \times 0.5^\circ$  latitude-longitude grid resolution has been implemented. This is generated daily for a period of 7 days. Following is a sample plot during 21-27 August 2012.

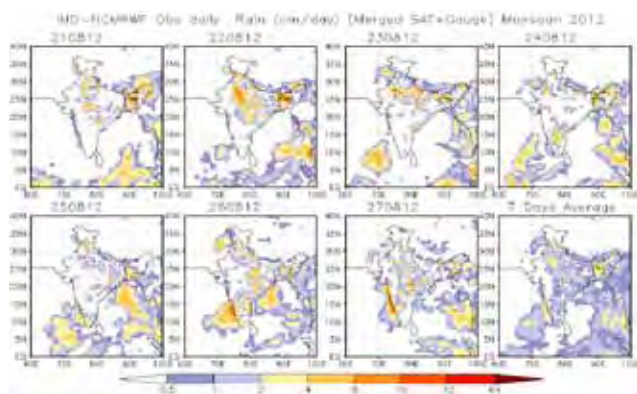


Fig. 3.5 Daily Merged Observed and Satellite Data

### iv) 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, it is pertinent to utilize a fully coupled model. A coupled ocean atmosphere model along with ocean data assimilation has been implemented and trial runs are underway. Hind-cast data from the coupled model have been analysed for 14 seasons from 1996 to 2009. These runs were made with May initial condition each year and the resultant rainfall bias in millimeter for June, July, August period is studied. This shows good simulation of monsoon rain over India; however the simulation over east equatorial Indian Ocean has to be improved by increasing the model resolution and proper ocean initialization (Fig. 3.6).

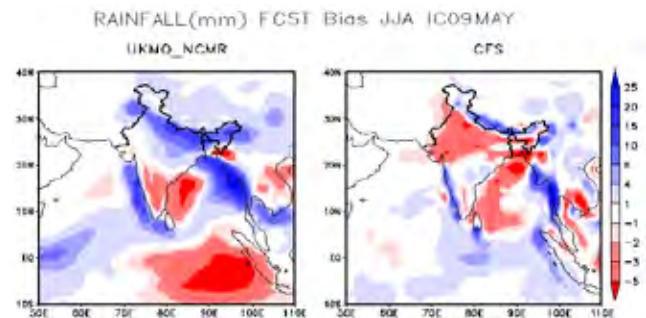


Fig. 3.6 Rainfall bias (in mm) from the UM coupled model runs (left) and the CFS model (right).

### v) The Global Ensemble Forecast System (GEFS)

#### Towards Week 2 forecasts

Week two forecasts is one of the important requirements for various sectors especially the farming community and water sector. Classical predictability theory suggests that skilful daily forecasts may be realized up to two weeks ahead. However, model integrations from slightly different initial conditions produce different forecasts. To address this problem it is pertinent to move towards probabilistic forecasts quantifying the distribution of likely outcomes as opposed to a deterministic forecast. In view of this, a global Ensemble Forecasting System at 70 km resolution with 20 members has been



implemented that produces 10 day forecast. It generates mean and spread of various fields along with probabilistic quantitative precipitation forecast for various threshold of rainfall over India. The forecasts beyond four days show improvement vis-a-vis deterministic forecasts. A typical case of 3-day forecast valid for 7<sup>th</sup> September 2012 generated by the GEFS involving light (1-2 cm/day), moderate (2-5 cm/day) and heavy (5-10 cm/day) rainfall is presented in Fig. 3.7 along with corresponding verification of observed rainfall.

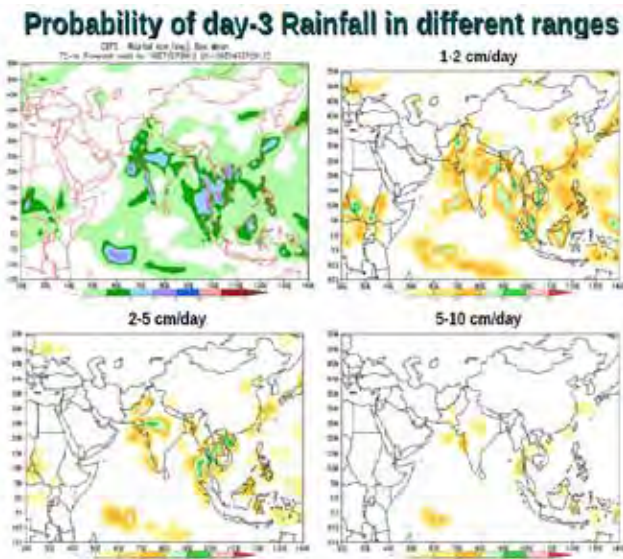


Fig. 3.7 Day-3 rainfall forecast valid for 7th Sept 2012 (top left) along with the forecast of probability of rainfall in the range 1-2cm/day (top right), 2-5cm/day (bottom left) and 5-10cm/day (bottom right)

### 3.4.2 Climate prediction modeling

#### i) Monsoon forecast on extended range:

An objective criterion is developed to generate the real-time monsoon onset forecast using CFSv2. Extended range forecasts started from 16 and 21 May 2012 have been used for generating the onset forecast. Extended range forecast of rainfall and zonal wind at 850 hPa is used to prepare the forecasts. Both the forecasts based on 16 and 21 May initial conditions indicated monsoon onset around 6 or 7 June. However, actual

onset over Kerala had taken place on 5<sup>th</sup> June 2012. The forecast indicated that monsoon will be in weak mode during most of the July and in reality that turned out to be deficit by 13% for the country as a whole.

#### ii) Model biases in long coupled runs of NCEP CFS:

Performance of the CFS over the Indian monsoon region in 100 years long coupled run, in terms of biases of SST, rainfall and circulation, is examined and the role of the feedback processes in maintaining these biases is explored. The model simulates reasonable monsoon climatology during JJAS (June-September). It shows dry (wet) rainfall bias concomitant with cold (warm) SST bias over the east (west) equatorial Indian Ocean. These biases of SST and rainfall affect both lower- and upper-level circulations in a feedback process, which in turn regulates the SST and rainfall biases by maintaining a coupled feedback process. A dry (wet) rainfall bias over the east (west) Indian Ocean induces anomalous low level easterlies over the tropical Indian Ocean and causes cold SST bias over east Indian Ocean by triggering evaporation and warm SST bias over the west Indian Ocean through advection of warm waters (Fig. 3.8). The persistent SST bias retains the zonal asymmetric heating and meridional temperature gradient resulting in a circum-global subtropical westerly jet core, which in turn magnifies the mid-latitude disturbances and decreases the Mascarene high. The decreased Mascarene high diminishes the strength of monsoon cross-equatorial flow and results in less upwelling as compared to that in the observation. It further increases the SST bias over the West Indian Ocean. The coupled interaction among SST, rainfall and circulation works in tandem through a closed feedback loop to maintain the model biases over tropical Indian Ocean.

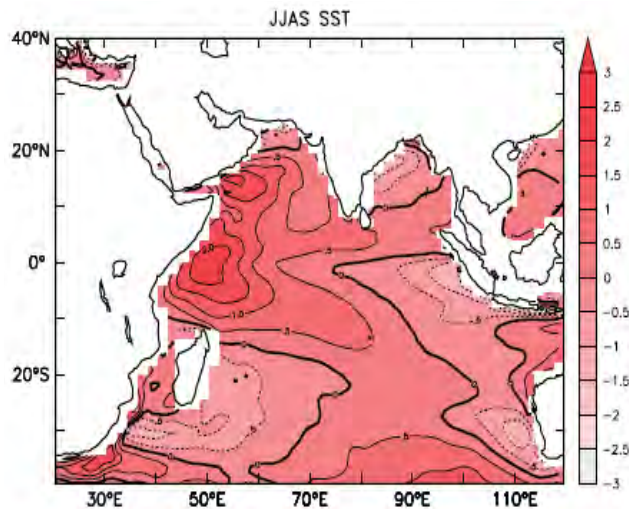


Fig. 3.8 Model SST bias. Warm (positive) bias is shown by continuous contours and cold (negative) bias is shown by dotted contours

### iii) MISO index for real time monitoring and forecast verification:

The wet/dry spells of the Indian summer monsoon (ISM) rainfall are governed by northward propagating boreal summer monsoon intraseasonal oscillations (MISO). Unlike for the Madden Julian Oscillation (e.g. RMM indices), a low dimensional real-time monitoring and forecast verification metric for the MISO is not currently available. For the first time, a real time monitoring index is developed for identifying the amplitude and phase of the MISO over the ISM domain. The index is constructed by applying extended empirical orthogonal function (EEOF) analysis on daily unfiltered rainfall anomalies averaged over the longitudinal domain  $60.5^{\circ}$ - $95.5^{\circ}$ E. The gravest two modes of the EEOFs together explain about 23% of the total variance, similar to the variance explained by MISO in observation.

## 3.5 REGIONAL CLIMATE CHANGE PROJECTION

### CORDEX South Asia Program

In order to build scientific capacity for generating relevant knowledge for regional climate

assessment for the Asian region, the World Climate Research Program (WCRP) Coordinated Regional Climate Downscaling Experiment (CORDEX)-South Asia program has been undertaken. Various international climate modeling groups/centres from Sweden, Australia, UK, Japan, Norway and Germany are contributing to the CORDEX South Asia simulations.

### CORDEX: Model Experiments

**Model Zooming over CORDEX South Asia** ~ 35 km resolution runs for the following have been completed.

- **Historical:** Includes natural and anthropogenic (GHG, aerosols, land cover etc) climate forcing during (1886 - 2005) ~ 120 years.
- **Historical Natural:** Includes only natural climate forcing during (1886- 2005) ~ 120 yrs.

**RCP-4.5:** Future projection (2006-2100) including both natural and anthropogenic forcing based on the IPCC AR5 RCP 4.5 climate scenario. The evolution of GHG and anthropogenic aerosols in RCP 4.5 scenario produces a global radiative forcing of  $+4.5 \text{ W m}^{-2}$  by 2100.

**Earth System Model:** Successfully incorporation of Ocean Biogeochemistry & Ecosystem modules into the CFS2 climate model has resulted in the manifestation of the first prototype of the ESSO-IITM Earth System Model (IITM ESM 1.1). A test run was initiated at the end of July 2012 to examine the general fidelity of the outputs. Efforts are on for isolating the aerosol module from the new version of the ECHAM-HAM model for incorporating it into the above prototype of the ESM.

## 3.6 MONSOON MISSION

An accurate prediction of monsoon variability on all spatial and time scales can improve planning to mitigate the adverse impacts of monsoon variability and to take advantage of beneficial conditions for many important sectors like agriculture, water resources management, power generation, etc. The “**Monsoon Mission**”



has been launched with a vision to develop the state-of-the-art dynamical prediction system for predicting monsoon rainfall on different spatial and time scales. The main objective of the monsoon mission is to set up a state-of-the-art dynamical modelling frame work for improving the prediction skill of short to medium range forecasts of rainfall, temperature, winds and extreme weather events and extended range to seasonal forecasts of monsoon rainfall over the country.

The mission has two sub-missions on two different time scales, i) extended range to seasonal time scale and b) short to medium range scale. For extended and seasonal forecasts, the state-of-the-art coupled climate model, the Coupled Forecasting System (CFS) [developed by the National Centers for Environmental Prediction (NCEP), USA] implemented. Retrospective forecast (hindcast) experiments are carried out using the CFS V 2.0 high resolution model (T382, 38 km) and 28 years of retrospective forecasts (hindcasts) using February Initial conditions, for the period, 1981-2008 have been completed. Research work on identification and reduction of systematic biases of the couple model also has been initiated.

For short to medium range forecasts, a global unified model (UM) of the UK Meteorological Office with a horizontal resolution of about 25 km and 70 vertical levels and the associated data assimilation system has been implemented. Since May 2012, daily experimental forecasts are being generated. A coupled ocean-atmosphere model based on the UM also has been implemented for extended range to seasonal range forecasts.

The major thrust of the mission is to have an active collaboration with academic and research institutes both in India and abroad to fulfil the objectives of the mission. The mission is supporting focused research by national and international research groups with definitive objectives and deliverables. So far, 16 research proposals (8 national and 8 international) were approved for funding under the monsoon mission.

The successful monsoon mission will achieve the implementation of the state-of-the-art dynamical prediction system for more accurate monsoon prediction on all spatial and time scales over the country with significant economic benefits.

## COSTAL AND OCEAN OBSERVATION SYSTEMS, SCIENCE AND SERVICES

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 program envisages deployment of a network of state-of-the-art technology ocean platforms equipped with satellite communication for real-time data reception. 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 modeling purposes and validation of satellite data, which are important to weather and climate of this region.

**Table 4.1**

Sl. No.	Type of Platform	Target	Commissioned 2012-13	Data received. 2012-13
1	Moored Buoys	16	19	12
	- Omni Buys	06	11	11
	- Met Ocean Buys	10	08	08
2	Tsunami Buoys	12	11	2
3	Current Meter Array	10	7	7
4	Acoustic Doppler Current Profiler(ADCP)	20	12	12
5	High Frequency(HF) Radars	10	10	5
6	RAMA Mooring	20	12	12
7	Argo Float	200	183	108
8	Drifters	150	66	23*
9	Tide Gauges	36	25	21
10	Wave Rider Buoy	16	7	6

### 4.1 MOORED PLATFORMS

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

#### 4.1.1 Buoy Network

The buoy network has been augmented to 16, out of which six are OMNI buoys and 10 are Met-Ocean buoys. The moored data buoy and an optical buoy was designed, tested and deployed successfully off Karvaratti under CALVAL Phase - II project during December 2011. A new optical



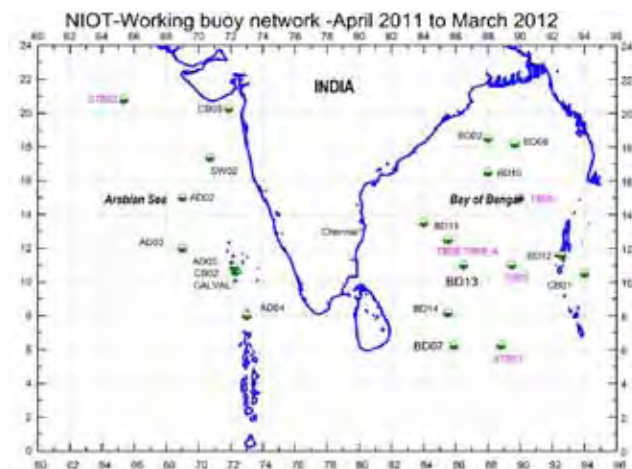
instrument under water frame was designed and fabricated for this application. The OMNI buoy are capable of making measurements of both surface and subsurface parameters upto 500 m

using induction mooring. The Met buoys measure also surface measurements. The details are given in Table 4.2

**Table 4.2** Parameters measured by Buoys.

Met Ocean Buoys	OMNI Buoys
Humidity	Humidity
Air Pressure	Air Pressure
Air Temperature	Air Temperature
Wind (Speed, Direction, Gust)	Wind (Speed, Direction, Gust)
Currents (Speed & Direction)	Currents (Speed & Direction) @ 1.2, 10, 10, 30, 50, 100 metres depth
SST Skin / SST (Optionally both)	Water Temperature @ 1, 5, 10, 15, 20, 30, 50, 75, 100, 200, 500 metres depth
Conductivity/Salinity	Conductivity/Salinity @ 1, 5, 10, 15, 20, 30, 50, 75, 100, 200, 500 metres depth
Waves (Optional)	Waves
Dissolved Oxygen	---
Conductivity	---
---	Irradiance
---	Net Radiation
Turbidity	Rainfall
Chlorophyll	Pressure @ 500

During this period, over 12 cruises were carried out involving 53 operations at Sea which involved 1722 man days and sailing of ~18000 nautical miles (~31000 K) in the Bay of Bengal and the Arabian Sea.



**Fig. 4.1** Data Buoy and Tsunami Buoy Locations

Freshening of the Northern bay by high river discharges during the South West Monsoon (SWM) and the barrier layer formation in the Bay

of Bengal as observed during North East Monsoon (NEM) 2011 were captured/retrieved and analyzed from the observations. These buoys could capture the variability in ocean properties caused by the THANE cyclone during December 2011.

A coastal buoy was successfully re-deployed at the Mahatma Gandhi Marine National park, A & N Islands and data is being provided to the Andaman and Nicobar Island Administration. A coastal buoy at the Agatti, Lakshadweep Islands was serviced. A coastal data buoy was assembled, tested and deployed off the Gulf of Khambhat for the Kalpasar project.

Tsunami buoys at TB08, TB05 and TB06 locations in the Bay of Bengal and TB12 in the Arabian sea are being maintained. A buoy with hidden INMARSAT antenna was tested to protect against vandalism and worked satisfactorily for tsunami buoys. In order to overcome the time slot constraints with INSAT communication and high power consumption in INMARSAT terminals a hybrid communication system

in tsunami buoy system with both INMARSAT and INSAT is being worked out. The field trials are expected to commence by the end of 2012.

A moored data buoy and an optical buoy was designed, tested and deployed successfully off Kavaratti under CALVAL Phase II project during December 2011. A new optical instrument under water frame was designed and fabricated for this application.

An Indigenous Buoy Data Acquisition System (IDAS) for Met-Ocean Buoy, Wave Buoy and Tsunami Buoy had been developed. The technology was transferred to an industry to supply and mass production of units. Presently, all the buoys deployed are equipped with IDAS.

For the first time, armed guards were engaged to carry out deployment operations in piracy prone area and successfully carried out 6 deployments and 7 retrievals in the Arabian Sea. Further to the efforts on awareness on vandalism, preservation and protection of buoys in India among fishers continued by organizing awareness programmes through a Deep sea going Artisanal Fishermen meet on 'Call from the Deep sea 2012' held in two places, viz. from 16th to 20th July at Thuthoor Village, Kanyakumari and subsequently at Chennai from 6th to 8th August 2012. These meetings were attended by artisanal deep sea fishers with Fisheries Experts, Fisheries Scientists, Marine and Coastal Environmentalists, Academic Scientists, Researchers, Scholars, Professionals in Information and Communication Technology, from neighbouring countries viz., Srilanka, Bangladesh, Indonesia, Malaysia, Maldives, Myanmar, Thailand and Australia.

A *Regional workshop on The Best of Practices for Instruments and Methods of Ocean Observation* was held from 19 to 21 November 2012 at NIOT Chennai. This workshop concentrated on present and future trends in ocean observation systems, methods, standards that are followed worldwide and the calibration techniques.

#### 4.1.2 Reference Weather Station

A **Reference Weather Station** was installed at ESSO-NIOT to provide meteorological data such as air temperature, relative humidity, wind speed, wind direction, atmospheric pressure and precipitation. On request through SMS the data transmission module transmit data to user by means of a global system for mobile communication (GSM) or a General Packet Radio Service (GPRS) network. The OOS Data Reception Centre can display the real-time data through a graphical user interface (GUI).

#### 4.1.3 Current Meter Arrays

Towards long term measurements of currents in the Equatorial Indian Ocean, a set of current meter array were deployed between 100 to 3000 m depth. Presently the array consists of 7 deep-sea moorings along the equator (77°E, 83°E and 93°E) and across the equator (1°N, 10S at 77°E and 10N, 10S at 93°E).

The across-equator currents was observed for the first time. The zonal velocity provides the important information on the simultaneous existence of Equatorial Undercurrent (EUC) during the first week of April 2010 across the equator from 1°N to 1°S covering the width of about 220 km. The zonal velocity structures also suggest the presence of intra-seasonal monsoonal jets occurring July-September 2010.

Large eastward transport occurs in November and during Feb-April and prevails at 1°N and 1°S during mid-March 2010. Westward transport occurs in January and May from January to mid-February, the transport at 1°N is towards west and at 1°S it is eastward. This opposite transport across the equator may be associated with the biweekly oscillation. From February to early May, eastward transport at 1°N is larger than that at 1°S. All the above results are being compiled into research publications.





#### 4.1.4 Acoustic Doppler Current Meter Profiles (ADCP)

The project aimed at enabling a forecasting system for the Indian Seas. During the year, retrieval and re-deployment of moorings off the west & east coast was carried out by organizing a number of long cruises. There were 7 recoveries and 9 deployments on the west coast and 10 recoveries and 11 deployments on the east coast. The analysis of the ADCP data from the slope off both east and west coasts shows the existence of beams, with the energy bending down considerably for intra-seasonal periods.

#### 4.1.5 Coastal High Frequency Radar

5 pairs of HF Radar Remote Stations and two Central Stations have been working satisfactorily. The general maintenance of all the sites is done at regular intervals and the problems arising at the sites are solved at the earliest possible time so as to make the entire system running continuously and data being received continuously at the central sites.

#### 4.1.6 Research Moored Array for African–Asian–Australian Monsoon Analysis and Prediction (RAMA) Buoys

The Research Moored Array for African–Asian–Australian Monsoon Analysis and Prediction (RAMA) moorings is an international research effort by various countries primarily US, and India for collection of meteorological and oceanographic data from the equatorial Indian Ocean. The RAMA moorings provide measurements from the Indian Ocean to advance monsoon research and forecasting. The two cruises are undertaken to deploy various moorings in the Indian Ocean. **The Bay of Bengal Mooring Buoy** was successfully deployed at 18°N, 89.5°E onboard ORV-Sagar Kanya voyage # SK-288.

## 4.2 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 realtime data.

#### 4.2.1 ARGO Floats

Argo profiling floats provide real-time data of temperature and salinity profiles in the Indian Ocean upto a depth of 2000m. During the period, India has deployed 24 floats in the Indian Ocean for collection and real-time dissemination of temperature and salinity data upto 2000 m depth in the Indian Ocean at periodical intervals. In total, 108 floats are active at present, out of which 9 floats are having biogeochemical Sensors. All the active floats (108) data are subjected to real time quality control and the data are being sent to GDAC and GTS. The Web-GIS based site for the Indian Argo Program is maintained. These are about 22,000 users of this site according to ARGO data centre. All the Argo data are being assimilated in the Ocean Model for providing Global ocean analysis. At the Indian Ocean Argo Region Centre (ARC), where all floats data from the Indian Ocean region are archived and distributed. Apart from a number of data products are also generated for research and operational utility.

#### 4.2.2 Drifters

66 SVP-B drifters were deployed during 2011-2012 in the Indian Ocean and data has been made available in real-time for operational weather forecast. The data collected was mainly surface ocean currents velocity, atmospheric pressure and temperature. The development of data transmitter compatible with INSAT has been initiated.

#### 4.2.3 XBT Observations

The XBT measurements on vertical temperature/salinity profiles, surface meteorology parameters and biological measurements are primarily made along the shipping route using the passengers and cargo vessel's plying in these areas. The routes include (a) Cochin – Kavaratti – Minicoy – Cochin, (b) Chennai - Port Blair and (c) Kolkata – Port Blair. Scientists participated in

over 42 XBT / XCTD voyages and collected 649 vertical temperature/salinity profiles, 1078 sea surface salinity samples and 213 phytoplankton samples. The major scientific outcome from these data are (i) documentation of intra-seasonal to inter-annual variability of upper ocean thermal fields in the South Eastern Arabian Sea (ii) understand the processes of summer intra-seasonal sea surface temperature variability along the coasts of India.

### 4.3 BIOGEOCHEMICAL PROCESSES OF THE INDIAN OCEAN

Towards addressing issues relating to understanding the carbon and nitrogen biogeochemical process and associated trace elements in the seas around India, with a view to increase understanding climate change and marine biogeochemistry, two programs viz., SIBER and GEOTRACES have been launched.

#### 4.3.1 Sustained Indian Ocean Biogeochemistry (SIBER)

The SIBER is a multi-disciplinary and multi-institutions program dealing open ocean biogeochemical studies and estuarine/coastal waters. One of the main objectives of the SIBER programme was to establish the open ocean time series stations in the Arabian Sea and the Bay of Bengal. The sampling station in the Arabian Sea is located at 17°N 68°E termed as the Arabian Sea Time Series (ASTS) station whereas in the Bay of Bengal it is located at 18°N 89°E and is termed as the Bay of Bengal Time Series (BoBTS) station (Figure 4.1). In addition to the open ocean, sampling was also done along the coastal transect, off Goa named as the Candolim Time Series (CaTS) station on a monthly basis.

Chl based measurements of phytoplankton biomass since January 2010, show variations spanning over two order of magnitude (0.06 to 5.64 mg m<sup>-3</sup>; average 1.05). Higher concentrations were generally found during post-monsoon season and vertically at ~9m. Secondary

Chlorophyll Maximum (SCM) were generally found associated with the nutricline. Phytoplankton community (> 5 µm) was represented by ca. 45 genera and was dominated by diatoms (~60%). Species of *Coscinodiscus*, *Navicula*, *Plurosigma* and *Thalassiosira* were common among the diatom community while *Ceratium* and *Gymnodium* dominated dinoflagellates. Heterotrophic nanoflagellates (HNF, predators of marine bacteria) showed increasing trend with maxima during October-December similar to bacterial counts suggesting a close coupling between these two microbial components. As usual bacterial density was ~3-4 orders of magnitude higher than that of the HNF, especially during the post-monsoon season. The organic matter derived from high phytoplankton productivity during the monsoon possibly serves as the main nutrient source to the microbial fauna during this period and also the operation of multi-step microbial food web. This is also obvious by the dominance of carnivorous copepods of order *Poecilostomatoida* and *Cyclopoida* during post monsoon. Other carnivores/filter feeders abundantly present were chaetognaths, appendicularians, cladocerans (*Penilia*).

#### 4.3.2 GEOTRACES (India)

A network of research projects being executed by a number of research and academic institutions. The objective is to map the distribution of trace elements and isotopes in the Indian Ocean and to identify the factors influencing these distributions. The activities are various stages of implementation and currently involved in acquisition and analysis of samples. One Oceanographic cruise onboard Sagar Sampada was conducted in the Arabian Sea. Samples from several water profiles were collected along 68° E transect for analysis of trace elements and their isotopes in sediments and corals of the northern Indian Ocean. Trace elements and isotopes (TEIs) play important role in the ocean as nutrients and as tracers of the contemporary and the past processes. Trace elements regulate ocean processes, such as marine ecosystem dynamics and carbon cycling. Several other trace elements





also play vital roles in cell physiology and in biochemical reactions.

#### 4.4 OCEAN INFORMATION ADVISORY SERVICES (O-IAS)

##### 4.4.1 Potential Fishing Zone Advisories

The operational generation and dissemination of multi-lingual Potential Fishing Zone (PFZ) Advisories based on Sea Surface Temperature (SST) and Chlorophyll to the fishing community has been continued. PFZ advisories for the entire Indian coast were issued. The availability of data from multiple satellites (NOAA-18, NOAA-19, METOP, MODIS Aqua and OceanSat-2 satellites) the PFZ advisories are now issued on a daily basis.



Fig. 4.2 Sector wise listing of PFZ advisories issued during 2012

##### 4.4.2 Tuna Fishery Advisories

Tuna fishery advisories in the form of maps and text information were generated and disseminated to the registered users through emails and website thrice a week. To understand the vertical and horizontal migration patterns of Tuna, 20 Yellowfin Tunas (off Visakhapatnam -8, Chennai - 5 and Lakshadweep Islands - 7) were tagged with light weight tags (~40 gm in air) during November 2011 to March 2012 in collaboration with CMFRI, FSI and ESSO-CMLRE.

##### 4.4.3 Ocean State Forecast

The ocean state forecasts were issued (waves, tides, surface currents, SST, mixed layer depth,

depth of thermocline) on a daily basis. A new service named “Ocean State Forecasts along ship routes” was made operational during this year. The location specific Ocean State Forecasting and Real-Time Information system for South Tamil Nadu districts also was made operational. This system includes the high resolution ocean wave forecasts, continuous validation using a wave rider buoy, and the dissemination of forecasts through a webpage and voice message in Tamil language through mobile phones.

##### 4.4.4 Dissemination and User interaction

To disseminate the information of on PFZ advisories and ocean state forecasts, in addition to the existing modes like Electronic Display Boards (99), information Kiosks (28 Nos.), Doordarshan, Local TV channels, FM and Community Radios, print media, emails, website and telephone / fax (97 nodes), several new modes that used the mobile applications (FFMA, mKRI-SHI), IVRS (1 service provider) and Fishermen Help-line systems (in Tamil Nadu and Andhra Pradesh) were used. Also about 25,000 users registered directly to receive the Potential Fishing Zone (PFZ) advisories and Ocean State Forecast.

##### 4.4.5 User interaction workshops and awareness campaigns

The second User Interaction Workshop was conducted on 10 May 2012. About 150 users representing the fishing community, NGOs, shipping industry, Navy, Coast Guard, Marine Police, Oil Industry, Maritime Boards, Offshore Industries, academia, media, etc. participated in the meeting. Several fishermen training programme cum workshops (62 programmes) were conducted at different locations to train the fishermen on how to use PFZ advisories and ocean state forecasts. Notable among them are “PFZ, Conservation and Policy of Marine Fisheries and Problem of Fisherman” conducted on May 2, 2012 at Digha Mohona. The Digha Fishermen and Fish Traders Association, Jadavpur University, Department of Fisheries, MPEDA, EIA and Indian Coast Guard also were part of this

programme. About 1300 fishermen participated in this training programme.

## 4.5 OCEAN MODELING

### 4.5.1 Global Ocean Data Assimilation System – Modular-Ocean-Model (GODAS-MOM)

To generate real time global ocean analysis for 5-days using GODAS, a new system, Real-time-ESSO-INCOIS-GODAS (RIG), has been set up successfully. This new system assimilate real time GTS *in-situ* temperature and salinity profiles and its ocean model component is forced by Atmospheric fluxes obtained from ESSO-NCMRWF global atmospheric model (T574L64). Reynolds-V2 Sea Surface Temperature (SST) is used to relax the model's top 5m temperature. Two new products have been generated after assimilation of *in-situ* temperature and salinity (TS) and *in-situ* temperature, *in-situ* salinity and synthetic salinity (TSS). The assimilation of *in situ* salinity and temperature improved the surface salinity and surface currents significantly.

### 4.5.2 MOM4p1

The Modular Ocean Model (MOM4p1) was used to understand the intraseasonal variability of the North Indian Ocean. The model well simulated the salinity field and reproduced the observed variability of SSS along the east and west coasts of India, the south eastern Arabian Sea and the Bay of Bengal. The mean bias of SSS and fresh water (FW) flux were only within 10% when compared with the observations. Further, the model could reproduce the strong haline stratification in the northern Bay of Bengal during winter season (Fig. 4.3).

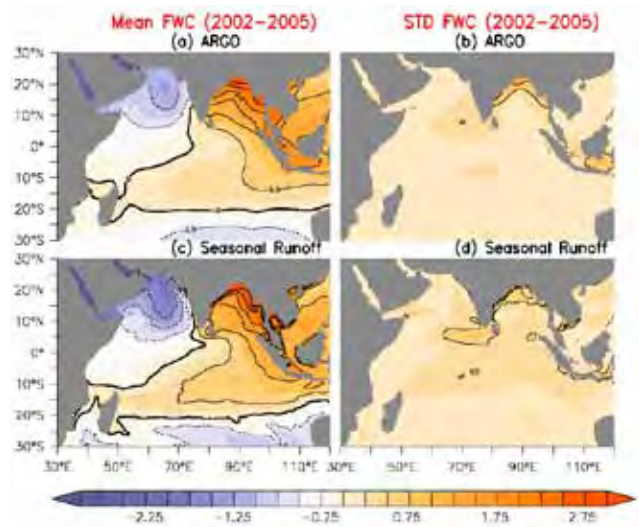


Fig. 4.3 Mean upper ocean (0-30 m) fresh water content (m) and its standard deviation (STD) from ARGO (a, b) and model simulations (c, d).

### 4.5.3 Simulating Waves Nearshore (SWAN)

SWAN40.85 has been set up around Puducherry at a spatial resolution of 250 m. The model was nested with WW III. The model was tested for different wind forcings ESSO-NCMRWF analysed, ECMWF analysed, IFREMER/CERSAT blended, ECMWF forecast. Model simulated significant wave heights ( $H_s$ ) were validated against the wave rider buoy observations at shallow water location off Puducherry.

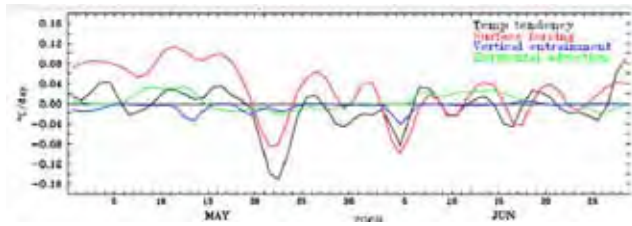
### 4.5.4 Research Findings

*An anomalous cooling event observed in the Bay of Bengal during June 2009.*

Sea surface temperature (SST) variability over the Bay of Bengal (BoB) has the potential to trigger deep moist convection thereby affecting the active-break cycle of the monsoons. Normally, during the summer monsoon season, SST over the BoB is observed to be greater than 28°C which is a pre-requisite for convection. During June 2009, satellite observations revealed an anomalous basin-wide cooling and the month is noted for reduced rainfall over the Indian subcontinent. The likely mechanisms of this cooling event using both satellite and moored buoy observations were analyzed. Observations showed deepened mixed layer, stronger surface



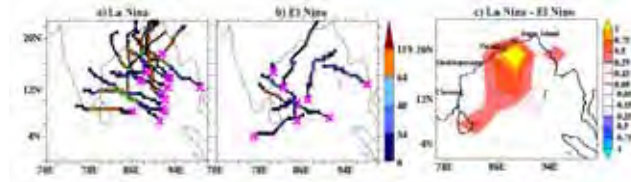
currents, and enhanced heat loss at the surface in the BoB. Mixed layer heat balance analysis is carried out to resolve the relative importance of various processes involved. The cooling event is primarily induced by the heat losses at the surface resulting from the strong wind anomalies, and advection and vertical entrainment playing secondary roles.



**Fig. 4.4** Mixed layer heat budget terms at 15° N, 90° E derived from RAMA buoy observation. The temporal evolution of the mixed layer temperature tendency (black) and contributions from surface heat forcing (red), horizontal advection (green) and vertical advection (blue)

#### *Influence of ENSO on post monsoon tropical cyclone activity in the Bay of Bengal*

The influence of El Niño/Southern Oscillation (ENSO) on the tropical cyclone activity in the BoB during the primary tropical cyclone peak season (October-December) was investigated. During 1993-2010, the La Niña and negative Indian Ocean Dipole regime, the number of extreme tropical cyclone cases (wind speed > 64 kt) increased significantly in the BoB. The existence of low level cyclonic (anticyclonic) vorticity, enhanced (suppressed) convection, and high (low) tropical cyclonic heat potential in the BoB provided favourable conditions for the tropical cyclone activity under La Niña (El Niño) regimes together with weak vertical wind shear and high SST. The favourable location of tropical cyclone genesis shifted to the east (west) of 87°E in the BoB during La Niña (El Niño) regime due to the variability in convective activity. Under La Niña regime, convective activity and cyclonic vorticity field associated with positive phase of the Madden-Julian Oscillation (MJO) that amplifies the background tropical cyclone conditions and it leads to enhancement of tropical cyclone formation.



**Fig. 4.5** Tropical cyclone activity in the BoB under (a) La Niña and (b) El Niño regime during primary tropical cyclone peak season for the year 1993-2010 (color bar indicates the wind speed in knots). (c) Difference of Accumulated Cyclone Energy (104 kt<sup>2</sup>) per year in El Niño and La Niña years

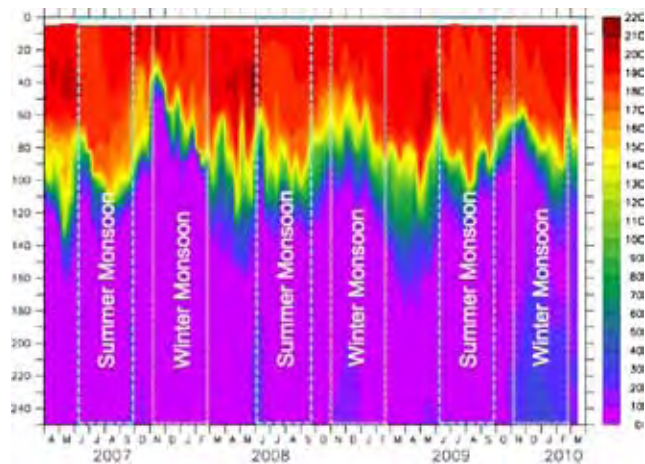
#### *Weakening of spring Wyrтки jets in the Indian Ocean during 2006-2011*

The HYCOM simulations and observations were used to understand the dynamics of spring Wyrтки Jet (WJ) in the Indian Ocean. During 2006-2011, the jet weakened and even reversed as a westward flow in 2008. The weakening coincided with uniformly high sea-level and positive east-west gradient of sea level anomalies along the equatorial Indian Ocean during the month of May. The weak jets occurred in conjunction with the latitude of zero zonal wind. During these years, the latitude of zero zonal wind moved to equator resulting in weaker than normal zonal winds along the equator. Further during 2006-2011, the normal tendency of westward propagation of the annual harmonic mode switched to eastward propagation, coherent with the wind forcing. The weak Wyrтки Jets are mainly associated with the semi-annual harmonic rather than the annual harmonic component of the zonal current. The variance explained by the semi-annual harmonic was reduced to less than half (30-40%) at the core of the WJ in 2006 and later years, in comparison to the earlier years when it stood at 70-80%.

#### *Oxycline Variability in the central Arabian Sea: An Argo-Oxygen study*

The observations and model data suggested that there is a decline in the concentration of dissolved oxygen and the oxygen minimum zones have expanded over the past 50 years in the tropical Indian Ocean. The Arabian Sea and the BoB experienced severe oxygen depletion

at the subsurface layer (~150-1000 m). The dissolved oxygen data from Argo float (WMO-ID 2900776) confirmed the presence of perennial subsurface oxygen minimum zone in the central Arabian Sea with large variations and strong seasonality in oxycline depth. The depth of oxycline varied semi-annually, shallowing (~60 m) during November-January and deepening (~120 m) during April-May. The shoaling during early winter monsoon is possibly due to the westward propagating upwelling Rossby waves.

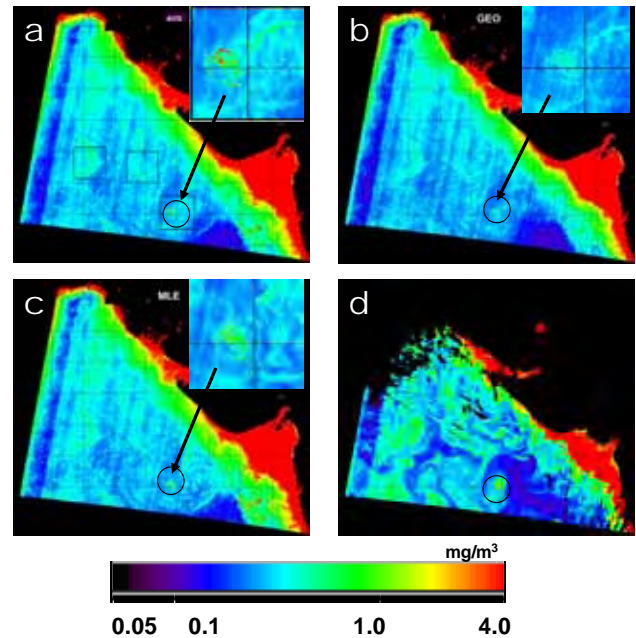


**Fig. 4.6** Time series of dissolved oxygen ( $\mu\text{-mol/kg}$ ) in the upper 250 m obtained from the oxygen sensor on Argo float (WMO ID 2900776)

#### 4.6 OCEAN COLOUR RESEARCH

##### *Weekly composites of IRS-P4 OCM chlorophyll*

To select a suitable binning algorithm to produce weekly and monthly composites of chlorophyll-*a*, three averaging algorithms—arithmetic mean (AVG), geometric mean (GEO) and maximum likelihood estimator (MLE) were experimented with atmospherically corrected and geo-corrected IRS P4-OCM data. The AVG algorithm was found to suit the best compared to the other two algorithms. The weekly composite data generated using AVG algorithm for January 2003 to April 2006 is available on INCOIS-LAS server (<http://las.incois.gov.in/>).



**Fig. 4.7** Monthly average of Chlorophyll-*a* using three averaging methods (a) AVG, (b) GEO, and (c) MLE were calculated for February 2004 and (d) for the day of 24 February 2004.

##### *Observed variability of chlorophyll-a using Argo profiling floats in the southeastern Arabian Sea.*

One year data (March 2010 to March 2011) obtained from an Argo float equipped with biogeochemical (chlorophyll-*a*, backscatter at 700 nm, and oxygen profiles), temperature and salinity sensors, which was deployed in the southeastern Arabian Sea (11°N, 68°E), are used to examine the observed variability of chlorophyll-*a* and the role of upper ocean processes in its regulation. The analysis revealed that, in addition to entrainment of nutrients from rich subsurface water in the near surface layer, vertical fluxes from the subsurface chlorophyll maximum also contribute significantly to mixed layer blooms. Further, availability of light plays an active role in the mixed layer bloom, particularly during the summer monsoon season.

The *in situ* biological and physico-chemical data generated at one time-series station off the Rushikulya Estuary, Odisha was analyzed. Time series measurement of the Odisha Coast to understand the distribution of chlorophyll-*a*



(Chla) and physico-chemical parameters at spatio-temporal scale and to identify the impact of physico-chemical parameters on distribution of Chla. The data set included five stations, sampled monthly, from February 2010 to January 2011, at seven depths. The physico-chemical parameters analyzed were temperature, inorganic nutrients (nitrite, nitrate, ammonium, phosphate and silicate), DO and pH. The multivariate statistics and factor analysis applied to datasets, uncovered three underlying factors each during the pre-monsoon, monsoon and post-monsoon seasons

influencing the water to the extent of 75.02 %, 67.33 % and 66.37 % respectively. The analysis suggested that the Chla exhibited strong positive correlation with dissolved oxygen and it is negatively correlated with salinity. There was wide spatio-temporal variability in Chla concentration that varied from 0.11 to 10.05 mg m<sup>-3</sup>. The highest concentration was recorded during the pre-monsoon season. The study indicated that the Rushikulya Estuary adds sufficiently well-oxygenated, nutrient-rich water to the coastal region.

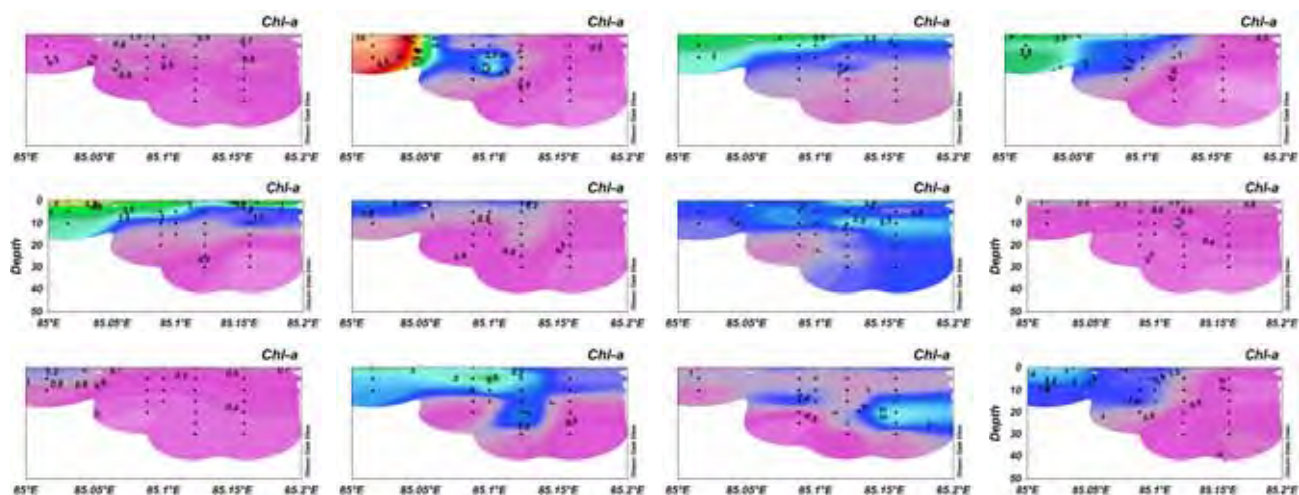


Fig. 4.8 Spatial distribution of Chla off Rushikulya Estuary during the month February, March, April, May (top panel), June, July, August, September (middle panel), October, November, December, 2010 and January 2011 (bottom panel)

## 4.7 COASTAL GEOSPATIAL APPLICATIONS

The maps of Coastal Vulnerability Index (CVI) for the entire country was prepared using seven basic parameters - Shoreline Change, Geomorphology, Coastal Regional Elevations, Coastal Slope, Sea-level Change Rate, Mean Significant Wave Height and Tidal Range. A CVI atlas comprising 157 maps on 1:100000 scales was prepared for nine coastal states and Islands.

### 4.7.1 Coral Bleaching Alert System (CBAS)

A satellite based Coral Bleaching Alert System (CBAS) generated 92 advisories during Jan-Sept 2012 based on the HotSpot, Degree of Heating Weeks and time-series plots.

## 4.8 OCEAN DATA MANAGEMENT & DISSEMINATION

ESSO-INCOIS is the central repository for the oceanographic data in the country. Further, ESSO-INCOIS serves as the National Argo Data Centre and the Argo Regional Data Centre for the Indian Ocean Region.

### 4.8.1 In-situ data reception and processing

During the period, the data centre sustained and strengthened the real-time data reception, processing, quality control of surface meteorological and oceanographic data from wide variety of ocean observing system such as Argo floats, moored buoys, drifting buoys, wave rider buoys, tide gauges, wave height meter, ship mounted

autonomous weather stations and HF radars. Further, surface met-ocean data has been disseminated to various operational agencies in the country through email/web-site/ftp in near-real time.

In addition to the data received from ocean observing systems [moored buoys, RAMA buoy, drifting buoys, ship mounted AWS, wave rider buoys and HF Radar] in real-time, the data centre also received data from various agencies in delayed mode and the details are listed below:

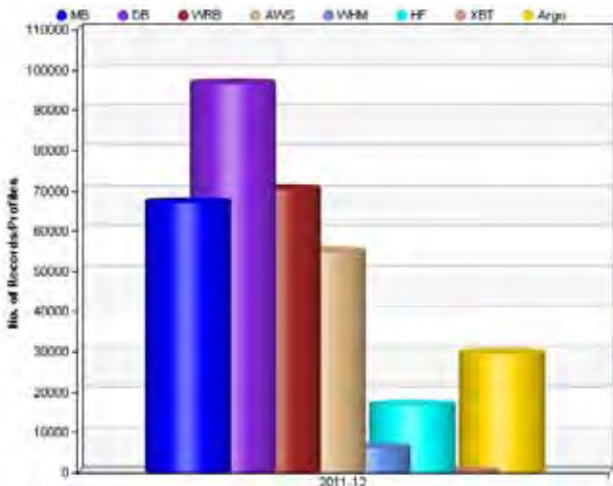


Fig. 4.9 Data growth during the period April 2011 - March 2012

A climatic atlas of Mixed Layer and Sonic Layer for the Tropical Indian Ocean was prepared comprising approximately 1,11,000

profiles from Argo floats and other sources. A software application also was developed for viewing the Mixed Layer and Sonic Layer Depth

The number of users accessing the INCOIS web pages increased compared to previous years (Fig. 4.10).

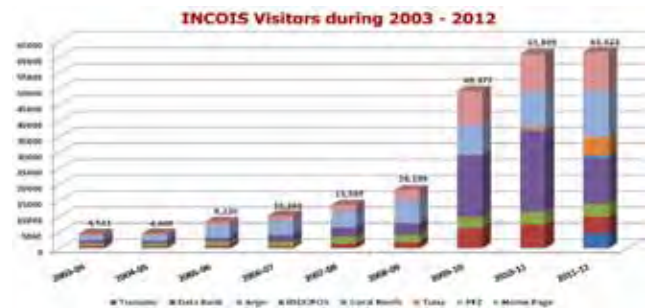


Fig. 4.10 Number of users accessed the web pages since 2003

#### 4.8.2 Indian Tsunami Early Warning Centre (ITEWC)

##### Operational Services of ITEWC

The Centre recorded 39 earthquakes of magnitude  $M > 6.5$  during 1 January, 2012 - 30 September, 2012 of which, tsunami advisories were issued for 4 major earthquakes occurred in the Indian Ocean. Model simulations were analyzed for all these events before issuing the tsunami bulletins. Details of the earthquakes and tsunami bulletins issued are listed in Table-4.3

Table 4.3 Details of the tsunamigenic earthquakes recorded at ITEWC

S. No	Date & Time (UTC)	Magnitude (Mw)	Region	ITEWC Bulletin
1	10-January-2012 18:36	7.3	Off West coast of Northern Sumatra	Tsunami Watch for Indira Point in A & N Islands
2	11-April-2012 8:38	8.5	Off the West coast of Northern Sumatra	<b>Warning:</b> Indira Point and Komatra & Katchal islands of Andaman & Nicobar; <b>Alert:</b> Andhra Pradesh, TamilNadu, Kerala, Orissa, few of the A&N Islands and Lakshadweep Islands <b>Watch:</b> Rest of the Indian mainland regions
3	11-April-2012 10:43	8.2	Off the west coast of Northern Sumatra	<b>Alert:</b> Andaman & Nicobar Islands, Andhra Pradesh, and Tamil Nadu; <b>Watch:</b> Orissa, Kerala, Lakshadweep, Karnataka, and Goa
4	03-Septmber-2012 18:23	6.6	South of Java, Indonesia	No tsunami threat for India



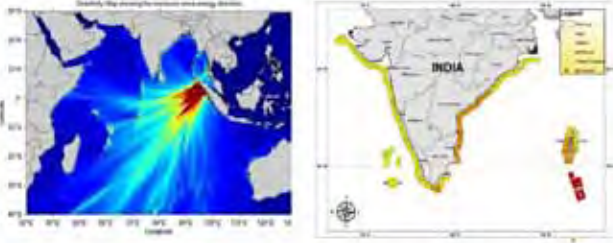


Fig. 4.11 Directivity and threat Maps of Off West coast of Northern Sumatra of Magnitude 8.5

All the systems, *i.e.* automatic location of earthquake, estimation of tsunami arrival time and height, and dissemination of messages through SMS, email, Fax, GTS and Website, as well as bottom pressure recorder and tidal gauges to record sea level changes have performed as envisaged. It may also be noted that, for both these events, ESSO-INCOIS disseminated regional tsunami advisories to 21 countries in the Indian Ocean region as part of its Regional Tsunami Advisory Service Provider (RTSP) operations.

#### Communications network

Nine metre INSAT hub station has been established at ESSO INCOIS, Hyderabad and ESSO-NCMRWF, Noida to receive real time seismic and GPS data from 90 stations that are part of the National Integrated Seismic and GPS network. The hub stations will operate with two different INSAT satellites, each supporting half of the VSAT's.

INSAT UHF transmitter was integrated with drifting buoy and wave rider buoy to support the real time reception of data.

A one-day tsunami awareness workshop was conducted for the Reliance Industries Ltd (RIL) based on their request at Mumbai held on 24 May, 2012.

## 4.9 MARINE LIVING RESOURCES

Marine Living Resources Programme (MLRP): Include Monitoring and Modelling of the Marine Ecosystems (MMME) mapping of the Deep Sea and Distant Water Fishery Resources (DDWFR), an Integrated Taxonomic Information

System (ITIS) and promoting research in the field of Marine Living Resources.

#### i) Monitoring and Modelling of Marine Ecosystems (MMME)

During 2012-13, a total of seven hydrographic surveys onboard FORV Sagar Sampada and 5 surveys onboard hired boats were undertaken. Spring Intermonsoon (Mar-May 2012) was characterised by the annually recurring green *Noctiluca* (*N.scintillans*) blooms in the North East Arabian Sea. Surface distribution of chlorophyll *a* during early March showed broad variations from  $0.56 \text{ mgm}^{-3}$  in the non-bloom open ocean regions to  $59.2 \text{ mgm}^{-3}$  in the *Noctiluca scintillans* bloom regions of the Northern Arabian Sea. Intense bloom of *Noctiluca scintillans* along with diatom aggregations were observed along open ocean regions of  $21^{\circ}\text{N}$  (cell density of *N. scintillans*  $37 \times 10^5 \text{ cell L}^{-1}$ ). In the coastal waters the surface chlorophyll *a* was considerably low ( $1.8 \text{ mg m}^{-3}$  at  $21^{\circ}\text{N}$  and  $0.9 \text{ mgm}^{-3}$  in  $22^{\circ}\text{N}$ ). Further south, along  $17^{\circ}\text{N}$ , the surface chlorophyll *a* was  $av 0.12 \pm 0.1 \text{ mgm}^{-3}$  (Fig. 4.12).

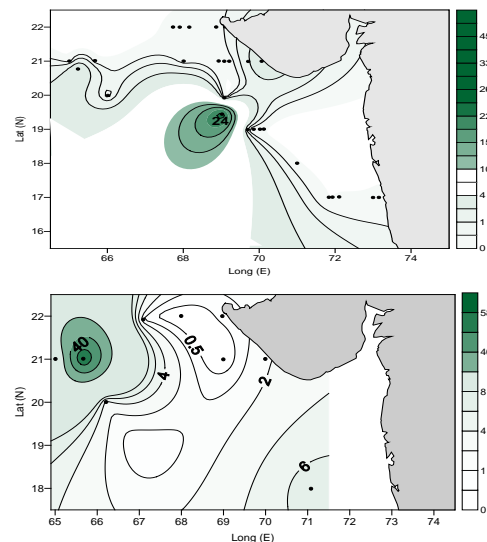


Fig. 4.12 Distribution of surface chlorophyll *a* ( $\text{mgm}^{-3}$ ) concentrations during early March-April 2012

Long-term trend in Oil-Sardine fishery was observed to have a thirty year cyclicity corresponding to the wet and dry epochs in summer monsoon rainfall. Summer Monsoon

(Jun-Sep) 2012 was characterised by delayed monsoon. Number of fish eggs and larvae were considerably low during Jun-Jul 2012, which suggests that spawning of pelagic fishes might have been effected due to the delayed monsoon.

### ii) Deep-Sea and Distant water Fishery

During the period two fishery cruises were carried out onboard FORV *Sagar Sampada*. A total of 28 trawling operations were carried along the continental slope region of the Indian EEZ. Catch Per Unit Effort (CPUE) recorded was 31.14 kg/h, 112.9 kg/h/hr and 153kg/h from West Coast, East coast and Andamans, respectively. Record catch of deep sea fish *Lamprogrammus* sp (Family: Ophidiidae) obtained from the east coast of India (10° 58'N; 80°19'E) with CPUE of 540 kg/h. The dominant size range was 55 -59cm. A new four panel 45m myctophid trawl was designed and two prototype trawls were fabricated for experimental operations in the depth range of 100-1000 m, for myctophid surveys. The occurrence of Garman's lantern fish *Diaphus garmani* (family: Myctophidae) was reported for the first time from the Indian EEZ (Fig. 4.13).



Fig. 4.13 *Diaphus garmani*

### iii) Marine Biodiversity

Ocean Biogeographic Information System (OBIS) is an international activity coordinated by the IOC to develop a web based information system on the distribution of marine species in world oceans. The ESSO-CMLRE is the recognized regional node for the Northern Indian Ocean (IndOBIS). At

present the IndOBIS has approximately 60, 000 records of species mainly from the Indian EEZ. During the year, approximately 5000 records of species were added to the IndOBIS.

A total of 375 species of macrofauna belonging to 4 groups, polychaetes (241 species), crustaceans (77 species) and molluscs (41 species) were recorded from the east coast shelf. 8 species of polychaetes, 7 species of brachyuran crabs and 4 species of amphipods from the southeast coast of India, 20 species of polychaetes from the Andaman waters and 116 species of free-living marine nematodes were found to be new records for the region (Fig. 4.14).

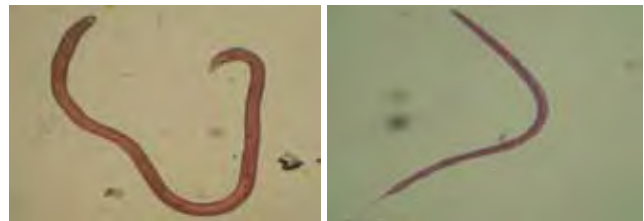


Fig. 4.14 New records of free-living marine nematodes

Five new records of deep sea fishes such as: *Pycnocraspedum squamipinne*, Alcock, 1889 (620m, south west coast of India - 10°04. 26'N ;75°37.10 E), *Aphanopus microphthalmus* Norman, 1939 (1000m, south west coast of India; Lat 8° 36'N;Long.76°17'E), *Hoplostethus leiogaster melanopus* & *Hoplostethus leiogaster rubellopterus* from SW coast, Andaman legskate *Cruriraja andamanica* Lloyd, 1909 from Andaman waters were reported (Fig. 4.15).



Fig. 4.15 *Cruriraja andamanica* Lloyd, 1909



Sightings of killer whale *Orcinus orca* was recorded for the first time from the Andaman waters (Fig 4.16). *Balaenoptera musculus* (blue whale) was recorded on one occasion. High frequency of occurrence of baleen whale (*Balaenoptera* sp) was observed in the southern Sri Lankan waters.



Fig. 4.16 Killer whale *Orcinus orca* sighted in the Andaman waters

#### iv) Marine Living Resources - Technology Development

Commercial scale production and marketing of 4 species of clown fish and one species of Damsel fish was initiated during the year. During the first half of the year 25000 juvenile fishes were marketed from the hatchery located in Agatti, Lakshadweep Islands. The technology for the production of black pearls from the black lip pearl oyster *Pinctada margaritifera* was perfected in the hatchery unit at Andamans. Two black pearls with a golden hue colouration were produced on experimental basis (Fig. 4.17).



Fig. 4.17 Ornamental fish culture hatchery centre at Agatti and Blacklip pearls produced in Andaman and Nicobar.

## 4.10 COASTAL RESEARCH

### 4.10.1 Coastal Quality Monitoring

Monitoring the health of coastal seas is highly essential for fisheries and other human

related uses. Data on twenty five environmental parameters including physical, chemical, biological and microbiological characteristics of water and sediment at twenty locations are being collected with the help of seven R&D institutions in the 0 - 5 km sector of the coastline of the country. The findings pertaining to coastal water quality are as given below:

**Gujarat:** The monitoring was carried out at Vadinar (Apr'12) and Hazira/Tapi estuary (Apr'12, Oct'12). Water quality of is observed to be good with normal values of DO (5-8mg/l) and nutrients. Water quality off the Tapi Estuary shows build up of nutrients and low DO, indicating that the estuary is in stress condition in premonsoon. However, in monsoon, though nutrients were high in estuary, DO was normal (4-7mg/l), indicating flushing due to rainfall. The sea off Hazira is under the influence of the outflow from the Tapi estuary.

**Maharashtra:** The monitoring was carried out at Mumbai (Thane, Worli), Ratnagiri and Malvan (Sep/Oct'12). Levels of nutrients were observed to be high at the Thane creek ( $\text{NO}_3$ : 9-44  $\mu\text{mol/l}$ ). However water quality off Mumbai, showed normal DO and moderate levels of nutrients. Water quality off Ratnagiri and Malvan is observed to be good with normal values of DO (5-8mg/l) and nutrients.

**Karnataka:** The monitoring was carried out at Mangalore (May'12). DO (3-7 mg/l) and levels of nutrients were in normal range. Higher incidence of pathogenic bacteria (SFLO: NG-2840 CFU/ml) indicates contamination due to domestic sewage and riverine discharge.

**Kerala:** At Kochi (May'12), moderate DO (2-7 mg/l), nutrients (nitrate: 9-19  $\mu\text{mol/l}$ ) and significant high levels of pathogenic bacteria (SFLO: NG-16000 CFU/ml) indicate contamination due to domestic wastes.

**Lakshdweep Islands:** At Kavaratti (Apr'12), DO (4-8 mg/l) and nutrients were in normal range. However, levels of pathogenic bacteria (SFLO: NG-1240 CFU/ml) indicate contamination due to domestic wastes.

**West Bengal:** Coastal waters off Sandheads and the Hooghly estuary were monitored during Jul'12. High levels of DO (6-8 mg/l) and moderate levels of nutrients indicate good water quality. Moderate levels of pathogenic bacteria at Sandheads (SFLO: 15-650 CFU/ml) indicate contamination due to domestic sewage. However at the Hooghly estuary levels of bacteria were relatively less (SFLO: 5-215 CFU/ml).

**Orissa:** The coastal waters of Paradip are characterized by continued high DO values (6-7 mg/l) in Jul'12. Levels of nutrients were within normal range. However, moderate levels of pathogenic bacteria (SFLO: 5-155 CFU/ml) indicate contamination due to domestic sewage.

**Andhra Pradesh:** The monitoring was carried out at Visakhapatnam and Kakinada during Jun'12. Levels of nutrients were higher at the Visakhapatnam harbour than the Kakinada Bay, indicating terrestrial organic load. However, water quality off Visakhapatnam and Kakinada were observed to be within normal range indicating fairly good water quality.

**Tamil Nadu and Puducherry:** The coastal waters of Ennore, Puducherry and Tuticorin were monitored (May/Jun'12 and Sep'12). Levels of DO, BOD and nutrients were within normal range. However, significantly high levels of pathogenic bacteria were observed at many shore locations, indicating contamination due to domestic sewage. Heavy metals in water at the Ennore were within normal range.

**Andaman & Nicobar Islands:** Coastal water quality at Port Blair and Wandoor during May'12, is observed to be good with normal levels of DO (5-7mg/L) and nutrients. However high levels of pathogenic bacteria was observed at the Junglighat bay.

**Database :** Data collected under COMAPS programme over the years have been compiled and organized into a database. Databases for Sandheads, Hooghly estuary, Saptamukhi, Subarnarekha, Digha, Haldia Port, Diamond harbor, Port Blair, Andaman & Nicobar islands were completed. GIS based database on marine

pollution was completed for Kochi, Vishakhapatnam, Koodankulam and Veraval.

**Marine Microbial Reference Facility (MMRF):** 138 isolates were lyophilized and identification of 158 bacterial isolates is under progress.

#### 4.10.2 Oil Spill Modelling

The Oil spill trajectory modelling and sensitivity mapping is aimed to understand the local habitat specific issues related to oil spill risks and to identify potential resources / areas at risk and priority identification of most sensitive coastal resources. The local hydrodynamic models were set up for Chennai, Kakinada, Visakhapatnam, Kanyakumari, Kochin, Kavaratti, Goa, Mumbai, Dahanu, Hazira, etc to generate oil spill trajectory scenarios. Performance of local hydrodynamic models were compared with field measured data. The model outputs showed very good comparison of measured and simulated results. After successful validation of hydrodynamic models, the same was coupled with the MIKE 21/3 oil spill model to compute oil spill trajectories for different environmental conditions including oil characteristics, bathymetry, oceanographic and meteorological parameters, etc. The model was run for predicting fate and trajectory of oil spilled with the actual wind data and simulation was carried out for 48 h of the oil spill about 100 m<sup>3</sup> of Crude oil off Chennai.

GIS-based information system with two scenarios for three seasons set in GNOME were used for risk assessment of coastal resources. The scenarios were set in GNOME with different seasons and spill types, for the risk assessment of oil impact on the coast. Model output from GNOME was imported into GIS and overlaid on the resource information and the risk was calculated based on the proximity of oil from the coast. The oil transport, weathering and oil thickness computation provide a way to analyze the environmental risks to the marine as well as coastal ecosystem due to spill. The oil slick movement and areal coverage (km<sup>2</sup>) of the





slick were calculated in GIS to analyze possible impact in each scenario. Oil Spill Sensitivity and Risk Assessment maps of the study areas, have been prepared.

#### 4.10.3 Marine Ecotoxicology

Toxicity studies (acute/chronic) are carried out with different marine organisms, to prescribe seawater quality criteria, for protection of marine organisms, from harmful effects of various pollutants including heavy metals. Draft Seawater Quality Criteria (SWQC) for heavy metals Cadmium, Copper, Mercury, Zinc and Lead for Ennore and adjacent coastal waters of Chennai was derived and a revised proposal was submitted to the Central Pollution Control Board (CPCB) for evaluation for considering notifying as Primary Water Quality Criteria for coastal uses. Draft SWQC for Arsenic, Chromium and Monocrotophos is under preparation. Considering such criteria for ecologically sensitive area, for e.g. Coral reef ecosystem of the Gulf of Mannar, toxicity studies for Cadmium, Copper, Mercury were completed. The results are under process to derive the safe limits of the chemicals. Toxicity experiments for other metals like Zinc, Lead and Arsenic are under progress.

#### 4.10.4 Shoreline Management

Coastal processes and/or manmade structures along the coastline cause coastal erosion/accretion. Aspects such as nearshore bathymetry, currents, waves, sediment transport, shoreline mapping, coastal morphology, beach profiles, impact of mudbanks, etc. are studied for different seasons to analyse the cause of erosion/accretion and to recommend best possible interventions in the form of Shoreline Management Plans (SMPs) to manage the coast.

##### Kerala coast

A comprehensive analysis of erosion problem for 3 locations, namely Muthalapozhi, Vadanappally and Kozhikode was carried out to understand the issue and prescribe effective coastal protection measures based on field observations

and numerical model studies. The construction of breakwaters at Munambam has caused deposition of beach sediment on north side of north breakwater for about 3 km. The eroding sectors along the Munambam - Chettuwa coast are Vadanappally, Kara and Snehatheeram where seawalls are constructed to protect the coast. It is recommended that there need not be any intervention along the Kara sector. Constant monitoring of mudbank formation, its migration and dissipation has to be continued. The major eroding site along the Kozhikode coast extends from Beypore breakwater to south of Kozhikode beach. The construction of breakwaters at Beypore, stabilization structures at tidal inlet at Kallai and mining of sand from Puthiyappa are major factors contributing to erosion. The necessary recommendations have been made for implementation by the state government.

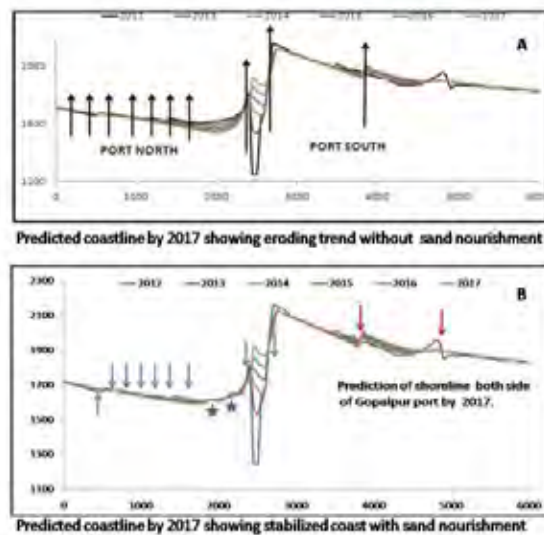
##### Karnataka Coast

The study carried out for 4 sites along Karnataka coast (Devbhag: Karwar, Pavinkurve, Honnavar, Kundapur Kodi, Kundapur, Uliargoli Padukere, Malpe revealed a slow rate of sediment accretion at the Devbag beach. The erosion is noticed along the river mouth. In the case of Pavinkurve beach, the annual gross and net LSTR are  $0.38 \times 10^6$  and  $0.25 \times 10^6 \text{ m}^3$  and at Kasargod it is  $0.43 \times 10^6$  and  $0.38 \times 10^6 \text{ m}^3$ . The Sharavathi River mouth shifted significantly (almost 1220 m) towards north during 1980-1998. In order to control erosion of the river mouth and Pavinkurve, revetments need to be made on river bank similar to the protection measures at Malpe. Annual gross LSTR estimated with Kamphius formulae gave value of  $3.1 \times 10^5 \text{ m}^3$ , which is more acceptable as it includes influences of beach slope, sediment size and peak wave period. Estimated annual net LST rate for the region is  $1.6 \times 10^5 \text{ m}^3$  based on Kamphius formulae. The annual net transport at Padukare was  $0.33 \times 10^6 \text{ m}^3$  northerly. Annual gross value is  $0.35 \times 10^6 \text{ m}^3$ . The necessary recommendations have been made for implementation by the state government.

### Gopalpur coast

The study investigated a 25km stretch of the coastline and assessed impact of development of an all weather port at Gopalpur on the neighboring coastline. The coast undergoes a variety of seasonal wave climate and experiences seasonal intermittent coastal erosion and deposition phases. The beaches within 1.5 to 2.0 km on both sides of the port are severely affected. The shoreline data for olive ridley rookery beaches near the Rushikulya River indicate that the beaches on the north side of the river mouth are highly dynamic and altered drastically due to shifting of the river inlet position on yearly basis.

Numerical simulation indicated that sediment nourishment at the rate of  $3111 \text{ m}^3 / \text{day}$  per km length may stabilize the coast within 5 years of time period (Fig. 4.18). It was recommended that sand nourishing at the shore face in between the groins is the best viable option to manage the erosion of the Gopalpur coast.

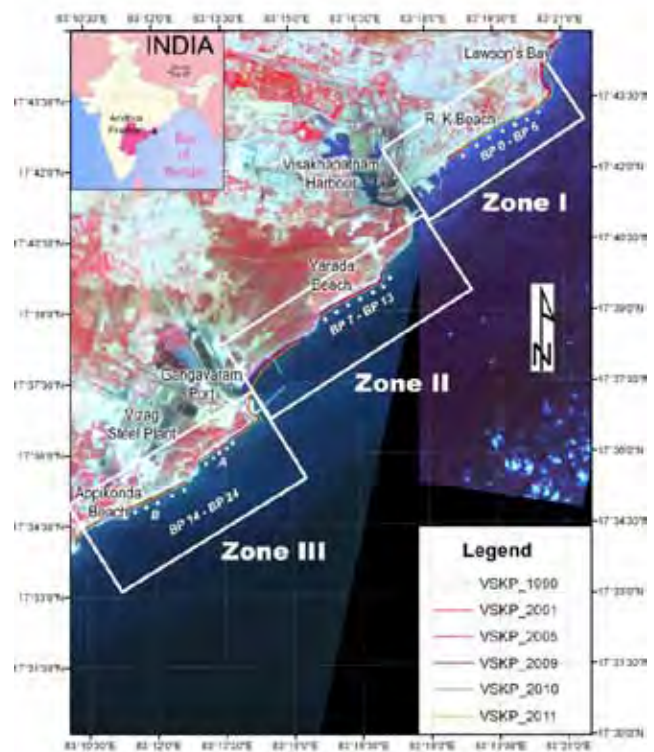


**Fig. 4.18** Simulation for 5 yrs (A) Coastline showing erosion without nourishment (B) coastline stabilized with sand nourishment (Coastline of June 2012- predicted June 2017). Arrow marks tentative position of ongoing constructions perpendicular to shoreline.

### Gangavaram-Visakhapatnam Coast (Andhra Pradesh)

High resolution IRS satellite data were processed and shoreline positions were extracted

for the years 2005, 2009, 2010 and 2011. The Survey of India (SOI) toposheets have been used for the extraction of shorelines for 1990 and 2001. Decadal shoreline changes (1990-2001 and 2001-2011) have been examined. Short-term shoreline changes prior to and after the construction of the Gangavaram port have been critically examined (Fig. 4.19).



**Fig. 4.19** Location map of study area (derived from mosaic of LISS-IV Satellite imageries - 2005 & 2009, coloured lines indicate respective shoreline during the study period) BP 0 to BP 25 represents Beach profiles.

Shoreline change during 1990-2001 reveals that the southern beaches of Zone I and III have undergone deposition at the rates of 5-8 m/year and 4-6 m/year, respectively; whereas in Zone II, most of the beach has undergone erosion. But during the next decade (2001-2011), all the beaches have shown severe erosion with -5 to -12m/year at Zone I, -10 to -13 m/year at Zone II and -10 to -12 m/year at Zone III. It is interesting to note that the beach to the north of Zone I is relatively stable with annual rate of shoreline changes ranging between 1 to -2 m/year.



### Functional Performance of Structures (Groins) along the North Chennai Coast:

Under this project, monthly monitoring of shoreline and beach profile along the North Chennai coast is being carried out. Sediment traps were deployed to estimate the quantity of sediment deposited in between groins. The total average sediment transport is about  $3.78 \times 10^4 \text{ m}^3$  and the net direction of transport is towards North. Around 0.55m of seabed is raised due to sediment deposition in between groins. Modelling on near shore wave transformation and near sediment transport is being carried out.

#### 4.10.5 Ecosystem Modelling for the Chilika Lake

The collection and estimation of river discharge and nutrient inputs from point sources, temporal/spatial variations (at 35 locations) of physico-chemical characteristics, evaluating

phyto/zooplankton distribution and other biota including microphytobenthos, assessing aquatic weeds (sea-grasses, micro-algae and free-floating), understanding water column-sediment nutrient fluxes has been carried out.

A Coupled Hydrodynamic-ecosystem model was configured for the Chilika lagoon. Fig 4.20 represents the validation of model output on spatio-temporal distribution of salinity.

Totally thirty-eight (38) coefficients relating to water quality, bio-geo-chemical parameters required for ecosystem modelling have been derived experimentally in field/laboratory conditions. The model is able to simulate the spatial and temporal variation of phytoplankton, nutrients and other water quality constituents in response to the variation of boundary and weather condition. Fig. 4.21 represents the simulated primary productivity ( $\text{g m}^2 \text{d}^{-1}$ ).

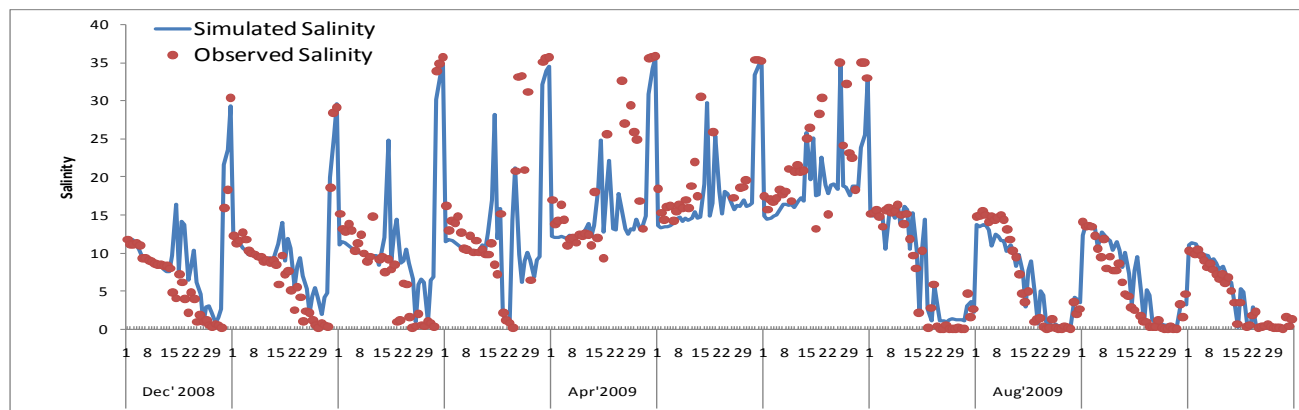


Fig. 4.20 Validation of salinity at exact time and station of observation.

### 4.11 DRUGS FROM SEA

During this period, collection data records of 383 marine organisms were submitted at the National Repository (National Institute of Oceanography, Goa). In addition, 198 new and 214 repeat marine samples from various centers were received at the Central Drugs Research Institute (CPRI), for the specified bio-activities, among them 235 were crude extract, 149 were fractions and 2 were pure compounds. Data of

New and repeat samples submitted were entered in the ESSO-MoES web-portal. 36 new hits (15 for Malaria, 2 for Leishmania, 5 for Trypanosoma, 1 for TB, 2 for Fungal, 4 for Hyper-glycaemic and 7 for Dislipidaemia) were identified during this reporting period. 29 repeat samples of identified bio-activity were received for revalidation.

Total samples submitted by various centers for bio-evaluation at the CDRI, Advanced Centre for Treatment, Research and Education in Cancer (ACTREC), Dr. ALM. P.G. Institute of Basic Medical Sciences (ALM) and National Institute

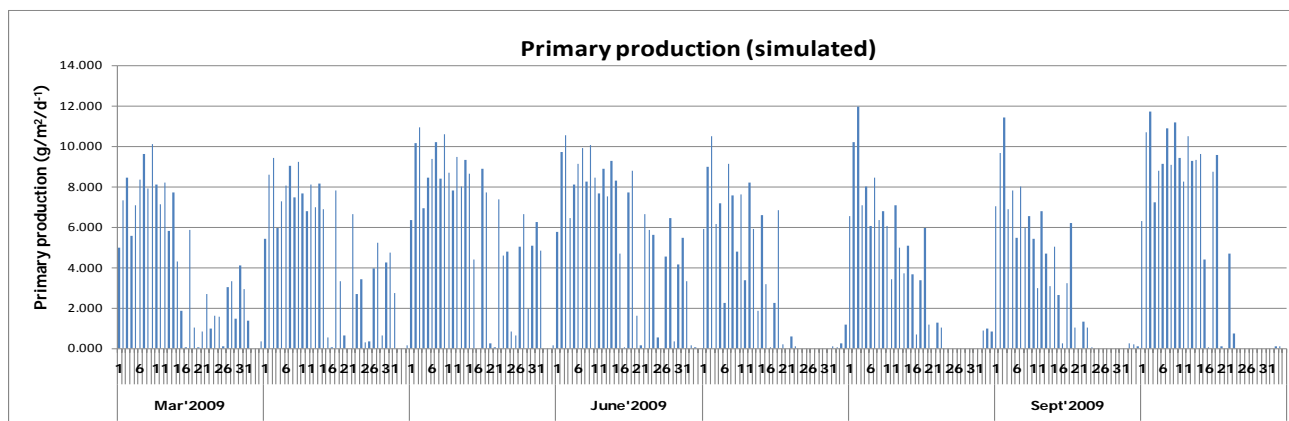


Fig. 4.21 Simulated Primary productivity (g/m<sup>2</sup>/d-1) at the time and station of observation.

of Ocean Technology (NIOT) were 13168, 13591, 1041 and 945 respectively. CDRI, ACTREC and NIOT identified 151, 54 and 81 samples were promising for further evaluations and have considered as initial hits, however no samples was found active at ALM. 46 marine samples were collected again and resubmitted which also included few fractions to confirm the bioactivity at the CDRI, while 54 samples including fractions and pure compounds have been confirmed for the anti-cancer activity at ACTREC. The toxicity studies on CDR-134-F194, an anti-hyperglycemic cum anti-dyslipidemic fraction

of CDR-134, Genotoxicity studies, single dose and sub-acute toxicity of CDR-267-F018 (Anti-dyslipidemic cum anti-hyperglycemic fraction), secondary screening of CDR-134-F194 & CDR-267-F018 for anti-diabetic and associated pathologies, single dose and multiple dose Phase I Clinical trial studies with anti-diabetic preparation CDR-134-D123 have been completed. This anti-diabetic product has been licensed to TVC-SKY SHOP LIMITED, THANE 401104 for fast track marketing. Monograph of CDR-134-D-123 has been submitted to Ayush for its inclusion in Extra Ayurvedic Pharmacopia.



# OCEAN TECHNOLOGY

Exploration and harnessing of ocean resources calls for development of a variety of complex multidisciplinary ocean technologies and systems. The major aim of Ocean Technology program is to develop reliable indigenous technology to address various technology issues associated harvesting of non-living and living resources from Ocean. Various technology developmental activities are being carried out for harnessing the resources from oceans in sustainable manner, the details of which are provided below:

## 5.1 COASTAL ENGINEERING

### 5.1.1 Engineering Investigations for the 'Kalpasar' Project

The geophysical, geotechnical, topographic and bathymetric survey of 24000 km line for the dam corridor has been completed and a suitable dam axis has been identified (Fig.5.1 and 5.2). Numerical model studies of hydrodynamics and sedimentation pattern in the Gulf with and

without the dam is under progress. To validate the model simulations, a network of twenty four observatories have been setup along the Gulf for recording tide, current, wind speed, direction, barometric pressure and temperature for one year duration. The study has resulted in generation of high resolution data sets for better understanding the hydro-morpho-dynamics of the Gulf.

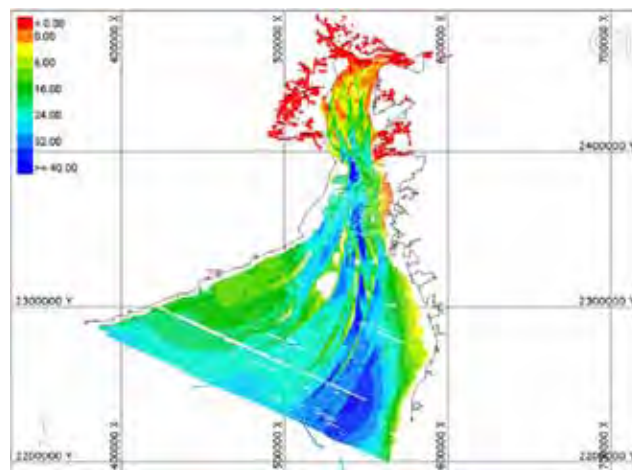


Fig. 5.1 Measured bathymetry at Gulf of Khambhat

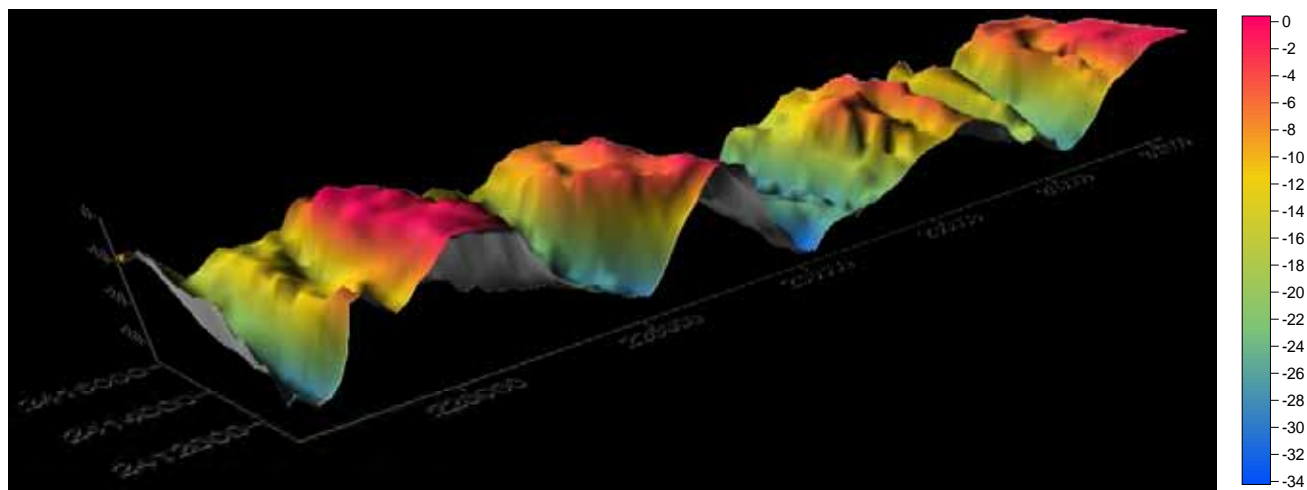


Fig. 5.2 3D view of dam corridor bathymetry

### 5.1.2 Demonstration of Shore Protection Measures

Along the Puducherry coast, four distinct zones, i.e.

- i) Puducherry port area with accretion on south and erosion on north,
- ii) Puducherry town protected by seawall,
- iii) Coast protected by groin field, and
- iv) Coast without any protection measures,

were identified to assess performance of coastal protection measures implemented by Puducherry and Tamil Nadu state governments. The zones are classified based on the extent of impact (positive or negative) caused by the structures built along the coast and hydrodynamic conditions. Shoreline change analysis along coastal stretch of 18 km was carried out using remote sensing data of 1991, 2000, 2006 and 2010 to delineate spatial/temporal changes of shoreline and to assess the impact of the structures.

The studies indicated that coastal erosion was aggravated by construction of Puducherry harbour due to blocking of northerly littoral drift. Seawall resulted in loss of natural beach to an extent of 70 m and shifting of problem to further north. Groin field could build beach in the area of interest but the down drift areas were subjected to severe erosion. Short-term/long-term shore protection measures including beach nourishment to the extent of 3.0 million cum, for length of 600 m near the Gandhi statue together with geo-textile based sand retaining structure, were evolved based on detailed hydrodynamic measurements conducted for period of one year.

## 5.2 DEEP SEA TECHNOLOGY AND OFFSHORE STRUCTURES

### 5.2.1 Remotely Operable Submersible (ROSUB 6000)

System Improvements and augmentation for scientific exploration of ROSUB 6000 have been carried out (Fig. 5.3). Additional luminaries were added to the system to increase the illumination

level from 22400 Lumens to 58360 Lumens. The pressure case for housing the lighting accessories was designed; fabricated and tested for 750 Bar pressure in the in-house hyperbaric testing facility. Fibre Optic Rotary Joint in the Tether Management System (TMS) slip ring was tested for required optical performance at temperatures between -20°C to 30°C at in-house environment test facility. Black box detector system was interfaced with the ROSUB System and qualified for operation in shallow waters.



Fig. 5.3 Indigenously designed, developed and tested underwater 6000m depth rated LED based Lights

### 5.2.2 Integrated Mining System

A detailed design of various subsystems like undercarriage systems, mechanical collector and pick-up device, belt conveyor, crusher, solids pumping system, hydraulic systems, electrical, electronics, sensors, data acquisition, instrumentation and control systems have been completed, as a part of development of a new crawler based mining machine capable of collecting and pumping polymetallic nodules from a water depth of 6000m.

### 5.2.3 Development of Suction Pile

Mooring constitutes critical component for the floating platforms in the sea. In this regard, use of suction pile anchor for floating mooring platforms (Fig. 5.4) has been demonstrated. All components like suction pump, electronics and pump skid of suction pile have been indigenously developed. Field trials were undertaken in the Royapuram Fisheries Harbour at water depth of 5m. After checking the integrity of electronics and various components, offshore



field tests were conducted off the Dabhol coast (Maharashtra) in 20m water depth.

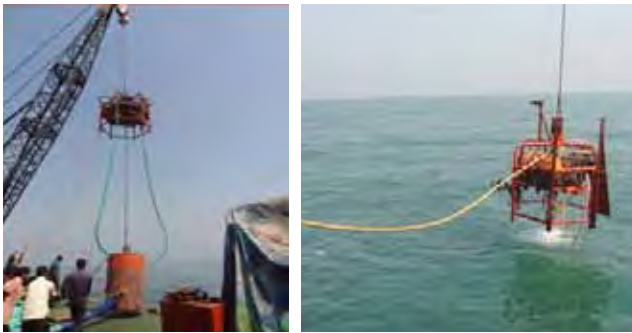


Fig. 5.4 Suction Pile Demonstration at Sea

### 5.3 FRESHWATER FROM SEA

#### 5.3.1 Solar- Multi Effect Distillation (MED) Desalination

A solar power based MED desalination plant is proposed to be developed. A trial testing was conducted by generating steam at 10 bar as an input to the 6-effect MED system to generate freshwater at 6 m<sup>3</sup>/h having a conductivity of 1 μS/cm (microSiemens/cm). The integration with solar field and testing of MED with steam generated from solar energy at Ramanathapuram is under progress (Fig.5.5).



Fig. 5.5 Solar MED System

#### 5.3.2 Low Temperature Thermal Desalination (LTTD) Plants in the Lakshadweep Islands

The Low Temperature Thermal Desalination (LTTD) Plants set up at the Minicoy and Agatti Islands in the Lakshadweep Islands are in continuous operation and each plant is generating 1 lakh litre per day of potable water, which is being distributed to the island community by

the Public Works Department, Lakshadweep Islands.

### 5.4 OCEAN ENERGY

#### 5.4.1 Current Turbines

The main objective is to develop turbines to harness power using different forms of ocean energy. Ocean turbines to suit low current speeds prevailing in the Indian waters are being developed. A helical blade turbine was designed, fabricated and tested in towing tank for its performance. The simulations and measurements are found to be matching. The turbine has been successfully tested in the field.

#### 5.4.2 Backward Bent Ducted Buoy (BBDB)

The objective of the project is to provide power supply to ocean observing systems. The second and third sea trials of BBDB, a floating-type wave energy converter, with improvised instrumentation were conducted. The device was exposed to vigorous wave climate during these months. During the third sea trial, the buoy withstood very high waves (upto 12 m) of the cyclone Thane which ravaged the coastal Tamil Nadu and Puducherry regions.

### 5.5 MARINE BIOTECHNOLOGY

#### 5.5.1 Marine Micro Algal Biotechnology

Mixotrophic culture of *Chlorella vulgaris* (NIOT-74/POSA), in continuous flow bubble column photobioreactor with trisodium citrate as carbon source yielded 0.3g/l dry biomass with a maximum lutein content of 9.44 mg/l on third day. To minimize the energy consumption and efficient solar power utilization in raceway culture system DC powered programmable ON/OFF control system of continuous and intermittent operation of paddle wheel has been developed. Different methods (liquid nitrogen, ultrasonication & enzyme) for extraction and purification of lutein were tested and the enzyme assisted cell disruption with purification

of lutein upto 95% by saturated salt solution using HPLC was standardized.

Screening for biomass and lutein production by mutated (physical and chemical) *Chlorella vulgaris* was completed. Although mutation did not enhance biomass in *Chlorella vulgaris* significantly, it enhanced the level of biolipid and lipid classes. Gene sequencing analysis of UV and chemical mutated *Chlorella vulgaris* indicated non conservative missense point mutations, confirming enhancement of lipid and saturated fatty acids levels of mutagen treated cells.

### 5.5.2 Open Sea Cage Culture

Nursery rearing of seabass fingerling from 7g - 30g with 95% survival was completed in 40 days in indigenous nursery cages and deployed inside the grow out cages. The fishes were successfully weaned from slow sinking nursery feed to floating grow out feed. A disease outbreak was diagnosed and effectively treated with broad spectrum antibiotics in open sea cage at Olaikuda. The fishes reared at Olaikuda and Kothachatram have reached an average weight of 250 g and 300 g in 130 days and 145 days, respectively. The culture of sea bass in grow out cages are being continued in Olaikuda and Kothachatram.

## 5.6 MARINE SENSORS, ELECTRONICS AND OCEAN ACOUSTICS

### 5.6.1 Marine Sensors

The development of sensors for marine applications have been taken up under this programme. Fabrication of prototype tow body (Fig. 5.6) to accommodate all the subsystems and hydrophone array of Buried Object Scanning Sonar (BOSS) has been completed and testing has been successfully performed at the Ocean Engineering towing test facility, IIT Chennai. Custom based fixtures and load cell modifications for a tow test up to 4 knots is under progress for the tow body.

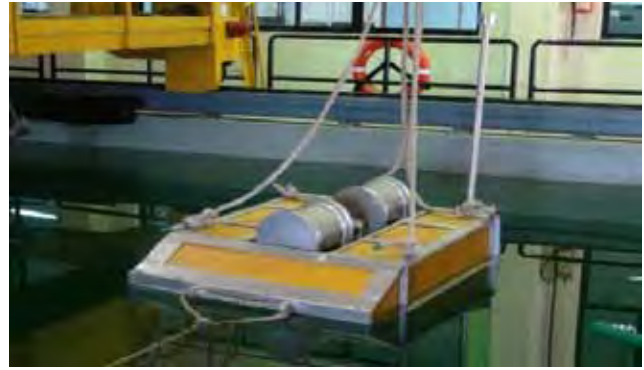


Fig. 5.6 Tow body during Buoyancy Test

### 5.6.2 Development of Drifter with INSAT Communication

The indigenously developed Pradyu Drifter (Fig. 5.7) with INSAT Communication was deployed off Sri Lanka on 21<sup>st</sup> April 2012 using Buoy Tender Vessel (BTV) Sagar Manjusha. The drifter worked satisfactorily and drifted towards the Andaman Islands due to onset of monsoon (Fig. 5.8).



Fig. 5.7 Pradyu-II





Fig. 5.8 Drifter track

### 5.6.3 Measurement and Characterization of Ocean Ambient Noise in Shallow Waters

Acoustics is the only way of communication under the water and constitutes an important area of research. The main focus of the project is time series measurements spanning seasonal scale and characterisation of the noise field at specific shallow water locations. Time series measurements of ocean ambient noise along with environmental parameters have been made during the monsoon period of 2012 in the

shallow waters off Visakhapatnam and Goa. The autonomous system withstood the extreme events such as the Thane cyclone and proved its stability. The system is improved with real time communication and testing of the system is successfully completed off Chennai.

The National Accreditation Board Laboratory (NABL) accredited the Acoustic Test Facility (ATF) upto 500 kHz. Establishment for low frequency calibration (in the range 100 Hz to 3kHz) of transducers as a peripheral facility to ATF is underway.

## 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 with seasonal, annual, decadal and centennial resolutions. In order to understand these changes better, it is essential to evaluate the climate variability from a perspective provided by the long-term proxy climate records like ice cores. Further, to retrieve more accurate and better climate information from proxy based studies, it is essential to have a sufficiently detailed and fundamental understanding on the biogeochemical processes involved in the air to snow transfers.

### 6.1 SCIENTIFIC STUDIES IN ANTARCTICA

#### Snow and ice core studies

An integrated study of the biogeochemical processes and ice core records from Antarctica has been initiated to understand the role and response of the cryosphere within the climate system in polar region and their global linkages.

Molecular level characterization of organic carbon was carried out on the snow samples collected from the coast to inland transect from two geographically distinct regions of the East Antarctica namely, the Princess Elizabeth Land and the Dronning Maud Land regions. Lignin molecules and compounds derived from algal and microbial biomass dominated the organic

carbon pool. The identification of a variety of lignin compounds demonstrates substantial input of vascular plant-derived materials, presumably from long range atmospheric transport and deposition. The detection of proteins, lipids and amino sugars suggests that a large proportion of the identified glacial organic matter likely originates from *in situ* microbial activity. This corroborates well with the presence of significant numbers of bacteria, picoplankton and microalgae in these samples. These results suggest that organic matter in the glacial environments have both a microbial and terrestrial provenance.

#### Study of Optically Thin Clouds

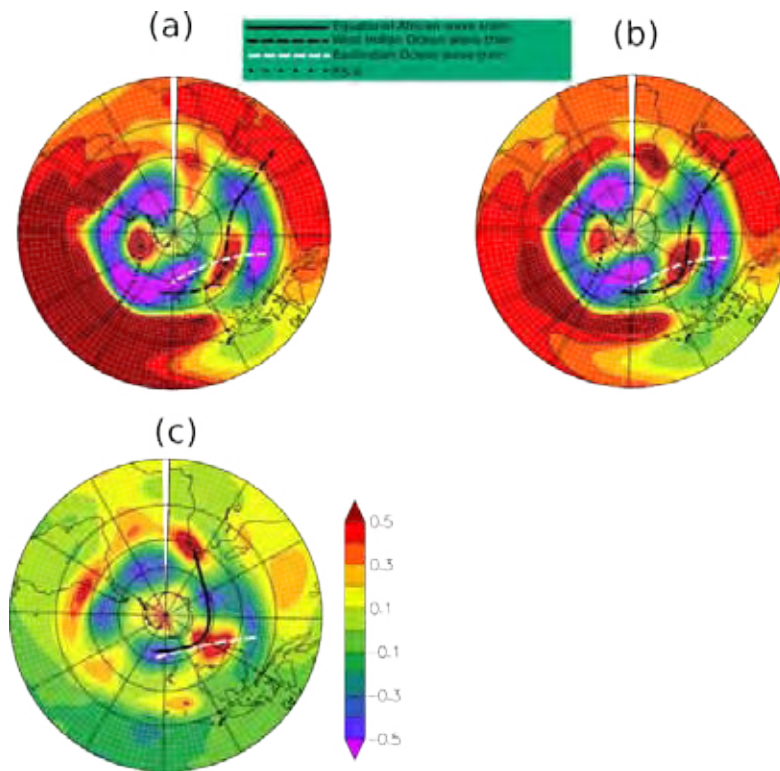
Cloud aerosol LIDAR with orthogonal polarization (CALIOP) instrument on board CALIPSO (Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation) satellite provides unique opportunity to study the distribution of optically-thin clouds over Antarctica. Data pertaining to Antarctic region obtained from the CALIPSO dataset for the period from June 2006 to June 2012 was used to classify clouds into water phase, ice phase and mixed phase clouds separately. The data was also separated into four seasons viz: winter (JJA), spring (SON), summer (DJF) and autumn (MAM) to study the seasonal variability. It was observed in summer that multiple layered cloud systems, with up to six to seven layers also occur frequently. Ice phase clouds predominantly occupy altitudes between 3 km and 8 km. Population of mixed phased clouds is more in the western side of Antarctic circle than the eastern side.



### Influence of Indian Ocean Dipole on Antarctic Sea-Ice

The study carried out during the period 2012-13 explored the impact of the Indian Ocean Dipole (IOD) on the southern hemisphere sea-ice (Fig. 6.1). IOD generate a low pressure cell north of the Ross sea where as the effect of ENSO introduce a high pressure cell just west of this low pressure centre. The sea-ice growth and decay west of the Rose Sea can be associated with the cold meridional flow between high and low pressure cells mentioned above. But the location of these positive and negative pressure anomalies generated by the IOD tend to move away from sea-ice zone during when the IOD occur along with the ENSO.

In the combined scenario, the low pressure pressure centre generated due to IOD in the ROSS sea tend to move eastward towards the high pressure cell just south of Australia. This reduces the impact of IOD on the sea-ice. However IOD is correlated maximum to the high pressure cell located just south of Australia. In the eastern Indian Ocean at about 100°E southward warm flow could have an impact on sea-ice but the warm and moist air associated with this southward flow result in enhanced precipitation, that lead to snow-ice conversion. Thus the thermodynamic effect of the warm southward flow takes a secondary role, where as snow-ice conversion and displacement of pressure centres controls the sea-ice evolution in the eastern Indian Ocean.



**Fig. 6.1** Correlation of 250 Hpa Geopotential anomaly with (a) Nino3 index (b) Dipole mode Index (DMI) and (c) Partial correlation between DMI and 250 hPa geopotential height anomalies (ENSO effect removed). The negative/positive centres indicate low and high pressure centre during positive phase of ENSO and Indian ocean dipole. When compared to 'c' in the figure above, it is clear that from 'a' that the negative correlation (low pressure) southeast of Australia extends beyond 150°E corresponding we notice a northward shift of the positively correlated region (High pressure) south of Australia.

### Biogeochemical conditions under Sea ice in Antarctica during late austral summer of 2012

Biogeochemical parameters were measured in the water samples collected during January-February 2012 from under sea ice (by drilling up to 2 m thick sea ice) and from the surface around the Larsemann Hills. Water samples under sea

ice were characterized by elevated dissolved oxygen concentrations (range 8.8–14.1 ml/l) when compared to surface seawater (7ml/l) and is attributed to the sea ice cover which greatly affects the exchange of dissolved oxygen between the atmosphere and the sea. Nutrients such as nitrate, dissolved inorganic phosphate

and silicate concentrations under sea ice were depleted when compared to surface seawater. The reason being, nutrient demand of ice algae under the ice cover exceeded resupply which might have led to the depletion of the major nutrients. Ice samples exhibited higher algal biomass, chlorophyll, and low pCO<sub>2</sub> concentrations. The study infers that the photosynthetic activity drives pCO<sub>2</sub> concentration, accumulation of dissolved oxygen, and an increase in pH under the ice covered region. This study highlights the pristine environment available under the ice cover.

### Accurate DEM of the Larsemann Hills region

An enhanced Digital Elevation Model (DEM) of the Larsemann Hills region, east Antarctica was constructed synergistically by using highly accurate ground-based GPS measurements, satellite-derived laser altimetry (GLAS/ICESat) and Radarsat Antarctic Mapping Project (RAMPv2) DEM-based point elevation dataset. With the use of accurate GPS data as ground control points reference elevations, the newly constructed DEM achieved accuracy with the least average elevation difference of 0.27 m.

### Paleoenvironmental reconstruction from the lake sediments of Antarctica

The pristine lakes of Antarctica are excellent archives of environmental changes, both present and the past. A few lakes from the Schirmacher Oasis and Larsemann Hills have been studied. The Holocene paleoenvironmental conditions were reconstructed by studying the biogenic silica, sand and organic carbon contents of a sediment core from the L2 Lake, Larsemann Hills. It was inferred that the high sand (%) during the ~ 8.3 - ~ 5 cal ka B.P period was due to increased glacio-fluvial deposition. The high values of TOC in the upper part of the core indicate the presence of algal mat which is due to the ice-free conditions due to warming.

### 31<sup>st</sup> Indian Scientific Expedition to Antarctica

The 31<sup>st</sup> Indian Scientific Expedition to Antarctica was launched in October 2011 and culminated in March 2012 with the commissioning of India's Third Antarctic Station "Bharati" on 18<sup>th</sup> March 2012. A team of 47 construction workers with support from two helicopters and two ships was involved in the activities and nearly 92% of the construction was completed during the 126 days of available austral summer period. Most of the services have been made operational and the first winter-over team of 13 members led by Dr. Rupesh M. Das, scientist from the National Physical Laboratory moved in immediately thereafter.

A 23-member team led by Shri Uttam Chand, Scientist from the Snow and Avalanche Study Establishment (DRDO) and Leader of the 31<sup>st</sup> Indian Scientific Expedition to Antarctica stayed back at the Maitri Station for conducting scientific experiments and logistic services during the austral winter of 2012-13. Some of the major projects implemented by the Indian Scientists at Maitri and Bharati during the summer and winter months of 2011-12 comprise: ionospheric studies by the National Physical laboratory, Temporal and Spatial Variations of meteorological parameters, by Snow and Avalanche Study Establishment (SASE), Meteorological parameter observations by ESSO IMD, Geophysical Studies by the Indian Institute of Geomagnetism and National Geophysical Research Institute, Hydrographic Surveys by the National Hydrographic Office, Glaciological Studies by the Geological Survey of India and Geochemical and petrological studies of lamprophyres of Central Dronning Maud Land (CDML), by Nagpur University.

### 32<sup>nd</sup> Indian Scientific Expedition to Antarctica

For the 32<sup>nd</sup> Indian Scientific Expedition to Antarctica (2012-13), scientific and logistics teams from different national organizations/institutes/laboratories is led by Shri. P. S. Negi (SASE), Shri. Ajay Dhar (IIG) and Dr. Raghava





as the Leader, Voyage Leader and the Nodal Officer for supervision of the construction activity of the research base at Larsemann Hills. The Expedition to Antarctica was launched in November 2012 from Cape Town. The major activity include construction of seawater intake facility and an earth station to receive remote sensing data at Bharati. In view of the mammoth tasks ahead, a logistic team of 40 members comprising doctors, engineers, mechanics and technicians has been working at Bharati presently (Fig. 6.2).



Fig. 6.2 Bharati Station

### India in International Antarctic forums

#### 35<sup>th</sup> Antarctica Treaty Consultative Meeting (ATCM) and 15<sup>th</sup> Committee on Environmental Protection (CEP)

The 35<sup>th</sup> Antarctica Treaty Consultative Meeting (ATCM) and 15<sup>th</sup> Committee for Environmental Protection (CEP) meetings were held in Hobart, Tasmania from 11th June to 20th June 2012. India is a member of the Antarctica Treaty and is holding a consultative status. The ATCM being an annual event related to Antarctica had the participation of the Antarctic program managers and logistics experts, and polar scientists from 50 countries, with scientific presence in Antarctica. The meeting was also attended by representatives from several non-governmental organizations. The Parties discussed issues including environmental protection, the

advancement of science, and the management of tourism.

#### XXIV Council of Managers on National Antarctic Programme (COMNAP)

The XXIV meeting of the COMNAP and a Symposium “Sustainable Solutions to Antarctic Challenges: Supporting Polar Research in the 21st Century”, were held from 15<sup>th</sup> to 20<sup>th</sup> July 2012 at Portland, Oregon, USA. The COMNAP AGM was attended by representatives from 28 COMNAP Member Organizations. India also chaired the annual meeting of Larsemann (ASMA-6) Management Group during the sidelines of COMNAP.

#### Asian Forum for Polar Science (AFoPS)

India hosted the XIII Asian Forum for Polar Sciences Meeting at ESSO, New Delhi from 06-07 August 2012. China, Japan, Korea, Malaysia and host India participated in the two-day meeting which exchanged information on the activities carried out in the Antarctic, the Arctic and the Southern Ocean. It was also decided to have AFoPS journal (one volume in year), the first volume to come out in December 2013, with scientific contributions from each member nations.

## 6.2 INDIAN SCIENTIFIC ENDEAVORS IN THE ARCTIC

### Mass balance studies of Vestre Broggerbreen glacier, Arctic

As a part of the long-term studies of the Vestre Broggerbreen glacier at Ny-Alesund, stakes were installed during the summer of 2011 at representative locations on the glacier. These stakes were remeasured during the late spring/early summer of 2012 to calculate the winter/spring balance (Fig. 6.3). Snow depth was measured with the help of a snow probe and hand held GPS. In addition, snow samples were collected at different altitudes and also at different depth. Analysis is in progress.



Fig. 6.3 Stake and pit locations (Red circles and open rectangles respectively) in Vestre Broggerbreen

### Nitrate localization in snow and its reactivity

This study initiated during 2012 seeks to identify the atmospheric sources of snow- $\text{NO}_3^-$  to understand the nitrate localization and reactivity in snow taking into consideration the interference of other ionic species and trace gases in Ny-Ålesund during the spring time. Trace gases ( $\text{HNO}_3$ ,  $\text{NO}_2$ ,  $\text{SO}_2$ ,  $\text{HCl}$ ,  $\text{HBr}$ ) measurement and ionic species in fine aerosol particles were collected. To study the flux between the air and snow boundary layer, the surface snow samples were also collected simultaneously from the same area. Analytical work is in progress.

### Long-term monitoring of the Kongsfjorden system for climate change studies

As a part of the long-term studies initiated in the Kongsfjorden system, repeat measurements of the physical, chemical and biological characteristics of the water column at 16 identified stations were resumed from the summer of 2012 (Fig. 6.4). The measurements were directed to understand following aspects:

- The variability in the Arctic/Atlantic climate signal by understanding the interaction between the freshwater and Atlantic water.
- 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.
- The winter convection and its role in the biogeochemical cycling.
- The trigger mechanism of spring bloom and its temporal variability and biomass production.
- The production and export of organic carbon in the fjord with a view to quantify the  $\text{CO}_2$  flux.

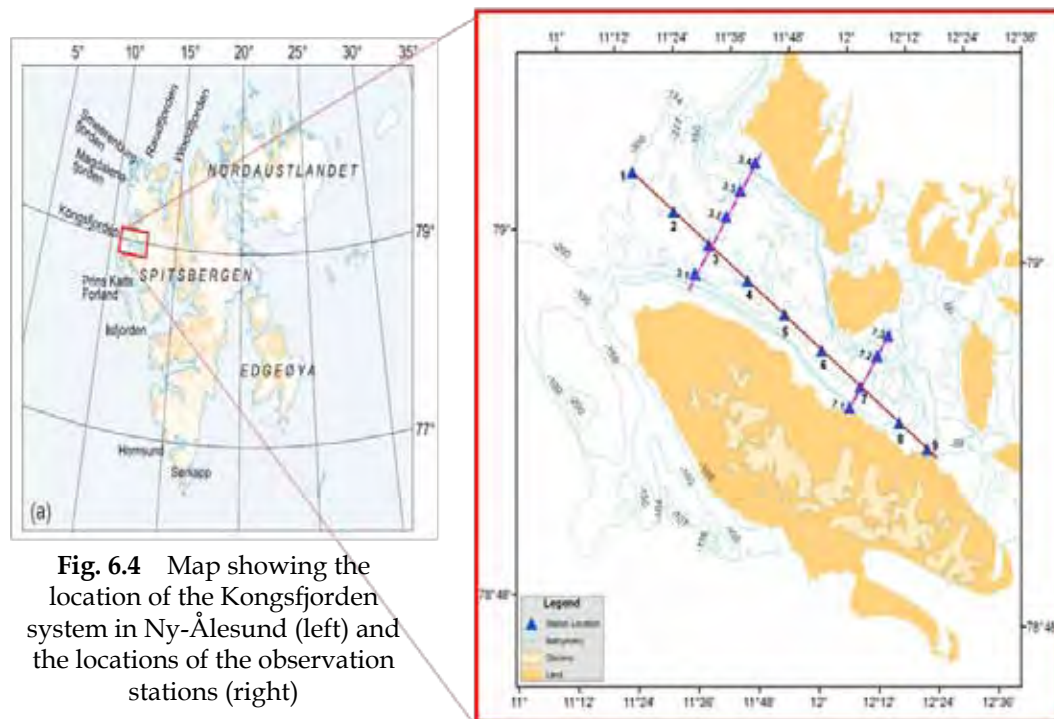


Fig. 6.4 Map showing the location of the Kongsfjorden system in Ny-Ålesund (left) and the locations of the observation stations (right)



Some of the salient field measurements carried out and the observations made during the period Jun–October 2012 are as below:

CTD measurements were carried at 15 days interval followed by water sampling at selected depths phytoplanktons for pigment analysis using HPLC. Measurement of biological parameters were carried out to study the community composition and abundance of bacteria and phytoplanktons assemblage and to identify non-culturable fractions of bacterial community after community DNA extraction and cloning. The community DNA obtained could also be cloned for molecular identification of phytoplanktons. Long term measurement of biological parameters will facilitate to track the changes in the community composition of this sensitive ecosystem. In addition, the study will lead to monitor the response of bacterial and phytoplankton community to the changing climatic conditions in the form of various levels of adaptations.

Sampling of sea water was done within the euphotic zone and at standard depths for various chemical parameters such as total inorganic carbon, total organic carbon, nutrients (nitrate, nitrite, phosphate, silicate), pH, dissolved oxygen. All the analysis was completed. Sediment samples were also collected for Diatom and paleoproductivity related studies.

### International Arctic Science Committee (IASC)

At the Arctic Science Summit Meeting at Montreal, Canada from 19-22 April 2012 India was unanimously admitted to the International Arctic Science Committee (IASC)- an ICSU supported scientific body devoted to international research in Arctic.

## 6.3 INDIAN SCIENTIFIC EXPEDITIONS TO THE SOUTHERN OCEAN

### Southern Ocean Expedition 2011-12

The 6<sup>th</sup> expedition to the Indian sector of Southern Ocean in 2011-12 on Sagar Nidhi, sailed off from Goa on 25<sup>th</sup> December 2011 with

20 scientists, representing 9 different research institutions and universities of India besides 3 engineers. The ship called on Port Louis (Mauritius) on 6<sup>th</sup> February 2012 after completion of all targeted objectives.

During this expedition, high resolution sampling was carried out in the water column of the Subtropical Front (STF), to understand the various biogeochemical processes and biological productivity potential. Satellite images showed STF as a productive region, *in situ* observations were not in accordance with it. This contrast could mainly be due to the discrete and few sampling locations which may not enough to explain the food-web dynamics and biogeochemistry in relation to the prevailing oceanographic conditions. A time-series observation for 48 h was conducted to understand the short-term variations, both in hydrography, biological productivity and biogeochemistry. Few stations were also sampled in the Polar Front up to 53°S, mainly for comparative purpose.

CTD and microstructure profiler (turbulence measurement) were operated at all 21 stations. Water samples up to 1000 m depth were collected at nine stations using the rosette system attached to CTD for all chemical and biological parameters, MPN was operated for stratified sampling of mesozooplankton and WP equivalent net was hauled for surface mesozooplankton. Primary productivity estimation using <sup>14</sup>C was made at selected stations. XCTDs and XBTs were launched (15 to 50 km interval) at regular intervals. Different experimental studies were also conducted, particularly microcosm experiments on bacteria to understand the response to nutrient alterations, photosynthetic irradiance and phytoplankton physiology, bacterial carbon turnover, etc. Squid jigging was carried out, mostly at night time, to study the biological and biochemical characteristics of the squid species inhabiting this water. Atmospheric studies were carried out all along the cruise track.

Besides, continuous underway observations were made for ocean currents, atmospheric parameters and bathymetric data by operating

Acoustic Doppler Current Profiler (ADCP), Automatic Weather Station (AWS), Multi-beam, Echo-sounder and Sub-bottom profiler.

### Southern Ocean Expedition 2012-13

In continuation of the studies carried out during the earlier years and based on the results obtained, the seventh multi-institutional scientific expedition to the Southern Ocean realm from Mauritius has been launched during late January 2013. This Expedition, on board RV Sagar Nidhi would comprise scientists/researchers from 11 national institutes/universities and would have as its objectives, the following focus themes:

- Observations at high resolution in the PF for detailed understanding about the complex food web dynamics [conventional and microbial] observed from previous expeditions.
- Influence of high nutrients, light limitation and sea ice on productivity.
- Carbon dioxide fluxes within PF- comparing  $p\text{CO}_2$  and primary production.

## 6.4 HIMALAYAN CRYOSPHERE STUDIES

This is new multi-institutional, long-term initiative have following objectives:

- To study the dynamics and the rate of change of select glaciers of the Himalaya to understand its impact on hydrology, ecology and climate
- To assess the climate change using ice as an archive of information on past climate and its future implications
- To study the biogeochemical aspects of the Himalayan ice and compare it with the polar environment.

The study area include the Chhota Shigri and the Hamata glacier in the Chandra Basin, the Patsio glacier in the Bhaga Basin and the Mamtusa and the Miyad glaciers in the Miyar basin. Subsequently in September, sampling from two high altitude glaciers of Ladakh (at 5600 m altitude) was carried out and study the recent accumulation layers by deep pitting (1-1.5 m). The analysis of these samples will help us to understand the preservation of environmental/ climatic signals and will help us to identify possible glaciers for an ice core based climate reconstruction study.





# GEOSCIENCES

The field of geosciences has important applications in harnessing the resources of oceans. Of late, deep sea mineral resources are gaining importance owing to rising metal prices. Of these, the polymetallic nodules, cobalt crusts, hydro thermal sulphide and gas hydrates are of specific interests. Understanding the underneath geology assumes significance in this context. The deep sea drilling constitutes an important tool for geosciences which opens up a plethora of new paleo-climate findings apart from discovering interesting aspects of marine geology. The detailed topographic survey constitutes another critical pre-requisite for such studies. The systematic geophysical surveys have enabled to delineate the continentals shelf of the country. The details of various activities undertaken are provided below:

## 7.1 GEOSCIENTIFIC STUDIES OF THE EXCLUSIVE ECONOMIC ZONE

The geoscientific study of the Exclusive Economic Zone (EEZ) of India is primarily designed to gather accurate multibeam bathymetric information to facilitate understanding of the seabed geo-morphological features. The bathymetry constitutes the fundamental prerequisite for oceanographic research, geological and tectonic studies for its use in defence, communication and navigation sectors. The study also aims at acquiring systematic sediment sampling and its analysis in order to assess the seabed resources and to understand the paleoclimatic regime. Sediment cores, at regular intervals, were collected to understand the source of sediment fluxes and their transport mechanism.

The status of survey is given below (Table 7.1):

**Table 7.1** Status of EEZ survey

	Survey completed Up to 2011-12 (in lakh sq km)	Survey done in 2012-13 ( in lakh sq km)	Total Area ( in lakh sq km)	Area
Deep water beyond, 500 m (Total area 15 lakh sq km)	5.74	0.56	6.30	Bay of Bengal-Western Andaman sector, Eastern offshore, Arabian Sea- Western Offshore off Goa region.
Shallow water Up to 500 m (Total area 5 lakh sq km)	0.18	0.04	0.22	Arabian Sea -Off Marmagoa, off Bombay High and Karnataka coasts, West off Vengurla/Malwan offshore, Bay of Bengal-Off Chennai, Cheyyur, Marakkanam, Cuddalore

The total area surveyed so far is 32 % of the area of EEZ. Two sediment core samples from the Arabian Sea viz., SK-221/GC-05 and SK-221/GC-07 were subjected to detailed

sedimentological and geochemical analysis to understand the sediment source, diagenetic processes and controlling factors using the multi-proxy technique.

## 7.2 DELINEATION OF INDIA'S CONTINENTAL SHELF

The first partial submission for extended continental shelf was made by India in May 2009 to the United Nations Commission on the Limits of the Continental Shelf (UN-CLCS). The activities during the year have been largely confined to provide additional information/clarifications sought by the UN on the Submission. In addition, the finalization of the second partial Submission for an extended shelf under the provisions of the Statement of Understanding has also been taken up and the first draft is in an advanced stage of completion.

Bangladesh initiated Arbitration proceedings for determination of the India-Bangladesh maritime boundary. The technical inputs were provided to the MEA to prepare a counter-memorial in respect of the arbitration by Bangladesh.

## 7.3 INDIAN OCEAN DEEP-DRILLING PROGRAMME (IODP)

As a major national initiative of the Indian scientific activities under the Integrated Ocean Drilling Program (IODP), a scientific proposal entitled "Deep sea drilling in the Arabian Sea: Discovering the tectono-climatic unknowns" was submitted to the IODP as a Complimentary Project Proposal (IODP-793\_CPP). This proposal which is currently under an advanced stage of

review, aims at recovering deep sea cores from four different sites in the Arabian Sea to address the following objectives:

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

The Indian scientific participation onboard IODP platforms till date has helped to get hands-on experience of scientific drilling in the ocean realm. A glimpse of Indian scientific participation onboard IODP platform *JOIDES Resolution* is shown in the Fig-7.1 (highlighted in red boxes). Besides, Indian scientists have also participated on the other platforms like CHIKYU and MSPs. Indian scientists have participated in programmes related to paleo-climate, paleo-oceanography, geophysics and geochemistry. The shipboard experience through IODP has provided scientists an avenue for long-term capacity building in terms of deep sea geoscientific research in India.

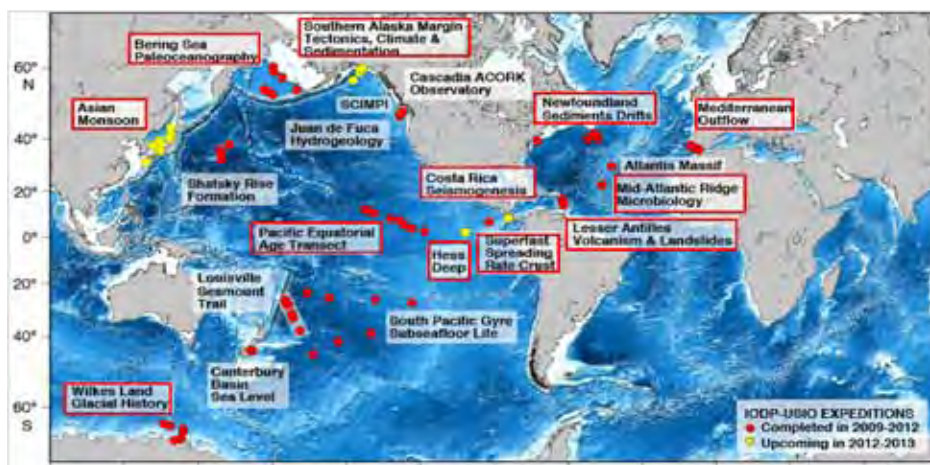


Fig. 7.1 Map showing IODP expeditions around the world with Indian scientific participation highlighted in red boxes (map courtesy: United States Implementing Organisation (USIO)).



The first meeting of the Science Implementation and Policy Committee (SIPCom) of the IODP was held in Goa during 18-20th January 2012 along with the International Working Group Plus (IWG+) meeting. This meeting was attended by the delegates from all IODP member countries and discussed the future course of action of IODP consortium.

## 7.4 GAS HYDRATES EXPLORATION

Gas hydrates are a naturally occurring, solid compounds containing natural gas (mainly methane) and water. The gas hydrates programme is being implemented with a view to understand their mode of occurrence and its likely potential. A detailed seismic survey was undertaken. The preliminary results are given below.

### Physical parameters derived from a Bottom Simulating Reflector (BSR) in the Andaman offshore:

Using the BSR and associated seismic velocity, the computation for the porosity, density, thermal conductivity, geothermal gradient, heat flow, resistivity and gas-hydrates saturation were carried out in the Andaman fore-arc basin. The present study brought out low geothermal gradient (20.0 °C/km), low thermal conductivity (0.8472 W/m/K), low heat flow (16.9mW/m<sup>2</sup>), average resistivity (1.53Ωm), medium saturation (14%) of gas hydrates and 8.13× 10<sup>8</sup> m<sup>3</sup> volume of gas at BSR. The low heat flow is attributed to the high effective sedimentation (5.6 cm/ky) rate that was caused by the tectonic thickening in the study region. The greater depth of BSR (600 m

below sea floor) is attributed to the low geothermal gradient.

### Velocity-porosity and Velocity-density Relationships:

Drilling and coring were done at one site on the Kerala-Konkan basin. Downhole logs were used and established empirical relationships between the P-wave velocity ( $V_p$ ), S-wave velocity ( $V_s$ ), density ( $\rho$ ) and porosity ( $\emptyset$ ). The relations between  $V_p$ ,  $V_s$ ,  $\rho$  and  $\emptyset$  with high R<sup>2</sup> value (>0.73) can be used for various studies in this region.

### Gas-hydrates in KG basin :

Presence of gas-hydrates changes the seismic velocity and normalized resistivity (formation factor). A relation between these two parameters for the hydrate-bearing and water-saturated sediments in the KG basin has been established and the saturation of gas-hydrates using the modified Archie's equation was calculated. The advantage of this approach is that the Archie's constants (a & m), porosity ( $\emptyset$ ) and anisotropy (due to fractures) are automatically incorporated while calculating the formation factor. The pressure core data for calibrating the saturation exponent (n), and extend the method for estimating saturations of gas-hydrates from seismic velocities along some lines around the well have been used. The results show that gas-hydrates vary both laterally and vertically from 5-50% in the study area (Fig.7.2).

### Effect of silica particles on the stability of methane hydrates:

A systematic study of methane hydrate formation and dissociation was carried out in the

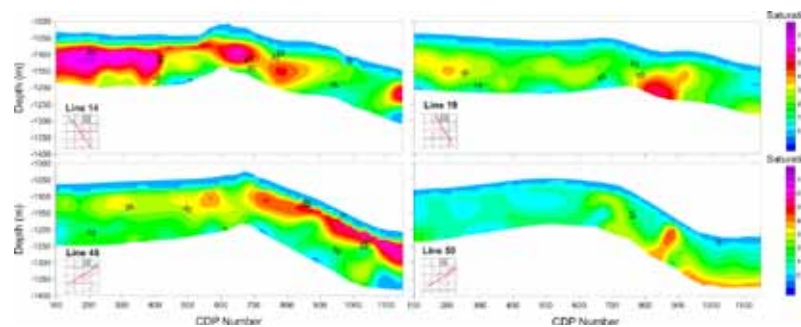


Fig. 7.2 Gas-hydrates saturation along some lines in the KG basin.

suspensions of silica and natural clay. All the experiments were carried out in a stirred reactor using 10 wt % of silica and natural sediment samples. The silica grains have also shown considerable effect on release of methane during dissociation. It is used suspensions of silica (10 wt%) with 50, 150 and 250  $\mu\text{m}$  diameter and naturally occurring clay sediment (characterized as bentonite) in the KG basin and compared the hydrate kinetics and conversion efficiency. The results indicate that the hydrate induction and growth is significantly faster (typically 1/3 of pure hydrates) in suspensions of silica with 150 and 250  $\mu\text{m}$ . Measured induction time is slightly longer ( $\sim 1/2$  of pure hydrates) for suspensions with 50  $\mu\text{m}$  silica and natural clay sediment. In comparison with pure methane hydrates the conversion decreased by about 20 - 30 % in silica suspensions, while it is comparable in clay sample.

## 7.5 POLYMETALLIC NODULES (PMN)

Polymetallic nodules are potato shaped, porous and black earthy deposits, with size ranging from 2 to 10 cm in diameter. These nodules occur at nearly 4 to 5 km depth in the deep oceans lying on the seabed. They comprise, besides manganese and iron, nickel, copper, cobalt, lead, molybdenum, cadmium, vanadium, titanium. India presently has 75000 sq km area in the Central Indian Ocean Basin (CIOB) for developmental activities targeted at harnessing of metals, viz. Copper, Nickel, and Cobalt. This Programme has four components, viz. Survey and Exploration, Environmental Impact Assessment (EIA) Study, Technology Development for Mining and Extractive Metallurgy.

### 7.5.1 Survey & Exploration

The identification of a First Generation Minesite (FGM) area in the CIOB is an important milestone achieved during 11<sup>th</sup> plan period. The minesite containing an area of 7858 km<sup>2</sup> is divided into 42 blocks of equal grid size (0.125° x 0.125°) and all the future exploration activities

such as Remotely Operable Vehicle (ROV) surveys, videography surveys, etc., would be concentrated in this FGM area.

The details of major activities undertaken are provided below:

- A bathymetry map and Digital Terrain Model (DTM) of the FGM area were generated. The maximum area of the FGM site have a slope angle of 0° to 6°. Slope angle map of the FGM area is crucial for the operation of mining system .
- Values of abundance and grade were calculated for all the 42 blocks of the FGM area .
- Preliminary observation of the soil tester and ROSUB data that was collected showed carpet of nodules in the FGM area in the southwest part which is in agreement with the generated maps and figures arrived after processing the exploration data.

### 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.

#### Effect of sample storage on biochemical and microbial parameters

Nodules occur along with deep-sea sediments under extreme conditions such as  $\sim 2^{\circ}\text{C}$ , 500 bar pressure and no natural sunlight, with a total microbial count of  $\sim 10^8$  cells  $\text{g}^{-1}$ . Between lifting of ores at sea, transportation to land and actual processing there is a time lag during which the sediments are stored under tropical conditions of 1 bar, 28 + 2°C temperature. For this purpose, sediment samples from 4 different sediment types in the CIOB were analysed. It has been found that, although stored deep-sea sediments altered in their bacterial and biochemical properties, the integrity of the net metallurgical content and properties was nearly stable for the test period and conditions.





### Fauna associated with Nodules

The association of faunal diversity and abundance with nodules that are likely to be disturbed as a result of mining was evaluated. The results showed that 30-80% nodules (avg. 40%) have associated fauna belonging to 10 groups of meiofauna dominated by *Nematoda* (30%), *harpacticoida* (20%), *polychaetes* (15%) (Fig. 7.3). There were 1-14 individuals per nodule and 2-8 groups of meiofauna per nodule. It was also observed that nodule morphology plays a major role in hosting sediments with faunal groups. However, nodule surface area and faunal abundance have a weak correlation.

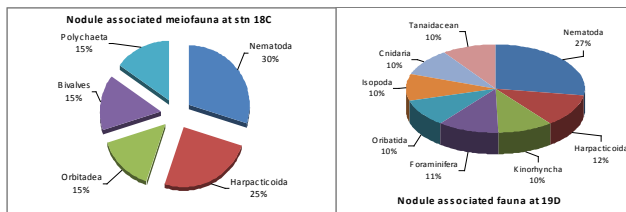


Fig. 7.3 Faunal diversity associated with nodules

The macrofaunal community comprises 30 taxa belonging to 11 groups with an average abundance of 316 no./m<sup>2</sup> and 148 no./m<sup>2</sup>. These were dominated by *Tanaids* (35%), *polychaetes* (22%), *amphipods* (20%).

### 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:

- Separation of metal values using hollow fiber non-dispersive extraction module.
- Preparation of Electrolytic Manganese Dioxide for use in Rechargeable Batteries from Manganese Cake.
- Process development for extraction of metal values from Mn Nodule by HPAL.
- Electro chemical splitting/Lime boil.
- Charcoal as a reducing agent for extraction of metals values from Mn nodules.

### 7.5.4 Technology Development (Mining)

The details are described in chapter on Ocean Technology.

## 7.6 STUDIES ON COBALT CRUSTS EXPLORATION

Seamount ferromanganese crusts are known to enrich several high-value metals such as cobalt, platinum, cerium, tellurium, etc, much above their crustal abundance. There are no known land deposits of Te in the world while Co in seamount crusts is 3-10 times more enriched than primary land deposits. The project is to identify areas of occurrence of cobalt-enriched ferromanganese crusts, assessment of resource potential of Co-rich deposits in the Afanasiy-Nikitin Seamount (ANS) region.

The first multibeam map has been generated for the Afanasiy-Nikitin Seamounts covering an area of around 40000 sq. km. Based on this map, it has been identified a plateau region in the southern part of the Afanasiy-Nikitin Seamounts. This region is at ~3200 m water depth and covers horizontal area of ~20000 sq. km. The initial reconnaissance sampling has yielded few crust samples containing up to 0.5 % cobalt as against average of 0.65 % cobalt in northern region. Merging of multibeam data from ABP32 and ABP37 was done after considering individual array of beams from both expeditions. Digital Terrain Model (DTM) of the area was achieved using further processing like making grid with optimum grid size.

## 7.7 STUDIES ON HYDROTHERMAL SULPHIDES

Recently, a major multi-disciplinary project aimed at exploration for potential sites of hydrothermal multi-metal sulphide mineralization in the Indian Ocean Ridge areas has been initiated. The major objectives are as under:

- Exploration for potential sites of hydrothermal multi-metal sulphide mineralization in the Indian Ocean Ridge areas.

- Identification of locales of hydrothermal sulphide deposition, including determination of the resource potential.
- Initiation of associated scientific research in the frontier areas of hydrothermal mineralization.

## 7.8 EARTHQUAKE REASEACH

Some of the salient achievements under this program are given below:

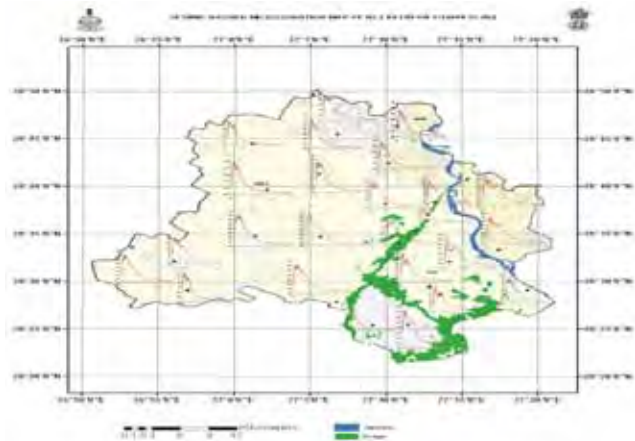
### Earthquake Monitoring

The National Seismological Network (NSN) has detected a total of 2819 earthquake events and auto-located during the period January-September, 2012. These include 1273 events of magnitude 5 and above. Information pertaining significant events were transmitted to all concerned state and central government agencies dealing with relief and rescue operations in the region. Establishment of Real Time Seismic Monitoring Network (RTSMN) has brought in improvements in the earthquake detection & location capabilities in the country in terms of timely and accurate dissemination of earthquake source parameters to user agencies. The network is capable of providing first hand information, within 4-5 minutes of the occurrence of any significant earthquake in the country, with an accuracy of magnitude and epicenter within +/- 0.2-0.3 units and 20-30 kilometer respectively.

### Microzonation

Preliminary Seismic Hazard Microzonation maps of NCT, Delhi for different themes, covering six districts of NCT, (namely North-West, district; North, district; North-East, district; East district & West District and part of South-West districts) have been generated on 1:10,000 scale. Based on these preliminary results, a brief report has also been generated and submitted to the different stake holders along with Ministry of Urban Development (UoD) to workout strategy/procedure for implementation of the results in building codes and land use planning of NCT

Delhi. For the selected 25 sites, acceleration response spectra at 5% damping are generated for maximum considered earthquake of return period 2475 years (i.e., 2 % probability of exceedance in ground motion in 50 years) and overlaid on the Geological Base Map of NCT Delhi on 1:10K scale is attached as Fig. 7.4.



**Fig. 7.4** Acceleration response spectra at 5% damping for selected 25 sites (maximum considered earthquake of return period 2475 years i.e., 2 % probability of exceedance in ground motion in 50 years) and overlain on the Geological Base Map of NCT Delhi on 1:10K scale)

### Precursor studies

A network of three field stations located at hot-spring and mud-volcano at Bakreswar (W.B.), TattaPani (Jammu, J&K) and Baratang (A&N) were upgraded with advanced instrumentation and made operational. These labs are equipped with on-line monitoring equipments to record hourly concentration changes in stable gases He, CH<sub>4</sub>, N<sub>2</sub> etc. as well as the radioactive constituents <sup>222</sup>Rn, <sup>218</sup>Po, <sup>214</sup>Po and gamma dose rate was made operational. Besides, to correlate with observed radon changes in the hot spring gases, 'Barasol' radon monitors were installed near the spring sites to monitor soil radon and associated meteorological parameters such as temperature, humidity, atmospheric pressure and rainfall that affect soil radon concentrations. During the last twelve months the installed network recorded five anomalies that were correlated with regional earthquakes of magnitude  $\geq 4.0M$ . These events occurred in



hypocentral distances ranging from ~250 km to ~1500 km.

### Geological Studies

- To delineate the offshore extension of Deccan Flood Basalt on the western continental margin of India, multi-channel seismic reflection profiles across the Southwest Continental Margin of India (SWCMI) was analyzed and interpreted. The results suggest presence of westerly dipping seismic reflectors beneath sedimentary strata along the western flank of the Laccadive Ridge. Velocity structure, seismic character, 2D gravity model and geographic locations of the dipping reflectors suggest that these reflectors are volcanic in origin, which are interpreted as Seaward Dipping Reflectors (SDRs). The SDRs; 15 to 27 km wide overlain by ~1 km thick sediment; are observed at three locations and characterized by stack of laterally continuous, divergent and off-lapping reflectors. Occurrence of SDRs along western flank of the Laccadive Ridge adjacent to oceanic crust of the Arabian Basin and 2D crustal model deduced from Free-air gravity anomaly suggest that they are genetically related to incipient volcanism during separation of Madagascar from India.
- Specific studies were carried out using different geophysical techniques, viz: GPR profiles across the fault section at the Baratang Island; Kamraj Nagar, South Andaman; Chidiyatapu; Collinpur, etc., orientation of fault structures in mud volcano using Electromagnetic Transient method; fault sections at Brookshabad and Rose Valley, South Andaman using 2D Electrical Resistivity Imaging. The overall analysis of fault pattern through various geophysical techniques illustrate the major fault system oriented along NW-SE; NE-SW and also along N-S direction in South Andaman.
- To delineate the faults in Indo-Burmese arc region, structural and geomorphological mapping was initiated. From the investigations of the earthquake occurrence processes and GPS data analysis, it is inferred that the earthquakes in the Indo-Burmese arc and Sagaing fault region occur due to slip partitioning of the predominantly northward relative motion of the India plate with respect to the Sunda plate. Also, the earthquake focal mechanisms in the Indo-Burmese arc region suggest predominantly northward relative motion through dextral strike slip on the NNE-SSW oriented planes and thrust motion on the WNW-ESE oriented planes. The derived stress state suggests that there is no significant variation in the stress state with depth.
- A network of broadband stations was established in the period 2011-2012 in Rajasthan, northwestern India to image the subsurface structure beneath the region encompassing the Malani igneous suites. A teleseismic waveform modeling technique (Receiver Function) was adopted to model the crustal thickness and the shallow sedimentary structure. Preliminary results indicate strong lateral variations in the crustal thickness and the thickness of the sedimentary layer. The variation in the arrival of the P-to-S (Pms) conversion from the Moho reflects variation in the crustal thickness/velocities as the stations encompass diverse geological regimes ranging from the Barmer basin to the Aravalli craton.
- Broadband and long period magnetotelluric data along the east-west profile of length 220 km in Cambay region were acquired at 24 stations with station spacing of 8-10 km, in the frequency range 300-2000 s and 12 long period stations, with station spacing of 15-20 km in the period range 1-10000 s + respectively. Preliminary two-dimensional (2D) model was obtained using the galvanic corrected data. The preliminary shallow model indicates, high conductive sediments within Cambay graben with resistivity 2-10 ohm,

thickness varying between 1-4 km and width of basin is approximately 60 km.

### Deep Borehole in the Koyna

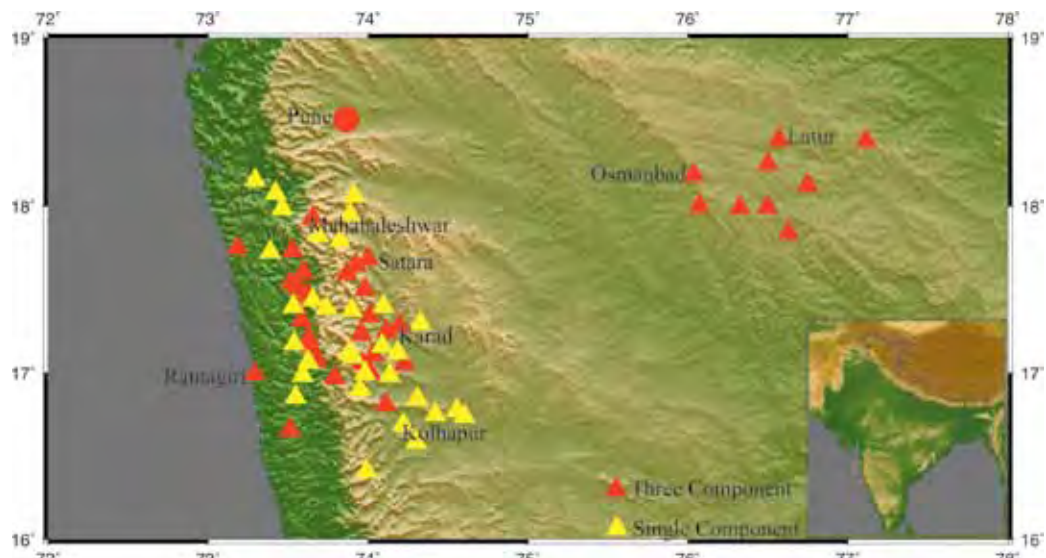
A Deep Borehole (~7 Km) Observatory in Koyna-Warna region for direct and continuous monitoring of intra-plate seismic zone at depth, leading to a better understanding of the mechanics of faulting, physics of reservoir triggered earthquakes as well as earthquake hazard assessment is being set-up. In this direction preparatory studies have been initiated to carry out scientific investigations and select the suitable site for deep borehole drilling in the Koyna-Warna region. The investigations include Seismological, Geophysical (seismic, gravity, magnetic), LIDAR, geomorphology and structural geological studies, apart from a few shallow (~ 1 km) exploratory boreholes.

Laboratories for core storage, sample analysis, computations and other research facilities,

are being set-up near Karad. A Foundation Stone was laid by Hon'ble Minister of Earth Science on 24<sup>th</sup> May 2012 in presence of the Hon'ble Chief Minister, Maharashtra and Secretary, MoES.

### Earthquake Awareness

Under the Western India schools earthquake lab programme, out of proposed 85, installation of 80 seismographs located in 8 districts namely Satara, Sangli, Kolhapur, Ratnagiri, Raigad, Latur, Osmanabad and Nanded (Fig. 7.5), has been completed. Training was imparted to teachers in five phases and also training was imparted to school children on processing of earthquake data. Educational material such as CD's and print material was also distributed to all the 80 schools. The Koyna earthquake of 4.9 M on 14<sup>th</sup> April which was widely felt including Mumbai was recorded in about 40 schools which comprised of 3 component and single component seismometers.



**Fig. 7.5** Locations of educational seismographs set-up under Western India schools earthquake lab programme.



## EARTH SCIENCE – DATA CENTRES

Expansion and spreading of artificial (man-made) information structures and the steady migration of various human activities into cyber space are integral features of development and progress in the present day world. We need to be concerned with the triad of data, information and knowledge as well as the delivery of services. In this context, the data centres play a cardinal role in realising the aims and objectives of ESSO. These conditions also shape and determine the current priorities in the purposes and functions of the data centres. The present priorities in this area are:

- (a) substantially strengthening existing data centres and expanding their activities and establishing new ones;
- (b) bringing about integration of 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 to working towards the above targets, ESSO is also an active partner in the national efforts in the field of data and its usage. It is worth mentioning that ESSO played a lead role in preparing the vision and also in formulating the implementation plans for the establishment of a National Geographical Information System (N-GIS) which is to become a reality in the near future. ESSO is also actively engaged in implementing the National Data Sharing and Accessibility Policy (NDSAP-2012) of the Government of India. As part of the latter activity, ESSO-MoES was the second organization to make available data through the Data Portal

India ([data.gov.in](http://data.gov.in)) established by the Ministry of Communication and Information Technology.

Brief descriptions of the various data centres under ESSO and their ongoing development activities are given below.

### 8.1 CLIMATE DATA CENTRE

At present, the National Data Centre (NDC) of the India Meteorological Department at Pune is the sole custodian of all meteorological data being collected from various parts of India. The data are available for more than 125 years. The mandate is to achieve quality controlled data and supply for weather prediction, aviation, agriculture, environmental studies, etc., to researchers of various institutions and universities.

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. These climate records are accompanied by metadata describing the history of the observing site. The present data centre is being improved to provide climate services in the country. The Climate Data Centre will have the following major components:

1. Updating of meteorological data base in digitized and GIS format. This will involve data rescue efforts to digitize plenty of meteorological data available in manuscripts and also to develop a metadata base describing the history of the observing site.

2. Improved real-time data acquisition system with automatic reception, quality control, archival and data monitoring
3. Web-based use interface for data services, e-commerce, development of climate data application tools and Climate Services Information System (CSIS).

The data centre will be also linked to other data centres of ESSO institutions. It is expected to complete the implementation of this climate data centre in a phased manner during the period 2013-2015. Towards its implementation, an expression of interest (EOI) has been issued and a request for procurement (RFP) document has been prepared.

## 8.2 OCEAN DATA AND INFORMATION SYSTEM (ODIS)

ESSO-INCOIS, being the central repository for marine data in the country, receives voluminous oceanographic data in real time, from a variety of in-situ and remote sensing observing systems. The Ocean Information Bank provides information on physical, chemical, biological and geological parameters of ocean and coasts on spatial and temporal domains that is vital for both research and operational oceanography. The Ocean Information Bank is supported by the data received from Ocean Observing Systems in the Indian Ocean (both the in-situ platforms and satellites) as well as by a chain of Marine Data Centres.

Further, ESSO-INCOIS has been designated as the National Oceanographic Data Centre and interacts with the International Oceanographic Data Exchange Programme (IODE) of International Oceanographic Commission (IOC), UNESCO. It also serves as the National Argo Data Centre, Regional Argo Data Centre, and also the regional data centre and clearing house for the Indian Ocean region for the IOGOOS Programme.

## 8.3 INDIAN OCEAN BIOGEOGRAPHIC INFORMATION SYSTEM (INDOBIS)

IndOBIS has been established by the Centre for Marine Living Resources and Ecology (CMLRE) at Kochi. IndOBIS allow users to explore data on location of marine animals and plants. It will also supply data tables, maps and predict distribution using environmental information. The system is under development ([www.indobis.org](http://www.indobis.org)). Currently it has over 500,000 records of marine species.

## 8.4 MARINE GEOPHYSICAL DATA CENTRE

During the course of Indian Continental Shelf Programme as well as other geophysical cruises in the Indian Ocean region, a huge volume of marine geophysical data has been archived at the ESSO-National Centre for Antarctic and Ocean Research (NCAOR). Considering the immense volume of data and its intrinsic value, a state-of-the-art National Marine Geophysical Data Centre has been established (Fig. 8.1). The web-based database 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.

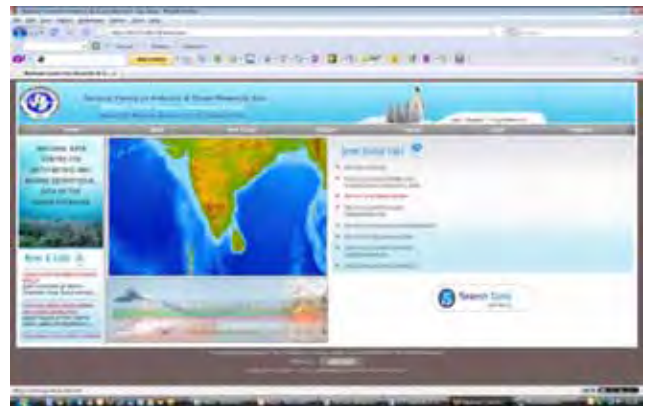


Fig. 8.1 Website of the National Geophysical Data Centre



### 8.5 NATIONAL SEISMOLOGICAL DATA BASE CENTRE (NSDC)

The seismological data from all the network stations is compiled, processed, analyzed and archived systematically at the National Seismological Database Centre (NSDC), on a regular basis. Seismology Division supplies earthquake data / seismicity reports of specific regions to insurance companies, industrial units, power houses, river valley projects, etc.. Consultancy services are also provided to various state and central government agencies on earthquake related matters. Seismological data and earthquake related information is also supplied to various user agencies dealing with relief and rehabilitation measures, earthquake disaster mitigation and management related matters, seismic zoning, etc. Earthquake data is also supplied, on request, to various scientific, academic and R&D institutions for research purposes.

### 8.6 NATIONAL ANTARCTIC DATA CENTRE (NADC)

National Antarctic Data Centre, is a repository of the Antarctic science database for India. The vast amount of data generated from all the Indian Antarctic expeditions to date are being collected, collated, formatted and synthesized for easy accessibility and utilization.

Easy online search tool and online data entry via internet facilitate easy and free exchange of the data to the scientific community. The international data format called Directory Interchange Format (DIF) has been implemented for easy and reliable exchange of data over the internet keeping the concurrency with Australian Antarctic Data Centre and Global Change Master Directory (NASA).

## CAPACITY BUILDING AND HUMAN RESOURCE DEVELOPMENT

To gain scientific understanding of the individual components of the earth system (the atmosphere, ocean, solid earth, biosphere) as well as to study the interactions between them and their response to the natural and human induced changes, several programmes have been launched in the XI and XII plan. However there is a dearth of Earth Scientists knowledgeable in atmospheric, oceanic and geosciences in the country to work on these programmes. In order to cater to the enormous requirement of skilled manpower in the field of Earth System Sciences and to develop adequate training modules with focus on operational and service-delivery oriented responsibilities of the various units, three training schools were proposed during the XI plan. While the Advanced training school in Earth Science and Climate Change was opened during the mid-term stage of the XI plan, the remaining two training centers on oceanography and meteorology will be established during the XII plan.

In addition to the in house training schools, 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 forecast. This can be effectively done through adoption of multi-institutional and multi-disciplinary approach involving amalgamation of expertise existing in various R & D institutes of the country. Therefore ESSO continuously supports focused R & D through networked projects involving various institutes within India and abroad, initiation of academic programmes, and establishment of Chair

Professors, establishment of National Lab facilities for benefit of researchers, opening of Centers of Excellence at various Universities with state-of the art research facilities.

### 9.1 CENTRE FOR ADVANCED TRAINING IN EARTH SYSTEM SCIENCES AND CLIMATE (CAT ESSC)

The Centre for Advanced Training in Earth System Sciences and Climate (CAT-ESSC) was established to create a large 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 and cryosphere with special emphasis on modeling. Seventeen meritorious students with Masters in Science/ Graduate Engineers were recruited and provided this induction training extending to eighteen months. The faculty consists of scientists from the various units of ESSO and national and international experts. On satisfactory completion of the training they will be placed as Scientist-B/C in any institute of the ESSO. In addition the trainees are also given the option to pursue M.Tech. or/and Ph.D before or after induction.

Ten trainee Scientists of the First Batch were deputed to the Abdus Salam International Centre for Theoretical Physics (ICTP), Italy to participate in ENSO-Monsoon Oscillation Workshop held during 31 July - 10 August 2012. Second batch of twenty candidates have been selected in August 2012 as trainee scientists in the academic year 2012-13.



## 9.2 TRAINING IN OPERATIONAL METEOROLOGY

Operational Meteorology training programme consists of three major training disciplines namely General Meteorology, Agricultural Meteorology and Meteorological telecommunication & observational systems. Training facilities have been recognised as Regional Training Centre (RTC) for Afro-Asian region (RA-II) in the field of General Meteorology & Meteorological telecommunication & observational systems, respectively by the World Meteorological Organization (WMO) in 1986.

Regular long duration training courses (3-12 months) are conducted for capacity building of the Operational Meteorologists in India and abroad (in RA-II region). During 2012-13, an advanced refresher course on “Application of DWR data in NWP” has been conducted during 19-23 Nov 2012. An international training course on General Meteorology with special emphasize on Aviation Meteorology was given to 6 Bhutan Met personnel for a period of 3 months during October-December 2012 followed by another during February 2013. The prestigious 25<sup>th</sup> Session of WMO EC panel of experts on Education and Training was organized during 26-30 March 2012.

## 9.3 TRAINING CENTRE FOR OPERATIONAL OCEANOGRAPHY

A need for establishing a state-of the art Training School in operational oceanography of International repute was felt when several requests for training were received from Indian Ocean Rim countries, the Bay of Bengal Initiative for Multi-Sectoral Technical and Economic Cooperation (BIMSTEC), South Asian Association for Regional Cooperation (SAARC), and Regional Integrated Multi-Hazard Early Warning System (RIMES) member countries. The establishment of the International Training School for Operational Oceanography at INCOIS has been approved.

As part of its training activities, several training programmes during 2012-13 were organised. “The Application of Ocean Colour Remote Sensing in Primary Productivity and Ecosystem Modelling” was organized from 5- 26 February, 2012, jointly by ESSO-INCOIS and Partnership for Observation of the Global Ocean (POGO) and Nippon Foundation (NF). The training programme with 23 participants from various Universities and Research Institutions had participants from China, Kenya, Indonesia and Tanzania apart from India. The training programme on “Marine GIS” was organized in collaboration with the International Oceanographic Data and Information Exchange (IODE) during 19-23 March 2012 for the benefit of trainees from India. A training course on the use of Tsunami Bulletins was organized for 25 officers working in the offshore and coastal installations of Reliance Industries Ltd, Mumbai in May, 2012.

## 9.4 ESTABLISHMENT OF 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 establishment of such a centre will enhance African countries’ capability to implement an end-to-end medium range weather forecasting system for generating and disseminating weather forecasts 3 to 10 days in advance over African continent.

## 9.5 NATIONAL GEOCHRONOLOGY FACILITY

In order to undertake contemporary cutting-edge research in isotope geochemistry and geochronology pertaining to earth, atmospheric, oceanic and planetary sciences, a National Facility for High-resolution Secondary Ionization Mass Spectrometry (HR-SIMS) & Accelerator Mass Spectrometry (AMS) is being set up. The

facility is expected to support several new lines of research in the areas of multi-element Isotope geochemistry and geochronology which are currently at the forefront of basic and applied research across the world.

## 9.6 EARTH SYSTEM SCIENCE & TECHNOLOGY CELLS

Earth System Science & Technology Cells (ESTCs) have been set up to support theme based focused Research & Development (R&D) activities in Earth Science & Technology. This is primarily aimed towards capacity building in various universities in the field of Earth System Science and Technology. Nine ESTCs have been established in the country in specific areas of Marine and atmospheric sciences in various Universities. During the year 2011-12, Following ESTCs worked on research projects of their specialization, as given below.

Sl.	Name of ESTC	Theme
1	Goa University	Marine Microbiology
2	Annamalai University	Marine Biology
3	Mangalore University	Geological Oceanography including palaeoclimate studies, coastal geomorphology & natural hazard management, coastal oceanic process
4	Andhra University	Coastal Marine Resources & Atmospheric Studies
5	Bhavnagar University	Marine Diversity & Pollution
6	Cochin University of Science and Technology (CUSAT)	Marine Benthos
7	IIT, Kharagpur	Ocean Engineering & Underwater Robotics

Some of the major outputs have been as following;

- (i) Sea trial of the indigenously developed Autonomous Underwater Vehicle was carried out by IIT Kharagpur. 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.

- ii) 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 (Bose Institute, Kolkata).
- iii) The antagonistic bacteria identified as Mesococcus strain was found to be safe and could be mass cultured. This was a significant finding in controlling pathogenic Vibrios in Shrimp hatchery (Andhra University).
- iv) Novel drugs and immune-stimulants were developed from marine actinomycetes and yeast for disease management in aquaculture. Study showed that the protection imparted by beneficial microbes would be highly helpful to farming industry (CUSAT).

Research infrastructure was built up through the funds provided by ESSO-MoES. The infrastructure include items of equipment such as UV-Visible Spectrophotometer, Fluorescence spectrophotometer, Carbon-Hydrogen-Nitrogen(CHN) analyzer, High Pressure Liquid Chromatography (HPLC), Particle size analyzer, etc. Manpower development was a major high light, as these projects helped several students to obtain their M.Phil./Ph.D. degrees, apart from good number of papers published in reviewed journals.

Seven Ph.D. got awarded, eight thesis for Ph.D. were submitted as outcome of the projects, during 2011-12. Also, there were 107 papers published and accepted for publication in the reviewed journals.

## 9.7 R&D IN MARINE SCIENCE

The ESSO-CMLRE was recognised as a Centre for undertaking Doctoral Research in Marine Science by the Cochin University of Science and Technology during the year





A training programme on “The Application of Ocean Colour Remote Sensing in Primary Productivity and Ecosystem Modelling” was conducted in collaboration with Nippon Foundation (NF) - Partnership for Observation of the Global Oceans (POGO) Centre of Excellence in Observational Oceanography at Bermuda Institute of Ocean Sciences (BIOS).

## 9.8 R & D FUNDING IN EARTH & ATMOSPHERIC SCIENCES

Several projects were launched to improve the understanding of the earth system (the atmosphere, ocean, solid earth, biosphere) and their response to the natural and human induced changes. To exploit the research capabilities existing in the country, the areas of funding identified are

1. Atmospheric Science including Climate Science
2. Geoscience
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 Research Board. An Apex committee has

also been constituted to consider specific proposals recommended by the PAMCs and Research Board.

### 9.8.1 Focussed Research Projects

The following research projects in focussed research areas were funded in 2012-13:

#### i) Geoscience

- Exhumation and denudation history of the western and central Arunachal Himalaya: Low Temperature Thermochronology investigation to be implemented - IIT, Bombay.
- “Petrogenesis of mafic and ultramafic magmatism at Madawara Igneous Complex, Bundelkhand Craton: Implications for Platinum Group Elements (PGE) Metallogeny” - National Geophysical Research Institute, Hyderabad.
- Evaluating structural control on gold mineralization in Gadag region (Karnataka) - a study based on fabric quantification and kinematic analysis - IIT, Kharagpur.

#### ii) Atmospheric Research:

- Establishment of Pulsed Laser Photolysis - Laser Induced Fluorescence (PLP-LIF) Spectrometer and measurement of atmospheric lifetimes of volatile organic compounds in the Earth’s atmosphere IIT, Madras.
- Size-resolved measurements and modeling of cloud condensation nuclei (CCN) in Indian continental and marine air to be implemented - IIT Madras
- Chemistry of snowfall and Atmospheric aerosols at selected sites in north-western Himalayan ranges - Jawaharlal Nehru University, Delhi
- Understanding of fate and transport of black carbon in the aquatic environment - Tezpur University, Assam.
- 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

- iii) **Ocean Science & Services:** The projects likely to be funded in the areas of ocean science include mussel farming, assessment of heavy metal pollution, numerical model validation for prediction of surf zone and rip currents, oil spills and hydrocarbon removal in the marine environment.

### 9.8.2 Economic Benefits of Weather and Hazard Services

Impact Assessment and Economic Benefits of Weather and Marine Services - Phase II" has been carried out by the National Council for Applied Economic Research (NCAER), Delhi. The services included (a) Aviation Service (b) Desalination (c) Lobster and Crab fattening (d) Ornamental fish. The study has shown that the Airport Authority of India should earmark Rs 85 crore at current Route Navigation Facility Charges (RNFC) rates or 6 per cent of RNFC to ESSO-IMD for provision of Met services. The overall cost works out to 75 paise per litre of desalinated water for Kavaratti and 10 paise per litre of desalinated water from the project in Thoothukodi using Low temperature Thermal Desalination Technology (LTTD). An important conclusion of the survey was that the with the adoption of LTTD technology in desalination and setting up of hatcheries in coral Islands, ESSO-MoES programmes can increase the domestic product and employment by over 10-20%.

### 9.8.3 Building indigenous capability

The following two proposals were approved for building indigenous capability:

- **Development of Ka Band Polarimetric Doppler Radar for cloud profiling** by Society for Applied Microwave Electronics Engineering and Research (SAMEER), Mumbai, a Society under DIT. SAMEER 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.

- **Advancing Integrated Wireless Sensor Networks for Real-time Monitoring and Detection of Disasters"** by 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.

### 9.8.4 Human Resource Development & Capacity Building

**Indian Center for Space Physics (ICSP), Kolkata:** An annual grant for a duration of 5 years has been given to support salary/fellowships of scientific manpower for carrying out research in areas of earth system science.

**Norwegian Polar Institute:** PhD Fellowship for 2 Indian students in Polar Science.

**IIT, Gandhinagar:** "Varāhamihira ESSO-MoES Chair" and Varāhamihira ESSO-MoES Research Fellow have been established to promote excellence and leadership in research and development in Earth System Science and Engineering. Dr Gregory A MacRae, University of Caterbury, New Zealand has joined IIT Gandhinagar as Varahamihira ESSO-MoES Chair.

**IIT, Delhi:** Continuation of Sir Gilbert Walker ESSO-MoES Chair and Sudhansu Kumar Banerji ESSO-MoES Outstanding Faculty Fellow and sponsored M.Tech and PhD programmes in the field of Earth & Atmospheric Sciences programme.

**IIT, Kharagpur:** Establishment of a "Samudragupta ESSO-MoES Chair" in the area of Earth System science and "James Rennell ESSO-MoES Young Fellow" Prof Avijit Gangopadhyay, Umass, Dartmouth has joined IIT Kharagpur as Samudragupta ESSO-MoES Chair

**IIT Kanpur :** D.N. Wadia MoES Chair at IIT Kanpur. The Chair was established at IIT Kanpur in 2011 in the area of Earth System Science





and Climate Change. Prof S.K.Tandon has joined as the Chair.

**Koteshwaram ESSO-MoES Chair Professorship** in the area of Aviation Services, Airborne Observations, Atmospheric Technology has been given to AVM Dr. Ajit Tyagi and **ESSO-MoES Panikkar Professorship** in the area of Cryosphere and Geo-science Research has been given to Shri Rasik Ravindra.

### 9.8.5 Progress of ongoing projects

#### A. Focussed Research

##### i) Atmospheric Research

- **Research for Seasonal Prediction of the Indian Monsoon (RESPIM) - IISc, Bangalore** The project with an aim to improve the accuracy in simulating the inter-annual variation of the Indian summer monsoon rainfall by different Atmospheric General Circulation Models (AGCM) and Coupled Global Climate Models (CGCM) **has been completed**. A detailed analysis of the simulation of the Indian monsoon by CGCMs and AGCMs showed that there are large biases in simulating even the mean summer monsoon rainfall. On the inter-annual scale it was found that simulation of the ENSO-monsoon linkage was realistic though the linkage of the Indian monsoon with Indian Ocean was not realistic.
- **Design and Development of a Unified Modelling System for Seamless Weather and Climate Predictions of Monsoons - IIT, Delhi**. The reference model LMDZ is being re-engineered for implementation on the GPU Cluster. The initial spin up in speed of computation for some of the modules implemented on a single GPU Compute node is by an order of magnitude in comparison to CPUs. Work is in progress to implement the complete reference model on the GPU cluster which is now ready for exploitation.

- **Cosmic Rays-Cloud-Climate Conundrum: Can Ion-Aerosol Near-Cloud Mechanism Explain the Observed Correlations? - IIT, Kanpur**. It aims to study the cosmic ray- cloud connection and its impact on climate. The **MOdel of Global Electrical Circuit (MOGEC)** has been developed to quantify the electrification of the aerosols in the altitude range from 5 - 24 km. A polydisperse distribution of aerosols is used in the model, which are obtained from the measurements of the total aerosol concentration. The uncharged aerosol concentration is compared with the measurements. In the upper troposphere and in the middle stratosphere, there is very good qualitative agreement between measurements and the modeling, for uncharged aerosols, where most of the aerosols are charged.

##### ii) Geoscience

- **River dynamics and Flood Risk evaluation of the Kosi River, North Bihar plains: an integrated approach" - IIT Kanpur**. The proposal is aimed at understanding river dynamics and flood risk evaluation of the Kosi River in north Bihar and development of flood management strategies. The electrical resistivity data suggest the occurrence of 30-40 meters thick sand bodies buried below thin silty cover. A detailed field survey using kinematic GPS was carried out in April-May 2012 to generate cross sections of the Kosi River at the reaches downstream of barrage, which are characterized by high potential of channel avulsion.
- **Monsoon driven changes as preserved in marine sediments off the Gujarat and Konkan coasts during the past 20Kys - IIT Kharagpur and NCAOR, Goa**. The project is based on foraminiferal and geochemical proxies from deep-sea samples from the study area. 890 samples collected from 6 locations (holes/cores) have been analysed for benthic foraminiferal.

All samples from 4 holes/cores have been dated using AMC  $^{14}\text{C}$  dating techniques at NOSAMS facility, Woods Hole, USA.

### iii) Climate Change

**Assessing the Impacts of Climate and Land Cover Changes on Hydrology - University of Kashmir.** Historical hydrological and climatic data has been procured for 24 watersheds of the Jhelum basin. PRECIS Regional Climate Model has been set up and the simulations for various emission scenarios are in progress.

### B. Building indigenous capability

- Under the New Millennium India Technology Leadership Initiative (NMITLI) project initiated in April 2010 jointly with the Council of Scientific and Industrial Research (CSIR) for producing biofuel from marine microalgae, a 200 km test-run of a regular vehicle on neat (B100) biodiesel from marine microalgal source was carried out on March 30, 2012.
- **Computational Aspects of Numerical Weather Prediction at C-DAC, Pune and NCMRWF, NOIDA.** Global Unified Model was successfully installed on the Linux Cluster (Param-Vayu) and tested at a coarse horizontal resolution ( $3.75 \times 2.5$  degree) with 70 vertical levels.

### C. National Coordinated program

- Continental Tropical Convergence Zone (CTCZ) involving multi-institutes 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 order to understand the north-south gradients in the thermal field over the Bay and to test hypotheses on the northward propagation of monsoon systems, ESSO-MoES provided ship time along with facility for launching GPS sondes on its two Research Vessels, Sagar Kanya and Sagar Nidhi from 9 July-8

August 2012 to the CTCZ team. The CTCZ team could successfully collect the ocean component data and are analyzing it further to study the peculiarity of monsoon 2012.

### D. Human Resource Development

- **NIAS, Bangalore:** National Institute of Advanced Studies (NIAS) has been given an annual grant for 5 years to support the various research and development activities including Ph.D programme in particular in the area of environment, climate change and energy sector. NIAS has carried out a study for estimating the year-round energy savings through advancing the Indian Standard Time (IST) and also through introduction of daylight saving time (DST). The study concluded that advancing IST by half an hour saves more energy than the corresponding DST option.

### E. National facility

- **Laser Raman Spectrometer: Center for Earth Science Studies (CESS), Trivandrum:** The facility will be used to study the application of fluid inclusion technique for oil exploration by using the drill core/cutting samples from ONGC. Preparation of fluid inclusion plates in the Lapidary Facility in CESS has been initiated. The observance of Hydrocarbon Fluid Inclusions (HCFIs) for the first time in India from quartz grains in the sedimentary rock cuttings collected at a depth of 3055m-3060m from the RV-1 Well (ONGC) in the Ratnagiri offshore basin has been reported.





# INFRASTRUCTURE DEVELOPMENT

## 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. Weather/climate forecasts, including those of extreme weather, are becoming increasingly important in many aspects. In-depth understanding of weather and climate is required for better prediction and to provide improved services, the presently available computing resources of 112 TF that was commissioned during 2009 has already shown improvement in the short and medium range scale with usage of high resolution models. However in order to enhance the skill further in all temporal and spatial scales including climate scale, the present infrastructure is sub critical.

Improved and reliable forecast of weather and climate requires routine integrations as well as research and development using very high resolution dynamical models with high complexity (e.g. coupled ocean-atmosphere-biosphere-cryosphere models). Integrations of these models and the necessary R & D to improve them are possible only if the existing HPC facility is

augmented substantially to Petaflops capacity. This will help to enhance resolution of numerical models to resolve clouds, improvement of monsoon forecasting at various spatial and temporal ranges as well as climate system modelling, interpolation and interpretation of sparse data in dynamically consistent way to produce 'now-cast' or analysis, studies related to observation simulation experiments (OSE), observation system simulation experiments (OSSE) and targeted observation experiments, ensemble predictions for weather, ocean state, cyclone track, short and medium range weather forecast, satellite and in-situ data assimilation, understand the science of climate change and climate variability etc.

It is estimated that about 3 Peta flop computing power and large storage is required in a phased manner with initial commissioning of about 1500 TFs. The managing of such system is a challenging task that involves setting up of facilities with low cost having lower power consumption, along with successful porting of codes, etc.

## 10.2 OCEAN RESEARCH VESSELS

A fleet of six scientific research vessels are under operation for undertaking oceanographic research activities (Table 1).

**Table 10.1 Utilization of Vessels in 2012-13 (April 2012 - January 2013)**

Name of Vessel	Days at sea/ utilization	Maintenance/Inspection/ Logistics/ Cruise Preparation	Number of cruises	No. of Port calls/ Port stay
ORV Sagar Kanya	252	25	17	29
FORV Sagar Sampada	125	159	16	22
TDV Sagar Nidhi	209	79	12	18
BTV Sagar Manjusha	158	68	18	80
CRV Sagar Paschimi	99	78	21	129
CRV Sagar Purvi	68	127	13	111

### **Oceanographic Research Vessel (ORV) Sagar Kanya**

ORV Sagar Kanya continued to provide services to scientists from several national institutions and universities. The vessel was also deployed for the National Institute of Ocean Technology-Ocean Observation Systems (NIOT-OOS); Sustained Indian Biogeochemistry and Ecosystem Research (SIBER), Science Applications International Corporation (SAIC) Buoy, The Continental Tropical Convergence Zone (CTCZ); the Research Moored Array for African-Asian-Australian Monsoon Analysis and Prediction (RAMA) moorings; Hydrothermal Mineralisation in the Indian Ocean; Current measurements and Geotracers, project.

### **Fishery Oceanographic Research Vessel (FORV) Sagar Sampada**

FORV Sagar Sampada undertook scientific cruises within the Indian EEZ towards undertaking environment and productivity surveys, Geotracers programme, SIBER, Studies on fish eggs and larvae, Deep-sea fishery survey and studies on marine benthos. Other scheduled activities are IndOBIS survey, and the Southern Ocean expedition.

### **Technology Demonstration Vessel (TDV) Sagar Nidhi**

TDV Sagar Nidhi, the sophisticated ice class multi-disciplinary vessel having fully automatic diesel-electric propulsion with azimuth and bow thrusters, Dynamic Positioning class II (DP II) system, is being used essentially for demonstration of ocean technologies, viz. Remotely Operable Submersible (ROSUB), Automatic Coring System (ACS), In-situ Soil Tester, and shallow water mining system, etc. The vessel was also utilized for deployment of RAMA mooring, ADCP Moorings, and deployment & retrieval of tsunami and OMNI buoys. The vessel is expected to undertake the Southern Ocean Expedition during the year. The Conductivity, Temperature, Depth recorder (CTD) Rosette is also commissioned to collect water samples at

different water depths upto 6000 meter along with Chlorophyll, Rhodamine, pH, etc. profiler. Separate sampling room is built adjacent to the wet lab and geological core cutter lab. Scientific winches like hydrographic winch, CTD winch, Active heave compensation winch, etc. are available onboard for deployment and retrieval of scientific equipments. All winches are facilitated with 6000 meter length cable. Vessel was dry-docked at Dry-Docks World, Singapore to complete dry-dock and afloat repairs.

### **Buoy Tender Vessel (BTV) Sagar Manjusha**

BTV Sagar Manjusha was actively involved in providing platform for deployment and retrieval of data buoys, suction pile operation, radiometer testing, water sampling and bathymetry survey.

### **Coastal Research Vessels (CRVs) Sagar Purvi and Sagar Paschimi**

CRVs Sagar Purvi and Sagar Paschimi were mainly used for the implementation of Coastal Ocean Monitoring and Prediction System (COMAPS) and Integrated Coastal and Marine Area Management (ICMAM) programmes. In addition, Sagar Paschimi was used for Kalpasar project and Marine Bio-technology-NIOT for water sampling. Sagar Purvi had undergone major overhauling of main and auxiliary engines at Cochin to cater the statutory / Class requirement.

The process of acquisition of two coastal research vessels as a replacement of CRVs Sagar Purvi and Sagar Paschimi, has been initiated.

## **10.3 AIRBORNE PLATFORMS**

Targeted 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. The recent successful experiment CAIPEEX (Cloud Aerosol Interaction and Precipitation Enhancement Experiment) by ESSO-IITM Pune using airborne platforms highlighted the need and use for airborne platforms for targeted atmospheric observations. With this motivation, a programme for the National Facility for Airborne Research (NAFR) under the 12th Five Year plan (2012-2017) 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

A conscious effort is made to propagate and bring awareness about the programmes and achievements among the general public, students and user communities. This is being done through sponsoring seminars/symposia, conferences, workshops and training modules organized by and held at schools, colleges, Universities, Centers of National Council for Science Museums and State Councils for Science and Technology; participation in National and International exhibitions, Celebrating the “Earth Day” in Schools, Colleges and Universities as well as myriad communities across the country. Besides, National and International Earth Science Olympiad is supported through grants etc.

### EXHIBITIONS

Stalls were setup in several exhibitions and fairs in India to disseminate information and educate students of all levels as well as the general public about the earth sciences in general, environmental issues, atmospheric sciences, polar and ocean sciences and technologies, geosciences in particular. Participation in the International Exhibitions is done where ever appropriate to showcase the achievements made by the country in earth sciences and allied fields. We participated in a total number of 15 international and national exhibitions.

### INTERNATIONAL EXHIBITIONS

An exhibition was organized at Yeosu Expo 2012 on the theme of “Living Coasts & Ocean” (12 May-12 August, 2012) in Republic of Korea. More than 100 countries participated in this

World Event. An exclusive pavilion in an area of 436 sq m showcasing the India’s history and achievements in Earth Sciences was set up. A booth was organised in the Indian International Trade Fair 2012” at Pragati Maidan, New Delhi (14-27 November, 2012). International exhibition “Pan Ocean Remote Sensing Conference-2012 (PORSEC-2012)” at Kochi.



Fig. 11.1 Indian pavilion at International Exhibition Yeosu Expo 2012 (12 May-12 August, 2012) in S.Korea



Fig. 11.2 Visit of Hon'ble Prime Minister of Republic of Korea in the India Pavilion at Yeosu Expo 2012



## NATIONAL EXHIBITIONS

An exhibition was organized on the Foundation Day (27 July 2012) at the Vigyan Bhawan, New Delhi, The other national exhibitions organized include “MTNL Health Mela 2012” at New Delhi, , “Tech Sumudra 2012 ” at Vishakhapatnam, “Acharya Satyendranath Basu Smarak Bijnan “O” Prajukti Mela-2013” at Kolkata, “ARGOVISION 2013 -Workshops, National Expo & Conference” at Nagpur, “5<sup>th</sup> Science Expo-2013” at Lucknow, “Research & Development achieved by Indian Scientific Institutions” New Delhi, and 100<sup>th</sup> Indian Science Congress at Kolkata.



Fig. 11.3 Exhibition at India International Trade Fair 2012

An onboard exhibition was arranged at Kochi on June 8<sup>th</sup> 2012 commemorating the World Ocean day with a view to spread mass awareness on ocean research amongst the public. More than 2000 school children visited the vessel during the period of exhibition.

## EXHIBITION ON WHEELS

Exhibition on Wheels has been launched on the foundation day by the Hon’ble Minister of State for Earth Sciences, Shri Ashwini Kumar to create awareness amongst students and general public in rural areas including School, College, Universities at Villages, Mandals, Talukas, District Headquarters, Cities etc. about Earth, Atmosphere and Ocean Sciences and Technologies.



Fig. 11.4 Exhibition on Wheels launched by Hon’ble Minister of State of MoES on Foundation Day

**Rural Exhibitions:** Exhibitions were set up at the “2<sup>nd</sup> Vision Haryana 2012” in October, 2012 at Sirsa, Haryana, 17<sup>th</sup> Sundarban Kristi Mela O Loko Sanskriti Utsab 2012” and “9<sup>th</sup> Jatiya Sanhati Utsav-O-Bharat Mela-2012” December, 2012 at 24 North parganas, West Bengal.

## EARTH DAY CELEBRATION-2012

Earth Day is the largest, most widely celebrated international event. “Earth Day” was celebrated across the country on 22<sup>nd</sup> April 2012 and the event was organized at 33 locations across the country including schools, college and universities. The theme was “Every Day is Earth Day”. Various competitions like drawing and painting, debate, essay, cycle rally amongst various age groups were arranged and cash prizes were offered to the students. Popular lectures by eminent scientists/local scholars on Earth Science related topics were delivered. About 4000 children participated, prizes at National level were distributed on the foundation day.



Painting Competition



Tree plantation



Bi-cycle rallies

Fig. 11.5 Earth Day activities

### PARTICIPATION IN INTERNATIONAL EARTH SCIENCE OLYMPIAD

International Earth Science Olympiad was held during September 2012 and four students were selected to represent India at the International Earth Science Olympiad, Olavarria, Argentina. Indian team won a silver medal and three bronze medals. Besides, in the International Field Team Investigation, and team also bagged the Award for the BEST PRESENTATION.



Fig. 11.6 Indian team at International Earth Science Olympiad 2012, Olavarria, Argentina.

### SEMINARS, SYMPOSIA, CONFERENCES AND WORKSHOPS

350 events have been supported in area of Earth system science to provide platform to scientists, engineers, technologists. Experts, social scientists and user communities. The beneficiaries are Indian Institute of Technology/ Indian Institutes of Management, CSIR labs, Universities, Non-Governmental organizations, government bodies, etc.

A few major areas 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 sciences; snow and avalanches processes; mathematical modelling and simulation; fish development, environmental law, shipping etc.



## INTERNATIONAL COOPERATION

The primary mandate of the ESSO-MoES 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 the work of ESSO-MoES. This is facilitated by bringing together the best researchers and facilities wherever they are placed in the world. By engaging internationally one is able to widen the scope of research by linking researchers with different skills and expertise and enhance their experience with overseas partners, introducing them to new skills and ideas, enable participation in large-scale research and observational programs that require international participation. 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 ESSO-MoES (on behalf of Govt. of India), and NOAA (on behalf of US Government) on 16<sup>th</sup> April 2008 under the broad umbrella Agreement of 2005 on Science and Technology between the two countries. Under this MoU, various Implementation Agreement (IA) are undertaken with specific strategy with identified PIs from India and US with well defined objectives, deliverables, individual as well as joint roles and monitoring/evaluating mechanism. 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*. Eight IAs have been signed so far. Good progress is seen in these projects.

#### South Asian Regional Reanalysis(SARR)

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

initialization and rainfall assimilation experiments using NCEP data.

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

A new moored buoy array in the Indian Ocean provided measurements to advance monsoon research and forecasting. It is designed specifically for studying large-scale ocean-atmosphere interactions, mixed-layer dynamics, and ocean circulation related to the monsoons on intraseasonal to decadal time scales. The planned array consists mainly of 38 surface moorings and 8 subsurface moorings. Presently, 21 surface moorings and 8 subsurface moorings have been deployed in the Indian Ocean by collaborative effort by many countries. India has deployed 3 subsurface moorings and 17 out of 38 surface moorings are deployed and maintained by India-US joint initiative. These data are being used for operational and research purposes which are relevant to Monsoon. NOAA and MoES will work to reach 100% implementation of the RAMA by 2014. During the last one year, India has provided 60 days of ship time for maintaining 17 moored buoys in the Indian Ocean. PMEL/NOAA has trained 3 engineers one week in US and 1 month onboard research vessel. During the next three months, India/US will jointly service the existing moorings.

### **Climate Modelling and Ocean Data Assimilation Analysis**

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

nonlinear technique like neural network in order to improve the performance of the forecast.

### **Climate Monitoring and Prediction System for the South Asian Region**

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

### **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

### **INSAT 3D Data Processing**

This involves development and evaluation of algorithms and techniques for satellite-based precipitation estimates, sea surface temperature, humidity and temperature profiles, ozone etc. using INSAT-3D satellite data over India

### **Tsunami Science, Detection, Analysis, Modeling & Forecasting**

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

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

Indian and US scientists are working jointly on 'Dynamical Seasonal Prediction of Indian Summer Monsoon Rainfall'. A "Monsoon Desk" has been established in this regard. A dedicated





scientist at the monsoon desk has been identified (Kate Howard). The model codes have been successfully implemented at the ESSO/MoES identified Centers. The performance of the model was assessed during monsoon 2011 vis a vis the existing operational model. Detailed evaluation of the performance by NCMRWF showed positive results (with practically 1 day gain in the performance of the flow pattern), has transferred the model to IMD. for its subsequent operational usage. Scientists from IMD and NCMRWF participated in a review meeting held in NCEP, USA to present the performance of the high resolution model over India during monsoon 2011.

## 12.2 INDIA-US COOPERATION ON WEATHER AND CLIMATE FORECASTING AND AGRICULTURE

### Agro-Climatological and Water Resource Availability Modeling for Agricultural Management

Under the framework for India-US Cooperation on Weather and Climate Forecasting and Agriculture, 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 Global Unified Model (UM) N512L70 with a resolution of 25 kms has been successfully implemented at NCMRWF which includes aerosol climatology. The regional version of the Unified model with upgraded physics was run

during monsoon season and validation studies are being carried out. The unified model with 4D-VAR data assimilation scheme is being run along with assimilation of Indian surface observations. The coupled ocean atmosphere model along with ocean data assimilation has been implemented and trial runs are underway.

## 12.4 COOPERATION WITH NERC (NATURAL ENVIRONMENTAL REGIONAL COUNCIL)

Ministry of Earth Sciences and the Natural Environment Research Council (NERC), UK entered into an MoU to work together to support research in the area of Changing Water Cycle in South Asia. Five projects have been undertaken. A NERC-MoES joint meeting to review the progress of the on-going projects on Changing Water Cycle was conducted on 7-8 February, 2013 at MoES, Prithvi Bhavan, in which 10 UK Scientists and 15 Indian Scientists have participated.

It is proposed to sign a memorandum of understanding (MoU) with NERC on collaboration in Earth Sciences. The cabinet approval for signing the MoU with NERC, UK has been received. A scoping workshop was conducted jointly by NERC and MoES at New Delhi during 4-6 February, 2013 to discuss potential areas for collaboration under monsoon research.

### Cooperation with 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 IITM Pune for training on the couple ocean model system.

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

The constituent units of ESSO-MoES have been taking leadership role 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 forecasts are provided for the RIMES member countries.

The First Ministerial Conference of the RIMES Executive Council, currently being chaired by India was held on 21 June 2012 at ESSO-MoES in New Delhi. The meeting emphasized on the need of providing meteorological and hazard related data and capacity building in the field of modelling and observations both in the ocean and atmosphere sectors.

### 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. It provides an opportunity to identify study and deliver international environmental research priorities, for the society, in an accelerated way through trans-national research collaboration between natural and social scientists and alignment of international resources. Australia, Brazil, Canada, France, Germany, Japan, Africa, UK and USA, India are members of the Belmont Forum. An MoU was signed between MoES and the Belmont forum Countries to support Indian Scientists for international collaborative research through joint calls in societally relevant global environmental change challenges. The Belmont forum has initially identified (i) Freshwater security, and (ii) Coastal Vulnerability as two Collaborative Research Action (CRA) points to be taken up under this agreement.

### 12.5 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. It is proposed to set up BIMSTEC

Centre for Weather & Climate (BCWC) at the NCMRWF, NOIDA for enhanced regional cooperation on forecast information, early warning systems, capacity building and observing systems.

### 12.6 COOPERATION WITH KOREA METEOROLOGICAL ADMINISTRATION (KMA)

A 4-member delegation visited KMA to attend the 2<sup>nd</sup> 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.

### 12.7 COLLABORATION WITH IRIS WASHINGTON, USA

A collaboration has been made with Incorporated Research Institutions of Seismology (IRIS), Washington, USA for transmission of Seismic waveform data of three IMD stations viz., Port Blair, Minicoy and Shillong to enable availability of continuous seismic waveform data to global community for early warning of tsunamis.

### 12.8 INTERNATIONAL GEOLOGICAL CONGRESS MEET



Fig. 12.1 The ESSO-MOES Delegation at the IGC meet, Brisbane



The 4-member MOES delegation led by Dr Shailesh Nayak, Secretary, MoES attended the 34<sup>th</sup> meeting of the International Geological Congress (IGC), at Brisbane, Australia during 5-10 August, 2012. As a part of this meeting, India, represented jointly by the Ministry of Mines/ Geological Survey of India, the Ministry of Earth Sciences and the Indian National Science Academy (INSA), presented a south Asian bid, on behalf of five countries viz., India, Bangladesh, Nepal, Pakistan and Sri Lanka, for holding the 36<sup>th</sup> meeting of IGC in India in 2020. India won the bid, with overwhelming response of 128 votes in its favor as against 51 votes for Canada, the only other contender.

### 12.9 INDIAN OCEAN GOOS (IOGOOS)

The IOGOOS secretariat has been functioning at ESSO-INCOIS since its inception in 2002. The IOGOOS membership has grown from 19 to 26 institutions representing 14 countries. The functioning of IOGOOS secretariat at INCOIS has been extended upto 2013.

### 12.10 MARINE SCIENCE

ESSO-CMLRE attended the meeting of the Intergovernmental panel on HAB (IP-HAB) held in Paris in April 2012.

ESSO-CMLRE attended the 16<sup>th</sup> session of the Subsidiary Body of Scientific Technical and Technological Advise (SBSTTA) to the Convention of Biological Diversity (CBO) held at Montreal, Canada from 30<sup>th</sup> April to 5<sup>th</sup> May 2012.

ESSO-CMLRE attended the meeting of the Convention of Biological Diversity (CBD) - Conference of Parties CoP-11 as a member of Indian delegate, held at Hyderabad from 8<sup>th</sup> to 19<sup>th</sup> Oct 2012.

CMLRE represented the Ministry in the meeting of the Commission for Conservation of Antarctic Marine Living Resources (CCAMLR) held at Hobart, Australia from 22<sup>nd</sup> October to 1<sup>st</sup> November 2012.

### 12.11 THE FOLLOWING ESSO/MOES SCIENTISTS WERE SELECTED TO JOIN IN DIFFERENT INTERNATIONAL PANELS

- UN Commission on the Limits of the Continental Shelf (CLCS): Dr. S. Rajan, 2012-17: Member
- PALCOMM (Palaeoclimate Commission), and International Quaternary Association (INQUA): Dr Thamban Meloth; Member
- Policy Board of SIOS; Dr. Rahul Mohan, 2012; Member
- WMO expert panel on Climate Services Information System (CSIS); ; Dr M. Rajeevan; 2012; Member
- Review and Monitoring Committee of the German Ministry for Education and Science research program on the role of the middle atmosphere in climate (ROMIC), German Aerospace Agency, Germany: Dr Gufran Beig, IITM Pune, 2011-2012, Member
- WMO/CAS Expert Team on Weather Modification Research, Dr J.R. Kulkarni, IITM Pune, 2012, Member.
- Tree-Ring Laboratory, Lamont Doherty Earth Observatory, Columbia University, USA: Dr H.P. Borgaonkar, IITM Pune, Adjunct Scientist
- International Commission on Clouds and Precipitation (ICCP): Dr Thara Prabhakaran, IITM Pune, 2012, Member.

## AWARDS AND HONOURS

### 13.1 AWARDS

- Certificate of Excellence by WMO's GURME program: Dr Gufran Beig, IITM Pune for the Development of System of Air quality Forecasting & Research (SAFAR) for the Commonwealth Games 2010, New Delhi.
- WCRP Award for outstanding presentation at the WCRP's Open Science Conference, held at the Denver, USA, 24-28 October 2011: Dr. Ayantika Dey Choudhury, IITM Pune for the paper entitled, 'Dynamical response of the South Asian monsoon trough to latent heating from stratiform and convective precipitation'.
- BOYSCAST Fellowship, 2010-2100 by the Department of Science and Technology (DST) to conduct advance research at the National Centre for Atmospheric Research (NCAR), Atmospheric Chemistry Division, USA: Dr Sachin D. Ghude, IITM, Pune

### 13.2 FELLOWSHIPS

1. International Society of Photogrammetry and Remote Sensing: Dr Shailesh Nayak, Secretary (MoES), Elected Fellow, 2012
2. Indian Academy of Sciences, Bangalore: Dr M. Rajeevan, Adviser & Scientist-G (MoES), Elected Fellow, 2012
3. Andhra Pradesh Akademi of Sciences (APAS): Dr. Srinivasa Kumar T, Head (ASG), INCOIS, elected distinguished Fellow, 2012
4. Scientific Committee on Antarctic Research (SCAR) Fellowship: Ms. Runa Antony, NCAOR, 2011-12
5. SCAR-COMNAP fellowship; Mr Jenson V George, NCAOR, 2012-13



## PATENTS & PUBLICATIONS

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# ADMINISTRATIVE SUPPORT

## 15.1 CITIZEN'S CHARTER

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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.
- iv. To undertake and support cryospheric research in the Antarctica, Arctic and Himalayas.
- v. To monitor earthquakes, conduct seismological and geosciences research.
- vi. To provide early warning on natural disasters like cyclone, storm surge and tsunami etc..
- vii. To assess the coastal and ocean marine living resources.
- viii. To encourage formulation of research and development schemes in the earth system science, create capacity building and promote human resource development.
- ix. To extend support to seminars, symposia, conferences, exhibitions, etc. and process applications 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.

## 15.2 IMPLEMENTATION OF THE 15-POINT PROGRAMME ON MINORITY WELFARE

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

### 15.3 BUDGET AND ACCOUNTS

Sl. No.	Major Head of Account	2010-11 Actual			2011-12 Actual			2012-13 Budget			Expenditure 2012-13 (up to 01.03.2013)		
		Plan	Non-Plan	Total	Plan	Non-Plan	Total	Plan	Non-Plan	Total	Plan	Non-Plan	Total
1	3403- Oceanographic Research	515.25	39.65	554.9	615.49	60.14	675.63	648.00	56.70	704.70	437.36	50.19	487.55
2	3425- Other Scientific Research	73.37	21.04	94.41	50.39	25.08	75.47	211.50	29.32	240.82	122.48	20.22	142.70
3	3451- Secretariate Expenditure	0.00	20.83	20.83	0.00	19.38	19.38	0.00	25.54	25.54	0.00	20.30	20.30
4	3455- Meteorology	51.06	245.01	296.07	51.93	246.88	298.81	214.00	275.10	489.10	81.25	251.48	332.73
	Capital Section												
1	5403 Capital outlay on Oceanographic Research	13.16	0.00	13.16	5.87	0.00	5.87	8.00	0.00	8.00	2.09	0.00	2.09
2	5425- Capital outlay on Other Scientific & environmental Research	0.00	0.00	0.00	2.10	0.00	2.10	12.50	0.00	12.50	4.15	0.00	4.15
3	5455- Capital Outlay on Meteorology	114.98	0.19	115.17	92.94	0.06	93.00	187.00	0.34	187.34	84.40	0.05	84.45
	Grand Total	767.82	326.72	1094.54	818.72	351.54	1170.26	1281.00	387.00	1668.00	731.73	342.24	1073.97



#### 15.4 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

Sl No.	Year	No. of Paras/ PAC reports on which ATNs have been submitted to Monitoring Cell after vetting by Audit	Details of the C&AG paras/PAC reports on which ATNs are pending	No. of ATNs 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	No. of ATNs with Audit
1	2002	Para 6.2 CA 5 of 2002 "Avoidable Expenditure of Water Charges" NIL comments have received from PDA (SD) vide their U.O. No. PDA(SD)/Report -5(17)/IMD/DST/MoES/ Mumbai/3-01/473-474 dated 22.10.2012	NIL	NIL	NIL	NIL
2	2007	NIL	NIL	NIL	NIL	Para 5.1 Report no. 2 of 2007 "Unfruitful Expenditure of ` 33.08 lakh by IMD for procurement of precision Ni-span 'C'- India Meteorological Department (IMD)
3	2008	NIL	NIL	NIL	NIL	Para 7.1 Report no. CA 3 of 2008 "Non-achievement of the objectives of Modernizing the Accounting & Personnel Management Functions"
4	2008-09	NIL	NIL	Para 7.1 Report no. CA 16 of 2008-09 "Construction of Residential Quarters and Hostel Units without demand"	NIL	NIL
5	2011-12	NIL	NIL	Para 5.1 Report no. CA 16 of 2011-12 " Wasteful expenditure on refurbishment of Vessel."	NIL	NIL

## 15.5 STAFF STRENGTH

Sl. No.	Groups of Posts	ESSO-MOES	NCMRWF	CMLRE	ICMAM	IMD	NIOT	NCAOR	INCOIS	IITM	TOTAL
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
1	Group A	79	49	10	11	460	88	43	42	159	941
2	Group B	47	21	04	05	4452	13	51	26	74	4693
3	Group C (including MTS)	64	23	15	06	3501	23	26	-	136	3794
	<b>TOTAL</b>	<b>190</b>	<b>93</b>	<b>29</b>	<b>22</b>	<b>8413</b>	<b>124</b>	<b>120</b>	<b>68</b>	<b>369</b>	<b>9428</b>

ESSO	= Earth System Science Organisation
MOES	= Ministry of Earth Sciences
NCMRWF	= National Centre for Medium Range Weather Forecasting
CMLRE	= Centre for Marine Living Resources and Ecology
ICMAM	= Integrated Coastal Marine Area Management
IMD	= India Meteorological Department
NIOT	= National Institute of Ocean Technology
NCAOR	= National Centre for Antarctic and Ocean Research
INCOIS	= Indian National Centre for Ocean Information Services
IITM	= Indian Institute of Tropical Meteorology

## 15.6 REPRESENTATION OF SCS/STS/OBCS IN GOVERNMENT SERVICES (AS ON 1.1.2012)

GROUP	Representation of SCS/STs/OBCs(as on 1.1.2012)				Number of appointment made during the calendar year 2012												
	Total No. of employees	SCs	STs	OBCs	By Direct Recruitment				By Promotion				By Deputation				
1	2	3	4	5	Total	SCs	STs	OBCs	Total	SCs	STs	OBCs	Total	SCs	STs	OBCs	
GROUP A	88	08	03	05	-	-	-	-	-	-	-	-	-	-	-	-	
GROUP B	56	06	02	03	-	-	-	-	-	-	-	-	-	-	-	-	
GROUP C Including MTS	71	27	04	07	-	-	-	-	-	-	-	-	-	-	-	-	
	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<b>TOTAL</b>	<b>215</b>	<b>41</b>	<b>09</b>	<b>15</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>-</b>	



## 15.7 REPRESENTATION OF PERSONS WITH DISABILITIES IN GOVERNMENT OF 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	In identified Post	VH	HH	OH	VH	HH	OH	Total	In Identified Post	VH	HH	OH
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
GROUP A	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
GROUP B	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
GROUP C Including MTS	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil

## 15.8 OFFICIAL LANGUAGE IMPLEMENTATION

Efforts are made constantly for promotion and propagation of the official Language. As per the directives and guidelines on Official Language policy, all official work like the Annual Report, Outcome Budget, Demand for Grants, all Cabinet Notes, Reports, Monthly Summary to Cabinet and documents relating to Consultative and Standing Committees, parliamentary papers, etc. were prepared bilingually.

A Hindi fortnight was organized from 10th to 25th September, 2012. During the period, various competitions including Hindi essay writing, noting, drafting, debate, typing, quiz, Administrative Terminology and Hindi Knowledge and recitation were held. All the winners were awarded and participation certificates were given to all the participants.

## 15.9 CAPACITY BUILDING AND HUMAN RESOURCES DEVELOPMENT

During the year officers/staff (from the Headquarters) were sent for different training/workshop/seminar programmes to update their

knowledge and skills. A capacity-building programme has been taken up in head-quarters and its Units in collaboration with the Training Division, Department of Personnel & Training (DoP&T). In this regard, several national-level training courses have been conducted.

## 15.10 IMPLEMENTATION OF THE JUDGMENTS/ORDERS OF THE CAT

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

## 15.11 VIGILANCE ACTIVITIES AND ACHIEVEMENTS

Dr. S. K. Das, Sct. 'G' had been declared as Chief Vigilance Officer in consultation with the Central Vigilance Commission. Senior level Officers have been appointed as Vigilance Officers in attached/subordinate offices and autonomous bodies. A preventive as well as punitive vigilance monitoring is rigorously pursued through the Chief Vigilance Officer and Vigilance Officers.

### 15.12 GRIEVANCE REDRESSAL OF PUBLIC AND STAFF

The Ministry of Earth Sciences is a Scientific Ministry and has no direct public dealings. However, the Ministry has taken steps to ensure that due attention is paid to the public/staff grievances. Sh Taranjit Singh, Director has been nominated as Staff Grievances Redressal Officer and Public Grievances Redressal Officer (upto January, 2013). The Ministry of Public Grievances and Administrative Reforms has launched an online public Grievances website [www.pgportal.gov.in](http://www.pgportal.gov.in) where grievances can be lodged online. Up to 27/02/2013, MoES has received 299 grievances out of which 279 were disposed of. The rate of disposal was 93%.

### 15.13 IMPLEMENTATION OF RIGHT TO INFORMATION ACT, 2005

Sh B.K.Thakur and Sh Taranjit Singh has been nominated as Central Public Information

Officers and First Appellate Authorities, respectively. CPIO and Ist Appeallate authorities have also been nominated for attached/subordinate offices and autonomous institutes. Applications received under RTI are being promptly addressed to by the CPIOs and information arranged/provided accordingly. The Ministry has uploaded the RTI Quarterly/Half Yearly/Annual report on CIC web-site.

### 15.14 PARLIAMENT MATTERS

The Ministry has Parliament Section which caters to the correspondence with the Parliament Secretariats. Between April 2012 to December 2012, the Ministry has replied a Parliament Question in Lok Sabha (44 Questions) & Rajya Sabha (49 Questions).





# PERFORMANCE EVALUATION REPORT

Objective	Weight	Action	Success	Unit	Weight	Target / Criteria Value					Performance		
						Excellence 100%	Very 90%	Good 80%	Fair 70%	Poor 60%	Achievement	Raw Score	Weighted Score
1 To improve weather forecast and the advisory for agriculture, shipping, sports including the extended, Long Range Seasonal Monsoon forecast	25.00	Integrated Agro Advisory Services	Number of Districts covered by Agro Advisory	number	5.00	600	550	525	515	500	560	92.0	4.6
						4	3	2	1	0	4	100.0	4.0
						1000	950	900	850	800	1015	100.0	6.0
						90	85	80	75	70	95	100.0	5.0
						25	27	30	32	35	25	100.0	3.0
						20	15	13	11	9	20	100.0	2.0
2 To provide a wide range of ocean information advisories including fishery information	10.00	Strengthening of Ocean Observational network	Number of deployments	number	2.00	250	240	230	220	210	250	100.0	2.0
						30/05/2011	30/06/2011	30/07/2011	30/08/2011	30/09/2011	30/05/2011	100.0	3.0
		Installation of ground station for the reception of Oceansat-II/OCM data	Operationalisation of Ground station for Oceansat-II	Date	3.00	30/05/2011	30/06/2011	30/07/2011	30/08/2011	30/09/2011	30/05/2011	100.0	3.0

Objective	Weight	Action	Success	Unit	Weight	Target / Criteria Value					Performan		
						Excell	Very	Good	Fair	Poor	Achiev-	Raw	
						100%	90%	80%	70%	60%	ement	Score	Weighted Score
		in real-time											
		Potential Fishing Zone Advisory & Ocean State Forecast Services	Potential Fishing Zone Advisory	number	2.00	140	130	120	100	90	140	100.0	2.0
		Ocean State Forecast Services	Ocean State Forecast	number	3.00	365	328	292	255	219	365	100.0	3.0
3 To improve our understanding of Polar Science and its implications for climate change	12.00	Planning, Coordination and implementation of Indian Antarctic Program	Launching of the 31st Expedition	Date	1.20	20/11/2011	01/12/2011	15/12/2011	31/12/2011	15/01/2012	26/10/2011	100.0	1.2
			Completion of targeted scientific and logistics tasks		1.20	100	90	80	70	60	100	100.0	1.2
			Initiation of Phase II construction-stage activities of the 3rd station	Date	0.00	01/12/2011	12/12/2011	27/12/2011	12/01/2012	27/01/2012	01/12/2011	100.0	0.0
			Launching of the summer (S) and winter (W) phases of study in the Arctic region	Date	2.40	01/06/2011	15/06/2011	20/06/2011	30/06/2011	15/07/2011	01/06/2011	100.0	2.4
			Completion of all targeted scientific and logistics activities at Ny-Alesund for the year	Date	2.40	25/03/2012	27/03/2012	29/03/2012	30/03/2012	31/03/2012	25/03/2012	100.0	2.4
		Planning, Coordination and implementation of Scientific studies in the Indian Ocean sector of the Southern Ocean	Launching of Southern Ocean Expedition (2011-12)	Date	2.40	15/01/2012	25/01/2012	05/02/2012	10/02/2012	15/02/2012	15/01/2012	100.0	2.4
			Completion of analytical work of data collected during the	Date	0.00	15/10/2011	31/10/2011	15/11/2011	30/11/2011	15/12/2011	15/10/2011	100.0	0.0



Objective	Weight	Action	Success	Unit	Weight	Target / Criteria Value						Performan			
						Excellence 100%	Very 90%	Good 80%	Fair 70%	Poor 60%	Achiev- ement	Raw Score	Weigh- ted Score		
			previous expedition and submission												
		In-house R&D projects in the fields of cytospheric studies, polar remote sensing, paleoclimatology, polar biology and environmental studies	Completion of targeted field data collection and analytical work and submission of reports	percentage	1.20	100	90	80	70	60	100	100.0		1.2	
			Publication of results in peer-reviewed journals	number of core samples collected	1.20	15	12	10	8	5	15	100.0		1.2	
4 To developing technology for harnessing marine resources	12.00	Design, Development, installation and Commissioning of Desalination Plant	Commission and Operation desalination plants in the Minicoy island	Date	4.32	30/12/2011	15/01/2012	31/01/2012	15/02/2012	01/03/2012	22/04/2011	100.0		4.32	
		Design, Development, installation, and Commissioning of Desalination Plant at Androth	Commission and operation of desalination plants in the Agatti island	Date	3.12	30/12/2011	15/01/2012	31/01/2012	15/02/2012	01/03/2012	15/08/2011	100.0		3.12	
		Development of Remotely Operable Vehicle ROSUB 6000 for survey of at PMN site	Deployment of ROSUB for research	Date	3.12	31/12/2011	31/01/2012	28/02/2012	15/03/2012	31/03/2012	31/12/2011	100.0		3.12	
		Development of Underwater Collector & Crushing Systems for manganese nodule mining and testing in shallow waters	Testing of system with reference solid pump	Date	1.44	15/12/2011	15/01/2012	15/02/2012	15/03/2012	31/03/2012	15/12/2011	100.0		1.44	
		Technology Development for Gas Hydrates – Development of Autonomous coring	Sea trials of Autonomous Coring System (ACS) more than 100 m	Date	0.00	30/11/2011	31/12/2011	28/02/2012	15/03/2012	31/03/2012	30/11/2011	100.0		0.0	

Objective	Weight	Action	Success	Unit	Weight	Target / Criteria Value					Performan		
						Excell	Very	Good	Fair	Poor	Achiev-	Raw	
						100%	90%	80%	70%	60%	ement	Score	Weighted Score
5 To conduct survey for assessing non-living resources	6.00	system and sea trials											
		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	24000	20800	16000	14400	11200	25000	100.0	3.0
6 To asses coastal marine productivity and Marine Ecosystems	5.00	Geological and Tectonic Evolution of the Northern Indian Ocean and activities related to Integrated Ocean Drilling Program (IODP)	Completion of Data analyses pertaining to the Laccadive offshore region; data collection from the forearc region of Andamans and field studies on Barren and Narcondam islands	Date	2.04	31/08/2011	30/09/2011	31/10/2011	01/01/2012	15/02/2012	31/08/2011	100.0	2.04
		Integration and analysis of field data, Simulation of models, validation of results and preparation of Shoreline management plan	IODP workshop on the Indian proposal for scientific drilling in the Arabian Sea; revision and submission of the scientific proposal to IODP based on the comments/ observations from the reviewers; Participation of Indian scientists in IODP cruise	Date	0.96	31/10/2011	15/11/2011	30/11/2011	15/12/2011	15/01/2012	30/10/2011	100.0	0.96
			Finalization of Shoreline Management Plan for Gopalpur coast	Date	2.00	31/01/2012	15/02/2012	29/02/2012	15/03/2012	31/03/2012	31/01/2012	100.0	2.0
				number	0.00							N/A	N/A



Objective	Weight	Action	Success	Unit	Weight	Target / Criteria Value					Performan		
						Exceller 100%	Very 90%	Good 80%	Fair 70%	Poor 60%	Achiev- ement	Raw Score	Weighted Score
		Establishment of Indian Ocean biogeographical Information System (IndOBIS)	No. of records.	number	1.00	5000	4000	3000	2000	1000	5000	100.0	1.0
		Perfect technology for breeding and rearing of 5 species of clownfish and one species of damsel fish at CMLRE hatchery at Lakshadweep and its commercialisation	No. of species.	number	2.00	25000	20000	15000	10000	5000		N/A	N/A
7	5.00	To set up Centre for Climate Change Research (CCCR) at IITM with dedicated research facilities	Recruitment of scientific positions	number	2.50	6	5	4	2	1	6	100.0	2.5
			Cumulative Impact Factor of the Research Papers	number	2.50	22	20	15	10	10	25	100.0	2.5
8	5.00	To provide early warning of natural hazards viz. cyclone, tsunami, sea level rise.	Number of EQ bulletins issued within 12 minutes after the earthquake(%)	percenta ge	2.00	100	98	95			100	100.0	2.0
		Issue of Tsunami Warning Bulletin issued within 30 minutes after the earthquake(%)	Number of Tsunami Bulletins issued within 30 minutes after the earthquake(%)	percenta ge	2.00	100	98	95			100	100.0	2.0
		Issue of Tsunami warning with minimum time lag after the earth quake on sea-bed	Accuracy of warning(%)	percenta ge	1.00	80	70	60			85	100.0	1.0
9	2.50	To strengthen capacity development and promote research outside the ministry	Supporting research and academic programmes in Earth System Science	Number of Projects	2.50	12	10	8	6	4	25	100.0	2.5

Objective	Weight	Action	Success	Unit	Weight	Target / Criteria Value					Performan		
						Excell	Very	Good	Fair	Poor	Achiev-	Raw	
						100%	90%	80%	70%	60%	ement	Score	Weighted Score
10 To promote awareness and educate the public by extending support to seminars, symposia, conferences and conduct workshops with stakeholders	2.50	Conducting user oriented workshops with key stakeholder to promote awareness	Conducting user oriented workshops with key stakeholder to promote awareness	Number	1.25	20	17	15	12	10	25	100.0	1.25
		Support seminar/symposium/conference in the field of earth sciences	Support seminar/symposium/conference in the field of earth sciences		1.25	75	50	30	40	20	80	100.0	1.25
* Efficient Functioning of the RFD System	3.00	Timely submission of Draft for Approval	On-time submission	Date	2.0	07/03/2011	08/03/2011	09/03/2011	10/03/2011	11/03/2011	07/03/2011	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
* Improving Internal Efficiency / Responsiveness / Service delivery of Ministry / Department	10.00	Implementation of Sevottam	Resubmission of revised draft of Citizens' / Clients' Charter	Date	2.0	16/01/2012	18/01/2012	20/01/2012	23/01/2012	25/01/2012	16/01/2012	100.0	2.0
		Ensure compliance with Section 4(1) (b) of the RTI Act, 2005	Independent Audit of Implementation of Grievance Redress Mechanism	%	2.0	100	90	80	70	60	77.35	77.35	1.55
		Identify potential areas of corruption related to departmental activities and develop an action plan to mitigate them	No. of items on which information is uploaded by February 10, 2012	No	2.0	16	15	14	13	12	16	100.0	2.0
		Develop an action plan to implement ISO 9001 certification	Finalize an action plan to mitigate potential areas of corruption.	Date	2.0	26/03/2012	27/03/2012	28/03/2012	29/03/2012	30/03/2012	26/03/2012	100.0	2.0
* Mandatory Objective(s)		Develop an action plan to implement ISO 9001 certification	Finalize an action plan to implement ISO 9001 certification	Date	2.0	16/04/2012	17/04/2012	18/04/2012	19/04/2012	20/04/2012	13/03/2012	100.0	2.0



Objective	Weight	Action	Success	Unit	Weight	Target / Criteria Value					Performan		
						Excell	Very	Good	Fair	Poor	Achiev-	Raw	
						100%	90%	80%	70%	60%	100	Score	Weight- ted Score
* 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 date of presentation of Report to Parliament by PAC during the year.	%	0.5	100	90	80	70	60	100	100.0	0.5
		Early disposal of pending ATNs on Audit Paras of C&AG Reports presented to Parliament before 31.3.2011.	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 31.3.2011	Percentage of outstanding ATRs disposed off during the year.	%	0.5	100	90	80	70	60	100	100.0	0.5

\* Mandatory Objective(s)

Total Composite

97.15



## 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 on-going 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. High Level Committee, High Performance Computer (HPC), chaired by Prof N. Balakrishnan, IISc, Bangalore.
  3. Technical Evaluation Committee, High Performance Computer, Chaired by Prof. O.P.Sharma, IIT Delhi.
  4. Program Advisory & Monitoring Committee (PAMC) on Atmospheric Sciences, Scientific Steering Committee, Monsoon mission and the Committee on vision document on Atmospheric and climate sciences, chaired by Prof. J. Srinivasan, IISc Bangalore.
  5. Scientific Review and Monitoring Committee, Monsoon mission, and the Scientific Steering Committee, CTCZ programme, chaired by Prof. D.R. Sikka, Delhi.
  6. Expert Committee on Airborne Research Facility, chaired by Dr A.R. Upadhyaya, Hon Scientist, NAL Bangalore.
  7. Scientific Steering Committee, CTCZ Programme, and the committee on continued scheme on Research and Development, Chaired by Prof. Sulochana Gadgil, IISc Bangalore.
  8. PAMC on Hydrology and Cryosphere and the Indian Panel of Changing Water Cycle Programme, Chaired by Prof V.K.Gaur, CM-MACS, Bangalore.
  9. Programme Advisory Committee of seismicity and early prediction for Koyna deep bore hole investigations and the programme management board on national programme on Earthquake precursors, chaired by Dr Harsh K Gupta, Member, NDMA, New Delhi.
  10. Technology Research Board for Earth System Science Technology and the Expert Committee to take over the Centre for Earth System Science Studies, chaired by Dr P.S.Goel, DRDO, Hyderabad.
  11. Group monitoring committee (GMC) on seismicity programme, chaired by Dr V.P.Dimri, NGRI, Hyderabad.
  12. Expert group on Active Fault Mapping, chaired by Dr P.Pande, GSI, Lucknow.
  13. PAMC on Geosciences, chaired by Prof. Ashok Singhvi, PRL, Ahmedabad.
  14. Committee on vision document on Oceanic Sciences, chaired by Prof Satish Shetye, Vice Chancellor, Goa University, Goa.
  15. PAMC on Ocean Science and Resources, chaired by Prof. S.Krishnaswami, PRL, Ahmedabad
  16. Steering Committee on Potential Drugs from Sea, chaired by Prof. Goverdhan Mehta, Hyderabad University.
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