INCOIS

Third Annual Report 2000-2001

INDIAN NATIONAL CENTRE FOR OCEAN INFORMATION SERVICES

(An Autonomous Body under the Department of Ocean Development, Government of India)
Plot No: 3 Nandagiri Hills Layout, Jubilee Hills Hyderabad 500 033

Contents

Director's Report

The Oceans play a significant role in the national development process as the driving force for monsoons, a potential source of food, drugs and energy, a cost effective medium for transport and a strategic space. Disasters such as cyclones originate in oceanic regions. Knowledge and information about the dynamic oceanic processes is of paramount importance in (i) harvesting the ocean resources, consistent with the principles of sustainable development (ii) effective forecast of weather, monsoons, climate and (iii) sustainable development of critical marine and coastal ecosystems.

As a sequel to the Marine Satellite Information Services (MARSIS) programme, the Indian National Centre for Ocean Information Services (INCOIS) was registered, in February 1999, as an autonomous body under the Department of Ocean Development (DOD), Government of India with a mandate to synthesise, generate, promote, provide and coordinate various endeavours in the field of ocean sciences, ocean observations, satellite oceanography, ocean information and advisory services.

It was my privilege to become the Director of INCOIS in July 2000 and contribute to this important national endeavour, building upon my three decades of experience in the Space Programme.

The vision of INCOIS is to emerge as a knowledge and information technology enterprise for the oceanic realm. The imminent mission of INCOIS is to provide timely and reliable ocean information and advisory services to a wide spectrum of users from scientific community, government, industry and society.

We believe that synergy and knowledge networking with centres of excellence in ocean and atmospheric sciences, space applications and information technology is the cornerstone for accomplishing this mission. INCOIS is carving out a unique niche for (i) facilitating the generation of scientific knowledge base, (ii) translating and transforming the scientific knowledge base into useful knowledge products and viable services and (iii) sustaining an effective delivery chain.

The Governing Council of INCOIS approved the Business Plan for 2000-02 and Road map for setting up information infrastructure and induction of human capital. During 2000-01, INCOIS crossed several important milestones, as elucidated further in this Report. The highlights are as follows:

1) Development of the permanent campus for INCOIS in a 50-acre land has commenced. INCOIS would function from a hired building till the permanent campus is ready,

2) Finalisation of the architecture of the information-processing infrastructure comprising high performance servers, workstations and storage area network along with application software for satellite data analysis, GIS, database management and web-based services, slated to be commissioned by November 2001,

3) Gearing up for delivery of ocean advisory services generated from IRS-P4 (Oceansat-1) Ocean Colour Monitor and Multi-frequency Scanning Microwave Radiometer,

4) Generation and dissemination of Potential Fishing Zone (PFZ) advisories based on Sea Surface Temperature (SST),

5) Market research to evolve strategies to make PFZ information as part of the value chain of the fishing community,

6) Launching of a multi-institutional pilot study on Experimental Ocean State Forecast,

7) Management of four Projects viz. (i) Indian Ocean Modelling and Dynamics, (ii) Satellite Coastal and Oceanographic Research, (iii) Argo - a global array of profiling floats to measure temperature and salinity of the upper ocean periodically and (iv) Other Ocean Observation Systems such as drifting buoys, current meter moorings, expendable bathy-thermographs, and sea truth campaigns,

8) Recruitment and development of a young and vibrant team and knowledge networking with premier Institutions and resource persons.

I take this opportunity to place on record the guidance, encouragement and support received from Dr. A.E. Muthunayagam (the former Chairman of Governing Council), Dr Harsh K. Gupta, Chairman, Governing Council, Members of the Governing Council and the Officials of DOD for charting out a meaningful course for this young Institution in its formative period. On behalf of the INCOIS team, I assure that we would soon present an organisation of national significance and international eminence.

(K. Radhakrishnan)
Director

1. The Organisation

INCOIS was registered as a Society under the Andhra Pradesh (Telangana Area) Public Societies Registration Act 1350 Fasli at Hyderabad on February 3, 1999. The affairs of the Society are managed, administered, directed and controlled, subject to the Byelaws of the Society, by Governing Council.

INCOIS Society		
1.	Secretary, DOD	President
2.	Director, NRSA	Vice-President
3.	Joint Secretary, DOD	Member
4.	Advisor, DOD	Member
5.	Director, NIO	Member
6.	Director, NIOT	Member
7.	Director, NCAOR	Member
8.	Director, INCOIS	General Secretary

INCOIS Governing Council		
1.	Secretary, DOD	Chairman
2.	Director, NRSA	Vice-Chairman
3.	Prof. V.K. Gaur, Distinguished Professor, IIA	Member
4.	Prof. B.L. Deekshatulu, Director, CSSTE-AP	Member
5.	Financial Advisor, DOD	Member
6.	Joint Secretary, DOD	Member
7.	Advisor, DOD	Member
8.	Director, NIO	Member
9.	Director, NIOT	Member
10.	Director, NCAOR	Member
11.	Principal Adviser (S&T), Planning Commission	Member
12.	Development Advisor, MoST	Member
13.	Director, SAC	Member
14.	Director, EOS, ISRO	Member
15.	Head, C-MMACS	Member
16.	Director, INCOIS	Member Secretary

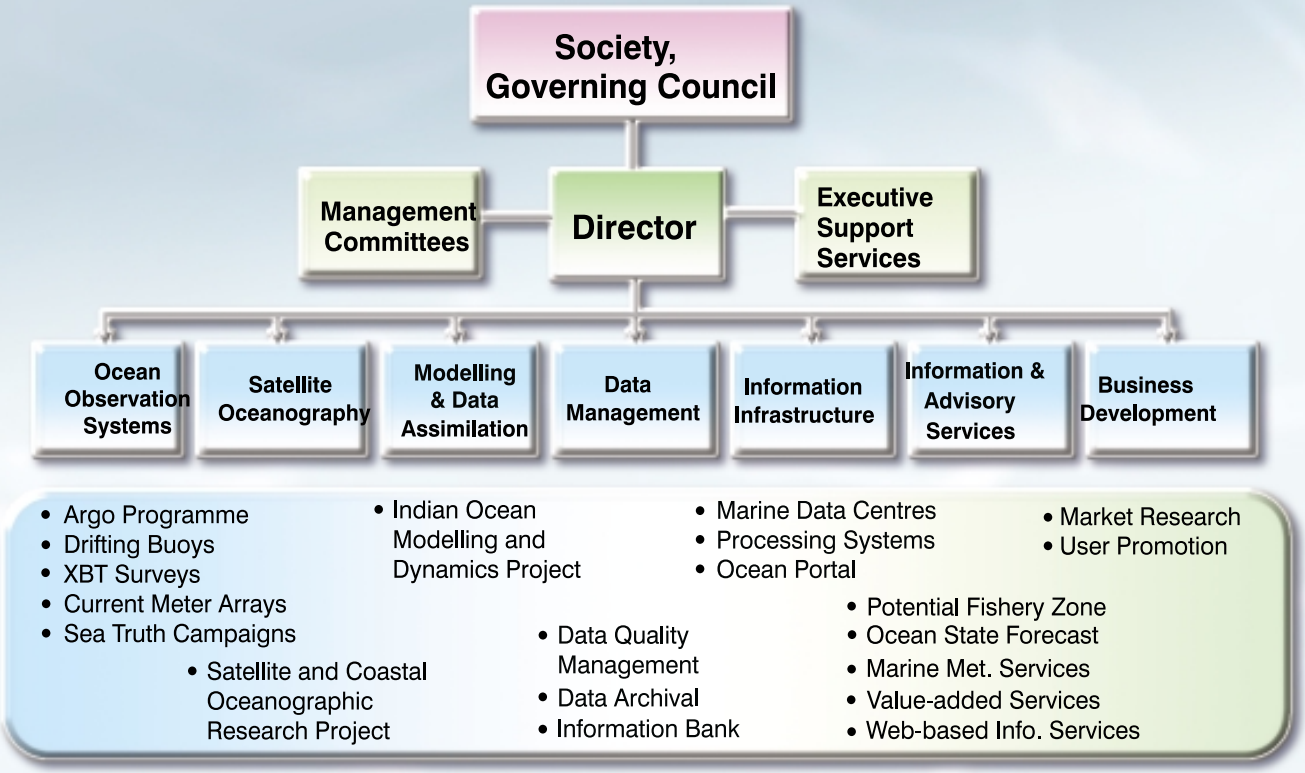

Fig. 1. The Organisation and Activity Spectrum

The first phase of manpower sanctioned for INCOIS comprises 11 scientific personnel, 4 Junior Research Fellows and 3 administrative personnel. Further, DOD has posted 3 Scientists at INCOIS for supporting the initial phase activities. Recruitment and development of a young and vibrant team and knowledge networking with premier institutions and resource persons have been important accomplishments of the year. The organisation and activity spectrum of INCOIS is given in Fig.1.

INCOIS is an active member of (i) Standing Committee of National Natural Resources Management System (NNRMS) on Ocean Resources and (ii) the International Argo Science Team.

2. Information and Advisory Services

Gearing up for delivery of ocean advisory services generated from the Multi-frequency Scanning Microwave Radiometer (MSMR) and Ocean Colour Monitor (OCM) data of IRS-P4 Satellite (Oceansat-1) in conjunction with other available ocean remote sensing data as well as in-situ data from the 14 Marine Data Centres has been a thrust area for INCOIS.

2.1 Potential Fishing Zone Advisories

SST-based PFZ Advisories: PFZ advisory service was sustained by INCOIS, jointly with National Remote Sensing Agency (NRSA). A 3-day-composite SST from cloud-free data of AVHRR sensor of NOAA Satellites is generated operationally. Upper ocean processes such as gyres, eddies, thermal fronts, advection, mixing and surface circulation that are relevant to surface biological processes, where fish tend to aggregate, are then delineated.

PFZ maps, thus generated, are disseminated to fishermen community through fax and print media along with explanatory text. During the year, biweekly (Tuesday and Friday) PFZ advisories were disseminated to 112 nodes from Gujarat, Maharastra, Goa, Karnataka, Kerala, Tamilnadu, Andhra Pradesh, Orissa, West Bengal, Lakshadweep as well as Andaman & Nicobar Islands.

In view of the cloud cover during the monsoon season and more importantly since that season corresponds to the breeding season, PFZ advisories are not given in the context of maintaining fishery stock at sustainable level.

Integrated PFZ Advisories: INCOIS is gearing up to acquire and operationalise the know-how developed by Space Applications Centre (SAC) under Satellite Coastal and Oceanographic Research (SATCORE) project for Integrated PFZ generation using SST in conjunction with the Ocean Colour Monitor (OCM) data from IRS-P4 Satellite.

Fig. 2. Potential Fishing Zone Advisory Service in Mission-Mode

Fig. 3. Potential Fishing Zone Advisory dissemination nodes

2.2 Experimental Ocean State Forecast

Pilot Study: INCOIS orchestrated a focused multi-institutional pilot study on Experimental Ocean State Forecast, drawing upon (i) algorithms and models developed under the MARSIS Programme and SATCORE Project, for retrieval of a variety of met-ocean parameters from satellite sensors, (ii) a suite of ocean models developed under the INDOMOD Project and (iii) the wind field forecast from NCMRWF. The MSMR of IRS-P4 Satellite is an important source of input for E-OSF.

The pilot study, conceived initially for five parameters viz. sea surface winds, wave parameters, sea surface temperature, mixed layer depth and storm surge, aims at (i) development of scientific methodology and forecast on a time-bound manner for three months from May 2001, (ii) validation with data from in-situ observations and other sources and (iii) evolving necessary institutional mechanisms. The potential users are involved in this pilot study right from the beginning. The specific responsibility of INCOIS in the pilot study is to organise in-situ observational data for validation of the forecast, creation of web site and for interaction with the user community.

INCOIS would start generating and disseminating these forecasts from January 2002 with active participation from the other contributing agencies.

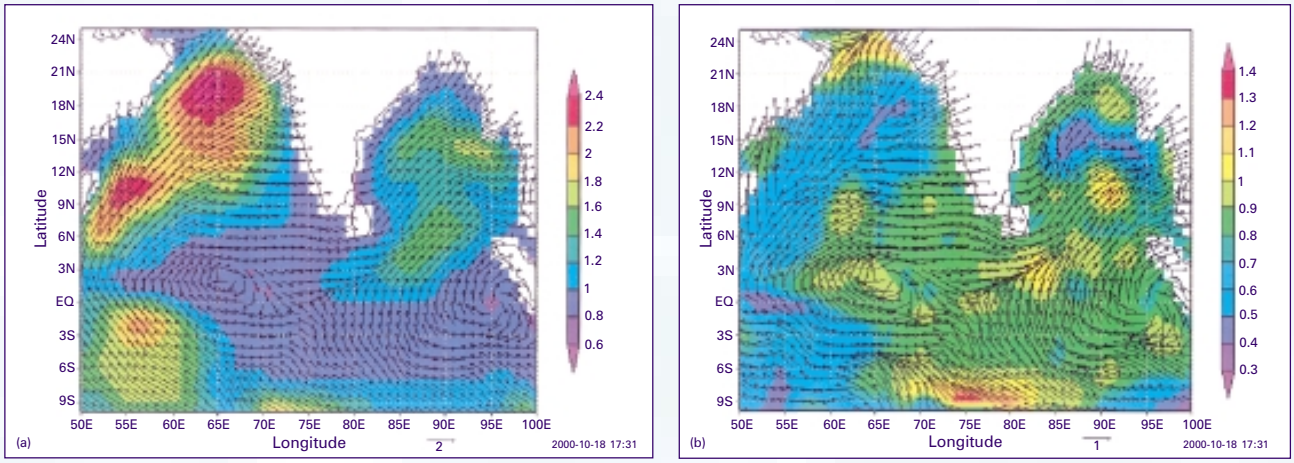

Fig. 4. (a) Significant Wave Height (m), (b) Swell Height (m) using WAM model with NCMRWF winds feilds.

2.3 Ocean Information Bank and Web-based Services

The Ocean Information Bank and Web-based Services comprise a crucial element of the mission on Ocean Information Services that is to be realised in the near future. This involves an institutional mechanism for collection of a wide spectrum of oceanic data, data processing, archival, value-added services and a system for timely delivery to the users from scientific community, government, industry and society.

Marine Data Centres: A network of 14 Marine Data Centres (MDC) were established by DOD in the 90's under the MARSIS Programme, in National Laboratories and Academic Institutions to collect and collate data, undertake quality control exercises and archive it in digital databases. During the year, in-situ assessment of the MDCs was conducted to draw up the future plan.

Data and Information residing in the INCOIS Information Bank
1. NOAA-AVHRR data and Sea Surface Temperature archives for North Indian Ocean from 1992 to 2001 including daily, weekly and monthly images, grid data, and brightness temperatures
2. PFZ Maps from 1992 onwards along the Indian coastline and Islands (for non-monsoon months)
3. XBT data, Drifting Buoy data and Moored Buoy data for the year 2000
4. Coastal area Maps of Andhra coast from Nellore to Orissa border

Data holdings of Marine Data Centres	
1. Geological Survey of India, Kolkata	Marine Geologiocal data
2. KD Malavia Institute of Petroleum Exploration, Dehradun	Magnetic, Seismic and Gravity data
3. India Meteorological Department, Pune	Ocean Surface Meteorological data
4. Survey of India, Dehradun	Tidal data
5. Naval Hydrographic Office, Dehradun	Hydrographic data
6. National Institute of Oceanography, Goa	Physical, Chemical and Biological Oceanographic data
7. Fishery Survey of India, Mumbai	Offshore Fisheries
8. Central Marine Fisheries Research Institute, Kochi	Coastal Fisheries
9. Central Drug Research Institute, Lucknow	Bio-active substances in the Sea
10. Central Salt and Marine Chemicals Research Institute, Bhavnagar	Marine Algal Resources
11. Orissa Remote Sensing Applications Centre, Bhuvaneswar	PFZ Validation, Coastal Zone Information for Orissa and West Bengal
12. Institute for Ocean Management, Chennai	Coastal Geomorphology, Coastal Zone
13. Regional Centre, National Institute of Oceanography, Mumbai	Marine Pollution
14. National Remote Sensing Agency, Hyderabad	Satellite Oceanography

3. Projects and Programmes

In October 2000, the Department entrusted to INCOIS the responsibility to coordinate and implement the ongoing multi-institutional projects viz. (a) Indian Ocean Modelling and Dynamics (INDOMOD) and (b) Satellite Coastal and Oceanographic Research (SATCORE). The project teams at the Space Applications Centre (SAC), National Institute of Oceanography (NIO), CSIR Centre for Mathematical Modelling and Computer Simulation (C-MMACS), Centre for Atmospheric and Ocean Sciences (CAOS) of IISc, Centre for Atmospheric Sciences (CAS) of IIT-Delhi, Indian Institute of Tropical Meteorology (IITM) and Cochin University of Science and Technology (CUSAT) have emerged as a knowledge pool for INCOIS. These knowledge products would be operationalised at INCOIS during 2002.

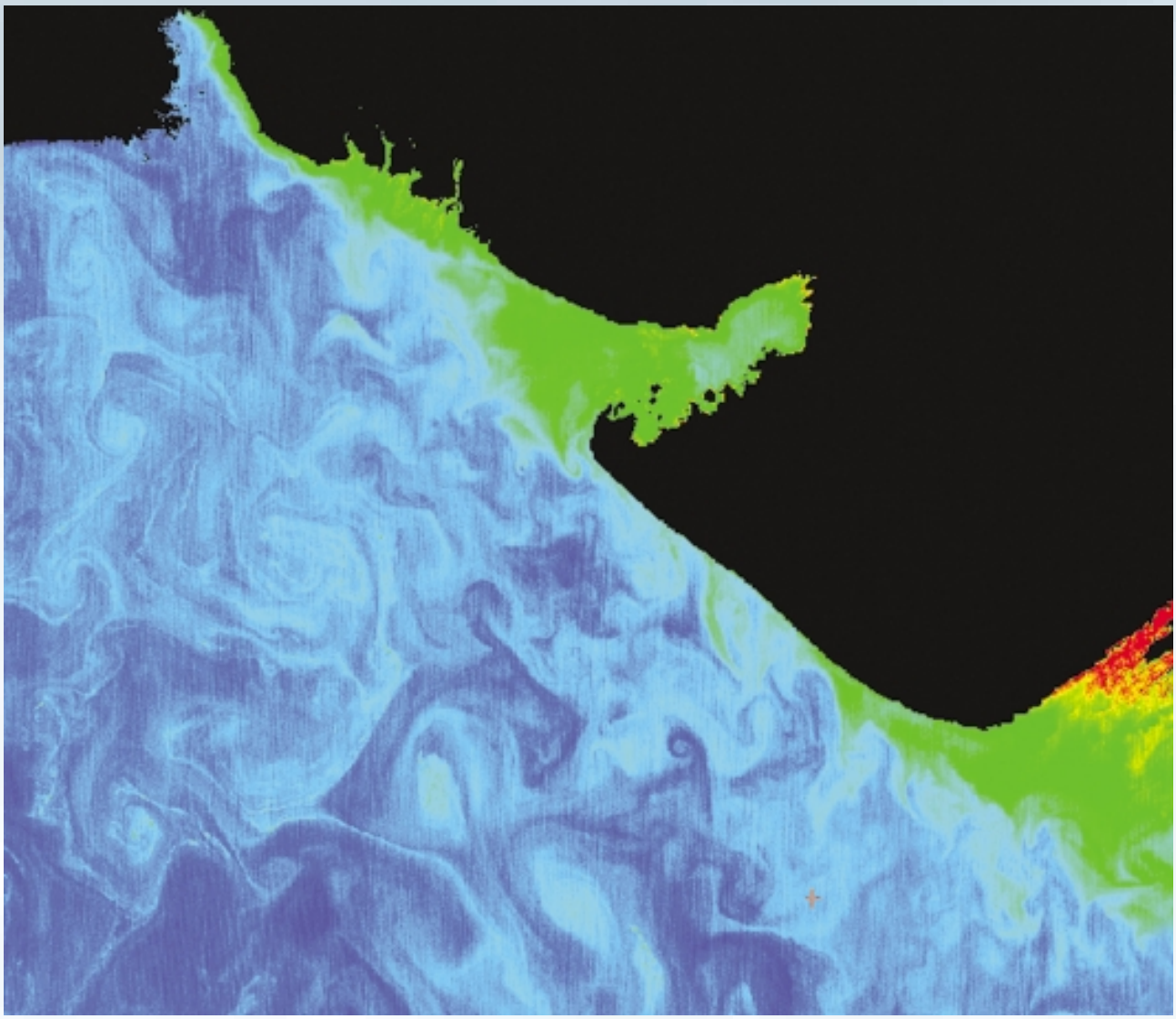

Fig. 5. Chlorophyll Imagery for Gujarat Coast, retrieved from Ocean Colour Monitor of IRS-P4 (March 1999)

3.1 SATCORE Project

The SATCORE project envisages development of various algorithms and models for retrieval of met-ocean parameters (e.g. sea surface temperature, winds, wave parameters, bathymetry, suspended matter, mixed layer depth, chlorophyll, aerosol, water vapour, clouds, currents and sea level) from the data of IRS-P4 satellite sensors viz., OCM and MSMR as well as foreign satellite sensors, diagnostic studies and forecast models, customisation of algorithms and development of related software packages.

SAC is executing this project. The project is nearing completion and efforts are underway to validate and fine-tune these algorithms and convert them into graphic user interface packages for operational use at INCOIS.

The targets and accomplishments are as follows:

Targets 1997-2002	Accomplishments up to March 31, 2001
● Parameter retrieval from satellite sensors ● Diagnostic studies and forecast models ● Development of software packages for operational and semi-operational use at INCOIS ● Customisation of algorithms for the retrieval of ocean parameters	● Algorithms developed for retrieval of oceanic and atmospheric parameters such as surface wind speed and direction, wave height, wave period, wave direction, bathymetry, SST, sea level variability, water vapour content, rainfall, aerosol, fluxes, MLD, oceanic eddies, snow ice mapping, chlorophyll, suspended sediments, yellow substance, attenuation co-efficient from remote sensing satellites (Indian and foreign) ● Developed (i) procedure for identification of PFZ using ocean colour and SST, (ii) preliminary model for estimation of primary productivity and (iii) procedure for generating advective velocity ● Packaging and customisation of software for retrieval of ocean parameters underway
Outlook for Near Future ● Finalise data assimilation models and regional algorithms ● Operationalise the algorithms at INCOIS ● Initiate development of parameter retrieval algorithms from Megha-Tropiques and other future satellite missions of ISRO including Oceansat-2 and Radar Imaging Satellite	

3.2 INDOMOD Project

The INDOMOD project envisages adaptation of a suite of ocean models for study of open and coastal ocean processes and coupled ocean-atmospheric processes. The primary applications of these models are prediction of monsoon variability, storm surges associated with cyclones, waves, biological productivity and coastal processes. The participating Institutes are Centre for Mathematical Modelling and Computer Stimulation (C-MMACS), National Institute of Oceanography (NIO), Indian Institute of Tropical Meteorology (IITM), Indian Institute of Science (IISc), Indian Institute of Technology at Delhi (IIT-D), and Cochin University of Science and Technology (CUSAT).

Significant progress was achieved in this project during the year 2000-01. The highlights of the targets for the IX plan period and accomplishments up to March 2001 are as follows:

Targets 1997-2002	Accomplishments up to March 31, 2001
Modelling and experimental forecast of the circulation in Indian Ocean and coastal Ocean (C-MMACS)	Modular Ocean Model (MOM) outputs for 12th year of integration were analysed with climatological forcing, along with Levitus climatological data. Development of experimental forecasting system for shorter (6 hour) temporal scale is in progress
Develop process models for air-sea interactions and sub-grid processes (C-MMACS)	Role of SST in the genesis and structure of tropical variability at different scales – intra seasonal to inter-annual was explored
Modelling and experimental forecasting of biological productivity (C-MMACS)	Simulation using primary productivity models and development of population dynamics model were initiated
Development of regional wave prediction model for Indian Seas (CAS/IIT-D)	Canadian model was implemented and validated with the extreme events of November 1977 in Bay of Bengal WAM-3G4C model implemented
Development of coupled atmospheric model for prediction of tropical cyclones and associated surges (CAS/IIT-D)	Evolved a vertically integrated hydrodynamic model for northern Indian Ocean. Carried out simulation experiments with past cyclone data
Development of model for prediction of upwelling (downwelling) and frontal regions over continental shelf of Indian Seas (CAS/IIT-D)	Developed Numerical 3-D baroclinic coastal Ocean circulation model for Andhra coast Developed coupled model (river-bay) for Godavari
Development of data assimilation and forecasting system for horizontal and vertical structures of currents, temperature, salinity in Indian Seas (CAS/IIT-D)	Developed 3-D barotropic circulation model Development of baroclinic model is in progress
Development of an Ocean model and hybrid coupled model for Indian monsoon region (CAOS/IISc)	Developed Regional Ocean General Circulation Model (based on MOM) SST oscillation studied
Development of Mathematical models for Indian estuarine and shelf environment (NIO)	Developed Mandovi-Zuari tidal model Simulation in progress

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Targets 1997-2002	Accomplishments up to March 31, 2001
Process modelling of Ocean-land-atmosphere-biosphere interactions in the coastal zone using a coupled column model (CUSAT)	2-D model developed. 3-D model underway
Simulation of surface wind stress on monthly and seasonal time scales to provide forcings for driving an OGCM (IITM)	Climatological surface wind stresses from three different sources were compared
Variability of north Indian Ocean and its impact on global Ocean and understanding the mechanism of a coastal circulation (IITM)	High-resolution gravity model was integrated successfully for three years
Development of high performance computing resources at CMMACS	High performance computing facility being established at CMMACS
Outlook for the Near Future Validation and operationalisation of the models at INCOIS	

3.3 Argo Programme

The Argo is an internationally coordinated programme for deployment of an array of 3000 profiling floats at a spatial resolution of 3° X 3° (300 km x 300 km) to measure temperature and salinity profiles of the upper ocean (up to a depth of 2000 m) periodically. These temperature and salinity profiles are expected to improve understanding the oceanic processes and contribute to improved prediction of climate variability.

The Argo floats, equipped with pressure, temperature and salinity sensors, would drift at a depth of about 2000 m and pop up to the surface every 10-15 days for a short period to transmit the data in real- time via Satellite to ground stations.

Data from the global array of profiling floats would be put on GTS immediately to enable its use in operational forecasting. Delayed mode data, after detailed quality control checks by the Argo Data Centres, would be available within a few months via Internet. The expected life of each Argo float is about 4 years.

Implementation of Argo programme in India was approved in October 2000. INCOIS was assigned the overall responsibility for implementation of Indian Argo Programme. India is participating in the Argo Programme and plan to deploy 150 floats in the North Indian Ocean (north of 10°S). Experimental design for the pilot phase of Argo has been evolved along with the National Institute

of Ocean Technology (NIOT) and CAOS, IISc. A national plan for utilisation of Argo data is being evolved.

Implementation of Argo Programme in Indian Ocean Region: INCOIS undertook the responsibility to organize the Indian Ocean Argo Implementation Planning Meeting at Hyderabad in July 2001, bringing together the Indian Ocean Rim countries and the Float-providing countries to arrive at a coordinated plan for implementing the Argo Programme in the Indian Ocean and for gearing up for its utilization.

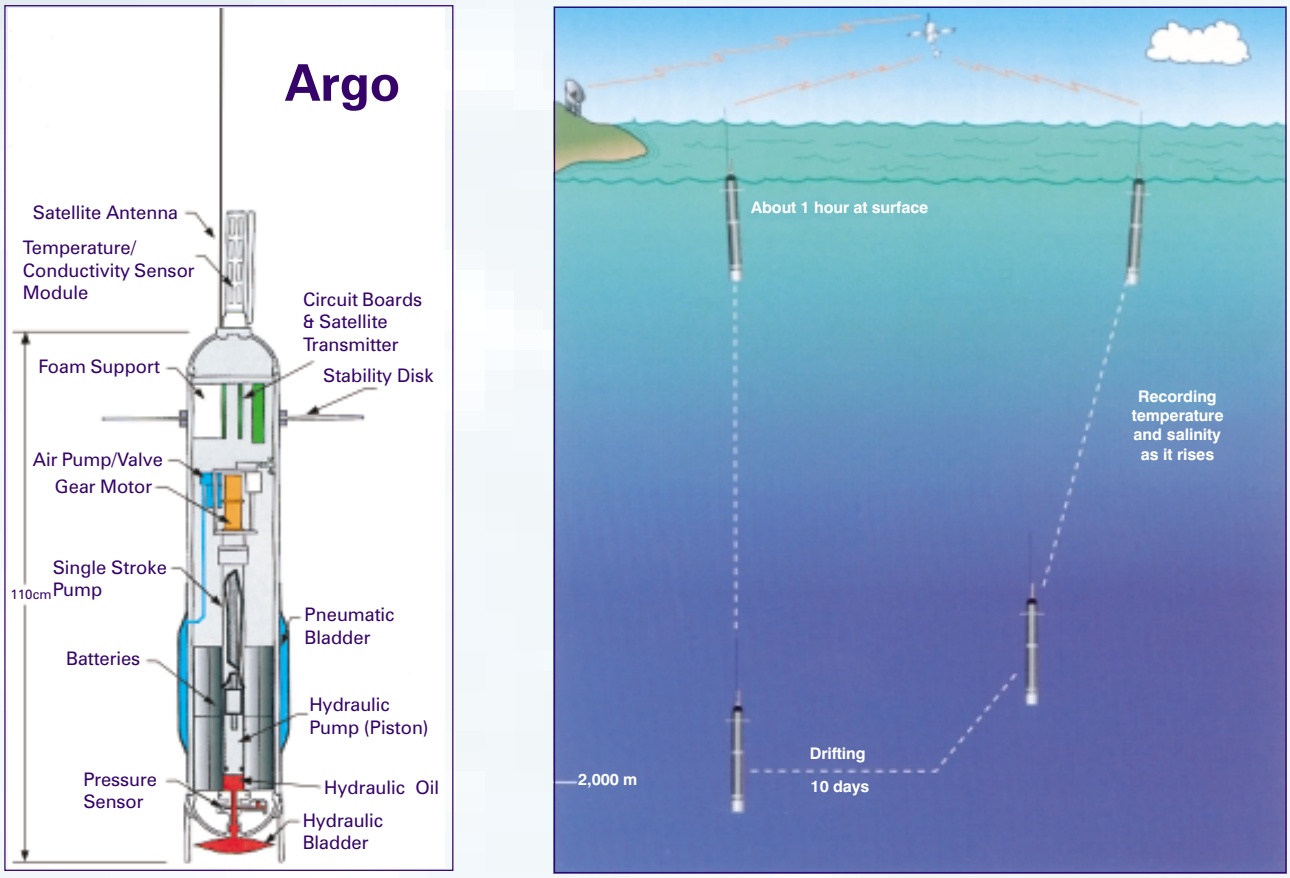


Fig. 6. A Sectional View of Argo Float and Schematic Diagram of Argo Float Cycle

3.4 Ocean Observation System

During the IX plan, the Department targeted to establish a comprehensive Ocean Observation System (OOS) programme for generation of surface meteorological and oceanographic data. This programme complements the Ocean Remote Sensing Satellite missions planned by the Indian Space Research Organisation. Responsibility to coordinate and implement, through NIO, Ocean Observation Systems such as drifting buoys, current meter moorings, expendable bathy-thermographs (XBT), and sea truth campaigns was also assigned to INCOIS in October 2000.

Drifting Buoys: Drifting buoys have the capability for continuous measurement of SST and atmospheric pressure for a period of about a year. The data generated by the buoys are required for estimation of surface currents, which are useful for climate research, synoptic updates for weather prediction and provide sea truth for calibration and validation of satellite sensors. The data sets are transmitted, in near-real time, through Global Telecommunication System (GTS) to various users.

The Project Team at NIO sends the processed data sets to INCOIS, NRSA, NCMRWF, IMD and SAC for utilization in the models and validation of Satellite sensors. Up-gradation of data archives for the Indian Ocean was carried out using the data collected from the buoys deployed during 1976-1999.

XBT Surveys: The XBT surveys are designed to collect vertical temperature profile data of the upper ocean up to a depth of 760 m, which would be useful to study the weather patterns, cyclones and variations in the mixed layer depth etc. The objectives of the programme are (i) to understand and document the evolution of upper ocean thermal structure along selected XBT sections on annual time scales and to examine its inter-annual variability (ii) to establish the relation between upper ocean summer heating and ensuing monsoon activity (iii) to establish the relation between the heat content in the upper layers after the monsoon cooling and post-monsoon storms in the Bay of Bengal and (iv) to provide sea truth information of subsurface temperature profiles for validation and calibration of data derived from satellite sensors.

XBT observations are carried out along (i) Chennai-Port Blair-Calcutta, (ii) Chennai-Singapore and (iii) Mumbai-Mauritius shipping routes onboard ships of opportunity (Merchant ships).

Current Meter Array: This project envisages deployment of a set of 3 Current Meter Arrays at pre-selected locations 93°E, 83°E and 76°E longitudes along the equator in the Indian Ocean for

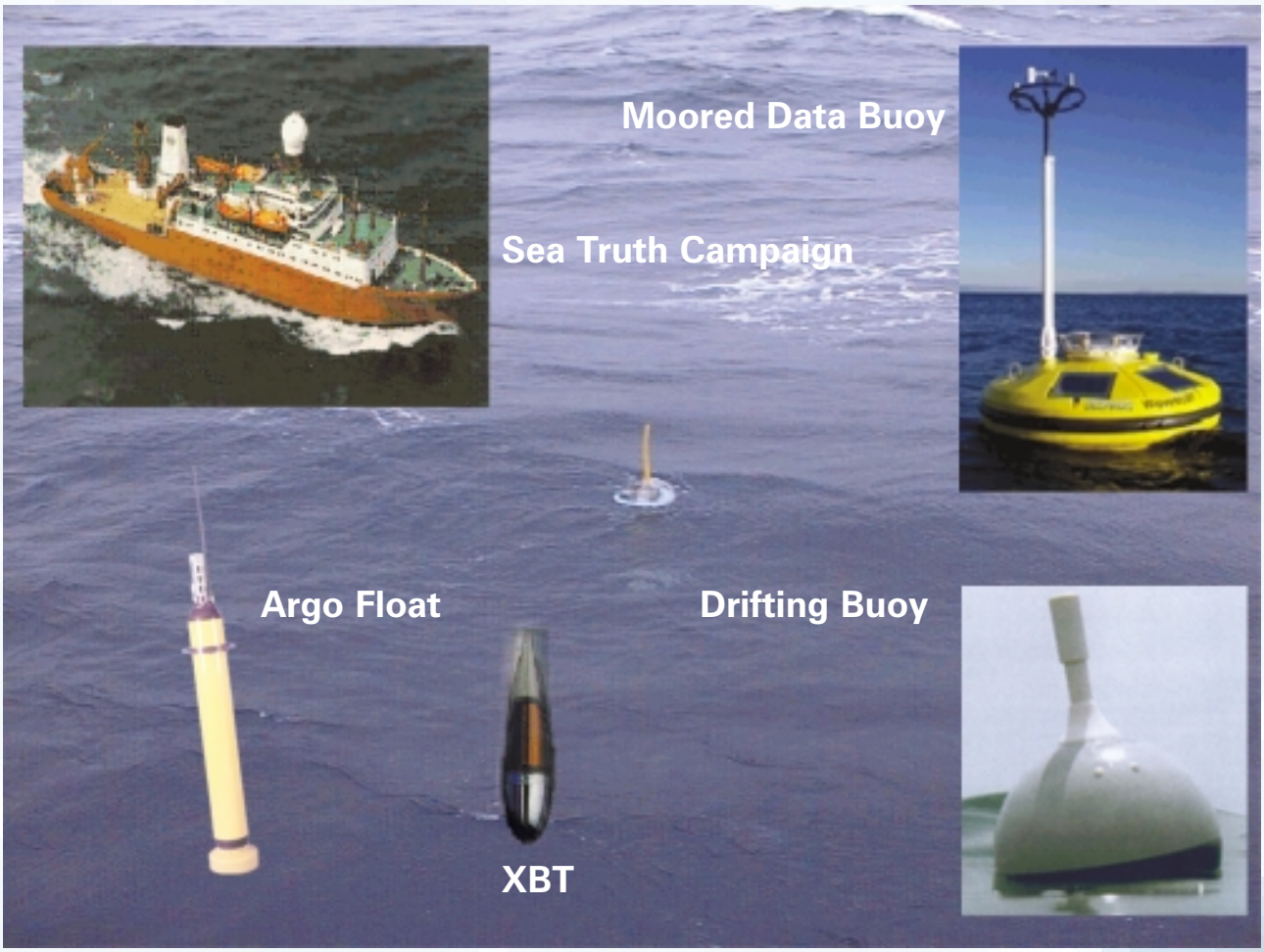


Fig. 7. In-situ Ocean Observation Systems

long-term monitoring of current structure. Each current meter array consists of 6 current meters (with pressure, temperature and conductivity sensors) placed at depths varying from near surface to near-bottom (50 m, 100 m, 200 m, 500 m, 1000 m, and near-bottom depth). The major objectives of the programme are (i) to deploy and maintain current meter arrays at three pre-selected locations along the equator in the Indian Ocean (ii) to understand the seasonal evolution of near surface and subsurface currents in the equatorial Indian Ocean. (iii) to understand the propagation of Kelvin waves and Rossby waves along the equator in relation to the evolution of surface mixed layer and upper layer heat content variability and (iv) to address the deep-sea current variability in the equatorial Indian ocean in relation to climate change and exchange of deep water masses across the equator.

Sea Truth Campaigns: Satellite sensors like Radiometer, Altimeter, Scatterometer and Ocean Colour Monitor are being used to retrieve oceanic parameters viz SST, sea surface winds, ocean eddies, ocean colour, chlorophyll concentration, ocean waves, mixed layer depth etc. Sea truth is essential for validation of the satellite sensors and algorithms used for retrieval of these parameters.

During the year under report, 10 drifting buoys, 400 XBTs, 2 current meter arrays were deployed and 2 sea truth campaigns for validation of IRS-P4 sensors were carried out by NIO.

4. Information Infrastructure

INCOIS has been functioning from the campus of National Remote Sensing Agency (NRSA), drawing upon the infrastructure support from NRSA under an arrangement effective up to March 31, 2001. Development of the permanent campus for INCOIS in a 50-acre land has commenced. The Civil Engineering Division of the Department of Space is progressing the construction of the compound wall and land development. Preparation of master plan and design of first phase of the buildings has been initiated. INCOIS would function from a hired building till the permanent campus is ready.

The architecture of the information-processing infrastructure was finalised drawing upon the expertise and experience of Regional Remote Sensing Service Centres and in consultation with NRSA, SAC and National Informatics Centre. The first phase of systems comprising high performance servers, workstations and storage area network along with application software for satellite data analysis, GIS and database management would be commissioned by November 2001.

A state-of-the-art website and ocean portal, web-based services and a chain of information kiosks that comprise the prime engines in the delivery chain of INCOIS have been conceived to be developed by 2002.

5. Business Development

Business development and user promotion are central to the objectives of INCOIS. The Governing Council of INCOIS approved the Business Plan for 2000-02 in September 2000.

Market Research on PFZ Advisories: To address issues pertaining to generation and effective dissemination of PFZ advisories including content, format, delivery chain, utility and market potential, a market research was launched initially in three coastal states i.e. Andhra Pradesh, Gujarat and Kerala. The sample population for the survey covers 96 villages, 57 PFZ nodes, 2300 Fishermen, 10 Focus groups, 8 Institutional players and 92 Associations.

PFZ awareness workshops and training programmes were organized in Karnataka, Orissa and Pondichery.

6. General Information

Publication

Radhakrishnan, K. (2000), Commercialisation of Earth Observation Systems: Issues and Perspectives, *Space Forum*, Vol. 5, No.1-3, pp 217-237.

Conferences/Symposia

Dr. K. Radhakrishnan presented a paper on "Ocean Information and Advisory Services- A Strategic Plan" in the International Conference on Remote Sensing and Geomatics held at Hyderabad in February 2-5, 2001.

Dr. K. Somasundar presented a paper on "Significance of upper ocean dynamics in the biogeochemical processes of the Arabian Sea" in the Fifth Pacific Ocean Remote Sensing Conference (PORSEC), held at Goa during December 5-8, 2000.

Shri. Prabir G. Dastidar presented a paper on " Ocean Research Across the Countries: A Cross-national Assessment" at NISTADS International Workshop on Emerging Trends in Science and Technology Indicators held at New Delhi during February 20-25, 2001.

Deputations abroad

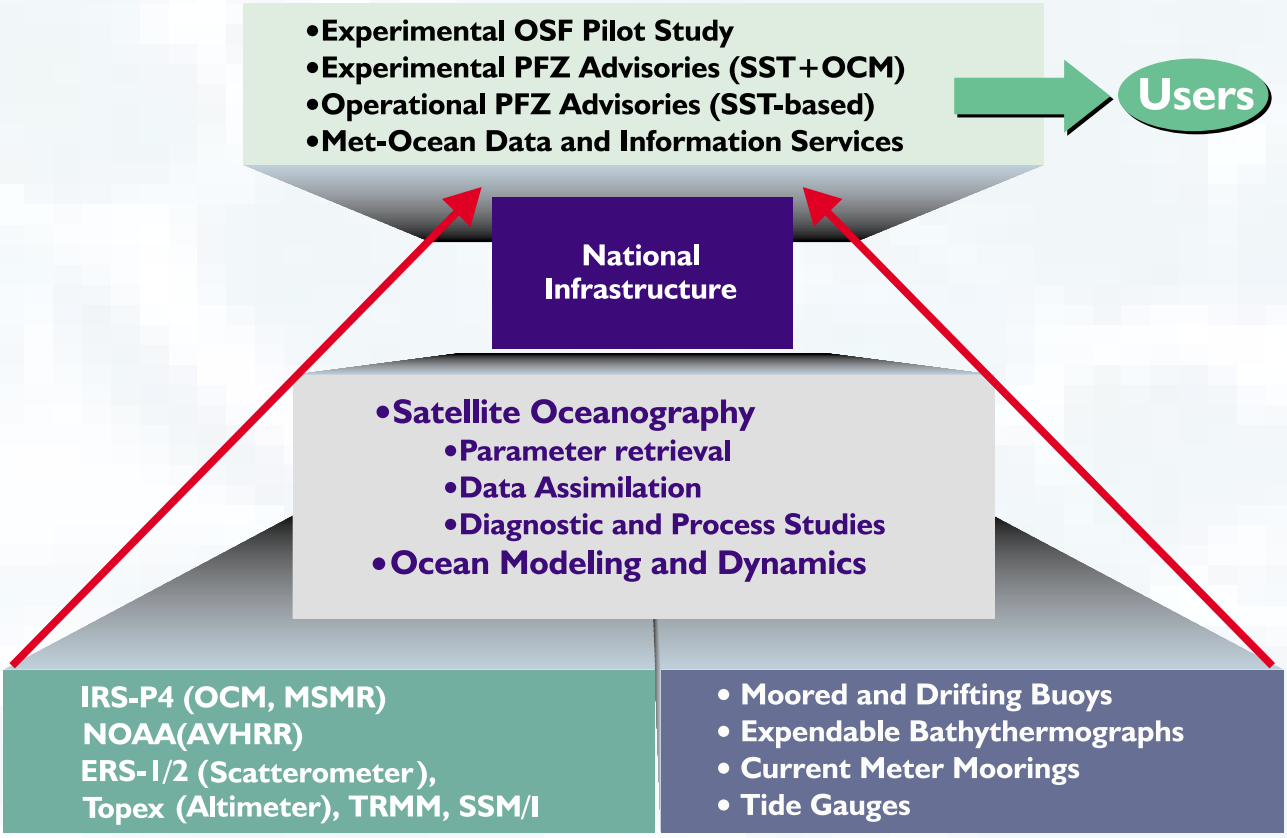
Dr. K. Radhakrishnan participated in the Third meeting of the International Argo Science Team held at Sidney, British Columbia, Canada during March 20-22, 2001.

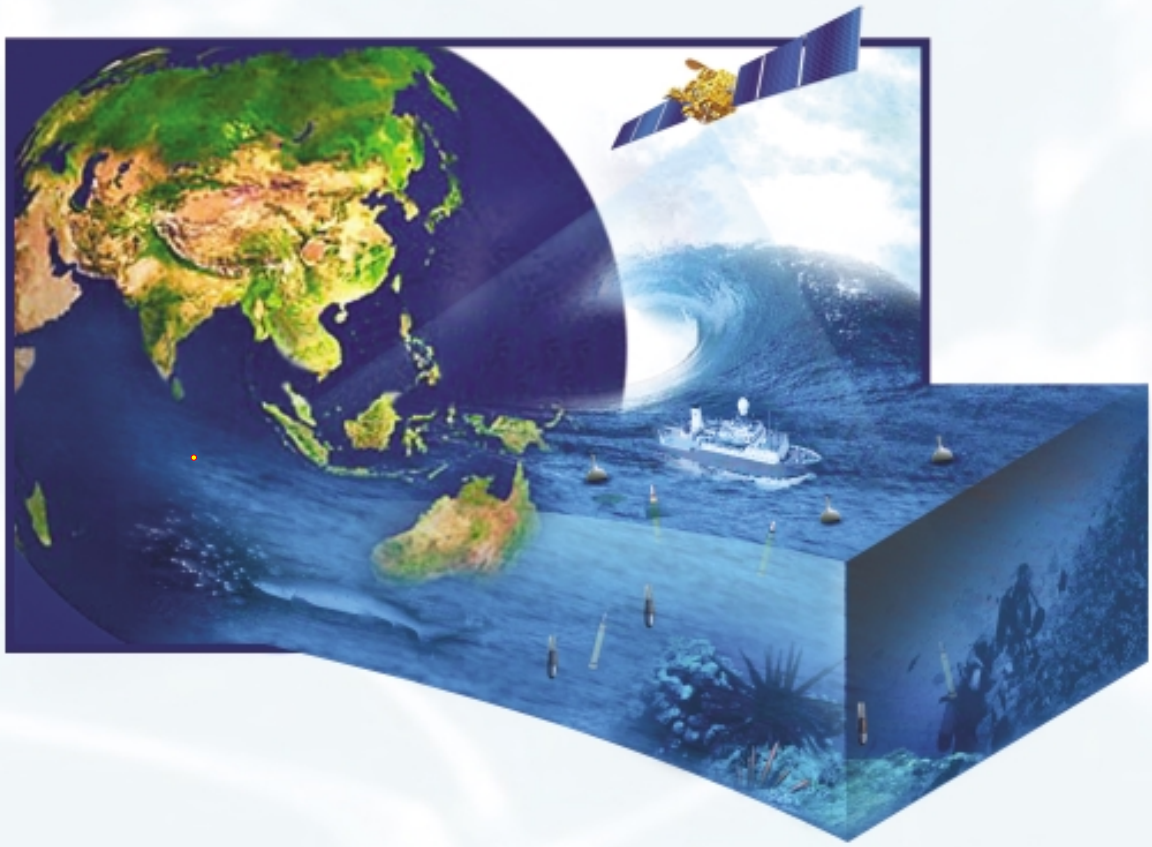
Membership in Governing Bodies/ National Committees

Dr. K. Radhakrishnan

- Member, International Argo Science Team
- Member, NNRMS Standing Committee on Ocean Resources
- Member-Convenor, SATCORE / INDOMOD Steering Committee
- Member-Secretary, INCOIS Governing Council
- Member, Governing Body of Kerala Forest Research Institute
- Member, Governing Body of Centre for Environment Development, Kerala

Ocean Science, Observation and Services
The Current Indian Scenario





Contact Address:
Director, Indian National Centre for Ocean Information Services,
Plot No. 3, Nandagiri Hills Layout, Jubilee Hills, Hyderabad, India - 500 033.
E-mail: radhakr_incois@vsnl.in