Nansen Environmental Research Centre (India)

A non-profit centre within Environmental, Climate and Energy research in the Nansen Group of Research Institutions

Annual Report 2008
REPORT FROM THE BOARD

VISION

To make a significant contribution to environmental, climate and earth sciences research and application in India through local capacity building as well as increased regional and international cooperation.

Main research foci of NERCI are:
- Climate change issues like Indian monsoon variability, sea level variation studies
- Numerical Ocean Modeling & Operational Oceanography
- Coastal Zone Management
- Satellite Remote Sensing and GIS Applications
- Appropriate Technology for Sustainable Environment Development.

NERCI has expertise in development and implementation of algorithms for satellite remote sensing data analysis, numerical ocean and coastal models for ocean circulation and eco-system studies as well as data assimilation techniques.

ORGANIZATION

The Nansen Environmental Research Center India (NERCI) was established in 1999 as a joint venture between Indian and Norwegian partners. NERCI conducts basic and applied research projects in ocean sciences funded by national and international agencies, organizations and industry. It is a non-profit environmental and climate research center within the Nansen Group of research centers, which includes:
- Nansen Scientific Society, Bergen, Norway
- Terra Orbit AS – a research company, Bergen, Norway.

NERCI capitalize on the joint expertise of the Nansen Group.

STAFF

NERC Centre (India) is currently functioned by three full time scientific staff with two consultant scientists and two administrative and technical staff members. Two Indian doctoral students conduct research at University of Bergen and NERSC, Norway and Cochin University of Science and Technology, are also affiliated with NERCI.

The NERCI scientific research advisory board was consulted for taking guidance for R&D activities and promotion of education and social interaction with institutes in India and abroad.

OFFICE AND ENVIRONMENT

NERCI moved to new office premises closer to the Marine School at CUSAT in March 2008. The office conditions are eco-friendly to accommodate more scientific staff. The activities of the center do not cause any damage to the environment.

DOCTORAL FELLOWSHIP PROGRAM

Two Doctoral fellowship studies are currently being implemented at NERCI on:
- Validation of the HYCOM model for the Indian Ocean region and mesoscale ocean studies of the area
- Synergistic application of Scatterometer and OCM data for the studies of coastal upwelling, southwest coast of India.

These studies are performed respectively at the Mohn-Sverdrup Centre at NERSC and University of Bergen, funded by Trond Mohn c/o Frank Mohn AS, Norway and at Cochin University of Science and Technology with NERCI funded by SAC-ISRO.

Six additional Indian doctoral fellowships are at various stages of implementation in cooperation with Indian National Centre for Ocean Information Services (INCOIS), Hyderabad, India, Cochin University of Science and Technology (CUSAT) and Anna University, Chennai in 2009. The Nansen Scientific Society gratuitously funds exchange visits to NERSC for these Indian students.

ONGOING AND FUTURE PROJECTS

NERCI expects a substantial expansion in its research activities in 2009 due to increased cooperation, manpower and projects accepted during this period.

NERCI has ongoing external funded projects from Asia Pacific Forum for Environment Development (APFED) Program of UNEP started in the year 2007. NERCI has already implemented a project from Space Application Centre - Indian Space Research Organization (SAC-ISRO) under the Oceansat II Utilization program and also two different projects under the AO for international partners by SAC-ISRO. It is expected to have moderate increase in its project outlay in the coming years through funding from bilateral Indo-Norwegian research cooperation, European Commission, Ministry of Earth Sciences, Dept. of Science and Technology, Govt. of India and ISRO-SAC.

NATIONAL AND INTERNATIONAL COOPERATION

A MoU between Indian National Centre for Ocean Information Services (INCOIS) and Nansen Environmental Remote Sensing Center, University of Bergen, Norway and NERCI was signed
on 18 January 2008. The MoU focuses on development of bilateral cooperation in operational oceanography and ocean modeling. In 2008 Dr. Sudheer Joseph, scientist from INCOIS has undergone two months training in HYCOM Indian Ocean Model at NERSC, Bergen funded by Nansen Scientific Society and is being implemented at INCOIS. The cooperation will start with two joint Indian Ph.D. students in ocean modeling and data assimilation in the year 2009.

Under the MoU from 2007 with Anna University, Chennai, India and Nansen Group of Research Institutions in Norway, India, China and Russia, Ms. Manohari V., master student from Institute of Remote Sensing, Anna University was trained at Mohn-Sverdrup Centre, NERSC, Bergen in 2008 on HYCOM modeling applications for the Indian Ocean.

Dr. M.S. Madhusoodanan from NERCi has received POGO-SCOR Fellowship and Nansen Scientific Society Fellowship for three months to undertake training in Ocean modeling at Mohn-Sverdrup Centre, Bergen.

**Outreach activities**

Two awareness campaigns, one on Protection of inland water bodies and the other on solid waste management was respectively organized at Kottayam District, and Cochin under the UNEP-APFED program. These campaigns approached the local communities with the participation of NGOs, Self Help Groups and women groups.

**Financial Situation**

NERCI is a non-profit research center registered in India in 1999 under Article 25 of the Company Act.

NERCI was registered with the Consultancy Development Centre, of Dept. of Scientific and Industrial research (DSIR), in 2007. The authorized share capital of NERCi is INR 2,000,000/-. The total grant received in 2008 is INR 2,280,205/- from various projects and a net balance of INR 463,251/- is reserved for 2009 to run existing projects.

**Prospects**

NERCI enters 2009 with extensive plans for increasing their national and international collaborations. Two Ph.D candidates from Anna University are schedule to visit NERSC, Bergen to work on HYCOM modeling and Ocean colour research, out of six new Indian Ph.D. fellowships earmarked for start in 2009. The prospects for the Indo-Norwegian cooperation within climate and ocean research and higher education are promising. An Indo-Russian joint workshop on regional climate change under the DST-RFBR is also planned in 2009.

Cochin, 5th March 2009.

Ola M. Johannessen, Chairman
Lasse H. Pettersson
N.R. Menon
Bente E. Johannessen
K.A. Joseph, Director
MAJOR SCIENTIFIC ACTIVITIES

SATELLITE EVIDENCE OF CLIMATE CHANGE IMPACTS ON ARABIAN SEA PRODUCTIVITY

Dr. K. Ajith Joseph, Research Director, NERCI
Prof. Ola M. Johannessen, Director, NERSC
Lasse H. Pettersson, Leading scientist, NERSC

The south-eastern Arabian Sea in the northern Indian Ocean is one of the most productive and important fishing zones among the world Oceans. The productivity in this region is attributed to high concentrations of phytoplankton, which is an annual recurrent phenomenon during the southwest Indian monsoon (June-September). Often it is reckoned that coastal upwelling during this season triggers the productivity in this region.

Over the years there has been many studies showing a decrease in fish catch from this region despite an increase observed in productivity of the entire Arabian Sea. However a recent study by NERCI scientists using satellite data observed that the Arabian Sea responds in a differential way to global climate change and associated warming in the Indian Ocean.

These observations from satellite data products of Chlorophyll-a concentration and SST for a ten year period found that different regions in the Arabian Sea behaved in a different way to global climate change and observe a declining trend in chlorophyll production in the SE Arabian sea with considerable decrease since 2004, (Figure 1 and 2) unlike the observed increase in the coastal regions around Somalia, Oman in the northern Indian Ocean.

Over this period a substantial decrease in the annual mean values of chlorophyll-a has been observed in the SE Arabian Sea with an increase in the annual mean SST (Figure 3).

The SLA, which is an indication of coastal upwelling, was also analyzed from 1998 to 2007 to understand the variability of upwelling and chlorophyll-a concentration in the southeastern
Arabian Sea. Mean SLA for the summer monsoon season in the region is showing an increase from 2001 till 2007 with an exception in 2005 (Figure 4).

Over this period a substantial decrease in the annual mean values of chlorophyll-a has been observed with an increase in the annual mean SST. The present study also shows that the world oceans should be studied on a case by case basis and also on a region specific using satellite data products to understand the differential biological response of regional seas to global climate change rather than considering each ocean basin as a single entity and further research on these lines is being carried out by NERCI.

**Upwelling in the Southeastern Arabian Sea observed from ARGO and Satellite data**

Ch.V.C. Jayaram, Research Student, SAC-ISRO Project, NERCI-CUSAT
Dr. K. Ajith Joseph, Research Director, NERCI
Lasse H. Pettersson, Leading scientist NERSC

Upwelling is the physical process of ascending motion of water column for a minimum duration and extent by which cool, nutrient rich subsurface waters brought to the surface layers replacing the warm surface waters of the ocean. This process has profound impact on the primary productivity and climate in different time and scales. The coastal areas of the Arabian Sea are well known major zones (see above) of upwelling during the southwest monsoon generally starting from May, continuing through to September (Johannessen et al., 1987 and Shenoi et al., 1999). This phenomenon begins to dissipate from October with the waning of southwest monsoon. It was also reported by in situ observations (Johannessen et al., 1987) and was subsequently modeled by Haugen et al., (2002). The present study focuses on upwelling signals as derived from satellite as well as in-situ observations made available from the ARGO datasets.

The characteristic features of any upwelling region are the low Sea Surface Temperature (SST), high Chlorophyll-a concentration, low Sea Level Anomalies (SLA). These surface signatures are to be well supported by the shoaling of thermocline and resultant isotherms from the subsurface. To study the upwelling features in the southeastern Arabian Sea, data for the above-mentioned parameters has been obtained from various sources for the period 2005: (i) gridded ARGO ocean temperature data from Indian National Centre for Ocean Information Services (INCOIS) with 1 x 1 spatial and 10 day temporal resolution, (ii) 3 day running mean of TMI – SST with 0.25 x 0.25 spatial resolution, (iii) 8 day mean of SeaWiFS chlorophyll-a concentration with 9x9 km spatial resolution and (iv) merged Sea Level Anomaly of 0.33 x0.33 spatial resolution.

The area considered for the study lies between 68° to 75° E longitudes and 8° to 12° N latitudes. Figure 5 shows the area averaged temperature profile for the year 2005 derived both from ARGO data set and World Ocean Atlas 2005. Both these profiles show similar patterns except that the climatology shows a greater smoothing. The isotherms 20°, 25° and 28° C were taken as representatives of variation of subsurface temperature profile over a year. From the figure, it is observed that the 28° C isotherm which is at a depth of 50-60m had risen
to the surface during Upwelling period (Southwest monsoon season). The 25° and 20°C isotherms, which are at 100 and 140m depths during, May (Pre-monsoon season) had raised to 50 and 100m respectively. This indicates the strength of Upwelling such that the subsurface waters can upwell approximately between 40 to 50 meter. A detailed structure of temperature profile offshore of Cochin i.e., along 10°N during the southwest monsoon months (JJAS) is shown in Figure 6. Here it is observed that the 28°C isotherm, during June and July is at 40m depth and in August it had reached the surface and in September the temperature is around 26°C. Another noticeable point is that the shoaling of isotherms started from 68°E longitude. Uniformity in the isotherm depth was observed from 70°E towards the coast for all the months.

These observations were well synergized with satellite observations of SST (Figure 7) and supported by Sea Level Anomaly (Figure 8). The main feature associated with this Upwelling is the decrease in surface temperature by 4° to 5°C and also the shoaling of isotherms by approximately 40m during the Upwelling season. Thus ARGO data sets when properly gridded can be utilized for identifying upwelling signatures.

**Sea surface Temperature and Tropical Indian Ocean Climate - a review**

Dr. Madhusoodanan M.S., Scientist, NERCI

The oceans which occupy 63% of the surface area of the tropics influence the climate of this region in a variety of spatial and temporal scales. Our understanding of the interaction between the atmosphere and the ocean has been substantially increased in the last two decades due to increased availability of observations over the oceans. Synoptic observations of the oceans are available through satellite data and the deployment of moored buoys in the oceans enable near real-time monitoring of the oceanic processes.

To a great extent, the sea surface temperature (SST) determines the formation of clouds over the tropical oceanic regions. SST determines the surface specific humidity and its spatial gradients determine where the moist air will converge to form clouds. Gadgil et al., (1984) showed that the SST must be above 27.5°C for the existence of deep clouds over the Indian Ocean. Waliser et al., (1993) examined the satellite data for the period 1971-1987 and obtained the number of cloudy days as a function of SST in different tropical oceanic regions.

Figure 9 explains that deep clouds occur when SST is above a certain threshold, which is different in different parts of the ocean.
Figure 9: Variation in number of days of highly reflective clouds as a function of SST (Source: Waliser et al., 2003).

Bhat et al., (1996) described the nonlinear relationship between the deep clouds and SST (Figure 10) and attributed it to Convective Available Potential Energy (CAPE). CAPE is an integral measure of the difference in density between a parcel lifted adiabatically from the surface and the environment. The CAPE depends upon the vertical profile of temperature and water vapor.

Both SST and CAPE play a crucial role in determining the occurrence of deep clouds in space and time over the tropical region. The existence of SST threshold for cloudiness also has a profound influence on the inter-annual variability of cloudiness in the tropics.

Figure 10: Variation of mean Highly Reflecting Clouds (HRC) with SST over tropical oceans (Source: Bhat et al., 1996).

Indian Ocean Warm Pool

From long-period averages of monthly mean SST data (Sadler et al., 1987) it is seen that beginning in March, the tropical north Indian Ocean warms very rapidly in the annual cycle and by May, a large area there attains SST greater than 29.5°C, which is called the Indian Ocean Warm Pool (IOWP). The western equatorial Pacific Ocean is much cooler in May. Soon after the onset of monsoon, the Indian Ocean’s surface layer cools rapidly and the centre of the warm pool is relocated in the western Pacific Ocean north of the equator, which slowly warms, from March to August.

A region of high SST such as the IOWP can cause large-scale moisture convergence, which in turn can lead to the build-up of an active equatorial trough there, with its associated deep convective clouds, heating of the tropospheric column above, lowering of surface pressure, strengthening of lower tropospheric westerlies that cause increased evaporation and cooling of the ocean surface that we associate with the onset of monsoon over India (Joseph, 1990). It appears that the time of onset of the monsoon over India depends on the prevailing SST in the north Indian Ocean. One of the predictors used by Kung and Sharief, 1982) in their scheme for the long-range forecasting of the date of onset of monsoon over Kerala is the SST over the north Indian Ocean.

Because of the non-linear relationship between SST and latent heat flux, the warm pool is a region of enhanced sensitivity of the atmosphere to small changes in the SST. Since the monsoon onset over India causes major changes to the Indian Ocean and to the global atmosphere, a better understanding of the IOWP is extremely important in the simulation of regional climate.

The ocean-atmosphere interactions on inter-annual time scale results in planetary scale fluctuations in climate. The climate variability has been documented using satellite and moored buoy data in the last two decades.

The inter-annual variations in SST in the Indian Ocean is much smaller than that observed in the Pacific Ocean which makes the long-term prediction of the evolution of SST in the Indian Ocean is much more challenging. The dominant modes of variability in the Indian Ocean are on seasonal and intra-seasonal time scales. The quality and quantity of observations available in this part of the tropical oceans is much less than that in the Pacific. The numerical modelling studies in the Indian Ocean are in the infant stage. The Indian Summer Monsoon rainfall is a major heat source for the tropical atmosphere. It controls the tropical atmospheric circulation. The relationship between the Indian Ocean conditions and the Indian Summer Monsoon still remain elusive.

To understand the mechanisms involved in regulating the SST of the Indian Ocean and heat budget, a comprehensive model study is required. A model with fine vertical and horizontal resolution, which can simulate realistic ocean current velocities, has to be used. For this purpose NERSC in Bergen and NERCI have developed the TOPAZ modeling system for the Indian Ocean. The model is forced with high frequency wind and
flux fields. The Indonesian Through Flow (ITF) is included as a barotropic flux entering south of Indonesia and exiting the model domain south of Australia along the boundaries, which is maintained constant in time.

In this context, considering the significance of the ITF in the Indian Ocean circulation and heat budget, a sensitivity study with different ITF fluxes in the TOPAZ Indian Ocean modeling system is in progress in collaboration with NERSC.

**SST Variability during Tropical Cyclone ‘Fanoos’ in the Bay of Bengal using HYCOM-INDIA**

Manohari V., Master Student, Anna University and NERCI
Dr. Laurent Bertino, Deputy Group Leader, NERSC

A modeling study has been performed as part of Masters thesis work at Mohn-Sverdrup Centre, Bergen to analyze the SST pattern during a tropical cyclone "Fanoos" in the Bay of Bengal using HYCOM INDIA by incorporating SST data from NOAA AVHRR for the simulation of an intense cyclone over the Bay of Bengal that crossed the Tamil Nadu coast near Chennai during December 2005.

The cyclone starting from 4 to 11 December 2005 (Figure 11) is considered with HYCOM model result. The weekly data is considered before and after cyclone (1, 7, 14 & 21 Dec, 2005) for HYCOM data (Figure 12).

The temperature has been considered from 1st to 21st December 2005. The comparison with the NOAA optimum interpolated data shows that the temperature is warmer before cyclone (Figure 11) and it gets cooler during the cyclone period. The model result shows that the temperature is maintained around 28ºC and the model temperature also shows warmer before cyclone and cooler after cyclone. The model field is smoother than observations as it is not strictly eddy resolving. However the tendencies are well represented by the model and amplitude of the cooling is about 2ºC, in agreement with observations () but when we compare the SST with GDEM climatology, it is clear that the temperature is warmer in the eastern part of Bay of Bengal. It is also found that HYCOM India model can be used for the modelling studies of upper ocean response to tropical cyclones and similar studies in the Indian Ocean region.

**Circulation features of the South-Indian Ocean from altimeter and drifter data**

Dr. Benny N. Peter, Consulting Scientist, NERCI

South Indian Ocean plays a major role in the thermohaline circulation by exchanging tropical surface and thermocline waters between Atlantic and Pacific oceans. The south Indian Ocean does not experience the monsoonal winds and hence the seasonal variation is not as large as in the north Indian Ocean. The annual cycle of currents in the south Indian Ocean is examined using ten-year average of monthly absolute velocities. The absolute velocities are estimated referring to the
mean velocity field derived by combining drifter and satellite observations (Benny et. al., 2008) and the time series Maps of Sea Level Anomaly (MSLA).

The mean velocity field of south Indian Ocean (Figure 13) depicts the anticyclonic gyral circulation, characterized by strong southward western boundary currents and weak eastern boundary currents. The zonal westward flow of the South Equatorial Current is comparatively strong, broad and exhibits multicore structure and in the mean field, whereas, the eastward flow is very powerful and meandering in the south. Strong currents prevails in the northern, western and southern parts whereas, the central and eastern parts exhibit dull circulation (velocity <0.25 m/s).

The Agulhas Current is the strongest current in the south Indian Ocean and its mean speed even reaches above 1.5 m/s. The Agulhas retroflection region (Figure 14) characterized by the recirculation eddy and the strong meandering eastward flow is conspicuous in the mean field. The southward flowing Leeuwin Current (eastern boundary current) is not obvious in the mean field. But, strong south-eastward flow is observed south of Java.

The long-term average monthly surface circulation pattern illustrates large variations in the flow field. Among the surface currents, the South Equatorial Current is subjected to latitudinal shift as well changes in its structure and characteristics. The SEC is strong, broad and meandering structure in southern summer period, whereas is weak and narrowed in winter.

In western region the East Madagascar Current and Agulhas Current shows slight seasonal changes. In winter, the circulation is weak compared to summer. In the eastern boundary the Leeuwin Current is well developed in January–April, but is weakened in July. In October even a reverse flow is occurring between 26°S and 28°S.

**Phytoremidation For Water Quality Improvement**

Dr. K. Ajith Joseph, Research Director, NERCI
Chethana, S.V. Research Associate, NERCI
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The increased rate of water pollution promotes the growth of noxious aquatic weeds and algae leading to the destruction of habitat of various aquatic species. Backwaters are the main attractions of Kerala but due to increased tourism activity, dense population at the riverbank directly disposes lot of nutrient rich waste, which leads to
the severe pollutions of backwaters. Phytoremediation, by plants and trees to remove or neutralize contaminants, as in polluted soil or water, is the ideal cost effective method suggested to improve the water quality. It is the use of living green plants for in situ risk reduction and removal of contaminants from contaminated soil, water, sediments, and air.

One of the main advantages of Phytoremediation is that of its relatively low cost compared to other remedial methods. Phytoremediation also offers a permanent in situ remediation rather than simply translocation the problem. The best example of phytoremediation is using Vetiver System (VS). The VS is a new phyto-technology based on the use of Vetiver grass for a wide range of applications.

VS were, first developed by the World Bank for soil and water conservation and now being used in over 100 countries.

Vetiver grass belongs to the family ‘Poaceae’ and the genus Vetiver contains more than 16 species, among that Vetiver Zizanoides L. is best suited for phytoremediation. This grass grows up to 2m above the ground with erect and stiff leaves. Growth is rapid (24 inches in 24 days) once soil temperature rises. It has very extensive root system which grows more than 4m. Root system of Vetiver is used for bio remediation or cleaning up of contaminated soils and cleaning up of water, with high capacity of removing N and P in polluted water. Vetiver also cleans up blue green algae within 4 days.

Vetiver ability to sequester deadly chemicals from our environment and transform them safely into plants makes it truly remarkable.

The Vetiver System was first developed for soil and water conservation purpose but in the last six years its role has been extended in to environmental protection field, particularly in the field of wastewater treatment and solid waste landfills. It is a simple, hygienic and low cost method of phytoremediation, which is suggested for improvement in the water quality of polluting backwaters of Kerala.

**Salient features of UNEP-APFED Project**

Under the ongoing UNEP-APFED project NERCI is trying to implement this phytoremediation system and riverbank protection (Figure 15 and 16) in a polluting waterway in the project site as a demonstrable activity and the results are encouraging to be applied for other regions.


Thomson B. and Madhusoodanan M.S.: On the variability of Arctic Ocean heat content (under review).
NERC

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