Nansen Environmental Research Centre (India)
A non-profit environmental and climate research centre recognised by the Department of Scientific and Industrial Research (DSIR), Govt. of India
**REPORT FROM THE BOARD FOR 2012**

**Vision**

Improve the understanding of climate change, its impact on the monsoon and ocean circulation and ecosystems in the Indian Ocean using in situ observations, satellite data and numerical ocean and climate models. The influence of climate change on the coastal zone and its impact on socio-economy is also a research priority. Dissemination of scientific results for the benefit of society and for the conservation of ecosystems is also our committed responsibility.

Main scientific research focuses of NERCI are a) Monsoon and ocean variability, Climate change, Sea level variations b) Marine Ecosystem studies including algal blooms and c) Coastal Zone Management and Societal issues.

**Organization**

The Nansen Environmental Research Centre India (NERCI) was established in 1999 as a joint venture between the Indian and Norwegian partners. NERCI conducts basic and applied research in ocean and atmospheric sciences funded by national and international agencies, organizations and industry. Core funding is received from the Nansen Centre and the Nansen Scientific Society, Bergen, Norway. NERCI is a non-profit research centre within the Nansen Group of research centres, registered with DSIR (Department of Scientific and Industrial Research) of Ministry of Science and Technology Govt. of India as a Industrial Research Organization (SIRO), which includes:
- Nansen Environmental and Remote Sensing Centre (NERSC), Bergen, Norway
- Nansen International Environmental and Remote Sensing Centre, St. Petersburg, Russia
- Nansen-Zhu International Research Centre, Beijing, China
- Nansen-Tutu Centre for Marine Environmental Research, Cape Town, South Africa
- Nansen-Bangladesh International Centre for Coastal Ocean and Climate Studies, Dhaka, Bangladesh
- Nansen Scientific Society, Bergen, Norway
- Terra Orbit AS – a research company, Bergen Norway.

NERCI capitalizes on the joint scientific expertise of the Nansen Group, which has about 180 staff including 65 Ph.D. and Master students.

**Accreditation from DSIR**

NERCI received accreditation from DSIR (Department of Scientific and Industrial Research) of Ministry of Science and Technology Govt. of India in the year 2012.

**Staff**

The Centre has at present a staff of 20, which includes four full time scientists, four associate scientists, one project scientist, two research associates, four full time Ph.D. students, three project fellows and two administrative staff.

During 2012, seven scientists from PML (U.K), NERSC (Norway), Alterra (Netherlands) and three research students have visited NERCI for periods from weeks to several months.

NERCI is an organisation with equal opportunity employer and 35% of the research staff are females. Among the PhD students and project fellows, 44% are females. In 2012, NERCI has improved the gender equality in the organisation.

The NERCI Scientific Research Advisory Board monitors the research activities of NERCI and gives guidance for R&D activities as well as promotion of education and interaction with institutes in India and abroad.

**Office and Environment**

The office maintains an eco-friendly atmosphere for the staff to work and it moved to a new premises with new research infrastructure facility and working environment.

An economy and environment committee constituted in 2010 with the Chairman, Vice chairman and the Executive Director as members supports the management of the Centre.

**Scientific Outreach**

Outreach is actively done through the press and popular science lectures in International and national workshops and conferences. Awareness campaigns and participation in PORSEC 2012 conference exhibitions promotes the visibility of NERCI in scientific activities in India.

**National and International Cooperation**

Memorandum of Understanding (MoU) between Indian National Centre for Ocean Information Services (INCOIS) in Hyderabad, Cochin University of Science And Technology (CUSAT), Kerala University of Fisheries and Ocean Studies (KUFOS), Anna University, Toc H Institute of Science and Technology (TIST), Nansen Environmental Remote Sensing Center, University of Bergen, Norway and NERCI signed is in operation and in the process of renewal. The MoU focuses on development of bilateral cooperation in operational satellite remote sensing, operational oceanography and ocean modelling.

Under the MoU between Anna University, Chennai, Nansen Environmental and Remote Sensing Centre, Bergen, and NERCI, two students from this institute have completed their internship at NERCI.

The Nansen Scientific Society's Fellowship programme was implemented at Faculty of Marine Sciences, Cochin University of Science and Technology under the MoU signed between NERSC, Bergen, CUSAT and NERCI.
Cooperation in Europe is an important part of research activities at NERCI. Five European partner institutions joined hands with NERCI and started a project entitled INDO-MARECLIM in February 1, 2012. INDO-MARECLIM is the first Indian initiative to utilise the EU INCO-LAB programme to increase the coordination of European institutions with those in the developing countries. The programme ensures strengthening of research infrastructure of the host institution and increase the scientific co-operation between researchers from the host country and the participants as well.

Another project which is funded by Norwegian Research Council entitled INDIA-CLIM is in progress with very significant scientific results which also involves participation from NERSC, Norway, Institute of Remote Sensing-Anna University, Dept. of Physical Oceanography-CUSAT and NERCI.

Sri. Ch. V. Chiranjivi Jayaram, part time research fellow at NERCI who was working as SRF under the SAC-ISRO funded project “Synergistic application of Scatterometer and OCM data from Oceansat II for the studies of coastal upwelling in the SW coast of India” has been awarded doctoral degree by CUSAT on 28th, May, 2012 for his thesis entitled “Remote Sensing the signatures of Upwelling in South Eastern Arabian Sea” under the guidance of Prof. A. N. Balchand and co-supervision of Dr. K. Ajith Joseph, NERCI, Dr. Jayaram currently working at Regional Remote Sensing Centre of ISRO, Calcutta.

Seven full time and two part time doctoral students are currently carrying out their studies at CUSAT or in affiliation NERCI and NERSC.

Ms. Smitha. A. is involved in ‘Marine ecosystem studies including algal blooms’ of the INDO-MARECLIM project and is registered with CUSAT for the doctoral degree.

Ms. Mary Swapna George currently with NERCI undertakes her studies on “Validation of the HYCOM model for the Indian Ocean region and Mesoscale Ocean studies in the area” at Mohn-Sverdrup Centre at NERSC and University of Bergen, funded by Trond Mohn c/o Frank Mohn AS, Norway.

Mr. Sachin Pavithran, full time Ph.D Scholar, is involved in “Coastal zone Management and Societal issues” of the INDO-MARECLIM project and registered for doctoral degree at CUSAT.

Mr. Muhammed Shafeequ was recruited as Junior Research Fellow to work in the SAC-ISRO joint project with CUSAT and NERCI “Application of satellite altimetry (Altika) and Ocean Colour (Oceansat II) in the studies of mesoscale features of the South-eastern Arabian Sea, registered for Ph.D under Prof. A.N Balchand of CUSAT.

Full Time Ph.D Scholars under Prof. N. R. Menon who have registered for Ph.D at CUSAT are:

1. Mr. Nashad M, Nansen PhD Fellow. Research Topic- Monitoring and Modelling of harmful algal blooms including the application of satellite remote sensing. Supervising guides: Prof. N. R. Menon (NERCI) and Lasse H. Pettersson (NERSC).
2. Ms. Shinu Shiela Wilson, Nansen Ph.D Fellow. Research Topic- Interannual variability of Monsoon over India. Supervising guides: Prof.K. Mohan Kumar (CUSAT) Dr. P. V. Joseph (NERCI) and Prof. Ola M. Johannessen (NERSC).
3. Mr. C. P. Abdulla, Nansen Ph. D Fellow. Research Topic- Sea level variability over Indian Ocean. Supervising guides: Prof. A. N. Balchand (CUSAT), Dr. K. Ajith Joseph (NERCI), Prof. Ola M. Johannessen (NERSC).

These studies are performed respectively at the Cochin University of Science and Technology (CUSAT), NERSC (Norway) and NERCI with funding from Nansen Scientific Society, Bergen, Norway.
Funding

NERCI is a non-profit research Centre registered under Article 25 and accredited SIRO under DSIR mainly funded by Nansen Environmental and Remote Sensing Center, Norway. It receives funding through projects from European Commission, Norwegian Research Council, United Nations Environmental Programme (UNEP) and other similar agencies like Department of Science and Technology, Govt. of India, Space Application Centre, ISRO and Dept of Environment and Climate Change, Govt. of Kerala.

Prospects for 2013

NERCI enters 2013 with plans for increasing their national and international cooperation, particularly strengthening the cooperation within the Nansen Group and other Indo-European research institutions. The ongoing EC FP7 project INDO-MARECLIM: Indo-European Research Facilities for Studies on Marine Ecosystem and Climate in India will be essential for strengthening the research infrastructure and increasing the research cooperation with European scientists. The Research Council of Norway project INDO-CLIM: Decadal to multi-decadal variability in the Indian Monsoon Rainfall and teleconnection with Atlantic Multidecadal Oscillation (AMO) is an important part of the bilateral Indo-Norwegian cooperation in climate research. To meet the new opportunities, NERCI has moved into new modern office premises during 2012. Scientists and Ph.D. candidates from NERCI will also visit European research institutions to work on ocean and atmospheric modelling, ecosystem modelling and satellite Earth observation research with Indian and European partners.

Cochin, 19th August 2013
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Board of Directors

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Key Research Areas

Main scientific research focuses of NERCI are a) Monsoon and ocean variability, Climate change, Sea level variations b) Marine Ecosystem studies including algal blooms and c) Coastal Zone Management and Societal issues

The current focus of research at NERCI are on the following:

1. **Monsoon and ocean variability, Climate change and Sea level variation**
   (Co-heads - Prof. P. V. Joseph, NERCI and Prof. Ola Johannessen, NERCI/NERSC)

   Research Topics:
   - Relation between Atlantic Multi-decadal Oscillation and the Indian Summer Monsoon Rainfall
   - The role of Indian Ocean in the intra-seasonal and inter annual variability of Indian monsoon rainfall
   - The rapid warming of the equatorial Indian Ocean and its impact on the regional climate
   - The cold pool of the Bay of Bengal during the summer monsoon season
   - Sea level variations in the Indian Ocean.

2. **Marine ecosystem studies including algal blooms**
   (Co-heads- Prof. N. R. Menon & Dr. Nandini Menon, N., NERCI, Lasse H. Pettersson, Dr. A Samuelsen, NERSC)

   Research Topics:
   - Vulnerability of marine ecosystems to climate changes and its relevance to marine food resources
   - The effect of seasonal and inter-annual monsoon variations on primary production and higher trophic levels of the food in the Indian Ocean
   - Increased incidence of HAB in the Indian EEZ and the relevance of physical and chemical oceanographic parameters
   - Modelling studies and possible development of early warning systems.

3. **Coastal zone Management and Societal issues**
   (Co-heads- Dr. K. Ajith Joseph, NERCI and Lasse H Pettersson, NERCI/NERSC)

   Research Topics:
   - Contemporary challenges in Coastal Zone Management in India including the impact on coastal society
   - Focus on the problem in fisheries sector and help in bringing up guidelines to policy makers in fishing sector
   - The formulation of more meaningful coastal zone regulations of regional relevance
   - Utilisation of satellite data for the development of decision making tools with linkage to the other research areas

SCIENCE REPORT FOR 2012

The role of wind stress and Mixed Layer in modulating surface Chlorophyll-a in the southeastern Arabian Sea during Upwelling

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Introduction

The Arabian Sea is subjected to variations in its state with seasons which are brought about by the monsoon induced biological and physical forcing. The Southeastern Arabian Sea [SEAS] (Fig.1) embedded between 7 – 15 N and 70 – 77 E is a unique region within the Arabian Sea and is of considerable interest due to processes like coastal upwelling during south west monsoon (SWM) and associated high productivity. Upwelling along the southwest coast of India, within the SEAS, is a typical eastern boundary upwelling system, where equator ward winds to the east of the ocean and also a pole ward undercurrent along the coast (Antony 1990) were present. Apart from winds, remote forcing from planetary waves also plays a major role in the initiation and progress of upwelling (Johannessen et al. 1987). Propagation of coastal Kelvin wave from the Bay of Bengal and the radiation of Rossby waves and together, their dynamics in this region (including their role in formation of Lakshadweep 'Low', with respect to sea level), during the upwelling period were explained by Shankar and Shetye (1997).

The surface cooling associated with upwelling, as observed from sea surface temperature (SST) and the resultant high concentration of surface chlorophyll-a (SCHL) happen only after the onset of SWM signifying the influence of winds on the region. The individual contribution of each of these forces viz., winds and remote forcing, towards upwelling and its strength are yet to be clearly established. Hence inorder to understand the relation between changes in wind pattern and the upwelling related productivity of this region,
a detailed analysis of the temporal variability of wind stress, SCHL and MLD is carried out in the SEAS for the years 2000 to 2008 and the results are discussed here under.

**Data and Methods**

Level 3 wind data of QuikScat obtained from the Centre ERS d' Archivage et de Traitement-French ERS Processing and Archiving Facility (CERSAT) of the French Research Institute for exploration of the Sea (IFREMER), from 2000 to 2008 with the spatial resolution of 0.5° x 0.5° were used and wind stresses are computed based on wind dependent drag coefficient following Smith (1988).

For MLD, the IFREMER-CORIOLIS in-situ analysis system [ISAS] (Gaillard 2010) generated temperature and salinity gridded profiles (2000 - 2007) based on the density criterion, as per Levitus (1982) was used.

The Sea viewing Wide Field of View Sensor (SeaWiFS) Level 3, 9km x 9km, 8-day data from 2000 to 2007 and the Moderate resolution Imaging Spectroradiometer (MODIS) on board satellite Aqua, Level 3, 9km x 9km, 8 day data for the year 2008 over the study area were obtained from the Ocean Color group of Goddard Space Flight Center (GSFC), NASA. Time series variations were obtained from the averaged SCHL for the study region and were compared with wind stress and MLD data for the same period.

**Wavelet Transforms**

Wavelet transforms have been employed in the geophysical studies extensively in understanding the localized variations within a time series. Decomposition of a time series into time – frequency space leads to determining the dominant modes of variability along with the information on how these modes vary in time (Torrence and Compo 1998). The online package for computing the wavelet transforms available at http://paos.colorado.edu/research/wavelets/software.html following Torrence and Compo (1998), was used extensively for this work.

**Results and Discussion**

Environmental forcing modulates the spatial and temporal changes leading to proliferation of phytoplankton communities by affecting the mixed layer light availability (Milutinovic et al. 2009). To study and understand the variability and distribution of the upwelling in SEAS, satellite measured surface wind stress products along with ocean color and MLD are used and here the temporal variability of these parameters and its interrelationship with coastal upwelling is discussed.

**Inter annual Variability of Wind stress, MLD and Chl-a**

In order to understand the role of wind stress and Mixed Layer in modulating SCHL, time series analysis has been carried out. Over the oceans, wind plays an important role in determining stratification and de-stratification processes that could determine timing of phytoplankton blooms. The stirring of upper layers by convective overturn, together with winds are the major mechanisms regulating the phytoplankton growth (Cushing 1976 and Kim et al. 2007). In order to understand these mechanisms, area averaged weekly wind stress; SCHL and MLD were considered for the period between 2000 and 2008, to closely understand upwelling features and related processes in this region.

From Fig.2, it was observed that the dominant mode of variability for wind stress is semi-annual with winds dominating during SWM. From the wavelet power spectrum of wind stress, it was observed that during every SWM, significant frequency of variability is observed in the 4 – 6 weeks band indicating intra-seasonal oscillations. Weekly time series plot of wind stress showed less intensity winds during 2001 and 2003 compared to rest of the years. The years 2005 and 2006 exhibited high wind stress over the entire period.

![Fig.2: (a) Weekly Wind Stress, (b) The wavelet power spectrum. The contour levels are chosen so that 75%, 50%, 25% and 5% of the wavelet power is above each level, respectively. (c) The global wavelet power spectrum (Jayaram et al. 2012)](image)

Power spectrum of MLD (Fig. 3) had a distinct semiannual variability similar to that of wind pattern; other leading signals were observed to be between 16 to 32 weeks with 95% confidence level which implies the influence of NE and SW monsoon winds in controlling the MLD variability in the SEAS. The time series of MLD also showed clear semiannual variability with inter-annual variations. Deeper MLDs were observed during 2004, 2005 and 2007; however MLD variance during 2003 was high between 48-64 weeks. The secondary peak during 2003 was feeble compared to other years indicating a weak NEM for that year in SEAS.

![Fig.3: (a) Weekly Mixed Layer Depth. (b) The wavelet power spectrum. The contour levels are chosen so that 75%, 50%, 25% and 5% of the wavelet power is above each level, respectively. (c) The global wavelet power spectrum (Jayaram et al. 2012)](image)
Wavelet power spectrum of SCHL (Fig.4) showed significant annual variability and secondary maxima were observed within the time scale of 3 to 8 weeks. The time series plot of chlorophyll showed interannual variability in this region. Comparison amongst all the years showed that years 2003, 2005, 2006 and 2007 had low chlorophyll concentration, while the years 2000, 2001 and 2004 showed high SCHL concentration.

To obtain a clear understanding on the temporal relationship between wind forcing, MLD and SCHL and thereby on the upwelling system in SEAS during 2000 to 2008, further analysis were carried out and the results are discussed in the following lines. Wind data was smoothed using an 8-day moving average to match the temporal resolution of SCHL and yet retaining the subtle variations in wind to decipher the influence of wind on SCHL following Kim et al. (2007). Following the same authors a hypothesis is put forth that the SCHL begins to bloom only when the wind stress had started to weaken. The rationale behind this hypothesis is that, gradual decrease in wind stress stabilizes the water column; thereby the upwelled nutrients are then utilized by phytoplankton in the presence of sunlight, resulting in primary production. In this whole chain of events, there should be a time lag between the decrease in wind stress and increase in SCHL concentration which allows phytoplankton cells to grow up to a measurable density.

Summary

This study attempts to bring about the relationship between wind, chlorophyll-a and MLD using satellite measured products and objectively analyzed gridded temperature and salinity profiles for the southeastern Arabian Sea. From this study, it is understood that the annual upwelling phenomenon driven by wind and remote forcing during the south west monsoon period is the driving force for the region to be productive. Wind and upwelling are responsible for shoaling of MLD along the coast during SWM, thereby facilitating the productivity in the euphotic zone by vertical transport of the nutrients and deeper MLDs are observed away from the coast and out of the upwelling system, due to higher south west monsoon winds. This result points out to the presence of vertical mixing in coastal region during the upwelling period, which pumps up nutrients into the upper layers thereby enhancing the plankton growth. During NEM, the wind stress was not as intense as in SWM, also the wind direction and the local circulation pattern are not conducive to cause upwelling and therefore the SCHL is low with deeper MLD in the region.

Bimodal variability of SCHL during SWM is observed primarily in this region which further needs to be substantiated by in-situ observations. It is observed that SCHL concentration was comparatively less during 2006, 2007 and 2008. It is observed that a drop in wind stress after attaining its peak is followed by a high SCHL concentration. Similarly, it is also found that, whenever there is an increase in the wind stress, MLD deepened during the subsequent weeks and shoaled when the wind stress dropped. It is also deduced that upwelling is pronounced when high wind speed is followed by a decrease or lull which can happen during the conventional break period within the monsoon. The above important observations can largely influence future monsoon and fisheries based studies pertaining to this region.

References
Inter-annual variability of the low level jetstream and Indian Summer Monsoon Rainfall

Joseph P V 1, Shinu S. Wilson1,2, Mohan Kumar K. 2, and Ola M Johannessen1,3,
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2 Cochin University of science and Technology, Cochin, India
3 Nansen Environmental and Remote sensing Center, Bergen, Norway

Introduction

According to Reiter (1961) a jet stream should have large gradients of wind speed in the horizontal and vertical. Bunker (1965) from the aircraft wind measurements made during the International Indian Ocean Expedition found that high winds of about 50 knots (1 knot = 0.51 m/s) occurred during the summer monsoon season over south-west Arabian Sea at about one kilometer above sea level and these winds showed strong shear in the vertical both below and above this wind maximum. The existence of a Low Level Jetstream (LLJ) over peninsular India during the summer monsoon month of July with strong shears both in the vertical and horizontal was established by Joseph and Raman (1966). Fig 5(a) gives the LLJ axis on a typical day in July and the isotachs of the wind showing strong horizontal wind shears. The vertical wind speed profile at Visakhapatnam on the east coast of India close to the axis of the LLJ may be seen in figure 5(b). Analysing wind data of 5 July months Joseph and Raman (1966) found that

(a) LLJ axis passes through peninsular India on many days in July with its core at about 1.5 kms above sea level (850 hpa) and core speeds of the order of 40-60 knots (20-30 m/s)
(b) The wind shear in the vertical below the jet core is more than that above it.

Fig 5: Low level jet stream of a day in July(a) winds, isotachs in knots (1 knots = 0.51m/s) and jet axis at 850 hPa, (b) vertical profile of wind speed at a point on the jet axis taken from Joseph and Raman (1966).

Findlater (1969) established the existence of a cross equatorial LLJ during the Asian Summer Monsoon. The wind maximum of Bunker (1965) and the LLJ found by Joseph and Raman (1966) are parts of this cross equatorial jet stream. Fig 6(a) gives the mean wind flow of the period 1950 to 2010 at 850 hPa over South Asia of June to September based on NCEP/NCAR reanalysis – Kalnay et.al (1996). The mean LLJ crosses the equator along the east African coast with strong southerly winds and has its maximum wind at 850 hPa of more than 15 m/s over the Arabian Sea. The jet axis passes through peninsular India and the westerly winds of the LLJ are seen extending to the West Pacific Ocean. Fig-6(b) gives the mean Outgoing Longwave Radiation (OLR) – taken as a proxy for rainfall – of the monsoon months June to September of the period 1979 to 2010. There are two major areas of rainfall A and B as marked in the figure. 'A' is the Asian monsoon rain area and 'B' marks the West Pacific monsoon rains. The strong cross equatorial flow near longitude 35E of fig-6(a) feeds moisture to Asian monsoon area 'A'. There is a weaker cross-equatorial flow between longitudes 120E and 160E which feeds moisture to the west Pacific monsoon area 'B'. The LLJ also supplies moisture to the west Pacific monsoon. Area 'B' gets rainfall from tropical cyclones that form in large numbers in the west Pacific ocean north of the equator during the monsoon months.

The LLJ passing through India has different locations for its axis in the active and break phases of monsoon as shown by Joseph and Sijikumar (2004). In the active phase of the monsoon, LLJ axis passes through Peninsular India along a latitude close to 15ºN. In break monsoon, the LLJ axis shifts to a position south of Peninsular India and close to the equator. LLJ has two main functions: (a) It acts as a conduit carrying the moisture generated by the trade winds over South Indian Ocean and the evaporative flux from the Arabian Sea to the areas of monsoon rainfall generation over South Asia including India and (b) the area of cyclonic vorticity in the atmosphere boundary layer close to the LLJ axis is a dynamic forcing for the generation of upward motion of the moist monsoon air for the production of monsoon rainfall. In the active phase of the monsoon, deep convection occurs north of the axis of the LLJ between...
Joseph and Sijikumar (2004) found that the linear correlation coefficient between the convective heating of the atmosphere in this area (as represented by the OLR) and the strength of the zonal winds of the LLJ through peninsular India is very high and statistically significant at a lag of 2-3 days, convective heating leading. In the break monsoon phase, deep convection shifts to an area close to and south of the equator in the Indian ocean. The birth of the LLJ coincides with the onset of monsoon according to Joseph et al (2006) and Boos and Emanuel (2009). After its formation at the time of monsoon onset over Kerala, LLJ has a life duration the same as that of the monsoon, with major fluctuations in the Active – Break cycle of the monsoon as described earlier. Joseph and Sabin (2008) have proposed an empirical model for the AB cycle, coupling the atmosphere and the ocean below in which Sea Surface Temperature, deep convective heating of the atmosphere, LLJ and the net heat flux at the ocean surface have important roles.

**Data**

The data used are Indian Summer Monsoon Rainfall (ISMR) of the period 01 June to 30 September as derived by Parthasarathy et al (1994) using data of 306 climatic rain gauge stations well distributed over India of the period 1871 to 2010. This data updated to the present is given in the website of the Indian Institute of Tropical Meteorology, Pune (www.tropmet.res.in). Wind data of 850 hpa of the period 1950 to 2010 are from the National Centres for Environmental Prediction/ National centre for Atmospheric Research (NCEP/NCAR) reanalysis (Kalnay et al.,1996). National Oceanic and Atmospheric Administration (NOAA) interpolated outgoing longwave radiation data for the period 1979-2010 are used for the strength of monsoon rains and the convective heating of the atmosphere-Liebmann and Smith (1996).

**Inter-annual variations of LLJ and ISMR**

ISMR has large interannual variability. Generally a drought monsoon year is followed by a normal or excess monsoon year, a sort of biennial oscillation named Tropospheric Biennial Oscillation (TBO) details of which may be found in the observational study by Meehl (1997) and modeling study by Chang and Li (2000) and the references therein. This is the most important inter-annual variability of the monsoon. A monsoon which gives ISMR one standard deviation less than its long term mean is taken as a drought monsoon by the India Meteorological Department. The standard deviation of ISMR is about 10% of ISMR. The details regarding the drought years of the period 1950 to 2010 are given in table-1. The SST anomalies averaged for the September to November periods of five very severe Indian monsoon drought years 1965, 1972, 1979, 1982 and 1987 are shown in fig-7.

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<th>RAINFALL (mm)</th>
<th>DEPARTURE</th>
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<tr>
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</tr>
<tr>
<td>2009</td>
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Table 1: ISMR of drought years(1950-2010) and their percentage rainfall departures.

Soon after a year of monsoon drought the ocean around India develops a warm SST anomaly and this warm anomaly persists till the following monsoon which has normal or excess monsoon rains. The warm anomaly is mainly around the LLJ as may be inferred from a comparison of fig-(7) and fig-6(a). It is forced by the weaker than normal LLJ of the drought monsoon which produces less upwelling and less evaporation from the ocean, both conducive to less cooling of the SST during monsoon leading to warm SST anomaly in the post-monsoon months. The linear correlation coefficient between the magnitude of the 850 hPa LLJ winds of June to September and the ISMR for the period 1950 to 2010 varies from 0.6 to 0.8 in different portions of the LLJ, which is very high and statistically significant figure not shown. Less cooling results in positive anomaly of SST after the monsoon season. During the same post-monsoon months, the west Pacific ocean has a cold SST anomaly which also has a yearlong persistence. The months following monsoons giving excess (more than 10%) ISMR have SST anomalies of opposite sign, but weaker.
Fig 8: LCC between ISMR and (a) zonal wind (b) meridional wind of JJAS (1950-2010) (Joseph et al., unpublished).

There is a lot more convection in the west Pacific monsoon area and the convection in the Asian monsoon area is weaker, particularly over its western part. It is the positive convection anomaly that has generated the westerly anomaly at 850 hPa over west Pacific ocean and the increased meridional flow at the same level east of longitude 120E. We propose a modeling study on the role of increased convective heating of the atmosphere over the west Pacific ocean on the zonal and meridional flows in the lower troposphere around 850 hPa and its impact on the monsoon rainfall.

Fig 9: Composite anomaly (JJAS) of 8 drought monsoons (1979-2010) of (a) OLR and (b) 850 hPa zonal wind (Joseph et al., unpublished).

Fig-8(a) gives the Linear Correlation Coefficient (LCC) between ISMR and the mean 850 hPa zonal wind of June to September of the period 1950 to 2010 and fig 8(b) gives the LCC for the 850 hPa meridional wind for the same period. The LCCs are statistically significant and large. It is inferred that the zonal winds of the LLJ over the Arabian Sea (C) becomes weak in a drought year where as the westerly zonal winds over the west Pacific (D) strengthen and cover larger areas. The meridional winds feeding moisture to the Asian monsoon (E) weaken in a drought monsoon whereas the meridional winds over the west Pacific ocean (F) have strengthened. The composite 850 hPa zonal wind anomaly of the 8 monsoon drought years of 1979 to 2010 listed in table-1 is given in fig-9(b) showing the large westerly wind anomaly over the west Pacific ocean and the weaker zonal winds over the Arabian Sea. Fig-9(a) gives the anomaly of OLR of the 8 drought monsoons of 1979 to 2010. In a drought monsoon there is a lot more convection in the west Pacific monsoon area and the convection in the Asian monsoon area is weaker, particularly over its western part. It is the positive convection anomaly that has generated the westerly anomaly at 850 hPa over west Pacific ocean and the increased meridional flow at the same level east of longitude 120E. We propose a modeling study on the role of increased convective heating of the atmosphere over the west Pacific ocean on the zonal and meridional flows in the lower troposphere around 850 hPa and its impact on the monsoon rainfall.

Our study shows that the increased convection over west Pacific ocean during the monsoon months of a drought monsoon has persistence of several months prior to the monsoon. In order to avoid contamination by the Madden Julian Oscillation we have studied three month moving averages of the composite OLR anomaly from six months prior to the 8 monsoon droughts of the period 1979 to 2010. These are shown in fig-10. There is negative OLR anomaly east of longitude 140E persisting from January-March to July-September in the composites. The anomaly weakened slightly around April as the ITCZ crossed the equator in its northward movement and was again much stronger from June onwards. It is well known that most of the monsoon droughts lead to El Nino warming of the central and east Pacific and increased convection there. The persistence of convection for more than six months over west Pacific ocean prior to a drought monsoon may give a clue for the development of methods for the long range (seasonal) forecasting of monsoon droughts. Process studies and GCM modeling studies are recommended.

Conclusion
Inter-annual variability of Indian Summer Monsoon Rainfall is found to be closely associated with the variability of the zonal and the meridional winds of the Low Level Jet stream which is in turn associated with the anomalies in deep convective heating of the atmosphere (anomalous OLR). We have found a large area of negative OLR (increased convection) over the west Pacific Ocean during a drought Indian monsoon. This anomalous convection has persistence of more than 6 months prior to a drought monsoon.
Introduction

The El Nino-Southern Oscillation (ENSO) is the largest known global climate variability signal that appears on interannual time scales. The ENSO is a quasi-periodic fluctuation between warm El Nino and cold La Nina states of the tropical Pacific sea surface temperature and it has a recurrence oscillation period of approximately 2 to 7 years (Philander, 1990). During the recent decade, a paradigm shift has occurred in the influence of ENSO on the atmospheric circulation patterns over the tropics. This shift has created a considerable amount of interest among researchers worldwide (Ashok et al. 2001; Vecchi and Soden 2007). The production and distribution of atmospheric aerosols significantly depends on the magnitude of the zonal winds. Therefore, any change in the strength of the zonal circulation due to ENSO significantly affects the transport and subsequent deposition of absorbing aerosols (eg, dust, soot). To validate this aspect, the present analysis investigates the probable association between anomalous SST over the tropical Pacific and the zonal circulations in controlling the aerosol loading over the Indo-Gangetic Plain (IGP), which comprises most of the North Indian region. The proliferation of the absorbing aerosols during the pre-monsoon season is shown to have modulated the cloud properties and on the overall performance of the Indian summer monsoon (Lau et al. 2006; Abish and Mohanakumar, 2011). Such an alteration in the normal weather pattern demands attention in a meteorologically sensitive region because of the location of Monsoon Trough and the apparent position of inter tropical convergence zone (ITCZ) during the summer monsoon season (June to September).

Data and analysis

The variability of aerosol loading from 1982 to 2011 has been studied using the Aerosol Index (AI) derived from the Total Ozone Monitoring Spectrometer (TOMS) onboard Nimbus-7, Earth Probe spacecrafts and the Ozone Monitoring Instrument (OMI) on Aura satellite. The AI gives a qualitative measure of the presence of UV absorbing aerosols, such as mineral dust and soot. Level 3 gridded AI data products from TOMS at 1.0 × 1.25° and OMI at 1.0° × 1.0° resolutions were obtained from the Giovanni website (http://giovanni.gsfc.nasa.gov/). For the present analysis, the TOMS AI dataset for the period January 1982–September 2004, and for the October 2004–December 2011 years OMI data sets were used. Since the OMI was designed to replace TOMS to continue the measurements of atmospheric constituents, their sensor characteristics are almost the same.

Results and Discussion

Fig 11 depicts the composite of prevailing zonal winds at 700 hPa during El Nino and La Nina phases, respectively. The figure confirms that zonal winds at 700 hPa level are stronger over the source locations in Arabian Peninsula during El Nino episodes compared to La Nina events. These high velocity winds are seen to be spread across vast areas of the Arabian Desert, which is one of the major sources of dust aerosols. Once emitted, these aerosols are transported by means of atmospheric circulation patterns to distant locations where they are deposited (Tegen and Miller, 1998; Slings et al. 2006). Moreover, the Shamal winds blowing from Iran and Pakistan carry significant amount of dust under favourable weather conditions (Middleton, 1986). These stronger zonal winds are capable of transporting aerosols in large quantities towards the IGP. Along with this intense westerly wind system, a significant amount of dust aerosols is carried towards the region resulting in a persistent dust loading and deposition over the area of interest. During the La Nina years, the wind is generally weaker over the longitudinal area extending from source to its sinking regions throughout this period. The weaker magnitude of upper level winds contributes to a lesser quantity of aerosols transported eastwards towards the Indian subcontinent.

References


Atmospheric aerosols concentration over India and its relationship with ENSO: A satellite perspective

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The dependence of aerosol concentration on the strength of the zonal westerlies is seen in the spatial distribution of AI between latitudes 70°N – 35°N, and longitudes 35°E – 100°E, covering both the Arabian Peninsula and Indian subcontinent (Fig 11). The composite of the El Nino and La Nina years shows the effect of the convergence of atmospheric aerosols and the consequent enhancement of AI. As illustrated in Fig 12, high concentration of aerosols is present in the active source regions of Arabian Desert and its sinking areas over the Indian subcontinent during the El Nino events. During the La Nina events, the AI values exhibit lesser concentration as compared to the El Nino events. During this phase of the ENSO, even though the source region over Arabia possesses a peak AI of 1.2, the AI in the transport pathways as well as over the subcontinent the AI varies from 1 to 1.45.

A declination in the AI values to 1.45 over the IGP shows the reduction in loading of absorbing aerosols due to weak westerlies during the La Nina. Since, most of the absorbing aerosols reaching the location are through the long distance transport by zonal winds, a weakening of the circulation affects the aerosol loading as evident by low AI values.

In order to quantify the degree of association between ONI and AI, it is required to perform a statistical analysis between these indices (Fig 13). During the strong El Nino events, ONI and AI are negatively correlated with a significant correlation coefficient value of -0.71. While during the La Nina event, the AI exhibits a strong positive correlation of 0.84 with the intensity of cold SST anomalies.

**Summary**

The study reveals that during the La Nina (El Nino), the development of cold (warm) SST anomalies strengthens (weakens) the zonal circulation over the tropical Pacific region, while weakening (strengthening) that over the Indian subcontinent. As a result, the quantity of absorbing aerosols transported during the La Nina (El Nino) decreases (increases), which explains the low (high) AI values during the period. Further analysis using Student’s-t test reveals that during both the La Nina and El Nino phases, the correlations between AI and ONI are statistically significant at 99% level of confidence.
Fig 13: Scatter plots for (a) El Nino (b) La Nina composites. In both the cases the correlations are highly significant at 99% level of confidence using a student’s t-test.

References

Introduction
Sandy beaches harbour a plethora of life forms in the interstices of fine and coarse sand grains. Interstitial animals have a wide spectrum of morphological adaptations to meet their biological demands. In sands containing particles coarser than 200µm and above have only meiofauna as interstitial forms. Below 100 to 125µm mean particle diameter, the interstitial fauna is usually absent. Well sorted sands with particle diameter greater than 100µm with the interstices filled with water rather than silt or clay, would harbour a good representation of interstitial animals comprising of turbellarians, gastrotrichs, oligochaetes, polychaetes, ostracods and others, apart from the dominant nematodes and harpacticoids. The work carried out on the taxonomy and distribution of various interstitial groups of animals have shown that the biodiversity of these groups can vary depending on the geomorphology, physical characteristics of the beach, geographical locations of the sampling site, the nature, quality and abundance of food particles and above all the tidal amplitude. Despite the heterogeneity of the numerous animal groups represented in the meiobenthos, in spite of their different organization, complexity in structure, taxonomic rank and probably phylogenetic age, all have been subject to integrating adaptations (Remane, 1952) by the constraints and dynamics of the habitat. In the light of enhanced rate of species extinction caused by anthropogenic activity, the need for a reliable estimate of the variety of species has become a need of the hour.

Materials and Methods
Samples of sediments were collected employing a corer of 8 cm inner diameter from the beaches of Cherai (lat.9°18'N., long 76°05'E), Arthungal (lat.9°10' long 76°23'), Sakthikulangara (lat.8°45'N., long.76°38'E), and Veli (lat.8°29'N., long.76°59'E) located on the south west coast of India. The animals were narcotized and fixed using standard procedures and meiofauna was represented by surface decantation method (Wieser, 1960). Specimens were examined under a Magnux 100X oil immersion objective (India) or with Nomarski differential interference contrast optics using an Eclipse 90i Nikon microscope (Italy).
Results and Discussion

The species composition, density and distribution of Gastrotricha vary considerably from area to area depending on the nature of the substratum (Table 2). Gastrotrichs were well represented in Cherai, Fort Cochin and Veli beaches. The survey revealed the occurrence of eight Gastrotrich species, (Fig 14) which included four macrodasysids (Pseudostomella cheraensis Priyalakshmi et al., 2007., Tetranchyroderma swedmarki Rao and Ganapati, 1968., Turbanella lutheri Remane, 1952 and Paraturbanella sp.), and four chaetonotids (Chaetonotus apolemmus Hummon, Balsamo et al, 1992; Halichaetonotus euromarinus Hummon and Todaro, 2010 (= H. spinosus Mock, 1979); Halichaetonotus sp. and Xenotrichula sp). Pseudostomella cheraensis is new to science (Priyalakshmi et al., 2007). All are premier reports from this coast and the Genus Hallochaetonotus is reported for the first time from Indian waters. Certain degree of habitat related species preference was evident in the distribution of Gastrotrichs. Discontinuous distribution accompanied by site specific abundance is a cardinal feature of gastrotrichs. A few successful species always dominate in their quantitative abundance, while a majority of the remaining ones occur in small numbers (Naidu and Rao, 2004). This was quiet evident in the abundance of Paraturbanella sp. at Fort Cochin and Tetranchyroderma swedmarki and Pseudostomella cheraensis at Cherai.

Since Gastrotrichs are living in an unstable environment subject to frequent disturbances, they always migrate seeking optimum conditions for successful existence. These qualities of Gastrotrichs make them an integral species component for utilization as 'keystone species' to recognize polluted and unpolluted sandy beaches. Gastrotrichs were altogether absent during the monsoon indicating that all the species recorded are typically marine and will be either killed or removed during the monsoon months when the surface waters of the Kerala Coast oscillate between oligohaline and mesohaline conditions.

Taxonomic studies of selected aberrant groups brought to light forty three species belonging to Nematoda, Gastropoda, Polychaeta, Kinorhyncha, Isopoda and Cnidaria. The order of numerical abundance of nine interstitial taxa from Cherai is represented as: Nematodes (45%), gastrotrichs (15%), turbellarians and kinorhynchs (8% each), harpacticoids and isopods (6% each), oligochaetes (3%), cnidarians (1%) and others (2%). The current investigation revealed the occupancy of gastrotrichs in second position in abundance after Nematodes at Cherai (Priyalakshmi and Menon, 2012).

The Gastrotrichs not only play an important role in the food chain of the aquatic ecosystem, but also contribute to the recycling or regeneration of nutrients basically required for sustaining life in their environment. It was found that the variety of animals found in the sand samples varied considerably from time to time. This may be due to the gregarious habit of the majority of the interstitial organisms. Patchiness could be considered as a unique feature of interstitial animals. Even though, high abundance of fauna is related to trophic richness of an environment, the quality of organic matter plays an important role in controlling the variety of benthic communities (Garcia et al., 2007).

Summary

A striking feature of the distribution of Gastrotrichs was the distinct discontinuity in species distribution, sampling error if any withstanding. Among 17 species described earlier none was recorded during a three year study from 2005-2008. Eight new records for this area along with the discovery of two new species is really fascinating. Further we should address the importance of global climate change and advocate more strongly than before, the value of using the ubiquitous meiofauna to assess the health of ecosystems (Giere, 2009). The increase in human population enhances the rate of species extinction and the Indian subcontinent is no exception to this universal phenomenon. When vast stretches of the Indian subcontinent still remains to be studied in detail for this fauna, it is a pity that many of these strange creatures perish undiscovered, undescribed and unknown.
Table 2: Relative abundance and distribution of gastrotrichs in five selected sandy beaches of Kerala

<table>
<thead>
<tr>
<th></th>
<th>Density/ 100cm³</th>
<th>P. cheraens is</th>
<th>T. swedmaraki</th>
<th>T. lutheri</th>
<th>Paraturbanella sp.</th>
<th>C. apolemmus</th>
<th>H. spinosus</th>
<th>Halichaetonotus sp.</th>
<th>Xenotrichula sp</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cherai</strong> (Feb-May)</td>
<td>140</td>
<td>R</td>
<td>R</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Fort Kochi</td>
<td>695</td>
<td></td>
<td>R</td>
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<td>Arthungal</td>
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<td>Sakthikulangara</td>
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<td></td>
<td></td>
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<tr>
<td>Veli</td>
<td>12</td>
<td>R</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Monsoon</strong> (Jun-Sept)</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
</tr>
<tr>
<td><strong>Post-Monsoon</strong> (Oct-Jan)</td>
<td>586</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
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<tr>
<td>Cherai</td>
<td>-</td>
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<td>Fort Kochi</td>
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<td>Sakthikulangara</td>
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</tr>
<tr>
<td>Veli</td>
<td>77</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
</tr>
</tbody>
</table>

R: Recorded  NR: Not Recorded

**References**


Wieser, W., 1960: Benthic studies in Buzzards Bay. II. The meiofauna. Limnology and Oceanography, 5: 121-137.

Phytoplankton abundance as a function of salinity and turbidity in a tropical estuary (Cochin backwaters - India)

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**Introduction**

Coastal seas and estuaries are ecosystems where mixing of fresh and marine waters leads to considerable changes in the physico-chemical properties and biological processes. Cochin estuary (CE), one of the largest estuarine systems (256 km²) in the west coast of India, (Menon et al, 2000) is highly influenced by the seasonally occurring monsoon driven rainfall and associated run off, which results in dramatic changes in salinity and the overall functioning of the trophic food web (Madhu et al., 2007). Further, both maintenance and capital dredging of the estuarine mouth to maintain constant depth in the shipping channels leads to increase in suspended load and also redistribution of the bottom deposits.

Time series measurements were conducted from 9 stations distributed along the length and breadth of CE from August 2007 to July 2008. Salinity was determined using a Salinometer (Model TSK, accuracy ± 0.001). Light transparency of the water column was measured using the Secchi disc (Ds m) and light extinction coefficient (ke, m⁻¹) was calculated following the relationship ke = 1.4/Ds, where 1.4 is an empirical constant for highly turbid waters (euphotic depth <5m; Holmes, 1970). Chlorophyll was estimated using spectrophotometric method (Strickland and Parsons, 1984). Phytoplankton were identified upto the generic level using standard taxonomic keys (Tomas, 1997).

The Pearson correlation analyses were performed to find out the linear relationship of chlorophyll a to salinity and turbidity.
Results

Salinity (Fig 15) showed distinct seasonality, wherein a pronounced decline was noticed in the surface (av. 2.2 ± 3.7 psu) during monsoon (June – Sept.) and the salt wedge resulting in higher salinity at the bottom (12.8 ± 6.3). Conversely, during the pre-monsoon (PRM - Feb. – May), the increased seawater incursion resulted in substantial increase in salinity (surface av. 20.3 ± 5.2 psu & bottom av. 22.5 ± 5.3 psu), wherein a definite south to north decrease was discernible. Due to reduced turbidity, the light attenuation coefficient (ke) was minimum during PRM (av. 1.2±0.2m⁻¹) as compared to monsoon (av. 1.7±1.0m⁻¹) and post monsoon (PM – Oct. – Jan.) (av. 1.58±0.4m⁻¹) seasons.

Surface chlorophyll a exhibited seasonal variation (Table 3) with high values (av. 10.25 ± 7.31 µg/l) during the PRM. Almost similar values (av. 8.64 ± 2.72 µg/l and 8.66 ± 4.86 µg/l) were recorded during monsoon and PM respectively. Very high chlorophyll a was observed in the fresh water stations (Bolghatty and Vaduthala) throughout the year, with the highest value recorded at Vaduthala (22.88 µg/l) during PRM. In the typical marine stations (Fairway buoy and Bar mouth), chl.a was high (>7 µg/l) during monsoon when the mixing of nutrient rich water rivers was maximum. In the estuarine stations, chl. a fluctuated depending on the rate of discharge of fresh water, pollutants and extent of turbidity, which in turn was closely associated with the circulation pattern prevalent in the estuary. This shows that chl. exhibits more spatial than temporal variation.

Table 3: Chlorophyll a (µg l⁻¹) recorded during the different seasons.

<table>
<thead>
<tr>
<th>Station</th>
<th>Monsoon</th>
<th>Post mon</th>
<th>Pre-mon</th>
</tr>
</thead>
<tbody>
<tr>
<td>FAIRWAY BUOY</td>
<td>7.2325</td>
<td>3.593</td>
<td>4.785</td>
</tr>
<tr>
<td>BAR MOUTH</td>
<td>6.1955</td>
<td>6.087</td>
<td>5.17</td>
</tr>
<tr>
<td>MATTANCHERY</td>
<td>6.05</td>
<td>4.29</td>
<td>9.8725</td>
</tr>
<tr>
<td>VALLARPADAM</td>
<td>6.4075</td>
<td>6.82</td>
<td>6.27</td>
</tr>
<tr>
<td>BOLGHATTY</td>
<td>14.6575</td>
<td>10.56</td>
<td>11.3025</td>
</tr>
<tr>
<td>VADUTHALA</td>
<td>8.4425</td>
<td>22.88</td>
<td>19.8</td>
</tr>
<tr>
<td>OIL TERMINAL</td>
<td>11</td>
<td>11.22</td>
<td>4.2075</td>
</tr>
<tr>
<td>WILLINGTON ISLAND</td>
<td>7.315</td>
<td>5.133</td>
<td>6.985</td>
</tr>
</tbody>
</table>

Diatoms were the dominant group at all stations during all the seasons (Fig. 16). But the maximum contribution (71%) was during the PRM. Different from the normal pattern, Chlorophyceae formed the second dominant group in all seasons. No variation in group dominance was observed along the salinity gradient irrespective of the seasons. The only exceptions were that during monsoon, Chlorophyceae were seen in all stations and other fresh water forms like Trebouxiophyceae & Zygnematophyceae were well represented in all the stations except the typical marine stations Fairway Buoy and Barmouth. During PM, fresh water forms like Trebouxiophyceae & Zygnematophyceae were totally absent in the estuary. Diversity was maximum during the monsoon season and minimum during the PRM season. Density was maximum during PM season and minimum during PRM season.

Despite the general dominance of the diatom group in all three seasons, the actual phytoplankton species present differed considerably in each season. Coscinodiscus radiatus was the most abundant species in monsoon, being represented in all stations, followed by Leptocylindrus danicus and Skeletonema costatum. Interestingly, during this season, highest density was noticed in case of the dinoflagellate Ceratium symmetricum (109.2 x 10³ cells l⁻¹) at the Fairway buoy, where exceptionally high numbers were noticed.

During post monsoon, the dominant phytoplankton was the diatom Leptocylindrus minimus, being represented in all the 9 stations, with high densities at Vallarpadam (251 x 10³ cells l⁻¹) and Vaduthala (110 x 10³ cells l⁻¹). This was followed by other dominant diatoms like Melosira sulcata, Coscinodiscus marginatus, C. radiatus and C. stellaris and the dinoflagellates Proteroperidinium oceanicum and Ceratium furca.

During pre-monsoon, Nitzschia longissima (936 x 10³ cells l⁻¹) and Coscinodiscus marginatus (666 x 10³ cells l⁻¹) outnumbered all other phytoplankton genera with highest density at Vaduthala. The other dominant forms in this season were the diatoms Bidulphia mobilisensis and Thalassiosira balica, even though not represented in all stations.

Discussion

Salinity is a well known controlling factor of phytoplankton activity and diversity in estuarine systems (Quinlan and Phils, 2007). It is therefore not surprising that osmotic stress induced by the mixing of the fresh water and seawater played some role in determining community structure. The phytoplankton abundance in the estuary throughout the year especially in stations like Vaduthala, Bolghatty, Mattancherry where large quantities of domestic sewage and industrial effluents are discharged, show that nutrients are available in surplus and they do not limit the growth of phytoplankton at any time of the year (Balachandran et al., 2005).

The productivity pattern in CE has shown that nanoplankton contributes a major portion (~60%) of the phytoplankton standing stock (Qasim et al., 1974). The abundance of nano plankton such as Skeletonema costatum, Thalassiosira balica and Nitzschia closterium throughout the year, provides a valid support to the above finding. Diatoms (eg. Skeletonema costatum) are conventionally considered as euryhaline and eurythermal...
phytoplankton group, which grow quickly under eutrophic conditions (Huang et al., 2004).

On the other hand, dinoflagellates mostly prefer oligotrophic waters and hence, fail to survive in eutrophic waters by competing with diatoms (Cushing, 1989). This was found to be true in the present study, as the dinoflagellate community was relatively less in abundance in the estuary throughout the year as compared to the diatoms.

Besides diatoms and dinoflagellates, presence of fresh water chlorophytes during monsoon season in study area shows the community shift of phytoplankton due to the changes in salinity commonly occurring in the CE (Devassy and Bhattathiri, 1974).

Increased chlorophyll a distribution was observed during dry season compared to wet season. The increased flushing during monsoon resulted in low chlorophyll concentration in surface layers where salinity was low. High riverine discharge leads to reduced residence time, leading to increased flushing of phytoplankton biomass out of the estuary (Lane et al., 2007). The linear correlation between the salinity and chlorophyll a was found to be more significant during the PM (r = 0.629, P<0.01, n = 108), as compared to the PRM (r = 0.285, P<0.01, n = 108) and monsoon (r = 0.367, P<0.01, n = 108). This indicates that to some extent, the increase in salinity seems to accelerate the phytoplankton growth in the estuary. Estuarine species and communities are well adapted to the variations in salinity that are related to tidal cycles and seasonal rainfall patterns. Such variation reduces competition among different phytoplankton groups, possibly causing high rates of estuarine primary productivity. However, salinity could not be considered as the only determining factor for triggering phytoplankton growth.

Water clarity was the second significant factor affecting variations in phytoplankton densities. Since the CE carries large quantity of suspended materials in the form of detritus and sediments (terrestrial origin) throughout the year, the resultant water column turbidity limits the light penetration in the euphotic zone (Qasim & Sankaranarayanan, 1972). Comparable values of light attenuation coefficients in the CE during the PRM (av.1.2 ± 0.2 m⁻¹) and the monsoon (av. 1.66 ± 0.2 m⁻¹) seasons substantiates the above statement. The light limitation controls phytoplankton biomass and prevents phytoplankton from using the available nutrients. The linear correlation of chlorophyll a and SPM did not show significant relationship during both PRM and PM (r=0.43 &0.09 respectively), whereas it depicted a negative correlation during the monsoon season (r = -0.59, P>0.05) and it suggests that suspended matter concentration in CE serves as a limiting factor only during monsoon season when its concentration is exceptionally high.

Conclusion

The spatial and temporal distributions of phytoplankton density in the Cochin estuary were found to be largely controlled by the salinity and turbidity gradients within the different regions of the ecosystem, with chlorophytes and cyanobacteria dominating the turbid freshwater habitat, and diatoms and dinoflagellates dominating the clear estuarine environment. The developments of mixed assemblages of riverine and estuarine species varied seasonally throughout the study period, mainly in accordance with the changes brought about by salinity and clarity of the water by means of rainfall or pollutant discharge.

References

standing stock and abundance in a tropical estuary (Cochin Backwaters - India). *Estuarine Coastal & Shelf Science*, 73, 54-64.


**ONGOING PROJECTS**

NERCI has the following ongoing external funded projects from Directorate of Environment and Climate Change, Govt. of Kerala, DST, SAC and ISRO. International joint projects like EU-FP7 Programme and Norwegian Research Council Programme and UNEP that are listed below.

**New Joint Research Projects**

**INDO-MARECLIM: Indo-European Research Facilities for Studies on Marine Ecosystem and Climate in India.**

Coordinator - Prof. N. R. Menon (NERCI), Deputy Coordinator - Lasse H. Pettersson (NERSC), Project Manager - Ajith Joseph, K. (NERCI), Chairman, Steering Committee - Prof. Ola M. Johannessen (NERSC), funded by EU-FP7 Programme. [http://www.indomareclim-nerci.in](http://www.indomareclim-nerci.in)

**INDO-MARECLIM** aims at analyzing and understanding some of the challenges of the Indian Ocean and the Indian subcontinent under past, current and future global change processes, by addressing three related and complementary scientific fields of research. Funded by EU-FP7 Programme. [http://www.indomareclim-nerci.in](http://www.indomareclim-nerci.in)

**INDIA-CLIM: Decadal to multi-decadal variability in the Indian Monsoon Rainfall and teleconnection with Atlantic Multidecadal Oscillation (AMO)**

Project Leader – Prof. Ola M. Johannessen (NERSC), Co-Principal Investigator - Prof. P. V. Joseph, funded by Norwegian Research Council.

**INDIA-CLIM** aims at analysing the Decadal to multi-decadal variability in the Indian Monsoon Rainfall and teleconnection with Atlantic Multidecadal Oscillation (AMO) funded by Norwegian Research Council and in kind contribution from NERSC.

**Application of Altimetry (AltiKa) and Ocean Color (Oceansat II) in the studies of meso-scale features of the South-eastern Arabian Sea**

Principal Investigator – Prof. A. N. Balchand, CUSAT Co-PI – Dr. K. Ajith Joseph, NERCI

The main objective of this study is to understand upwelling dynamics and its effect on sea level variability. The dissipation of algae blooms in the South-eastern Arabian Sea in relation to mesoscale features of Southwest coast of India. Funded by Space Application Centre (SAC-ISRO).

**Regional climate change issues and adaptation measures for low lying regions in the context of future sea level rise**

Principal Investigator - Dr. K. Ajith Joseph, NERCI Co-PI- Dr. K. Shadananan Nair, NERCI-CEREM

The main objective is to study the regional climate change issues and adaptation measures to future sea level changes of a region which is lying below the mean sea level to address: drinking water problems and salt water intrusion, land use pattern and identification of proper agriculture practices and disaster preparedness. Funded by UNEP-APFED programme.

**Effect of house boats on Vembanad lake ecosystem – an EIA study**

Principal investigator - Dr. Nandini Menon. N, Co-investigators - Prof. N. R. Menon and Dr. Ajith Joseph

The proposal is a scientific attempt to proclaim the significant role of houseboats, viewed and projected as integral part of Kerala in contaminating the ecosystem. The study area of the proposed project includes the part of Vembanad lake between Punnamada to Thanneermukkom bund, along which majority of the houseboats ply. Submitted to Directorate of Environment & Climate Change, Trivandrum.

**Commercial use of biomass from Musa sp. (banana) to reduce its negative impact on environmental quality of Kuttanad ecosystem**

Principal investigator – Dr. K. Suresh,TocH Institute of Science and Technology, Kochi Co-investigators - Dr. Nandini Menon. N,

The main objective of this project is to find commercial use of biomass of *Musa* sp. to prevent its accumulation in the environment. The study region is the Kuttanad wetland area.

**Publications in 2012**

**Referred Journals**


Jayaram, Ch.V.C., Udaya Bhaskar, T.V. Ajith Joseph, K. and Balchand, A.N.2012. Application of satellite products to study Upwelling, Chloropyll and Mixed Layer Depth of


*Book Chapter*


*Symposia and Workshops*

Joseph P. V. 2012. “Role of Ocean in the Variability of Indian Summer monsoon Rainfall” at the workshop on “Earth’s Hydrological Cycle” held at International Space Science Centre, Bern, Switzerland 6-10 February 2012.


*Conference Proceedings Papers*


*Awards and Honours*

Prof. P.V. Joseph was felicitated by the Ministry of Earth Sciences, Government of India in a function held at Delhi on 15 January 2012, the Foundation Day of India Meteorological Department, for his active and continued support to Meteorology in India for more than 50 years.

Prof. P.V. Joseph was honoured with the Swadeshi Sastra Puraskaram 2012 (National Science Award) in a function held on 6 November 2012 at Kasargode Kerala for his valuable contributions to the field of Meteorology, especially Monsoon studies for the last 50 years

*Completed Project:*

SAC-ISRO funded project “Synergistic application of Scatterometer and OCM data from Oceansat II for the studies of coastal upwelling in the SW coast of India” was completed and the project closure report was submitted to SAC in April, 2012.

*Technical Reports/Special Reports*


EU-FP7 - INDOMARECLIM Project implementation Workshop participants at Kochi

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