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SATELLITE DERIVED DIATOM DYNAMICS IN THE INDIAN OCEAN: MEAN SEASONAL PATTERNS AND TRENDS

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Abstract

Assessment of phytoplankton (diatom) dynamics was studied using NASA Ocean Biogeochemical Model (NOBM) from NASA Geospatial Interactive Online Visualization and analysis Infrastructure (Giovanni) system, from Jan 1998 to Dec 2015. It was carried out from Indian Ocean to Southern Ocean covering areas of various small seas (45–145°E, 35N–80°S). High and low abundance of diatoms were observed during two periods from September to November and March to May, respectively. The diatoms spatial distribution and richness were observed high between 40° and 60° South latitudes throughout the year. During December to February they increased between 40 to 70 degree south. In March to May between 40 to 45 degree south, during June to August near Gulf of Aden, Arabian Sea and in the months from September to November diatom increased in the southern ocean areas and dropped in other areas. This study reveals potential rich diatom areas with its seasons and results can be useful further in ecological studies.

Key words: Phytoplankton**,** Diatom, Indian Ocean, NOBM Model, Giovanni NASA, Ocean remote sensing.

Introduction

Phytoplankton play very important role in ecology and physical environment like in oceans, seas, and freshwater basin ecosystems, as well as in related biogeochemical cycles. Phytoplankton groups are considered as having large taxonomic diversity. These communities are strongly playing their role in the ecosystem and their biogeochemical functioning. In the aquatic environment whether they are coastal, inland and Open Ocean, is hardly comprised of a single algal class. Different groups of phytoplankton adapt to environmental conditions, these are sun light, sea surface temperature (SST), nutrient availability (Harrison & Cota, 1991), winds and turbulence level. Remote sensing algorithm now are able to classify phytoplankton groups by some specific pigments' biomarkers. Consequently, phytoplankton groups can also be identified from color catalogues. Now, different bio-optical and ecological models have been developed for identifying phytoplankton, their taxonomic composition, and specific phytoplankton species. Among the phytoplankton, diatoms are important species that flourish the biodiversity and productivity of oceans.

Diatoms (Bacillariophyceae) constitute the most important and dominant component of phytoplanktons (Tabassum & Saifullah, 2012). Seasonal and annual inconsistency of diatom is very important to understand the dynamics of primary production and ocean ecology (Yamada et *al*., 2004; Alvain *et al*., 2005). The spatial and temporal assessment of diatoms and their primary production are vital and also help in identifying the interactions between the physical climate and biogeochemical cycles of the oceans (Nair *et al.*, 2008; Lillesand *et al*., 2014) Abundance of diatoms has been related to the productivity of the sea (Shukla *et al*., 2009).

The environmental factors controlling diatom distribution are macro nutrients (nitrate, phosphate and silicate relationship), amount of radiation (photosynthetic available radiation), salinity and sea surface temperature. Other geographical factors also affect such as Coriolis affect, Winds, Oceanic currents and Gyres *i.e.* Indian Ocean Gyre (clockwise) and Southern Gyre (anti clock wise) (Garcia *et al*., 2008; Wiltshire *et al*., 2015; Lee *et al*., 2016).

Remote sensing data enables spatial and temporal assessment of marine environment. Advancement in satellite technology has made easier to monitor the global environment including oceans (Simis *et al*., 2007). It is also used more effectively with mathematical modeling for the assessment of ocean dynamics. These satellites data are being used for mapping, monitoring and detection of the phytoplankton with the help of computers and algorithms (Blondeau-Patissier *et al.*, 2014). From last two decades we have seen wonderful progress in remote sensing and methods to analyze the data (Banse, 1987; Jensen & Lulla, 1987; Mobley, 1999). Many studies verified the global and regional distribution of chlorophyll a (Chl-a) determined the proxy of phytoplankton biomass and primary production (Saifullah, 1979, Tan *et al*., 2006; Huston & Overton, 2009). Many statistical techniques with remote sensing and GIS data sets have made possible to time series and periodic analysis (Richardson, 1996). Trend analysis of phytoplankton data by satellites are now used in analysis of climate and ecosystem changes (Khan *et al.*, 2015).

The main purpose of the present study is to achieve quantitative data on the spatial and temporal distributions of abundance of the diatoms in the study area by remote sensing during the period 1998-2015, with a view to work out the seasonal periodicity in their peak production, areas of high and low productivity and also annual variations if there are any. This information is very important for conservation and management of marine resources of the area, because diatoms are primary producers in the sea.

Methodology

Study area: The study area covered Indian Ocean and Southern Ocean (45–145°E, 35N–80°S). This region is very important because it is characterized by high biological productivity in the global ocean. Several small and significant sea areas like Arabian Sea, Gulf of Aden, Persian Gulf, Bay of Bengal, Andaman Sea, Java Sea, and Part of Timor Sea near Australia to Southern Ocean (Antarctic Ocean) also part of this study area (Fig. 1).

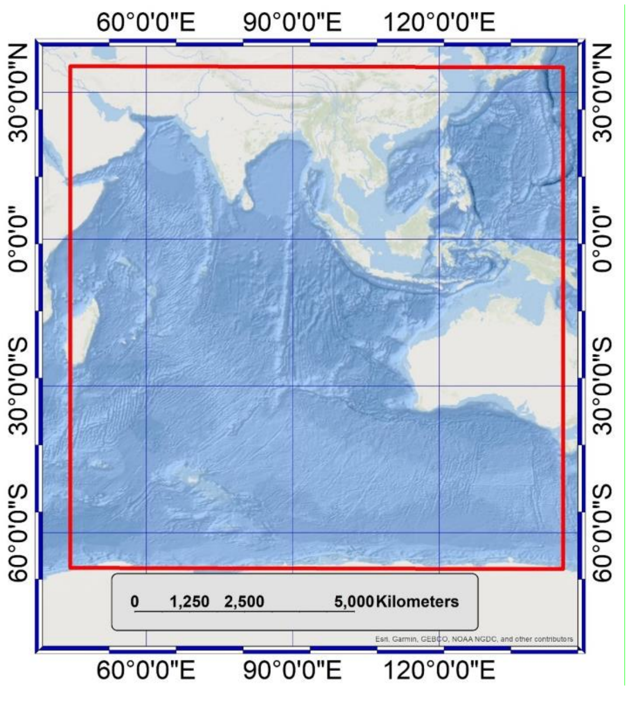

Fig. 1. Study area outline.

Remote sensing data: Many remote sensing algorithms have been developed that can identify phytoplankton type such as diatoms also other groups. Diatom dynamics can be assessed by getting daily and monthly data from NASA Ocean Biogeochemical Model (NOBM). The NOBM is a comprehensive, interactive ocean biogeochemical model coupled with a circulation and radiative model in the global oceans (Gregg, 2001; Gregg & Casey, 2007). NASA Ocean developed NOMB model by several in situ and remote sensing data. The model contains 4 explicit phytoplankton taxonomic groups: diatoms, cyanobacteria, chlorophytes, and coccolithophores. Many scientist assess and validated the NOMB model products with in situ data with nutrients and total chlorophyll, the phytoplankton groups (Rousseaux & Gregg, 2015). We assessed diatom data by using diatom-detection algorithm of NOMB Model, to assess month wise distribution and analysis from 1998-2015, from NASA Geospatial Interactive Online Visualization and analysis Infrastructure (Giovanni) system.

Results and Discussion

Three-dimensional data cube (latitude, longitude, time) was used by satellite data. It helped to analyze the final product through time and space dimension. The NOMB model product has been retrieved. Monthly data sets in Geotiff file format were taken. Finally resulting diatom maps were developed. All maps were combined into seasonal composite images, time series and spatial data graphs. The data showed that the diatoms were most abundant during September to November and low in the months of March to May (Fig. 2). The period from 1998 to 2015, year 2004 to 2006 and 2012 showed the peak accumulation of diatoms (Fig. 3). It was also revealed that diatom abundance remained high between the 40° and 60° South latitudes throughout the year (Fig. 4).

Regarding spatio-temporal observation most of the rich areas are in southern ocean part. Seasonal variation affected diatom dynamics in many regions. Fig. 5a, showed that during December to February diatom populations were increasing between 40 to 70 degree South. In March to May between 40 to 45 degree south (Fig. 5b), during June to August near Gulf of Aden, Arabian Sea and Persian Gulf as already reported earlier by Tabassum & Saifullah (2012) (Fig. 5c), during September to November diatom increased in the southern ocean areas and reduced from previous areas (Fig. 5d), Study area comprised of four major oceanic basin regions that are North Indian Ocean, equatorial Indian Ocean, south Indian Ocean and Antarctic region (Southern ocean), and each region has its own dynamics due to affecting factors. Some of the mechanisms driving these geographical variations of diatoms are because of several reasons discussed by scientists earlier (Yamada *et al*., 2004; Khan *et al.*, 2015).

In biogeochemistry the processes involve like the changes of carbon and nutrients its uptakes and cycling in the earth-system. This field is rising in many areas especially ocean studies. Physical and chemical process on spatiotemporal variability with remote sensing and in situ data are now an established science. Ocean geochemistry affect global ecology and primary production. Phytoplankton assessment with remote sensing involve many factors including geochemistry and in situ data in algorithms development. NOMB models are used in many studies including 4 phytoplankton groups, 4 nutrient groups, a single herbivore group, and 3 detrital pools. The phytoplankton groups differ in maximum growth rates, sinking rates, nutrient requirements, and optical properties. The 4 nutrients are nitrate, regenerated ammonium, silica to regulate diatom growth, and iron. Each ocean region has unique conditions that influenced on ocean ecology including phytoplankton type and diatoms. For example South Asian region is affected by monsoon cycle and seasonal wind patterns similarly other areas too. Many studies already described association between Chl-a and CDOM as proxies of primary production in other regions. The bimodal pattern of seasonal marine primary productivity suggests two peaks in chl-a abundance similarly for diatoms in many areas (Bjornstad & Dachevski, 2005; Wang *et al*., 2013; Ndah *et al*., 2019).

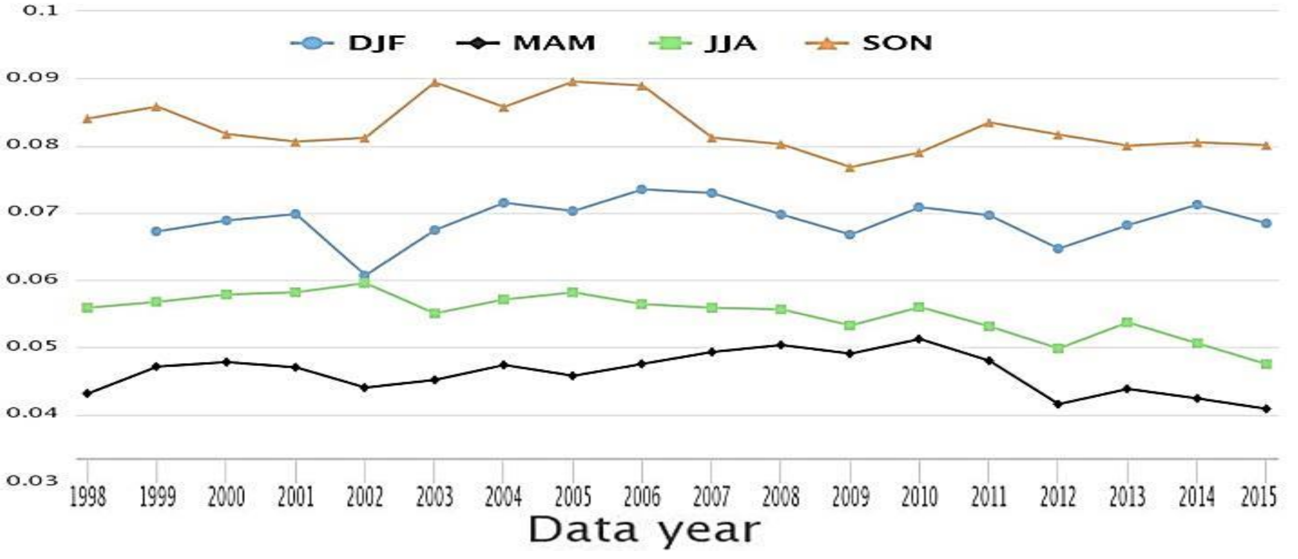

Fig. 2. Seasonal variation of Diatom in Indian Ocean.

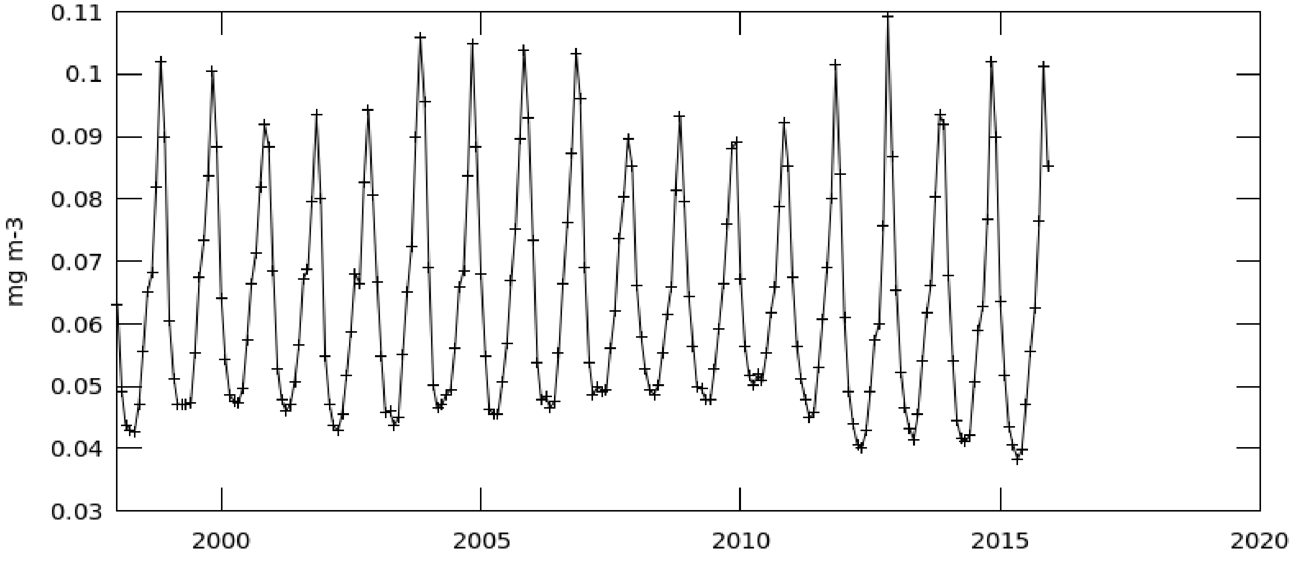

Fig. 3. Time series data of diatoms.

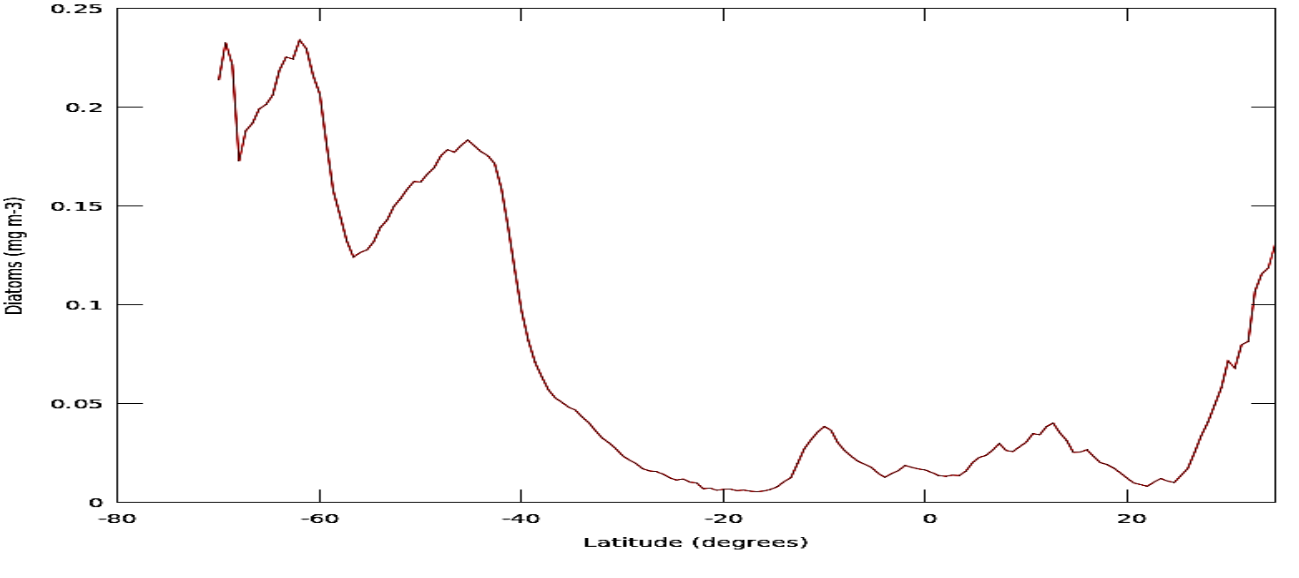

Fig. 4. Zonal values of diatoms.

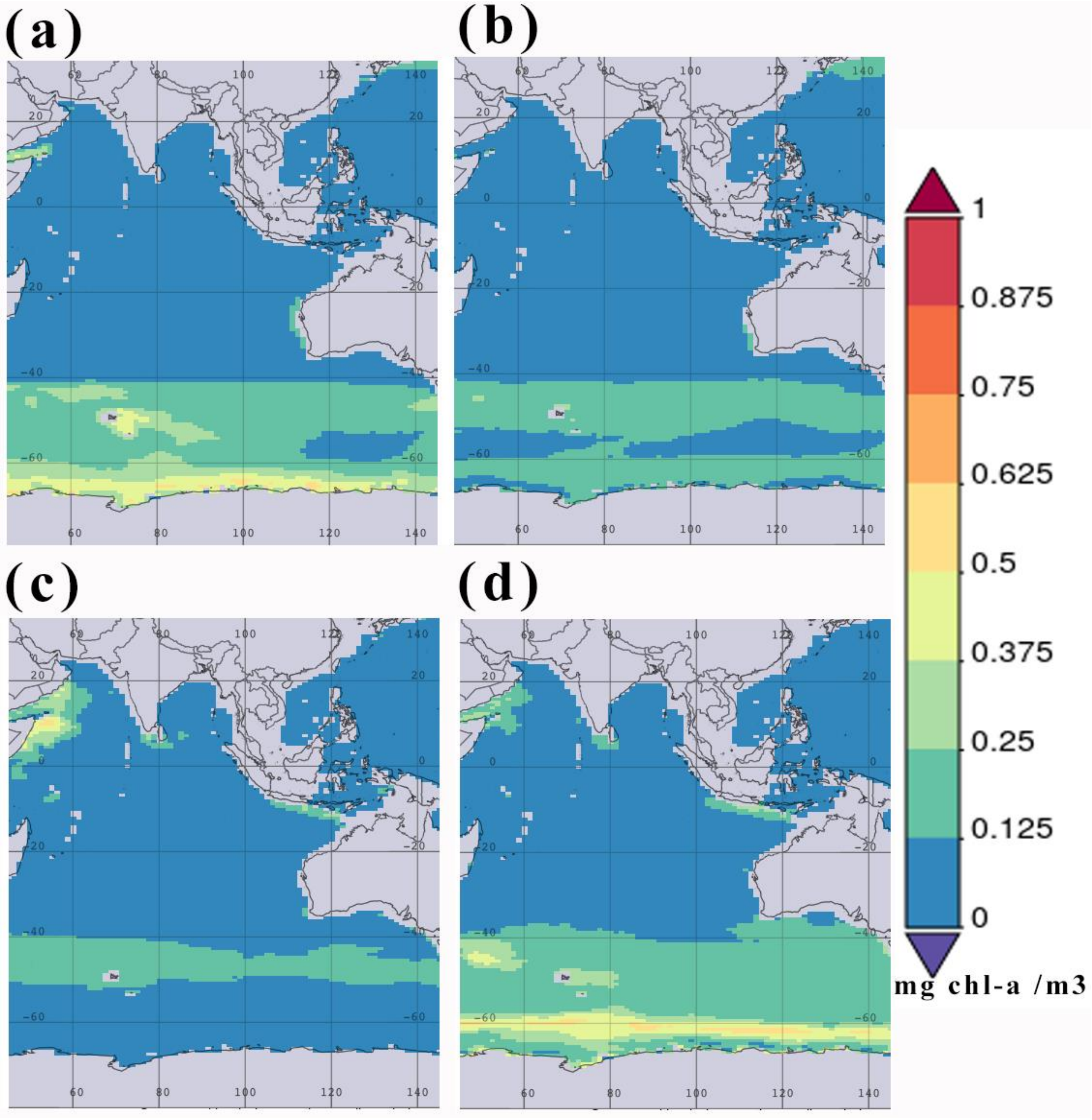

Fig. 5. Diatom distribution (a) December to February (b) March to May (c) June to August (d) Sep to November.

Strength and limitation: This study informed us about spatio-temporal distribution and diatoms rich areas. These finding are beneficial for biologist and could utilized for further ecological studies. However, the data is limited and no longer available after December 2015. Additionally, other environmental factors need to address further such as SST, Sea Surface winds and Photosynthetically Active Radiation with diatom data.

Conclusion

Diatoms plays great role to increase the productivity of ocean's ecosystem because of its photosynthetic activity. Remote sensing data sets provide a precious source of frequent, synoptic information of earth and environment. Recent advancement in remote sensing data and available algorithms make possible to understand phytoplankton dynamics including diatom. Spatio-temporal distribution of diatom in Indian Ocean to Southern Ocean has been evaluated in this study which describes spatial location and time duration of significant areas of diatom. This study will be beneficial to marine scientist in protecting our oceans and its ecology by assessing diatoms dynamics.

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