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Modulation of Chlorophyll Concentration by the Indian Ocean Dipole

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ABSTRACT: The Indian Ocean Dipole (IOD) is a climate mode that causes changes in the Indian Ocean sea surface temperature and precipitation. The IOD affects precipitation in far reaching areas such as Africa and Japan. It also impacts ocean biology such as chlorophyll concentration particularly in the Indian Ocean, and these changes are measureable. Using SeaWIFS chlorophyll data along with sea surface temperature anomalies, changes in chlorophyll concentration during IOD events can be seen and are measured to be statistically significant from non-IOD events. IOD events can change chlorophyll concentration so greatly that algal blooms can occur and conversely IODs can be strong enough to change upwelling to an extent that impacts fisheries resources. There is only a small sample space to analyze and this study serves to explore that data. In order to further resolve chlorophyll data, more remote sensing data with greater resolution is needed in the Indian Ocean area.

INTRODUCTION

The Indian Ocean Dipole (IOD) was discovered in the late 1990s by Saji et al. (1990). They determined that the Indian Ocean has internal modes of variability that is associated with sea surface temperature (SST). These changes in SST also change precipitation and wind. When winds change upwelling occurs which changes nutrient content in the upper ocean. Colder waters from below typically have higher nutrient content because they are older and have had more time to accumulate nutrients. When upwelling occurs it brings up colder water with more nutrients which allows for plankton growth (Behrenfeld et al 2006). Warmer surface waters indicate less upwelling and therefore fewer nutrients. This coincides with the action of the Indian Ocean Dipole, which is similar to ENSO, except on a smaller Indian Ocean scale and on a lesser temperature range. The IOD has two modes, also similar to ENSO, a positive and a negative mode. A positive IOD event is characterized by high SSTs over the western Indian Ocean and cooler SSTs over the western portion (Currie et al 2013). Chlorophyll in the ocean is mostly found in phytoplankton, photosynthetic plankton that exist mostly in the upper ocean (Lindsey and Scott 2010). Phytoplankton growth depends on light, nutrient growth and availability of carbon dioxide. An algal bloom is when phytoplankton populations grow explosively, these blooms can then persist for several weeks and can change the ocean ecosystem surrounding the bloom (Lindsey and Scott 2010). Algal blooms change euphotic depth, dissolved oxygen concentration, turbidity, and availability of bio-toxins, found in red tides (Lindsey and Scott 2010). Blooms can be caused by upwelling which makes nutrients more available. Alternatively phytoplankton production can be slowed in warmer waters because the water is more stratified and there is les ocean mixing to recycle nutrients though the water column (Yoder et al 1993).

METHODS

Chlorophyll SeaWIFS data was downloaded from the NASA Giovanni portal. This data has a 9 km by 9 km spatial resolution. This is monthly data from September 1997 to December 2010 that is in units of mg/m³. Sea surface temperature data comes from the HadISST data center.

Monthly averages were taken and sea surface temperature anomalies were generated to form the Dipole Mode Index seen in Figure 1. Then the monthly chlorophyll frequency was computed for the western and eastern portion of the Indian Ocean. Then all of the chlorophyll was averaged for the eastern and western portion. This was graphed and then compared to all of the positive and negative dipole moments, again in the western and eastern portion. Finally statistical tests (t-test) were run on the 1998 and 2006 positive and negative dipoles respectively.

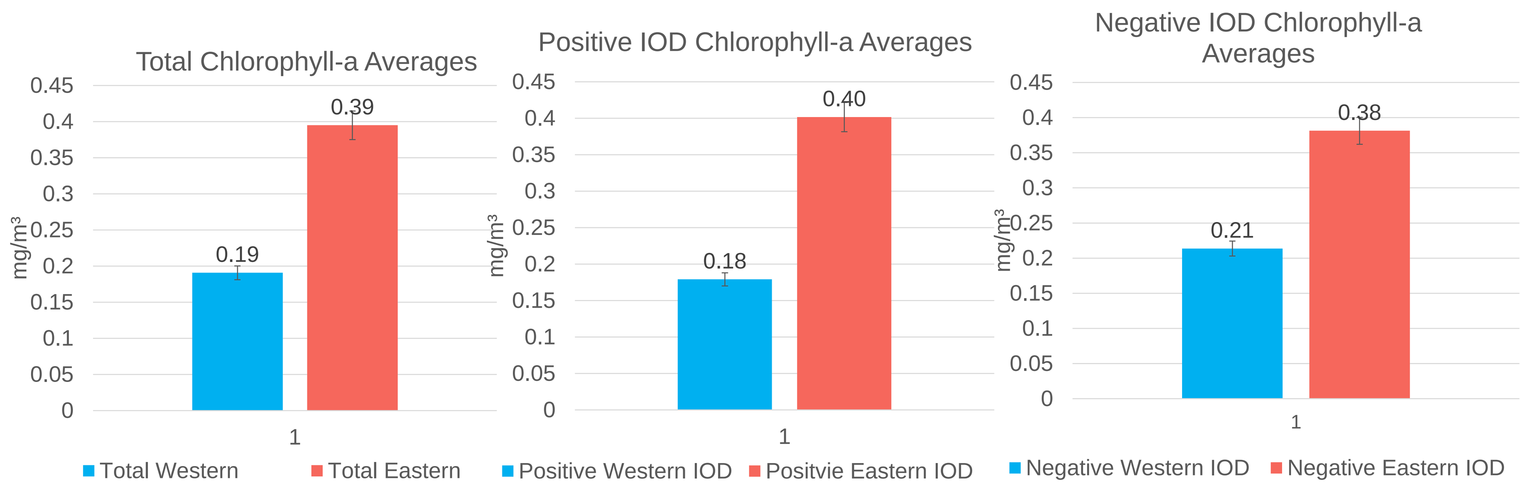

Figure 1: Average chlorophyll concentration in the Indian Ocean with IOD impacts

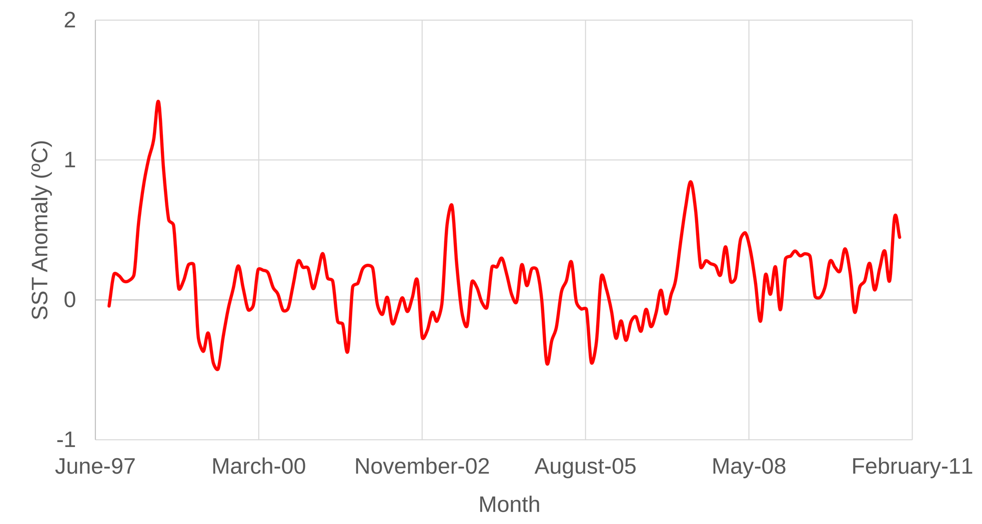

Figure 2: Dipole mode index, based off SST anomalies in western and eastern Indian Ocean. Peaks indicate positive IOD moments, and troughs are negative IOD moments

RESULTS

The results showed interesting differences for the positive and negative IOD events. During the 1998 positive IOD, the chlorophyll concentration was significantly different than the average chlorophyll content; this proves the alternative hypothesis of the study. The change in chlorophyll concentration in the eastern Indian Ocean is caused by the IOD which caused cooler sea surface temperature anomalies in this area during the positive IOD cycle.

However when the same test was done on the 2006 negative event there was no significant change in chlorophyll content in the western Indian Ocean. There are a number of reasons why this is so: the negative event was less intense than the positive one it is compared to and also occurs for a shorter time, additionally the sample space could have simply not been in an area where chlorophyll content changes greatly. If the study were redone with bounds that are different than those established by Saji et al, the results for the negative IOD might differ.

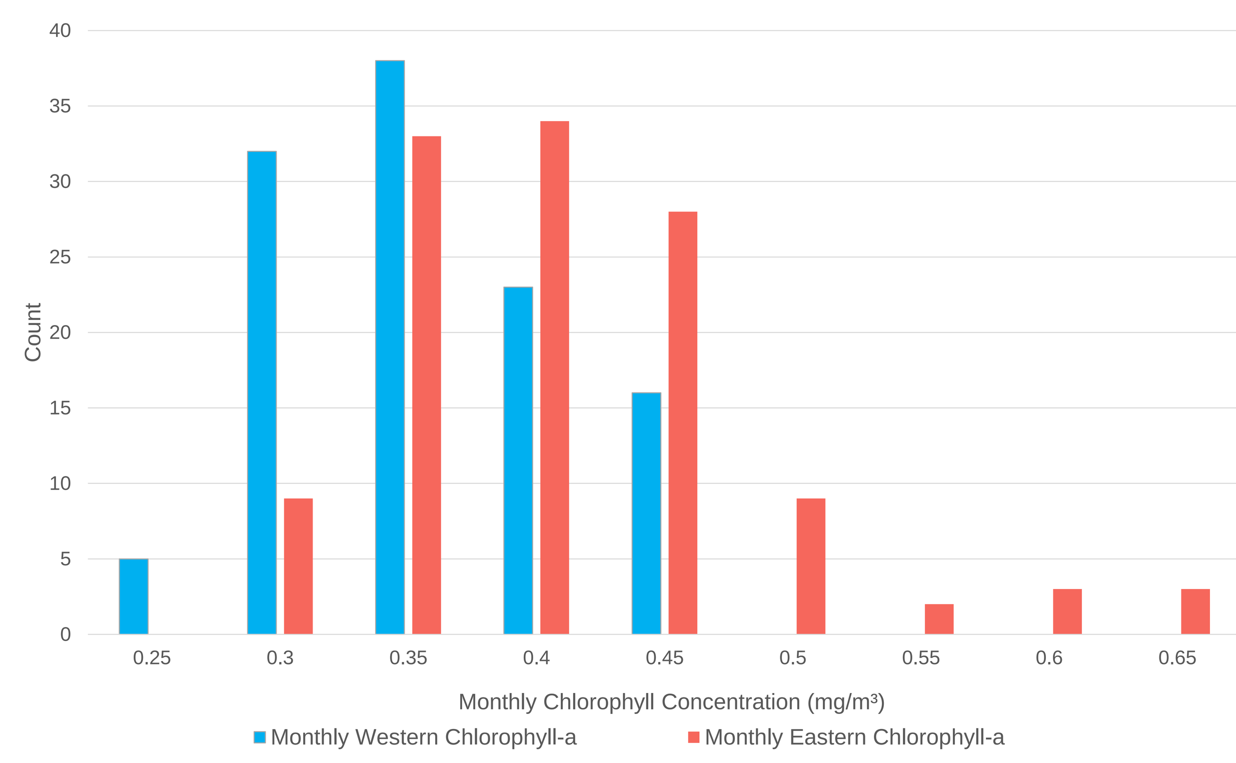

Figure 3: Chlorophyll-a concentration frequency diagram for the Western and Eastern Indian Ocean

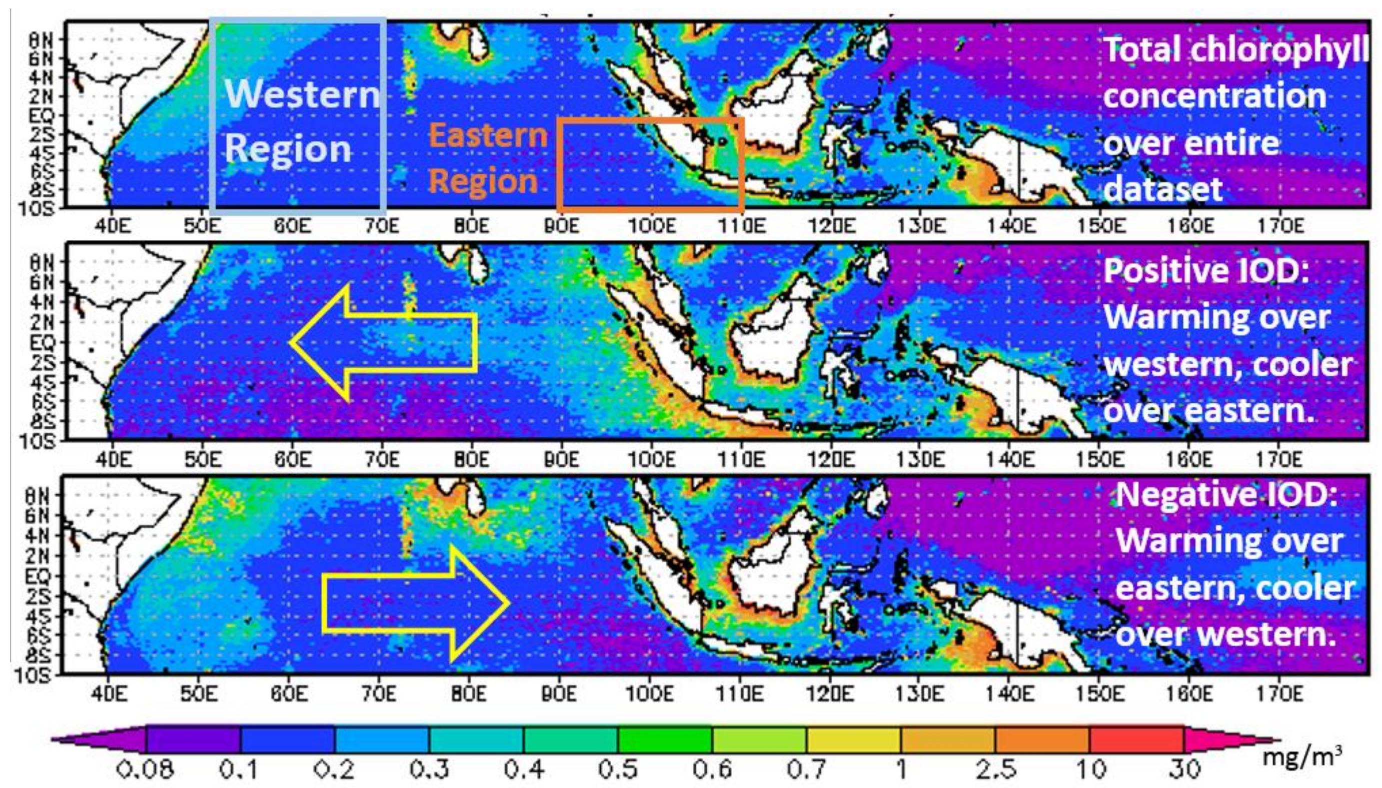

Figure 4: Average chlorophyll content over entire data set, in a positive IOD from September 1997-February 1998 and in a negative dipole IOD from March 2006-August 2006.

DISCUSSION and CONCLUSIONS

From this study, the importance of the IOD can only be heightened. Chlorophyll content in the oceans shows water productivity and a decrease in productivity from warming and subsequent stratification in the Indian Ocean not only impacts local ecosystems but affects the overall carbon dioxide content on the planet. Phytoplankton assimilate a large amount of carbon dioxide and when amounts of phytoplankton change, the carbon that is being removed from the atmosphere also is being changed. Additionally change in the productivity of waters impact the Indian Ocean in many other ways including fisheries resources. This study also gives new information for chlorophyll models to consider; there is a change with the IOD that models must now account for.

To get a clearer picture on the chlorophyll change in the Indian Ocean there needs to be a larger dataset to pull from. The current record for chlorophyll-a is less than 20 years which is not enough to encompass the many aspects and variations of the IOD. Additionally if the remote sensed data is a better resolution than the current SeaWIFS, predictions and models are expected to improve.

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