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Ocean Primary Productivity Variation due to the Cyclone: A Case Study at Bay of Bengal

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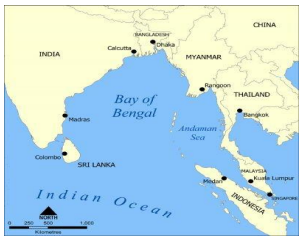
Graphical abstract



Abstract

Monitoring ocean primary productivity especially Chlorophyll-a (Chl-a) concentration is important as it contributes to the carbon cycle, global climate change and ocean health study. This study aims to examine the effects of cyclone events on the ocean productivity in the Bay of Bengal (BOB) considering its importance on global climate change. Level 2 SeaWiFS daily data from 2001 to 2010 were used to determine Chl-a concentration and data from the Indian Meteorological Department (IMD) were used to get information and locations of the cyclone events. Variation of Chl-a concentration was determined from the Chl-a concentration maps (pre-, during, and post-cyclone) using several transect lines parallel to the cyclone passages. Results indicated that there is a relationship between the variation of Chl-a concentration and the cyclone events at the BOB but the effect is varied according to the type of cyclone where very severe cyclonic storm (VSCS) has higher impact on Chl-a concentration compared to cyclonic storm (CS) and severe cyclonic storm (SCS). In most cases, Chl-a concentration was increased right after the cyclone event and the influence was observed over a wide area surrounding the cyclone passage.

Keywords: Ocean primary productivity; cyclone; chl-a concentration; bay of Bengal

Abstrak

Pemantauan produktiviti utama laut terutamanya kepekatan klorofil-a adalah penting kerana ia menyumbang kepada kitaran karbon, perubahan iklim global dan kajian berkenaan kesihatan laut. Kajian ini bertujuan untuk menilai kesan peristiwa taufan ke atas produktiviti laut di Teluk Bengal dengan mengambil kira kepentingannya ke atas perubahan iklim global. Data harian tahap 2 SeaWiFS dari tahun 2001 hingga 2010 telah digunakan untuk menentukan kepekatan klorofil-a dan data dari Jabatan Meteorologi India telah digunakan untuk mendapatkan maklumat dan lokasi peristiwa taufan. Kepelbagaian kepekatan klorofil-a telah ditentukan daripada peta kepekatan klorofil-a (sebelum, semasa, dan selepas taufan) dengan menggunakan beberapa garisan lintasan selari dengan laluan taufan. Hasil kajian menunjukkan adanya hubungan di antara kepelbagaian kepekatan klorofil-a dengan peristiwa taufan di Teluk Bengal tetapi kesannya berbeza-beza berdasarkan kepada jenis taufan dimana ribut taufan yang paling teruk mempunyai kesan yang tinggi kepada kepekatan klorofil-a berbanding dengan ribut taufan dan ribut taufan yang teruk. Dalam kebanyakan kes, kepekatan klorofil-a telah meningkat sejurus selepas peristiwa taufan dan kesannya telah dilihat di keseluruhan kawasan yang luas merangkumi laluan taufan.

Kata kunci: Produktiviti utama laut; taufan; kepekatan klorofil-a; teluk bengal

1.0 INTRODUCTION

The understanding of the ocean primary productivity is very important as it is one of the key components of the Earth's biogeochemical carbon cycles and climate change study.[1,2,4] Chlorophyll-a (Chl-a) has been known as the key indicator for ocean productivity estimation. Many studies have been conducted to determine the variation of Chl-a concentration due to several factors including cyclones.[2,4,5,10] Cyclones are known as tropical cyclone in tropical north Indian Ocean and the cyclonic events are characterized by a low-pressure center and numerous thunderstorms.[2] There are six factors for cyclone to occur and one of them is the sea surface temperature (SST).[3]

According to IMD, cyclone can be categorized into few types such as low pressure area (L), depression (D), deep depression (DD), cyclonic storm (CS), severe cyclonic storm (SCS), very severe cyclonic storm (VSCS), and super cyclonic storm (Table 1) based on the pressure gradient and wind speed.

Table 1 Type of Cyclone

System	Pressure deficient (hPa)	Associated wind speed Knots (Kmph)
Low pressure area (L)	1.0	<17 (<32)
Depression (D)	1.0 – 3.0	17 – 27 (32 – 50)
Deep Depression (DD)	3.0 – 4.5	28 – 33 (51 – 59)
Cyclonic Storm (CS)	4.5 – 8.5	34 – 47 (60 – 90)
Severe Cyclonic Storm (SCS)	8.5 – 15.5	48 – 63 (90 – 119)
Very Severe Cyclonic Storm (VSCS)	15.5 – 65.6	64 – 119 (119 – 220)
Super Cyclonic Storm	>65.6	>119(>220)

There is a relationship between cyclone and ocean productivity and study[2] found that the frequent occurrence of cyclonic events causes short-term nutrient enrichment of upper-stratified ocean resulting in enhanced biological productivity. On the other hand, [4] indicated that upwelling process due to strong winds associated with cyclone normally brings up nutrients from the sea bottom towards the surface, and this nutrient enrichment process due to the cyclone provides an ideal situation near the ocean surface for the phytoplankton growth. However, studies[5] found that Chl-a concentration increases shortly after the cyclone events under the cyclone passage and the blooms of phytoplankton are extended to a wider area due to ocean circulation.

Although many studies have been carried out, there is still a need to investigate the spatial and temporal effect of cyclone on Chl-a concentration, therefore, this study aims to examine the effects of various cyclone events on the ocean productivity in BOB considering the importance of the BOB's productivity to global climate change as well as to the large population along its coast and surrounding areas.

■2.0 STUDY AREA

Bay of Bengal (Figure 1) (Lat. 13° 31' 54.2634"N and Lon. 87° 32' 22.4982" E) is the largest semi-enclosed bay in the world which is located at the northeastern part of the Indian Ocean and bordered by India and Sri Lanka to the west, Bangladesh to the north, and Burma to the east. BOB is a place where cyclone occurs very frequently[4] and the northern part of BOB is well known as the most affected area by cyclone.[6] Scientists as well as the people around this area are very concerned about the probability of the increasing of frequency and intensity of cyclone due to global warming since cyclone is influences by the temperature.[7,8]

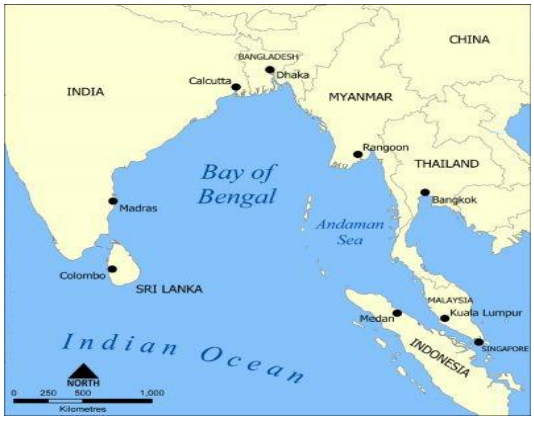


Figure 1 Map of study area

■3.0 DATA AND METHODOLOGY

Chl-a concentration maps were generated using Level 2 SeaWiFS daily data (http: //oceancolor.gsfc.nasa.gov) from 2001 to 2010 coinciding with the cyclone events. Information and locations of the cyclone events were collected from the Indian Meteorological Department (IMD). Due to cloud contamination, only several cyclone events were selected e.g. 1) D on Nov 2001, 2) DD on Oct 2010, 3) CS on Oct 2001, 4) SCS on Dec 2003 and 5) VSCS on Nov 2007.

Pre-processing steps were carried out for SeaWiFS Level 2 Chl-a products before further uses in order to remove data uncertainties. The pre-processing steps involved data reprojection, mosaicking, and high quality data selection. Apart from that, the locations of cyclone passage from IMD were converted from point form into line and these lines were overlaid with Chl-a concentration map to get the values of Chl-a concentration along the cyclone passages. SeaDAS software was used for pre-processing ocean color data product and the extraction of Chl-a concentration values from transect lines.

Variation of Chl-a concentration due to the cyclone was determined from the Chl-a concentration maps (pre-, during, and post-cyclone) using several transect lines parallel to the cyclone passages. Spatial and temporal analyses of Chl-a concentration were carried out in order to find out the effects of cyclones on the ocean productivity.

4.0 RESULTS AND DISCUSSION

Figure 2 shows Chl-a concentration variation with different types of cyclone. The direction and point source of cyclone depend on cyclone type and monsoon period (i.e. direction of wind blow). Mostly, cyclones are moved toward the land area and high intensity cyclone like SCS (Figure 2(d)) and VSCS (Figure 2(e)) are originated from offshore area.

In general, it is obvious from the findings that there is a relationship between cyclone events and Chl-a concentration. However, the relationship is mostly depended on the types of cyclone and variation of the Chl-a concentration is mainly observed along the cyclone passages. For example, low intensity cyclone like D (Figure 2(a)) and DD (Figure 2(b)) showed less variation of Chl-a concentration probably due the fact that these cyclones conjugated with low wind speed[2] (Table 1). On the other hand, high Chl-a concentration were found nearby the SCS and VSCS cyclone passage although the influence of cyclone was not clearly observed for D and DD cyclone. The findings of this study in agreement with previous studies[5,4] who found that cyclone events affect the Chl-a concentration and the influence of cyclone is normally covered a wide area along the cyclone passage.

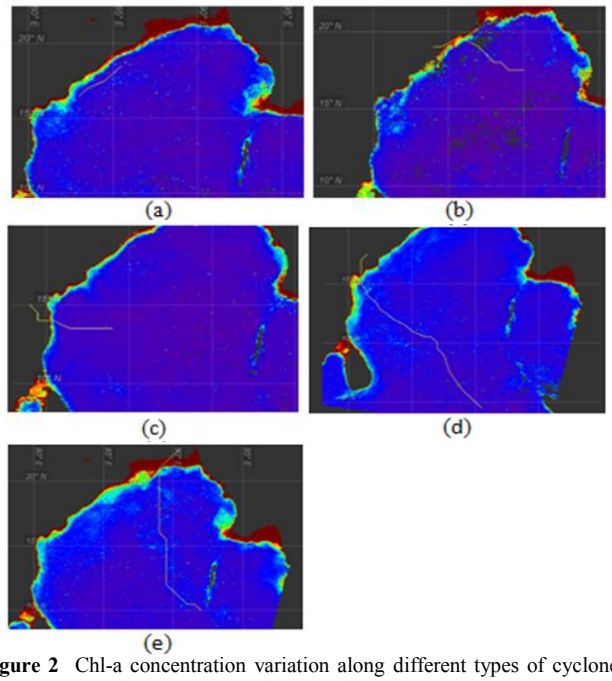
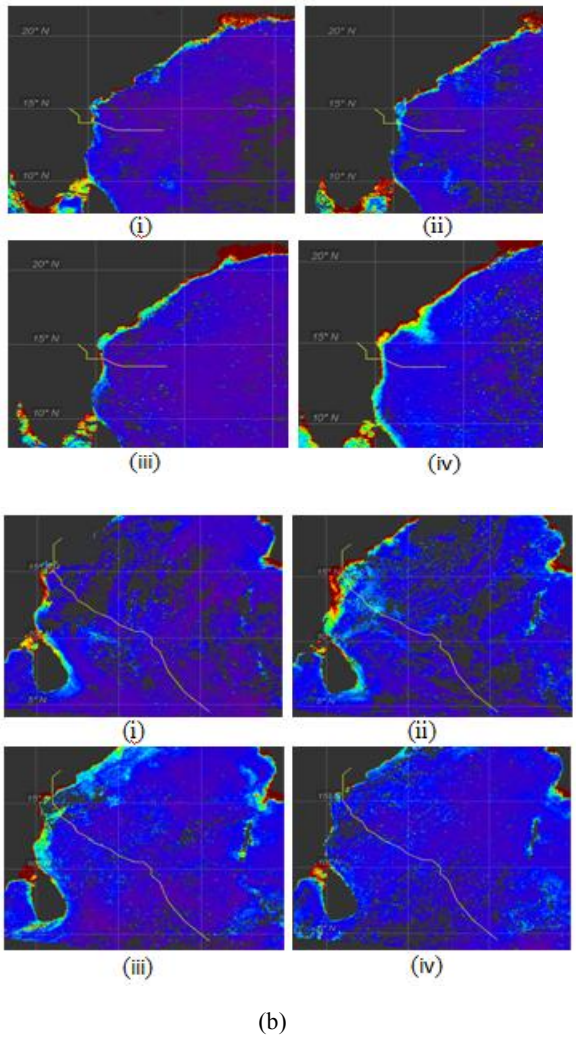


Figure 2 Chl-a concentration variation along different types of cyclone passage; (a) D, (b) DD, (c) CS, (d) SCS and (e) VSCS

The changes of Chl-a concentration from pre-cyclone to post-cyclone period were compared only among the high intensity cyclones (CS, SCS, and VSCS). Figure 3a and 3b depict the weekly changes of Chl-a concentration from pre-cyclone to post-cyclone period for CS and SCS respectively. It is clearly seen from both Figures (3a and 3b) that cyclone events affected coastal area extensively as high Chl-a concentration were observed at coastal area nearby cyclone passage during post-cyclone period. Nevertheless, the effect of SCS cyclone on the changes of Chl-a concentration at coastal area is higher than CS cyclone. Besides that, the blooming of phytoplankton was clearly observed at offshore area surrounding the passage of SCS cyclone (Figure 3(b)(ii) and (b)(iii)).



(b)

Figure 3 Chl-a concentration variation along different types of cyclone passage; (a) CS, and (b) SCS for (i) pre-cyclone, (ii) during cyclone and (iii), (iv) post-cyclone

VSCS, the highest intensity cyclone in BOB, is well-known in causing severe damage for both ocean and land ecosystem[4,9] because this cyclone is associated with very high wind speed (from 64 to 119 knots) that affect the Chl-a concentration for a longer period, as a result the effect of cyclone was noticeable prominently over a wide areas one week after the cyclone (Figure 4e), and high Chl-a concentration was observed nearby the cyclone passage until the second week after the cyclone event (Figure 4(d)). Our results agree with the finding of previous work[5] that indicated strong wind associated with the cyclone enhance Chl-a concentration over a wide region and influence of cyclone can be observed for a longer period.

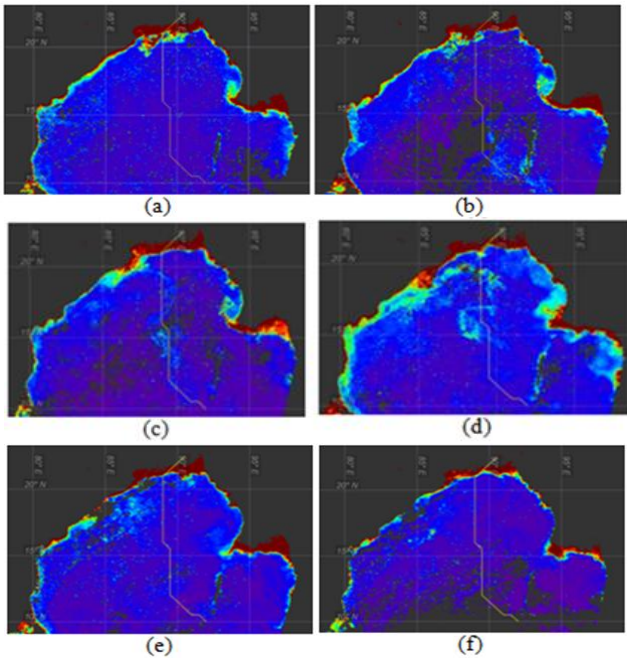


Figure 4 Chl-a concentration variation along VSCS cyclone passage; (a) pre-cyclone (b) during cyclone and (c), (d), (e), (f) post-cyclone

This study found that VSCS has longer impact on Chl-a concentration compared to CS and SCS (Figure 3) and the phytoplankton bloom covered wide areas along the passage while CS and SCS had high impact on coastal area. Study[10] observed that strong cyclone with long residence time sustained the continuous growth of phytoplankton. As can be seen from Figure 5 that Chl-a concentration is quite high along the cyclone passage during cyclone week and first week of post-cyclone, and the values of Chl-a were increased up to 10 mg/m³ at coastal areas (latitude of 20°N to 22°N).

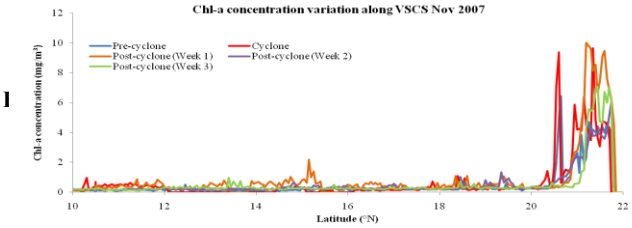


Figure 5 Chl-a concentration variation along VSCS cyclone passage

5.0 CONCLUSION

This study shows that a variety of cyclones occurred in different seasons at the Bay of Bengal has an unique spatial and temporal effect on the variation of Chl-a concentration. Results from the investigations clearly indicated a relationship between the change of Chl-a concentration and cyclone events. In most cases, Chl-a concentration was increased for a short-term period right after the cyclone events like CS and SCS (Figure 3). In contrary, Chl-a concentration was persistently high for a longer period (i.e. about three weeks after cyclone) during VSCS (Figure 4). The increase of Chl-a concentration was observed mostly following the passages of the cyclone and its wide surrounding areas. However, the effect of cyclone on the Chl-a concentration depends on the magnitude of the cyclone and this is clearly shown by the differences of Chl-a concentration variation due to different types of cyclone such as CS, SCS, and VSCS.

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