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Chlorophyll-a Concentration Variation over Terengganu Maritime

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Abstract

Chlorophyll-a (Chl-a) is a green pigment that is found in plants and algae. Chlorophyll-a concentration can be used as an indicator of phytoplankton biomass. This research is conducted to investigate the concentration of Chl-a distribution pattern over Terengganu maritime. In this study, monthly Chl-a acquired from MODIS Aqua (4 km) resolution is used. The result of this study shows that, the Chl-a concentration over the Terengganu maritime is seasonal dependence. The blooms of phytoplankton are observed starting November and reach the peak on January with the Chl-a concentration of 0.7 mg/m^3 over the north of Terengganu maritime. The Chl-a begin to decrease on February and reach the minimum value on March. The Chl-a concentration along the coastal line are higher during North East monsoon season (NEMS) of which value can reach as high as 10 mg/m^3. Average Chl-a concentration over the study area is about 0.3 mg/m^3.

Keywords: *Chlorophyll-a, MODIS, coastal, monsoon*

1. Introduction

Seasonal to inter-annual changes in phytoplankton biomass and productivity are an important components of the total variability associated with ocean biological and biogeochemical processes [1]. Chlorophyll-a which is found in plant and algae can be used as a proxy of phytoplankton biomass and photosynthesis potential. The distribution of Chl-a are highly varies highly in coastal and offshore environments and also over a broad spectrum of time and space scales. This variability renders most traditional field sampling methods as inadequate. However, the presences of remote sensing technology offer an alternative way for tracking spatial and temporal variation of Chl-a concentration. The use of remote sensing technology to map and study Chl-a concentration is well documented.

Numbers of studies have been conducted over different region utilizing remote sensing tool to investigate the Chl-a variability over the ocean. Chaturvedi and Narain [2] carried out inter-annual variability (1997–1999) and limited comparison of satellite (SeaWiFS) and ground derived Chl-a over the Arabian Sea in near-offshore, offshore and open sea. In the study, they have found that Cha-a varies in locations close to the coast. Various factors such as the river discharges, erosional, depositional, and upwelling processes in the coastal zone would influences sediments, chlorophyll, and calcite concentration. Tan et. al. [3] have conducted a research about seasonal variability of Chl-a in the Malacca Straits utilizing Sea-viewing Wide Field-of-view Sensor (SeaWiFS) in relation to Asian monsoon. SeaWiFS data for the period of November 1997 to January 2003 was used in the study. Results show that Chl-a in Malacca Straits experienced seasonal variability. The result also shows that, at northern Malacca Straits, Chl-a increased as much as twice during north east monsoon season (NEMS) compared to SWMS. Prasad and Singh [4] study about chlorophyll, calcite, and suspended sediment concentrations in the Bay of Bengal and the Arabian Sea at the river mouths using Using IRS P4 (Oceansat-1) Ocean Color Monitor (OCM) and Moderate Resolution Imaging Spectroradiometer (MODIS) data. The study found that highest Chl-a concentration (~14 mg/m^3) over the river mouth during the monsoon season. The characteristics of the chlorophyll at the mouth of these rivers show spatial and temporal variability along the eastern and westerns coasts of India which are found to differ widely. Recent studies [5], [6] , [7] show an influence of Aeolian dust in enhancing chlorophyll concentration of the Arabian Sea, thereby making it more productive compared to those of the Bay of Bengal. Shen et al. [8] used monthly climatology of Chl-a concentration based on nine years of SeaWiFS data to illustrate seasonal variations and spatial structures in the northern South China Sea (SCS).

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Chl-a starts to increase in September at the northern coast of Luzon Island, continues to increase in the autumn, and reaches its maximum in December or January.

This research is conducted to investigate the Chl-a concentration distribution pattern over Terengganu maritime. In this study, monthly Chl-a data acquired from MODIS Aqua (4 km) resolution is used. The data is processed and downloaded from Giovanni interface (http://disc.sci.gsfc.nasa.gov/giovanni/). The data is analyzed based on the image and the plotted time series.

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2. STUDY AREA

The study is conducted in the state of Terengganu which is located at the east coast of Malaysia peninsular. This state was bordered by Kelantan in the northwest, Pahang in the southwest and South China Sea at the east. The total area of this state is 13,035 km^2. This state is located between 4^o and 5.50^o latitude north and 102.25^o and 103.50^o longitude east. The coastal line stretch 225 km from north to south. East coast of Malaysia peninsular is influence most by the northeast monsoon season (NEMS) that occurs on November to March yearly. This area receives maximum precipitation, with values ranging from 600 to 800 mm of rainfall, which is recorded mostly in November and December (http://www.met.gov.my/). The main river in this state is Terengganu River. This river flow begins at Kenyir Lake and ending at Kuala Terengganu. The river mouth is located at Kuala Terengganu, state capital of Terengganu. The main economy activity of this state is fishery. The numbers of fisherman in this state are fluctuating with the highest are in the 80's with more than 13000 people. Terengganu contribute 11.01% of the total fish catch in Malaysia annually.

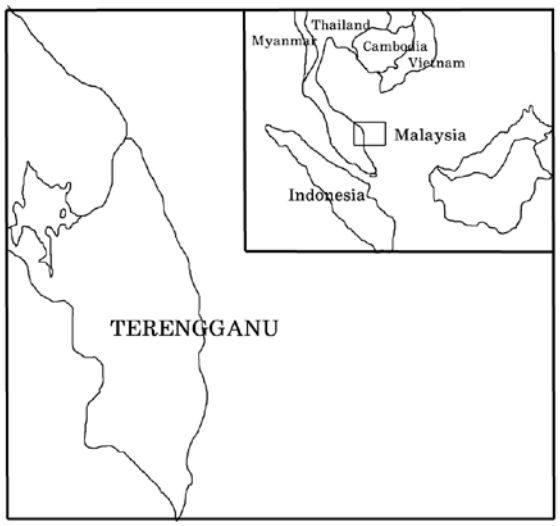

Figure 1: Study area

3. DATA AND METHODOLOGY

Chlorophyll-a data is the monthly MODIS Aqua (Version 5.1) Level 3 mapped product for the period from January 2003 to December 2012, which was processed by the NASA Ocean Biology Processing Group (OBPG). The Chl-a concentration are obtained utilizing OC3M that is extended from the OC4 and OC2 algorithms developed for the SeaWiFS sensor but adapted to the spectral bands of MODIS [9]. The algorithm is statistically derived based on chl-*a* ranging from 0.0008 to 90 mg/m^3 [10]. The OC3M algorithm is defined as:

$$[\mathrm{Chla}]_P = f(R_{3M}) = 10^{(0.283-2.753R_{3M}+1.457R_{3M}^2+0.659R_{3M}^3-1.403R_{3M}^4)}$$

$$R_{3M} = \log_{10}\frac{\max[R_{rs}(443\mathrm{nm}), R_{rs}(488\mathrm{nm})]}{R_{rs}(551\mathrm{nm})}$$

$$R_{rs}(\lambda) = \frac{L_W(\lambda)}{E_s(\lambda)}$$

Where,

[Chla]p = Chl-a concentration estimated at pixel's scale.

Rrs(λ) = above water remote sensing reflectance.

Lw(λ) = water leaving radiance.

Es(λ) = above-water incident irradiance.

Analyses and visualizations used in this study were produced with the Giovanni online data system, developed and maintained by the NASA GES DISC. The data for Chl-a and Sea Surface Temperature (SST) initially explored by using Giovanni system. Giovanni is a Web-based online visualization and analysis tool that allows a user to browse Earth science remote-sensed and numerical models data. Numbers of data for different temporal and resolution is handle by the Giovanni interface that will allow the investigation of short and long terms research. All products are updated routinely to provide the most recently available data.

4. RESULT AND DISCUSSION

4.1 Monthly Chl-a Variation: Images Study

Figure 2 shows the Chl-a variation over Terengganu maritime for the period of November 2011 to October 2012. This period is chooses because of the NEMS usually started in November every year. The concentration of the Chl-a is represented by the

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colour code. The lowest value is indicated by white colour and the highest is the red colour. The white area in this image a represent the land and cloud cover area. In this image, the highest Chl-a concentration is about 30 mg/m^3 and the lowest is 0 mg/m^3. The Chl-a concentration that is higher than 30 mg/m^3 cannot be detected due to the saturation of the ocean colour band over very turbid coastal water especially over the river mouth.

During NEMS season (November 2011 to March 2012) a dramatic increase in the Chl-a concentration indicate an increased of the phytoplankton in the study area. Chl-a begint to increase in November 2011 and reach its highest value in January 2012. The phytoplankton start to grow up on December 2012 which is shown by the green colour spots over the north of Terengganu offshore. The area covered by the phytoplankton reach the maximum value in January 2012. During this month, the Chl-a concentration which reach 0.7 mg/m^3 can be seen in the offshore of Terengganu maritime. The increment in the Chl-a in this area is probably due to the sea current that flows from the Vietnam and China coastal water that bring a lot of nutrient that is suitable to the phytoplankton growth. The presence of the Chl-a over the Terengganu offshore start to decrease constantly in February 2012 to March 2012. However, a constant Chl-a concentration can be observed along the Terengganu coastal line with the maximum value is about 2.5 mg/m^3 for whole NEMS months. During SWMS (May 2012-September 2012) the highest Chl-a over offshore region is only about 0.4 mg/m^3. The highest Chl-a area during this period can be seen on June 2012 with the value of about 0.4 mg/m^3. The Chl-a along Terengganu coastal line however remain constant with the highest value can reach as high as 2.5 mg/m^3 that can be seen in the south.

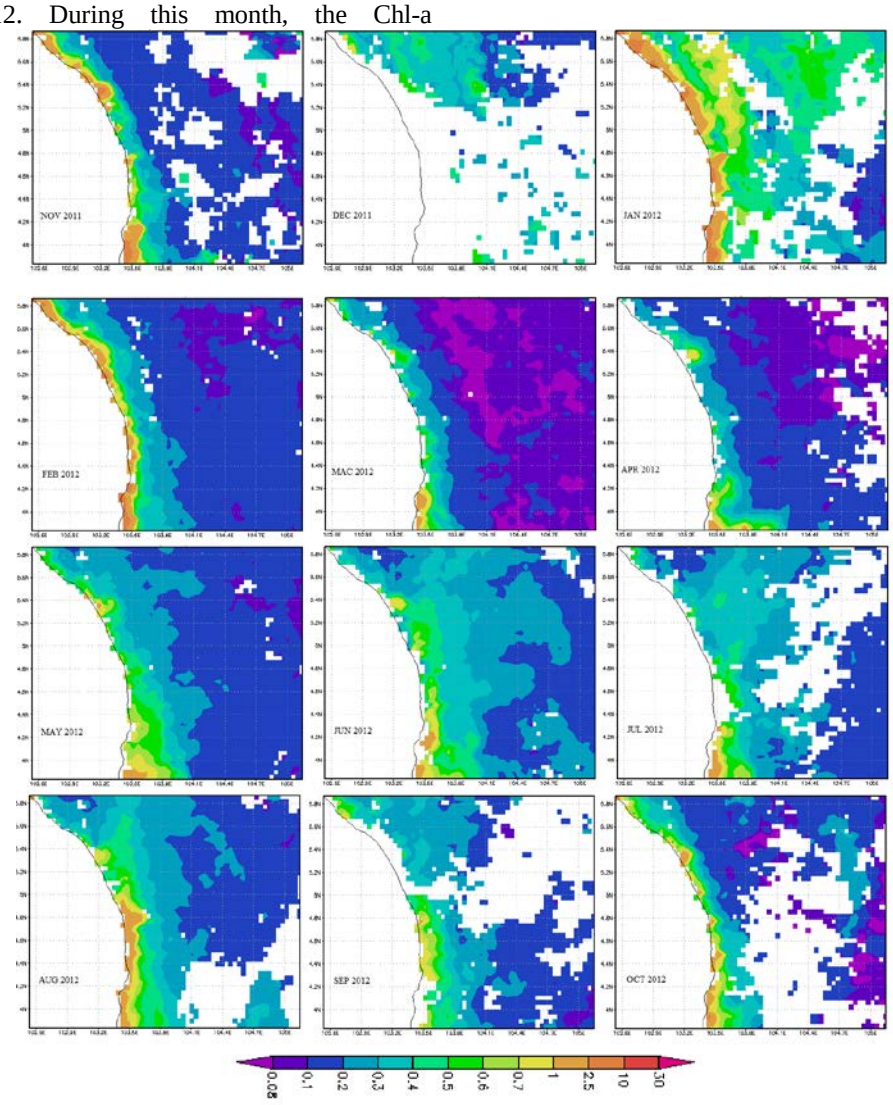

Figure 2: Images of monthly Chlorophyll-a concentration over Terengganu maritime for the period of November 2011 to October 2012.

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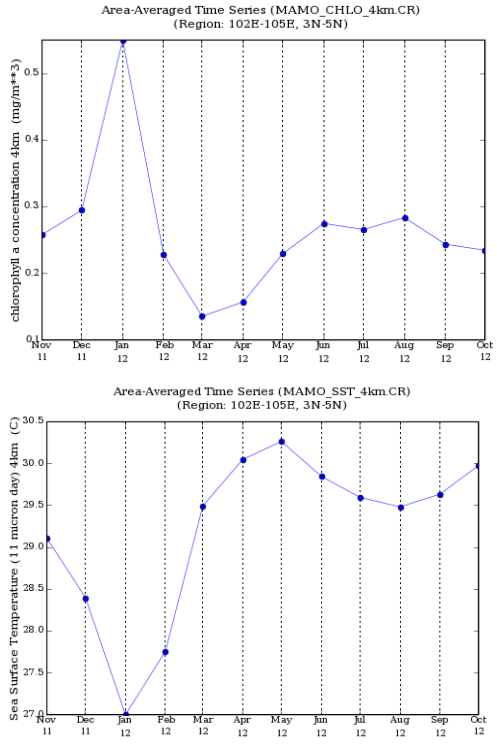
4.2 Monthly Chlorophyll-a Variation: Time Series

Figure 3 (a) shows the Chl-a monthly area averaged time series over the study area for the period of November 2011 to October 2012. This plot shows that the Chl-a start to grow in November 2011 and reach the peak on January 2012. The Chl-a is then start to decrease on February 2012 and reach the minimum on March 2012. After that the Chl-a concentration start to increase slowly and then remain constant until October 2012. Figure 3(b) shows the monthly area averaged time series of the SST for the study area. This plot shows negative correlation with the Chl-a concentration. Coincide with the highest Chl-a (January 2012) is the highest SST with the SST value is about 27^{o}C. The lowest Chl-a value is detected on March 2012 with the value is below than 0.15 mg/m^{3} and coincide with 29.5^{o}C of SST. The same plot pattern can be observed but in the negative direction of the Chl-a concentration. The SST starts to decrease in November 2011 and reach their lowest value on January 2012. The temperature is then increases gradually until it reaches the maximum in May 2012. These two plots show that, the Chl-a and the SST are in negative correlation. The highest Chl-a concentration are observed during the lowest SST value.



(a) (b)

Figure 3: Monthly area averaged time series over the study area. (a) Chl-a concentration, (b) Sea surface temperature of 11 µm channel.

4.3 Yearly Chl-a Concentration: Area Averaged Time Series

Figure 4 shows the yearly Chl-a area averaged time series over the study area for the period of January 2002 to December 2012. The Chl-a concentration are observed seasonal dependence. The lowest value of Chl-a concentration can be seen in April-May for every years which is coincide with the end of NEMS and inter-monsoon season. During this period, the Chl-a value are lower than 0.2 mg/m^{3}. Start from June, the Chl-a begin to increase and the value ranges between 0.2 mg/m^{3} to 0.3 mg/m^{3}. The Chl-a concentration increase significantly during November and reach the highest value on November to January for every study years. The Chl-a are higher than 0.4 mg/m^{3} during this period except for the years 2002 and 2003. The highest Chl-a concentration are observably on November 2009 with the value is more than 1.0 mg/m^{3}.

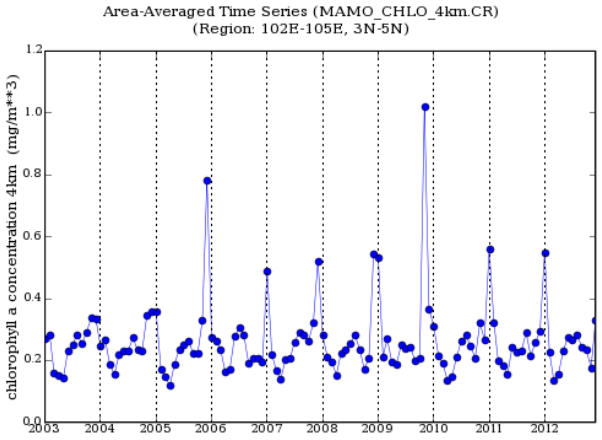


Figure 4: Chlorophyll-a area-averaged time series over the study area for the period of January 2003 to December 2012.

5 5. CONCLUSSION

This study has been conducted over Terengganu maritime located at the east coast of Malaysia Peninsula to investigate the Chl-a concentration distribution throughout the year. The study has utilized the Chl-a data acquired from MODIS Aqua (4 km) that distributed by NASA GES DISC through Giovanni interface. The data from January 2003 to 2012 have been analyses. The result shows that, the Chl-a concentration distribution over the study area is highly seasonal dependence especially over offshore area. High Chl-a concentration was observed along the coastal line during NEMS. During SWMS the Chl-a concentration are observably remain constant with no drastic change in their concentration.

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6. ACKNOWLEDGEMENT

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