Fresh water impact on chlorophyll a distribution at northeast coast of the Bay of Bengal analyzed through in-situ and satellite data

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ABSTRACT

The distribution of phytoplankton pigments were studied bimonthly at four stations from the mouth of Mahanadi River at Paradip to the 36.7km off coast in Bay of Bengal during April 2001 to December 2002. Bottom depth was shallower than 40m in all stations. The pigment concentration of Chl-a was measured. It increased from surface to bottom in the water column. The water column integrated chlorophyll-a concentration (Chl-a) varied between 6.1 and 48.5mg·m-^{2} with peaks during monsoon period (Aug & Oct). Spatial distribution of salinity depended strongly on freshwater runoff. The salinity was 5psu at river mouth and 25.15psu at offshore in monsoon period; however it was 30psu at the river mouth in summer. We found a linear relationship between the amount of river discharge and integrated Chl-a in coastal region from 2 years observations. Extending this result, we analyzed rainfall and coastal Chl-a using satellite data. The relationship between the river discharge and monthly accumulated rainfall estimated from TRMM and others data sources was analyzed in 2001 and 2002 using Giovanni infrastructure provided by NASA. The result depended on the specified area on TRMM images; the river delta area had sharper relationship than wider rain catchments area. Moreover, the relationship between monthly averaged Chl-a derived from SeaWiFS and monthly accumulated rainfall estimated from TRMM was analyzed from 1998 to 2005. It was clear that the broom in monsoon period was strongly controlled by rainfall on river delta.

Introduction

The Indian sub continent divides the Indian oceans into two basins: the larger Arabian Sea and the smaller Bay of Bengal. It is a semi enclosed tropical ocean basin that is highly influenced by south west monsoons and receives large volume of fresh water from both river discharge and rainfall. The circulation of the Bay of Bengal is forced by the equatorial Indian Ocean in addition to monsoon winds and freshwater input. During the summer monsoon (June-September), the east India coastal current (EICC) flows pole ward along the southern part of the Indian coast and equator ward farther north (Shetye et al., 1991). The EICC flows pole ward during February-April and equator ward during November-December. During southwest monsoon a weak pole ward flow develops in south and an equator ward in the north. Major deltas in India occur on the eastern coast. Mahanadi River delta is one of them. Fluvial and near shore marine processes flows the most dynamic impact on this coast. The deltaic river carries an annual average discharge of 49 x $10^9 m^3$ water with a southwest monsoonal component amounting to 41 x $10^9 m^3$ (Bharali et al.,1991). Gomes et al (2000) pointed out that the phytoplankton regime along the east coast of India is restricted by stratification caused by river discharge and monsoonal cloud cover. The impact of cyclone on the Chl-a off coast of Orissa examined through ocean color monitoring images (Nayak et al., 2001). The phytoplankton bloom in the Arabian sea have been studied in summer (Brock et al., 1991), winter (Banse and McClain, 1986) and monsoons (Prasanna et al., 2002), but it is still remains largely to explore except the north east bloom (Vinaychandran and Mathew., 2003) in the Bay of Bengal. In this paper we show the Mahanadi River intrusion triggered the phytoplankton bloom at small area Paradeep coast of northwest Bay of Bengal. And moreover, the rainfall in delta area was directly affected to the river discharge and therefore to the phytoplankton blooming.

Methods and Data Analysis

Sea water samples were collected at four stations near river mouse of the Mahanadi River in the north eastern Bay of Bengal shown in Fig.1. The distances from the river mouse were 7.1km, 11.4 km, 19.8 km and 36.7 km, respectively. Bottom depth was less than 40m at all stations. Sampling was carried out every two month from 2001 to 2002. Surface and every 10m depth waters were sampled by Niskin sampler attached to the CTD-profiling units for analysis of nutrient and pigments. Water samples from 1liter to 4 liter depending on expected Chl-a concentration were filtered through Whatman GF/F glass fiber filter giving vacuum 3300 Pa or less.

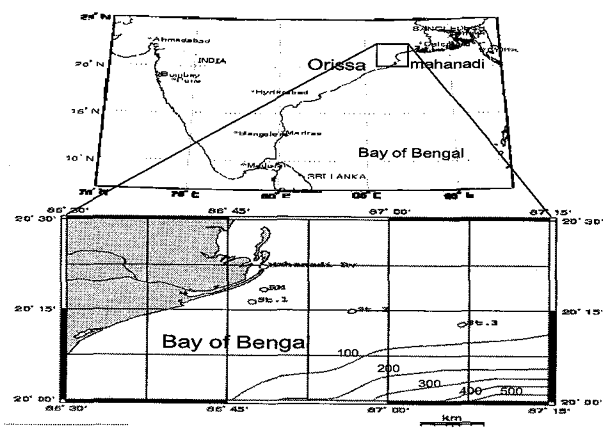

Fig.1.sampling stations at Paradip coast Bay of Bengal

Photosynthetic pigments were extracted by immersion of the filters in 7 ml of 90% acetone. After storage in the dark for 24 hours, the samples were shaken and centrifuged. Concentration of Chl-a with other pigment were determined using Beckman DU 68 spectrophotometer followed by the standard method by Parsons et al (1984). The amount of river discharge during monsoon period, July to October, in 2001 and 2002 collected from Water Resources Department (WRD, Lower Mahanadi Divison), Govt. of Orissa. The Giovanni infrastructure provided by NASA was used to estimate the global distribution and time series of surface Chl-a and rainfall: the monthly averaged Chl-a derived from SeaWiFS (OC4v2) with 9 km resolution and monthly accumulated rainfall estimated from TRMM and others data sources (3B43 V6) with spatial resolution of 0.25 deg x 0.25 deg.

Results

Figure 2 shows two years variation of the Mahanadi River discharges in monsoon period cited from WRD and the spatial distribution of water column integrated Chl-a in this study. The amount of river discharge was three fold higher in 2001 than 2002. The integrated Chl-a shows higher value at river mouth and monsoon period than offshore and summer period.

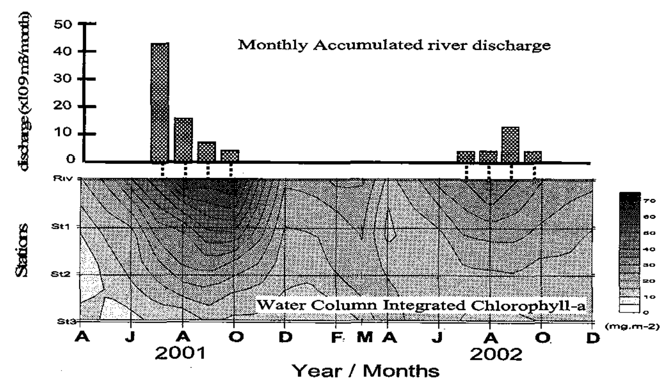

Fig.2 Seasonal in-situ integrated Chl-a biomass & river discharge

It is also higher in 2001 than 2002 similar with the river discharge A linear relationship between the amount of river discharge and the integrated Chl-awas observed. The surface Chl-a varied from 4.8 mg m^{-3} to 0.1 mg m^{-3}. The concentration cumulates subsurface and bottomward in all the stations.Figure 3 shows a satellite derived 8year average rainfall distribution from Jan.1998 to Dec.2005 and a monsoon period average Chl-a distribution from

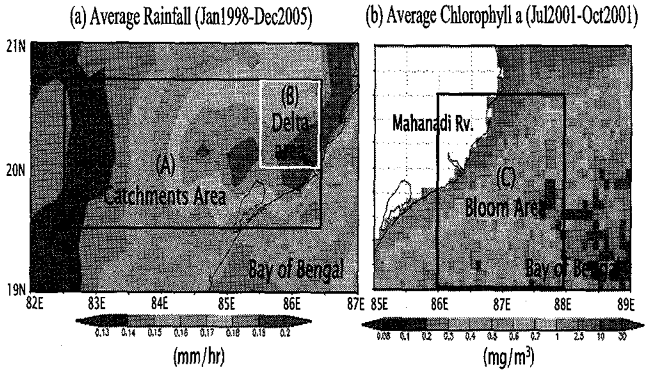

Fig.3 Montly accumulated Rain fall and average Chl-a July to October in 2001.Rectangulars shown in the rainfall image indicate a catchments area (A) and a delta area (B) of Mahanadi River. It is clear that the rainfall is concentrated in the delta area. The Chl-a image shows high concentration in coastal region, and it rapidly diminishes along the offshore within 100km. The relationship between satellite derived rainfall accumulated over a specific area and the amount of Mahanadi River discharge was analyzed for area A and B during 2001 and 2002. The result is shown in Fig.4. The rainfall at area A shows less significance (r=0.6) than area B (r=0.9). It results that rainfall at delta area predominates with Chl-a concentration than catchments area.

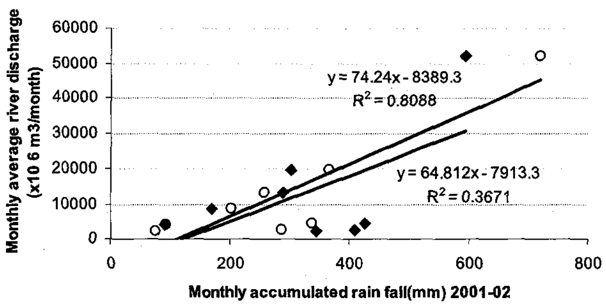

Fig.4 Correlation between Rain fall & Chl-a (2001-2002)

Figure 5 shows a time series variation of monthly accumulated rainfall and monthly averaged Chl-a from Jan.1998 to Dec.2005. The rainfall is accumulated over area B, the Chl-a is averaged in coastal area shown in Fig.3 as a bloom area (C). Rainfall increases in monsoon period, and is almost zero in summer. The time series of Chl-a shows similar variation with rainfall in spite of several losses in monsoon period because of a heavy cloud. Unlike the rainfall, Chl-a shows at least 0.8 $mg \cdot m^{-3}$ even in summer. Moreover, the rainfall at monsoon in 2001 shows a maximum within this 8 years, however Chl-a at this period is the 3rd peak followed 2000 and 1999.

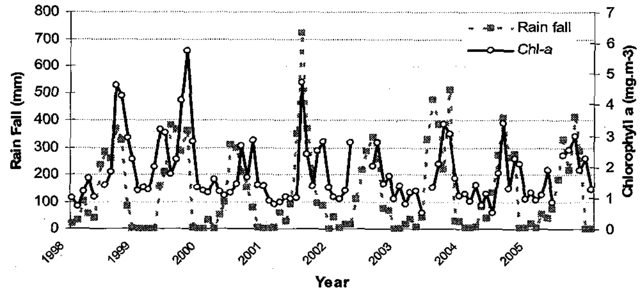

Fig5.Time series variation Rain fall & Chl-a (1998-2005)

Figure 6 shows a correlation between the rainfall and Chl-a concentration. The correlation coefficient(r=0.6) isn't so high, however, a linear relationship is recognized clearly. This figure also shows that Chl-a exists constantly around 1.3$mg \cdot m^{-3}$ even in dry period. This high Chl-a may be caused by the continual nutrient supply in coastal region by the steady river discharge.

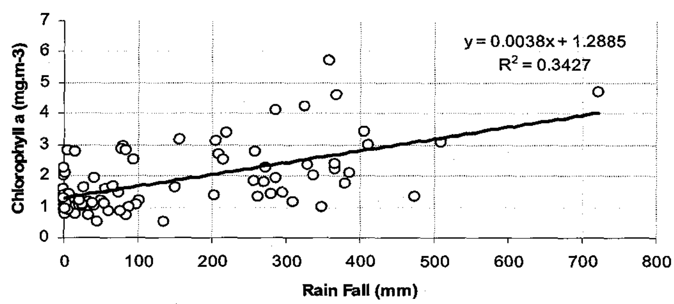

Fig.6 Time series relation between Rain fall & Chl-a

Discussion

The river discharge in monsoon period accounted for 83% of the annual discharge in the study period. Our results show that the monsoonal rainfall directly induces rapid increase of a river discharge, and then, it causes a phytoplankton bloom in the coastal area. The river discharge is more significantly related to the delta area than catchments area of Mahanadi River. This result is explained as the local anomaly of the rainfall. The delta area has a higher average rainfall than upstream area of the river.

The phytoplankton species were identified through a microscopic observation and a pigment composition analysis during study period. Diatoms were well concentrated through the year; however the chlorophyceaes were concentrated especially in monsoon period. They would be transferred from the delta area by the river discharge. The same results were observed at Netravati estury west coast of Arabian sea by Gowda et al.(2002); they found chlorophyceaes in monsoon period, and concluded it was brought from freshwater river discharge. Gomes et al (2000) also pointed out that the freshwater discharge caused phytoplankton blooms near southern coast of bay of Bengal.

Assuming that the coastal blooming is caused by the river discharge, the extent of the monsoonal blooming may related with the amount of discharged water mass. Our in situ observation results confirmed this; the blooming area was extended to 17km offshore in 2001, and 10km in 2002. The volume of the water mass corresponding to each distance was linearly related to the river discharge volume. Shetye et al (1991) found that the monsoonal blooming was sustained by weak upwelling driven by wind at southern coast of the Bay of Bengal. This phenomenon will enhance the spreading of phytoplankton bloom toward the offshore. The seasonal variation of the EICC also strongly affects the spreading of the near coast blooming. The spreading of blooming will be decreasing the relationship between the rainfall and Chl-a concentration shown in Fig.6. The definition of the blooming area will affect the result severely.

Conclusion

The 8 years time sires shows clear characteristics of the rainfall and Chl-a blooming. The rainfall in 2001 shows a maximum through the 8 years, however Chl-a at this period is not so high. In contrast, Chl-a shows highest in 1999 when the total rainfall is high while the maximum is less. This result suggests that the phytoplankton bloom is triggered by rapid river runoff, and it will be sustained by constant fresh water supply. We need further analyses with both spatially and temporally higher resolution images.

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Acknowledgments

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