Utilization of Satellite Imageries for Monitoring Algae Blooms at the Northern Borneo

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Abstract

Harmful algal bloom (HAB), or "red tide", at northern Borneo has occurred since 1976. The early HAB event is caused by *Phyrodinium bahamense var. compressum*, however, in year 2003, *Cochlodinium polykrikoides* was found starting to bloom in this area. By using MODIS Aqua satellite, we have started the monitoring of HAB at northern Borneo since early 2004. Results showed that the Baram River plume and upwelling in Northern Borneo are the sources of nutrient for the *Cochlodinium* bloom in the offshore region. The transboundary *Cochlodinium* bloom from northern Borneo not only cause economic lost to Brunei and Malaysia, it also caused serious aquaculture damages in Philippine. In short, the satellite information has proved to be very useful for the early detection and preparation for HAB mitigation in the region.

Keywords: Ocean color, northern Borneo, harmful algae bloom, upwelling, transboundary

INTRODUCTION

Harmful Algal Bloom at Borneo

First occurrence of harmful algal bloom (HAB) or red tide at Northern Borneo was recorded in 1976. The early HAB event is caused by *Phyrodinium bahamense var. compressum*, which could cause Paralytic Shellfish Poisonings (PSP). The *Phyrodinium* blooms that occur two times per year are observed to be coincided with the onset of monsoon wind (Usup et al., 1989). Azanza and Taylor (2001) found that the *Phyrodinium* bloom could be related to El-Nino event. During late 2003, another dinoflagellate blooms by *Cochlodinium polykrikoides,* was noticed off Northern Borneo. In Japan and Korea, bloom of *Cochlodinium* has caused severe damage to fisheries during summer and fall. However, the study on *Cochlodinium polykrikoides* in Southeast Asia is very limited and not much information was available for this species.

HAB Monitoring Using Ocean Color Remote Sensing

The effort of HAB monitoring using MODIS Aqua satellite for Northern Borneo started since early 2004. It is working on the voluntary basis. Daily MODIS Aqua images are processed and distributed to local authorities and researchers at northern Borneo. Besides, the product will also been uploaded to the "Ocean Color Satellite Observation of Borneo Red Tide" website (http://sg.geocities.com/myredtide/Index.htm).

MATERIALS AND METHODS

Daily Level 2 MODIS Aqua chlorophyll a (chl-a), sea surface temperature (SST) and normalized water leaving radiance at 551 nm (nLw 551) images were downloaded from Ocean Color Web (data available at http://oceancolor.gsfc.nasa.gov/cgi/browse.pl?sen=am). The imageries are processed by using SEADAS software (Software available at http://oceancolor.gsfc.nasa.gov/seadas/). Due to the chl-a over-estimation problem by the MODIS algorithm in turbid waters, the nLw 551 image is used to identify the turbid water areas, especially near the Baram River mouth. RGB image is provided as the additional reference for the ocean color image.

RESULTS AND DISCUSSIONS

Seasonal Upwelling off Northern Borneo

Our results showed that there was a seasonal upwelling phenomenon at the northern tip of Borneo Island (figure 1), which could be possibly caused by the alongshore northeast monsoon wind. Cooler upwelling water (about 25.5^{o}C) from the northern tip that extended toward the west is associated with higher surface chl-a (figure 1 top and bottom). The nutrient supply from the upwelling water is expected to be the main source that supporting the bloom of phytoplankton. We speculate that this upwelling

event is related to the offshore phytoplankton bloom and the continuing occurrence of HAB along northwestern Borneo during northeast monsoon.

In February 2005, we noticed that the upwelling was more intensified than other years. Isoguchi et al. (2005) revealed that wind jet formation off Northern Borneo will lead to offshore cooling and chl-a bloom during the subsequent El-Nino years. The strong upwelling in early 2005 could be attributed to the wind jet.

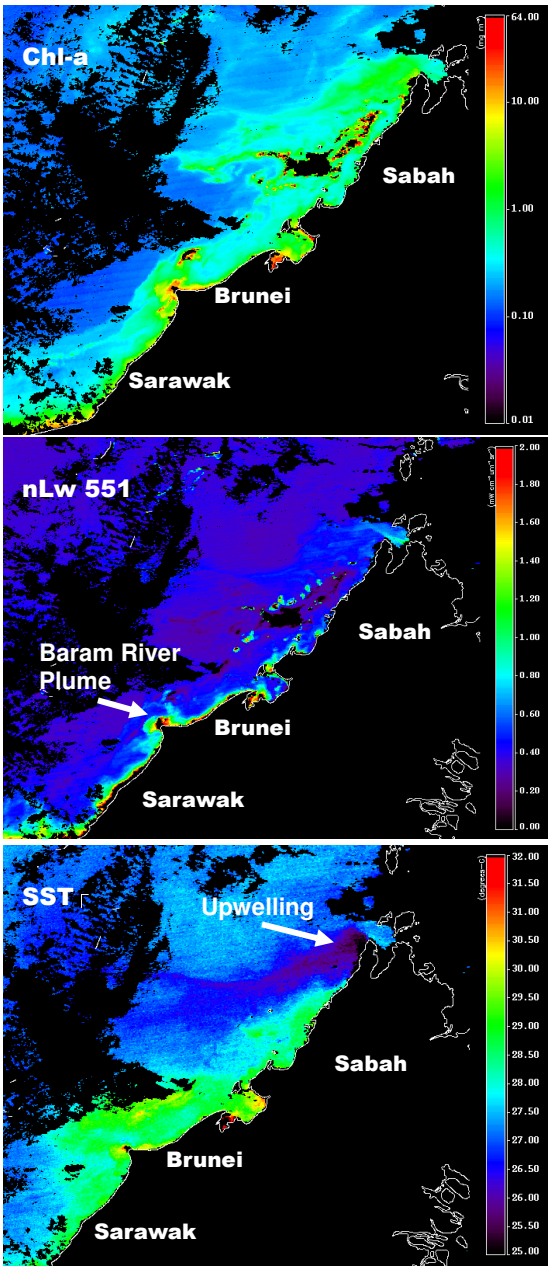


Figure 1. Daily MODIS Aqua chl-a (top), nLw 551 (middle) and SST (below) on 14 February 2005.

Baram River Plume

The large Baram River plume is another phenomenon that might contribute to the nutrient supply of *Cochlodinium* bloom at Northern Borneo. The river plume can be easily observed using both nLw 551 and RGB images. Very high chl-a is observed to be associate with the river plume, however, high nLw 551 indicate that the very high chl-a value at the near river mouth area could be over-estimated (figure 1 middle).

Since 2004, the extension of high chl-a patches to off shore waters from Baram River plume was found coincided with the new *Cochlodinium* bloom. Sometimes, the high chl-a water from the river plume meet with the upwelling water from the north at off shore region. With the continuing nutrient supply from the Northern Borneo upwelling water, the high chl-a patches from Baram River plume can maintain at the off shore region for a long period.

Transboundary HAB

Previously, the HAB event in Northern Borneo was believed to be spread by the current from Sabah, Malaysia to Brunei during northeast monsoon. Through the continuous satellite monitoring, we discovered that it could actually spread into northeast direction towards Philippine. In mid of February 2004, a large patch of high chl-a was observed off the upwelling area at Northern Borneo (figure 2). The patches moved northward towards the Balabac Straits a few days later. After a week (21 February 2004), the high chl-a patches reached Palawan Island at Southern Philippine.

Field monitoring at Palawan confirmed the occurrence of *Cochlodinium* HAB in the boundary between Palawan and Sabah in January 2005 (Azanza and Baula, 2005). Some fishermen in Palawan witnessed a red discoloration off the Quezon water with dense floating algae. The *Cochlodinium* HAB had caused fish kill in Palawan Island in 2005. The bloom was believed to be originated from Malaysian waters following the circulation pattern during northeast monsoon (Azanza and Baula, 2005).

In 2007, the *Cochlodinium* bloom has caused economic lost of aquaculture and tourism at Sabah, Malaysia. The dead fish cause by the HAB was washed up along the tourist beach. MODIS Aqua satellite image on 5 March 2007 shows that the dense bloom area covered about 8200 km^2 with 250 km in length (figure 3). The large bloom was observed remain a few months at this low nutrient off shore waters. The mechanism on how *Cochlodinium* maintaining their bloom at off shore waters remain unclear, but this strength has made this species a success in causing transboundary HAB.

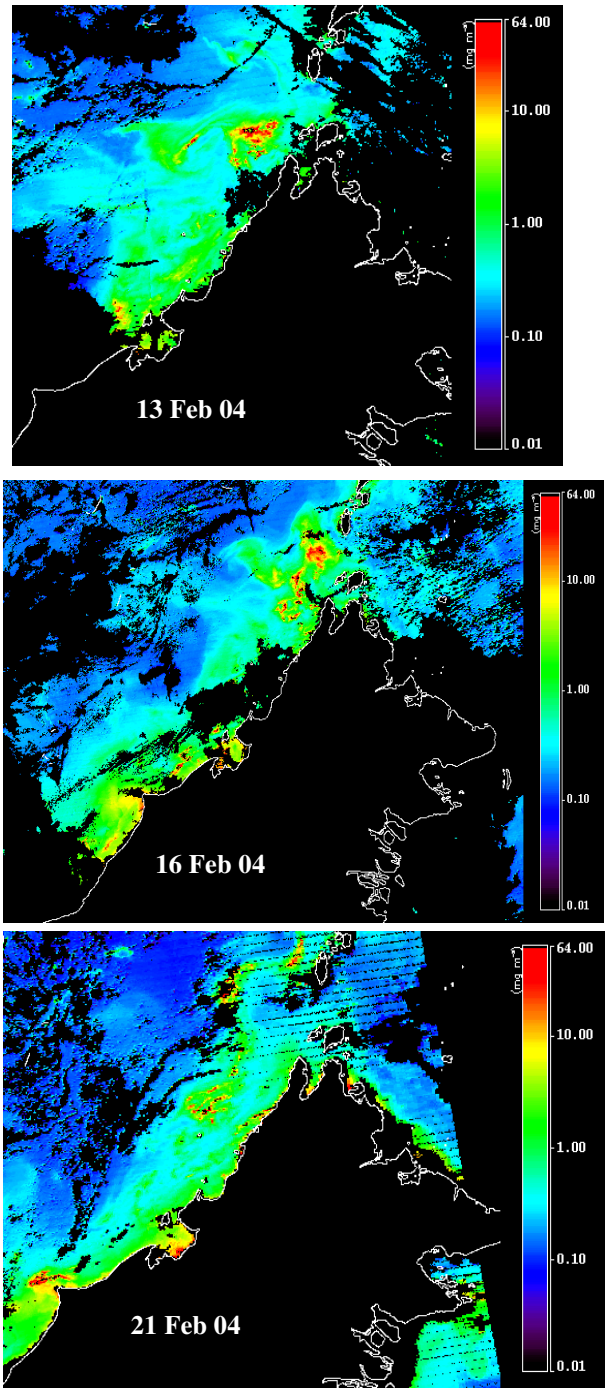
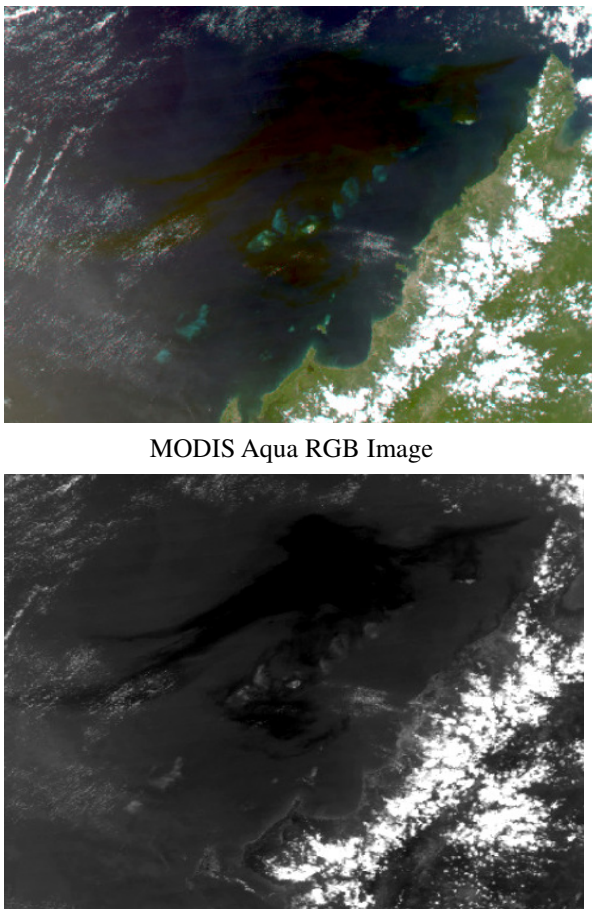


Figure 2. Transboundary harmful algal bloom in 2004.

CONCLUSION

The HAB monitoring using ocean color satellite at Northern Borneo showed some interesting findings that related to the HAB events. The transboundary HAB problem at Northern Borneo will be a big threat for the marine ecosystem in the region. We strongly recommend for a regional joint monitoring effort. Present observation effort using MODIS Aqua satellite is very successful in observing large HAB at off shore water, however, it usage is very limited at the coastal water due to lower spatial resolution. We are examining the application of high resolution satellite images like ALOS for the HAB monitoring in the coastal waters where most of the economic activities located. By the combination of high spatial (ALOS) and high frequency (MODIS) remote sensing monitoring, we hope it will help to establish an effective HAB monitoring and early warning system.



MODIS Aqua RGB Image

MODIS Aqua Band 1

Figure 3. MODIS Aqua RGB and Band 1 images on 5 March 2007. Dense bloom area observed to have strong blue band absorption that covered area about 8200 km^2 and about 250 km in length.

ACKNOWLEDGEMENTS

We would like to thank NASA Goddard Space Flight Center Ocean Color Web team for providing MODIA Aqua imagery. This research is conducted under the agreement of JAXA Research Announcement titled 'Monitoring Harmful Algal Bloom in Coastal Waters of Southeast Asia Using ALOS and Ocean Color Imageries' (PI 325).

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