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# Using SeaWiFS satellite data for monitoring algal bloom in Vietnam waters, the South China Sea

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**Abstract**—Vietnam waters are located in west of the South China Sea. Due to large area spreading in long latitude with different climate and oceanographic condition, it is very difficult to implement the field measurement in whole water areas for study the natural environment and ecological processes. Some studies on harmful marine micro algal were carried out, but the monitoring the occurrence of algal bloom, especially harmful algal bloom from satellite data was not implemented. This study uses the SeaWiFS satellite data for monitoring the algal bloom occurrence in Vietnam waters during 2002–2004. Chl-a concentration was calculated from SeaWiFS satellite data using OC4 algorithm of SeaDAS software. The study has identified the bloom areas in Vietnam waters during monitoring time. In the Gulf of Tonkin, algae blooms occur at the river mouths where nutrient discharge from rivers is rich. Other areas in the Gulf of Tonkin, the blooms sometimes occurred from November to next April, the same time of Northeast monsoon season. In Central Vietnam waters, the blooms occurred sometimes during Southwest monsoon season from May to September. The observed bloom areas are extended in Northeast direction from Mekong river mouths along the coast, then tendency spread out to off shore where the direction of the coast changes. This bloom occurrence relates to upwelling in Central Vietnam waters. In coastal area of Mekong river delta and Gulf of Thailand, the Chl-a concentration is usually high due to nutrient discharge from rivers. In Paracel Islands, algal bloom is observed in August 2002 and November 2003. Monitoring algae bloom from ocean color satellite data is necessary, especially for warning harmful algal bloom or red tide in Vietnam waters.

**Key words:** ocean color, remote sensing, algae bloom, Vietnam waters, South China Sea

## Introduction

Vietnam waters are located in west of the South China Sea (Fig. 1). Due to large area spreading in long latitude with different climate and oceanographic condition, it is very difficult to implement the field measurement in whole water areas for study the natural environment and ecological processes. Previous research and field measurement have undertaken mainly in coastal area, there are a few measurements carried out in whole Vietnam water (An and Du, 1999, Anh, 1999; Penjan et al. 1999; Suchint and Puntip, 1999). So that, collected data was not systematic and continuous.

Study on Chlorophyll-*a* (Chl-*a*) distribution and algal bloom in marine environment using satellite data was implemented by scientists in the World, but it is still new method and limit application in Vietnam. In recent year, studies of the distribution of Chl-*a*, primary production and algal bloom in Vietnam were conducted. The development of remote sensing technology with capability to observe the whole Earth environment from local to regional scale have become effective tools for monitoring and management of marine environmental issues.

There are some applications of remote sensing for study Vietnam waters and the South China Sea. Tang et al. (1998) analyzed the spatial pattern of temporal variation of pigment concentration derived from CZCS satellite data in continental shell of South China. Tang et al. (2003) studied the seasonal and spatial distributions of Chl-*a* concentration and water conditions in the Gulf of Tonkin from SeaWiFS, NOAA/AVHRR and QuikScat satellite data. These researches showed that high Chl-*a* concentration in North Gulf of Tonkin are normally occurred in winter season, which related with Northeast monsoon. Tang et al. (2004) observed offshore phytoplankton biomass increase and its oceanographic causes in the South China Sea. This research showed that there was an increase of Chl-*a* related to upwelling in West coast of the South China Sea. Dien et al. (2005) used remote sensing data for study distribution and seasonal variation of Chl-*a* and SST (Sea Surface Temperature) in Gulf of Tonkin for fishing ground detection. Kuo et al. (2000, 2003) observed upwelling in West coast of South China Sea from NOAA/AVHRR satellite data. There is not any study on monitoring of algal bloom in Vietnam waters from satellite. This paper presents an initial result of using SeaWiFS satellite data for study the spatial distribution of Chl-*a* concentra-

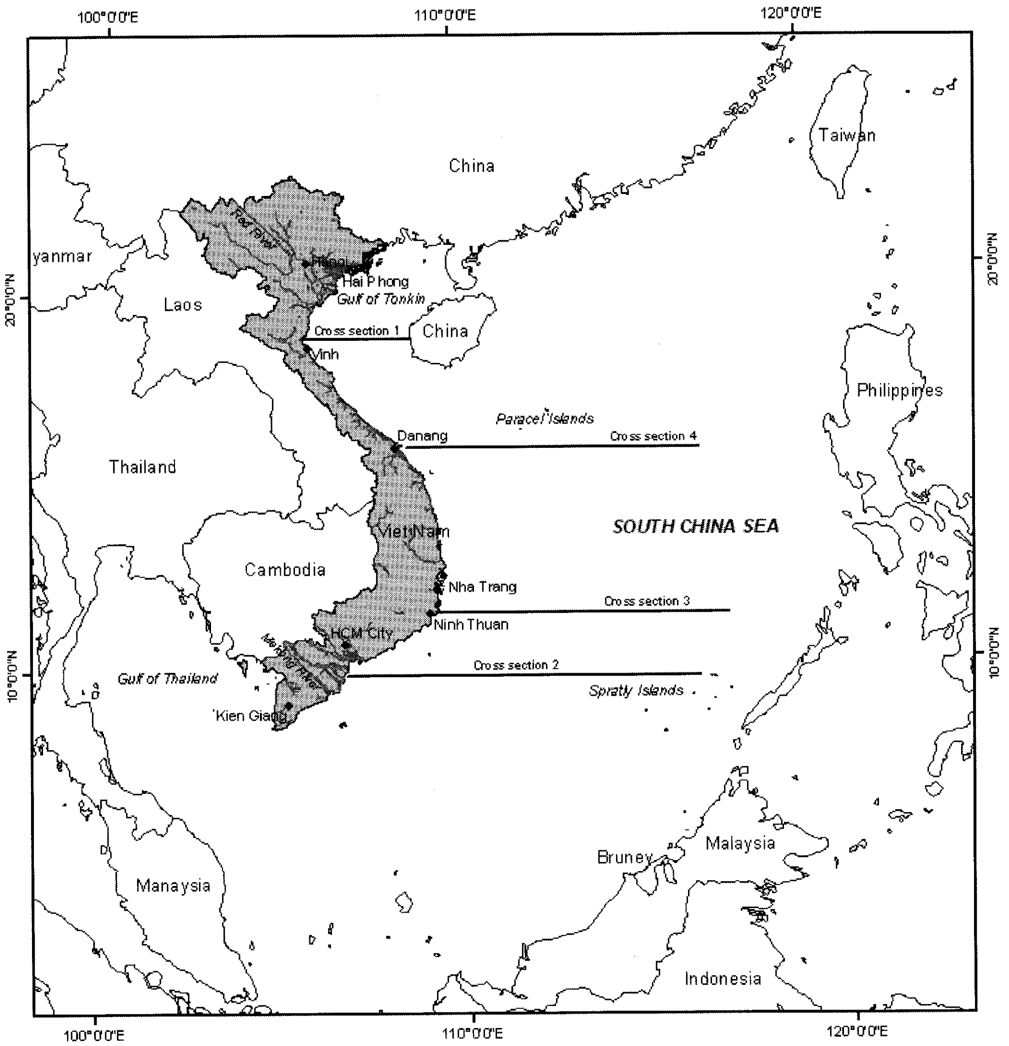


**Fig. 1.** Map of study area.

tion and detecting the algal bloom in Vietnam waters over 3 years, from 2002 to 2004.

Vietnam waters are located between tropic and equator (Fig. 1). Continental shelf extends in the North and the South, narrows in the Center. Gulf of Tonkin and Gulf of Thailand are two large gulfs. Northeast monsoon in winter and Southwest monsoon in summer are important factors of specific weather and current in this sea area.

### Data and Methodology

SeaWiFS satellite data with spatial resolution of 1.1 km were provided by NASA for research purpose. Total 408 SeaWiFS scenes with least cloud from 2002 to 2004 were selected for processing. SeaWiFS satellite data were processed by SeaDAS software using OC4 algorithm for calculating the Chl-*a* concentration. Processed level 2 products of Chl-*a* concentration is 1.1 km resolution. The daily data normally contain cloud, so that it is unable to present the distribution of Chl-*a* in whole Vietnam waters. Monthly average data will be able to cover whole area and present seasonal variation of Chl-*a* in Vietnam waters. These level 2 Chl-*a* data were composed to create a monthly average image at 2 km resolution.

OC4 algorithm was developed based on experimental formula of 2800 in-situ bio-optical measurements in the world (Baith et al. 2001). Accuracy of SeaWiFS-derived Chl-*a* using OC4 algorithm was validated and relative suitable for Vietnam waters (Dien et al. 2003). There are some differences at river mouth area due to high turbidity and suspended material discharge from river.

## Results and Discussion

### Spatial distribution of Chl-*a* concentration and marine algal bloom in Vietnam waters

Observation shows that high Chl-*a* concentration is normally occurred in coastal water and river mouths, where area is high nutrient and favorable condition for algal growing. In some special cases, high Chl-*a* concentration was observed around Paracel Islands in August 2002 and November 2003

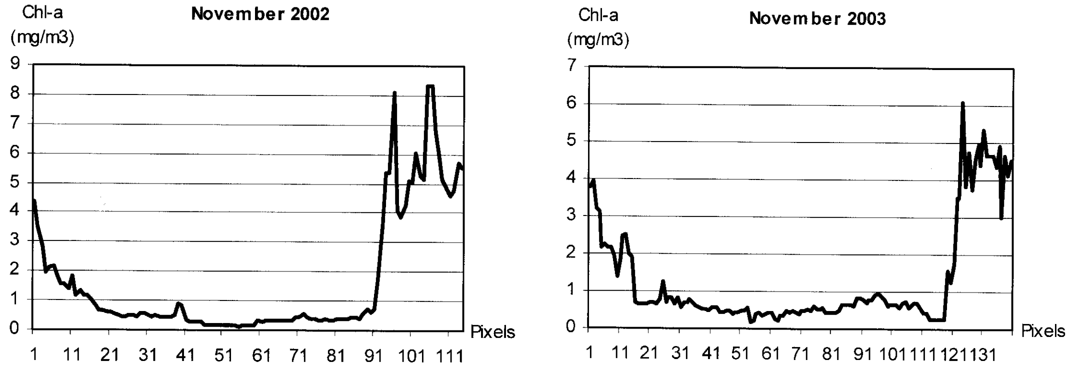


**Fig. 2.** Chl-*a* profile of cross section 1 in the Gulf of Tonkin.

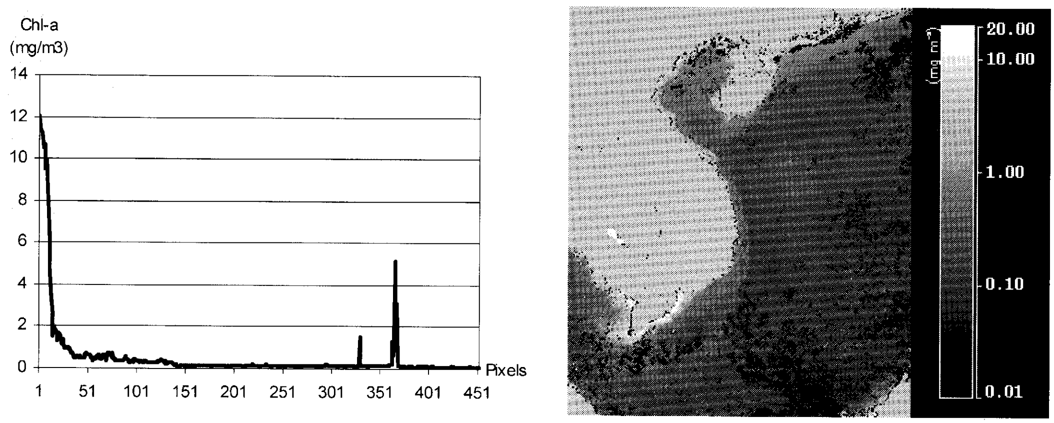


**Fig. 3.** Chl-*a* profile of cross section 2 at latitude 10°N from Mekong River Mouth in November 2003.

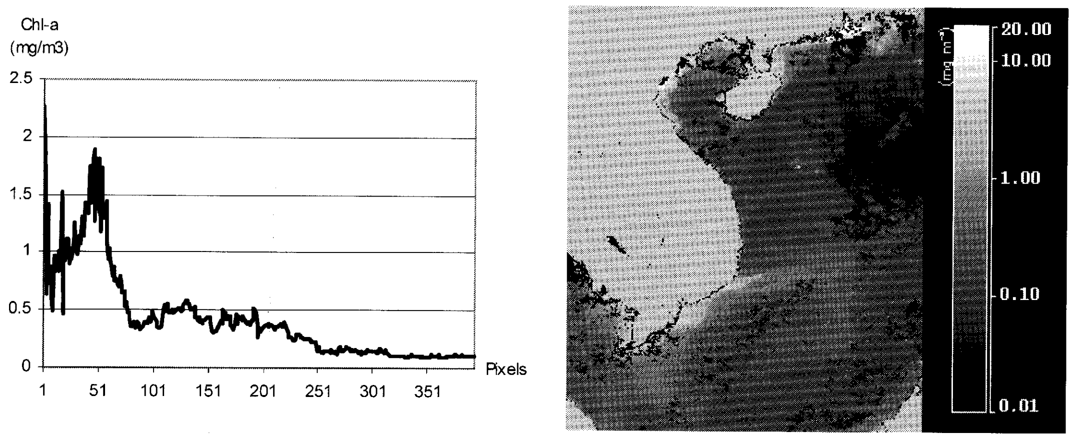


**Fig. 4.** Chl-*a* profile of cross section 3 in central water in July 2002.

and the Gulf of Thailand.

In the Gulf of Tonkin, high Chl-*a* concentration was observed in near shore waters regularly. Chl-*a* concentration decreases from coast to the center of the Gulf (Fig. 2). High Chl-*a* concentration was observed at Red River Mouth. In central waters, high Chl-*a* concentration was observed at near shore of Ninh Thuan-Khanh Hoa, Hue-Da Nang. Sometimes, bloom extended to offshore. Strong bloom was observed in near shore of Ninh Thuan-Binh Thuan provinces during Southwest monsoon (Fig. 4).

Southern waters are discharge area of Mekong River. High Chl-*a* concentration was observed throughout the year, especially in near shore strip (concentration of Chl-$a$>4 mg/m$^3$) (Fig. 3). Sometimes, this bloom extended to offshore. In the Gulf of Thailand, high Chl-*a* concentration was observed in near shore from April to October. In offshore waters, Chl-*a* concentration was very low. Rarely, high Chl-*a* concentration was observed in offshore. Sometimes, bloom occurred around Paracel Islands (Fig. 5).

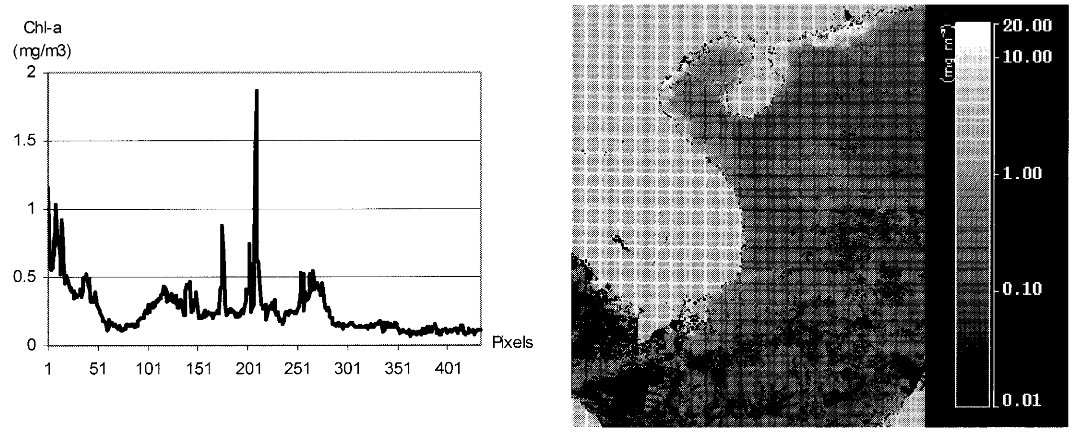


**Fig. 5.** Chl-*a* profile of cross section 4 around Paracel Islands in August 2002.

### Seasonal pattern of Chl-*a* and algal bloom

Algal bloom occurred normally in near shore within 30–40 km from the coast. These phenomena occurred due to the near shore water is good condition for phytoplankton growing (nutrient, temperature, salinity, wave action). Near shore area has many high production ecosystems (mangrove, sea grasses, coral reef). Nutrient in this area is rich due to receive nutrient supplemented from rivers and bottom regularly.

Nutrient is the fist and main factor to determine the growing of phytoplankton. In offshore water where Chl-*a* concentration was always low ($<0.2\ mg/m^3$) and uniform. At some big river mouths such as Red and Mekong, coastal waters receive big amount of material discharge from river. So that, concentration of Chl-*a* in these areas were quite high ($>5\ mg/m^3$), and always high in rainy season. Calculated total suspended material (TSM) from SeaWiFS satellite data was also high, so that calculated Chl-*a* concentration need to be corrected with the affect of suspended sediment in river mouth areas.

In the Gulf of Tonkin, a semi-closed Gulf in the Northwest of South China Sea, calculated Chl-*a* concentration is always high in near shore. Highest Chl-*a* concentration occurred at Red River Mouths. Chl-*a* concentration decreased from coast to the center of the Gulf. During 3 years observation, Chl-*a* concentration were high from November to next April ($>0.4\ mg/m^3$). Highest Chl-*a* concentration was in December and January. In April, high Chl-*a* concentration area decreased and disappeared. In winter season, algae bloom occurred not only in near shore but also in center of the Gulf. Algal bloom occurred in the Gulf of Tonkin at the same time of Northeast monsoon season (Fig. 2). In the Gulf of Tonkin, with rich nutrient condition, low water temperature in winter is favorable condition for phytoplankton growing.

In central waters, strong bloom was observed from May to September, strongest in July, bloom extended to Spratly Islands area (Fig. 4).

In April, nutrient was very high in Mekong river mouth. At the same time, Southwest monsoon season starts. Wind in Southwest direction along the coast creates upwelling which was mentioned by some researches (Lanh 1997, Kuo et al. 1997, 2000, Tang et al. 2003). This phenomenon is the reason of strong algal bloom occurred in this sea area. At the same time, summer northeastward ocean current (Fang 2002) transports nutrient from near shore to offshore and creates good condition for algal bloom not only in near shore but also in offshore. Existing of large bloom area depended on nutrient sources and ocean current. To the end of September, the northeastward current was replaced by southwestward current and starting of Northeast monsoon, bloom area retreated to southward and decayed.

In north of central waters, high Chl-*a* was observed from May to September in near shore. This may relate to long shore current. In the Gulf of Thailand, bloom was observed in near shore from May to September in Southwest monsoon. Algal bloom was observed in Paracel Islands in August 2002 and November 2003 (Fig. 5). These blooms may relate to upwelling due to local topography when ocean current hits the island shelf.

## Conclusions and Recommendations

SeaWiFS satellite data play important role in the study of physical, chemical, and biological processes. Chl-*a* concentration calculated from SeaWiFS satellite data using OC4 algorithm of SeaDAS software is useful for the study of seasonal pattern of phytoplankton in Vietnam waters. During 2002–2004, high Chl-*a* concentration was observed in near shore and river mouths. In offshore, Chl-*a* concentration was always low ($<0.2\ mg/m^3$). Research results determined the relation between algal bloom and nutrient sources, monsoon, and upwelling in some specific areas in Vietnam waters. In the Gulf of Tonkin, Chl-*a* concentration was high in winter from November to next April, the same time with northeast monsoon. In central waters, bloom occurred from May to September, same time with southwest monsoon. Algal bloom occurred in Paracel Islands in August 2002 and November 2003. This phenomenon has not been reported yet.

In Vietnam where survey equipment, manpower and finance are still not enough, ocean color data is necessary for the study of ocean processes. Remote sensing data with capability of covering large area and ability of providing accurate, multi-temporal and multi-spatial Earth surface are very useful. So we need a strategic plan for perfective application of remote sensing for ocean research in Vietnam. OC4 algorithm is quite accurate for calculate Chl-*a* concentration in Vietnam water condition. Although, this algorithm is low accurate in near shore area, where there is strong land-water interaction such as river mouth. Additional survey data is necessary for correction the calculated result in near shore area.

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