# PHYTOPLANKTON BLOOMING AND OCEANIC CONDITIONS IN THE SEAS AROUND THE SPRATLY ISLANDS

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**KEYWORDS:** remote sensing, phytoplankton blooming, oceanic conditions, Spratly slands, South China Sea

**ABSTRACT:** The oceanic currents in the South China Sea (SCS) are strongly influenced by monsoon winds. A review on the SCS currents has indicated that previous studies have pointed out an anticyclonic circulation in the area between the southern Vietnam coast and the Spratly Islands. However, its detail is not understood because of less information of in situ observations. The physical-biological interaction is quite new research area, which has been established and promoted by means of the ocean color remote sensing. Temporal/spatial variability of the phytoplankton activities are well captured by ocean color (OC) -derived Chlorophyll-a images. Combining the OC-Chl-a and the other high-resolution satellite data (e.g., SST images), the biological aspects of oceanographic variation is well described. The blooming phenomena in the area between the southern Vietnam coast and the Spratly islands are further investigated. Change in the wind-system related to the El Nino generates upwelling/SST-cooling in the sea south of the Spratly Islands through the air-sea-land interaction was studied. The seasonal upwelling is also associated with the harmful algal bloom (HAB) off two side of Indochina Peninsula have investigated. The seasonal variation of SCS phytoplankton blooming and related oceanic conditions in Vietnam coast was observed. Ocean color satellite data has effective contribute to study the oceanic condition and phytoplankton blooming in South China Sea.

## INTRODUCTION

Spratly Islands consisted of hundred of small islands located in South of South China Sea (SCS). This Islands occupied by 5 countries, so that very difficult to carry out field survey in this sea area. Remote sensing is effectively for monitoring environment of Spratly Islands area. Ocean color remote sensing data with capability of recover large area every day is effectively for monitoring biological, physical process, and environment in this sea area. This paper present an overview of oceanic condition in South of South China Sea and phytoplankton blooming detection and monitoring from ocean color remote sensing images.

## OCEANIC CONDITION

The oceanic currents in the South China Sea (SCS) are strongly influenced by monsoon winds. The southwest monsoon pushes the shelf water northward movements over the deep basin in eastern of SCS, while the northeast monsoon reverses direction and a strong boundary current is thus developed along Vietnam coast (Tomczak and Godfrey, 1994). Since the observation data were quite limited in this sea area, most of these researches were still qualitative, through some numerical model presented some relatively quantitative results while mostly focused on the circulation pattern. A review on the SCS currents has indicated that previous studies have pointed out an anticyclonic circulation in the area between the southern Vietnam coast and the Spratly Islands (Hu et al., 2000). However, its detail is not understood because of less information of in situ observations. In recent years, researchers have paid more attention to the south SCS (SSCS) circulation pattern. However, the basic feature and seasonal variation of SSCS are not yet well understood. Review pointed out that a large scale wind-driven anticyclonic circulation exists in upper layer (0-150m). There are four major currents in upper layer (0-400m) of SSCS: the Nansha Western Coastal Current (NWCC), the Nansha Eastern Coastal Current (NECC), the North Nansha Current (NNC) and the Nansha Counter-wind Current (NCC). These four currents except NECC indicate quite different pattern in respective monsoon period, and suggest a strong influence of monsoon wind on SSCS circulation. The NWCC flows northward along the southeastern coast of the Zhongnam Peninsula and then turns eastward to form the NSC at about 11°N, while an anticyclonic eddy exists during the southwest monsoon period. However, NWCC flows southward during the northeast monsoon period, being accompanied by a cyclonic eddy and other anticyclonic eddy. The anticyclonic Eddy Bs develops in May-June and grows up in August, centering around (9°N,112°E) with horizontal scale of 400km and vertical scale of 400m, and the cyclonic Eddy Bs stays near 112°E in an elliptic shape during the northeast monsoon period.

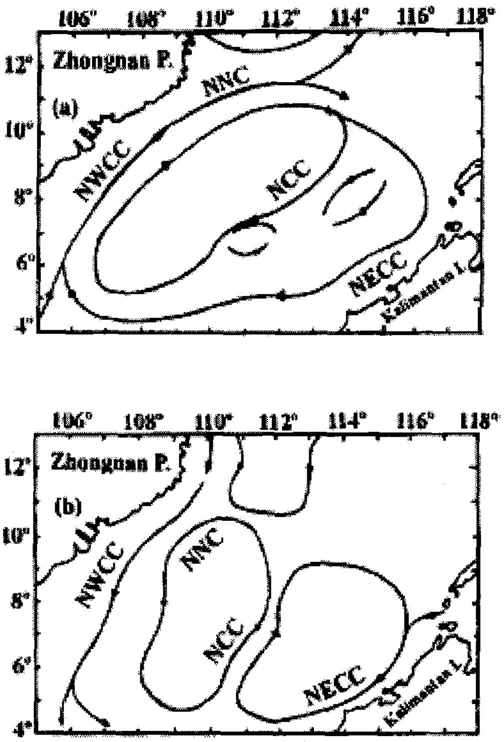


Figure 1. Upper layer circulation pattern in Spratly Insland area. (a) Southwest monsoon period and (b) northeast monsoon period. NWCC, NECC, NCC and NNC present Nansha West Coastal Current, Nansha East Coastal Current, Nansha Counter-wind Current, North Nansha Current respectively.

The physical-biological interaction is quite new research area, which has been established and promoted by means of the ocean color remote sensing. Temporal/spatial variability of the phytoplankton activities are well captured by ocean color (OC) -derived Chlorophyll-a images. Combining the OC-Chl-a and the other high-resolution satellite data (e.g., SST images), the biological aspects of oceanographic variation is well described.

## PHYTOPLANKTON BLOOM OBSERVATION

High phytoplankton biomass often occurs in plumes near river mouths or in eutrophic coastal waters for short time periods. However, we observed an increased phytoplankton biomass in a narrow jet-shaped protrusion into the western South China Sea (SCS) using satellite chlorophyll-a (chl *a*) data from the Sea-viewing Wide Field-of-view Sensor (SeaWiFS) and concurrent ship measurements in 1999 (Tang et al., 2004) . In June, regional phytoplankton biomass appeared as a large jet shape extending from the coastal waters of Vietnam eastward towards the SCS, about 200 km northeast of the mouth of the Mekong River; this feature intensified in the form of a large jet or gyre from July to September, decayed in October, and disappeared entirely in November. The gyre was about 400 km in diameter with chl *a* concentrations from 0.5 to 2 mg $m^{-3}$. Data on sea surface temperature (SST), winds, and sea surface height anomalies indicated a strong offshore upwelling during a period of strong southwesterly winds alongshore. The upwelling coincided with the regional increase in phytoplankton biomass in terms of shape, timing, and location.

The blooming phenomena in the area between the southern Vietnam coast and the Spratly islands are further investigated by Tang et al. (2004). An extensive bloom off southeastern Vietnamese waters during late June to July 2002 was presented with in situ observations and analyzes the oceanographic conditions using satellite remote sensing data. The bloom had high chlorophyll a (Chl-a) concentrations (up to 4.5 mg $m^{-3}$) occurring ~200 km off the coast and ~200 km northeast of the Mekong River mouth for a period of ~6 weeks. The bloom was dominated by the harmful algae haptophyte Phaeocystis cf. globosa and caused a very significant mortality of aquacultured fish and other marine life. In the same period, sea surface temperature (SST) imagery showed a cold water plume extending from the coast to the open sea, and QuikScat data showed strong southwesterly winds blowing parallel to the coastline. This study indicated that the bloom was induced and supported by offshore upwelling that brings nutrients from the deep ocean to the surface and from coastal water to offshore water and that the upwelling was driven by strong wind through Ekman transport when winds were parallel to the coastline.

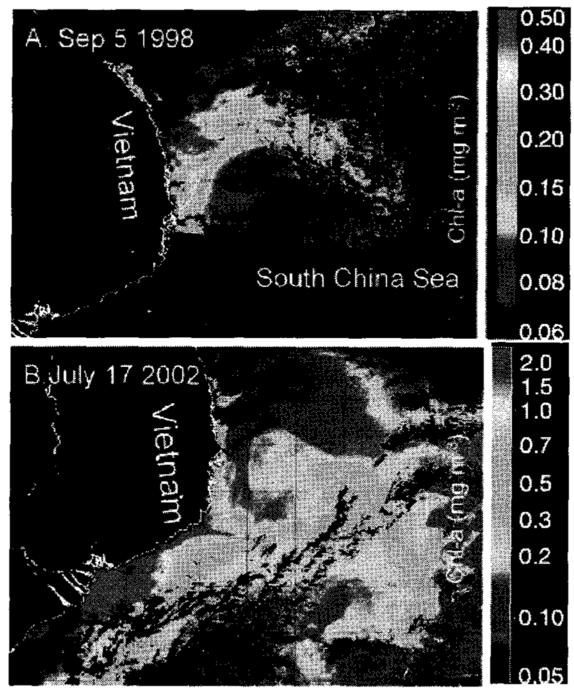


Figure 2. SeaWiFS derived chl *a* images showing a region of high phytoplankton concentration as (A) a jet and (B) a gyre from the Vietnamese coast toward the western SCS. Land, clouds and missing data are marked black, and coastlines are shown in white

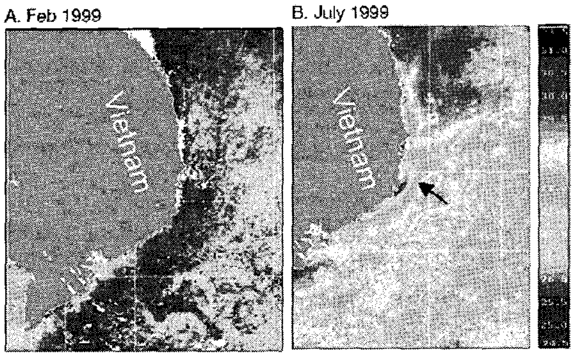


Figure 3. Images of monthly averaged sea surface temperature (SST) for (A) winter and (B) summer. Land regions are colored gray, and coastlines are shown in white. Arrow indicates cold water upwelling from the coast toward the open ocean

Change in the wind-system related to the El Nin˜o generates upwelling/SST-cooling in the sea south of the Spratly Islands through the air-sea-land interaction (Isoguchi et al., 2005). Satellite chlorophyll-a (Chl-a) observations reveal offshore phytoplankton bloom events with high Chl-a (>1 mg $m^{-3}$) spreading over 300 km off the coasts around the Spratly Islands in the South China Sea (SCS) during the spring of 1998 (Figure 4). The bloom entails anomalous wind jet and sea surface temperature (SST) cooling, suggesting that the wind jet-induced mixing and/or offshore upwelling bring about the cooling and the bloom through the supply of nutrient-rich waters into the euphotic zone. The strong wind jet is topographically formed responding to shifts in wind direction over the eastern SCS. The wind shift is connected with the Philippine Sea anomalous anticyclone that is established during El Nin˜o, indicating the El Nin˜o-related offshore bloom. The long-term reanalysis winds over the eastern SCS demonstrates that wind jet formation and associated offshore cooling/bloom are expected to occur in most cases of the subsequent El Nin˜o years.

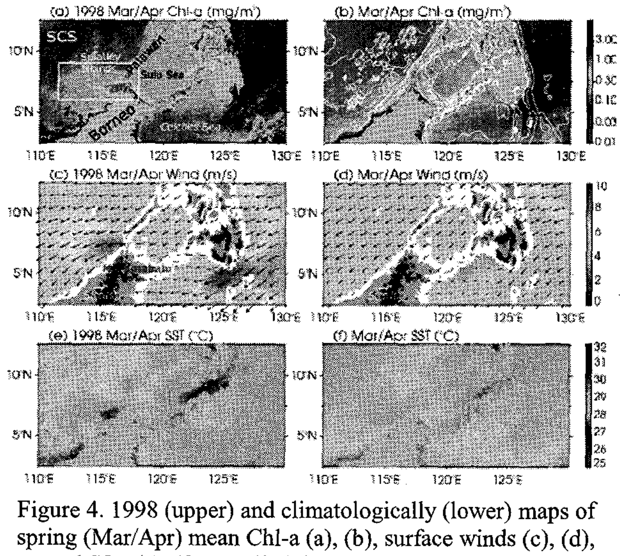


Figure 4. 1998 (upper) and climatologically (lower) maps of spring (Mar/Apr) mean Chl-a (a), (b), surface winds (c), (d), and SST (e), (f). Detailed data sources and periods for averaging are described in the text. Geographical features cited in the text are shown in the panel (a). Bathymetric lines of 50 m, 200 m, 500 m, and 2000 m are superimposed in the panel (b). Land topography higher than 500 m is filled with black in the panels (c) and (d), where the location of Mount Kinabalu is marked with a red diamond.

The seasonal upwelling is also associated with the harmful algal bloom (HAB) off two side of Indochina Peninsula was investigated (Tang et al., 2006). Seasonal variations of the phytoplankton blooms in this area are primarily controlled by the monsoonal winds and related coastal environments. The Gulf of Thailand and the near-coastal SCS have a peak in the averaged monthly Chl-a in December and January, which is associated with the winter northeaster monsoon. The near-coastal SCS have another big peak in the averaged monthly Chl-a in summer (July to September), which is associated with the summer southwest monsoon. The offshore bloom in the Gulf of Thailand occurs in its southern part and enhances the December-January peak of averaged monthly Chl-a. The Mekong River discharge waters flow in different directions, depending on the monsoon winds, and contributes to seasonal blooms on both sides of the Peninsula.

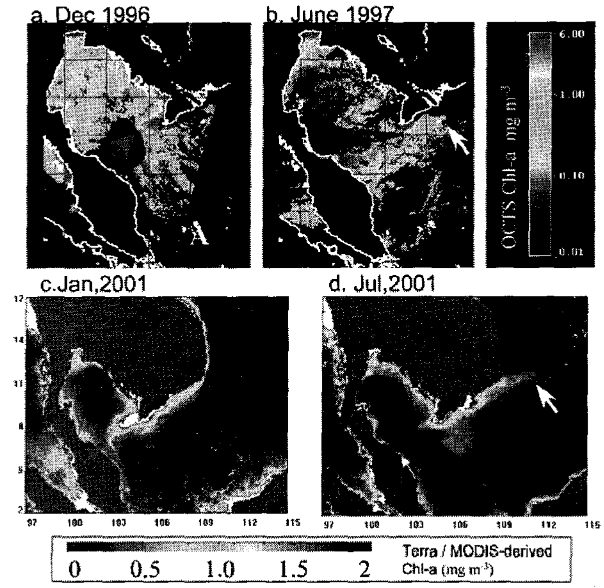


Figure 5. Monthly Chl a images derived from OCTS and MODIS.

Tang et. al. (2006) have studied the seasonal variations of SCS phytoplankton blooming and related oceanic environment. The spatial distribution of Chlorophyll-*a* (Chl-*a*) in the summer season for the South China Sea (SCS) was investigated using satellite measurements and discusses the mechanisms of spatial variation of phytoplankton. Results show that Chl-*a* concentrations are higher in the west than in the east of the SCS. Chl-*a* concentrations in the west central basin, southeast of Vietnam and a jet like band east of Phan Ri Bay are evidently higher than in the rest of the SCS. Their spatial characteristics are related to upwelling derived from Ekman pumping, Ekman transport induced by southwest monsoon winds, and the strong offshore current east of Vietnam.

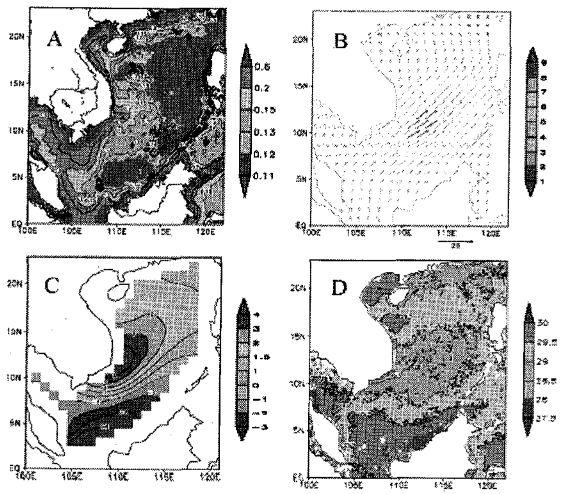

Figure 6. (A) SeaWiFS-derived Chl-*a* ($mgm^{-3}$) images in summer for the SCS averaged for June-August from 1998 to 2003. (B) FSU SWS vectors and their magnitude (contours in 10-2 Nm-2) for June-August from 1970 to 2003. (C) Summer Ekman Pumping velocity (upward positive in 10-6 m/s) derived from wind stress and averaged for June-August from 1970 to 2003 in the SCS. (D) Summer SST Image (in .C) averaged for June-August from 1998 to 2003 in the SCS.

## REFERENCES


Hu, J., H. Kawamura, H. Hong and Y. Qi (2000): A review on the currents in the South China Sea. Seasonal circulation, South China Sea Warm Current and Kuroshio intrusion. *Journal of Oceanography*, 56, pp. 607-624.

Isoguchi, O., H. Kawamura, and K. Ku-Yaacob (2005): El Nino-related offshore phytoplankton bloom events around the Spratly Islands in the South China Sea. *Geophys. Res. Lett.*. (in press)

Tang, D., H. Kawamura, Hai Doan Nhu, and W. Takahashi (2004): Remote sensing oceanography of a harmful algal bloom (HAB) off the coast of southeastern Vietnam. *J. Geophys.* Res., 109.

Tang, D. H Kawamura, T.V. Dien and M.A. Lee (2004): Offshore phytoplankton biomass increase and its oceanographic causes in the South China Sea. *Marine Ecology Progress Series*, 268: 31-41.

Tang, D., H. Kawamura, S. Ping, L. Guan, W. Takahashi, T. Shimada, F. Sakaida and O. Isoguchi (2006): Seasonal phytoplankton blooms associated with monsoonal influences and coastal environments in the sea areas either side of the Indochina Peninsula. *J. Geophys. Res - Biogeosciences*, Vol.111.

Tomczak, M. and J. S. Godfrey (1994): Adjacent seas of the Pacific Ocean, p.173-191. *In Regional Oceanography: An Introduction*, Pergamon Press Oxford.