IDEAS OF APPLICATION REMOTE SENSING TECHNIQUES FOR ALGAL BLOOM DETECTION IN MARINE REGIONS OF VIETNAM

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ABSTRACT

Algal bloom is a rapid increase of the community of algae. It can cause several negative impacts on environment and toxicity effects. Therefore, detection of algal bloom takes into account of preventing environment impacts. This paper reviewed the remote sensing techniques for algal bloom detection from ocean color images, including peak shift, red tide index and bio-optic methods. The paper also discussed the advantaged and disadvantaged potential application in the case of Vietnamese waters. By the results of testing algal bloom detection in the southern marine regions of Vietnam, the paper suggested that the bio-optic method could be used, but it is necessary to determinate the experiment constants of absorption and back-scattering of specific algal species.

Keywords: *Algal bloom detection, Red tide, Peak Shift, Red Tide Index, Bio-Optical, MODIS.*

1. INTRODUCTION

Algal bloom is a nature phenomenon which algae community becomes so numerous and discolors coastal waters. In case of harmful algal (or red tide), it may deplete oxygen to the water and/or release toxins that may cause illness in humans and other animals affecting directly to marine environment and economy. Therefore, early detection of algal bloom is a very important task; it is not only for preventing environment impacts, but also to reduce the affected to human and economy.

In Vietnam, the blooms of *Phaeocystis globosa* (red tide) have occurred more frequently from 2002 in coastal regions of Binh Thuan Province. According to Doan et al. (2010), about 90% of animal and plant species in tidal regions of Phan Ri Bay, causing a loss of over VND 10 billion (ca. US$ 650,000), were destroyed by a bloom in July 2002. The blooms were also recorded in 2005, 2006, 2007 and 2008 (Hai et al, 2010; reviewed by Liu & Tang, 2012). From July 2011 to July 2012, blooms of *Noctiluca scintillans* have occurred consecutive in Cat Ba, Hai Phong. As the result, about 70% clam production in Phu Long (Cat Ba – Hai Phong) were destroyed, causing a loss of over VND 40 billion in November 2011(MONRE website). Hence, the algal blooms should be addressed.

The use of ocean-color satellites for detection of red tides has been researched recently years (Hu et al., 2005; Ishizaka, 2006; Hu et al, 2011; Liu & Tang, 2012). Each research uses a distinct method to detect red tide in a different region. In general, these methods can be catalogued into two kinds by their approach techniques. (1) Empirical Approach, using water-leaving radiance as a function of chlorophyll (Chl) concentration, such as Peak Shift (PS) and Red Tide Index (RI); and (2) Bio-optical Technique (BOT), using particulate backscatter along with Chl concentration. This paper reviews remote sensing techniques for algal bloom detection and shows a preliminary result of red tide detection in the southern central of Vietnam coastal waters.

2. PREVIEW METHODS

2.1. Peak Shift (PS)

Based on spectra data distribution (Fig. 1a) of Red Tide and non Red Tide happened in Japanese sea, PS method estimate red tide phenomenon by identify the peak of normalized water-leaving radiance at 547 nm (nLw_{547}). The expression for SeaWiFS images was calculated as:

Where [$MAX(nLw_{547}, nLw_{488}, nLw_{443}) = nLw_{547}$] was estimated as Red Tide. (1)

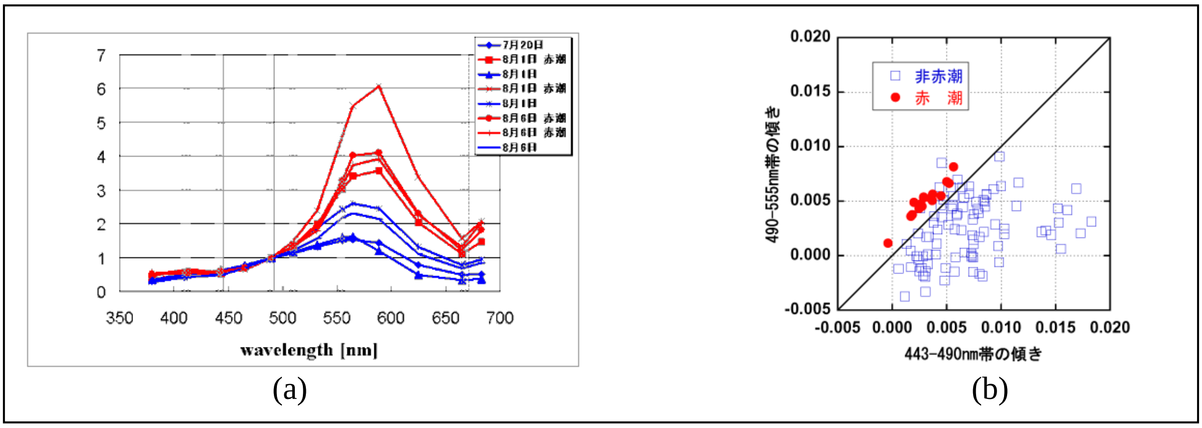


Figure 1: (a) Normalized Rrs spectra data distribution; (b) The relation of Slope $_{490\sim555nm}$ and Slope$_{443\sim490nm}$; (red color: red tide, blue color: no red tide) (Ishisaka, 2007)

According to the relation of Slope $_{490\sim555nm}$ and Slope$_{443\sim490nm}$ on red tide and non red tide (Fig. 1b), an extension of PS is plus a criterion on low at R_{rs443} and estimated when meeting the expression as below:

$MAX(nLw_{547}, nLw_{488}, nLw_{443})=nLw_{547}$ AND ($nLw_{488\text{-}443}$ slope < $nlw_{547\text{-}488}$ slope) (2)

2.2. Red Tide Index (RI)

The RI method (Ahn, 2006) employs the water-leaving radiances (L_w), collected from in-situ radiometric measurements to achieve derivation of indices that are related to absorbing characteristics of HABs (Harmful Algal Blooms) from which a best fit with a cubic polynomial function is obtained providing indices of higher ranges for HABs and slightly reduced ranges for turbid and non-bloom water.

Instead of taking the direct radiance ratio between the blue and green wavelengths, RI is built by normalizing the deducted and combined ratio $L_w(510)/L_w(555)$ with the absolute values of $L_w(443)$ as follows,

$$RI = \frac{[L_w(510)/L_w(555) - L_w(443)]}{[L_w(510)/L_w(555) + L_w(443)]} \quad (3)$$

Derived RI equation

$$RI_{(DII)} = 10^{(-0.1069 \times X^3 + 0.6259 \times X^2 - 1.3936 \times X + 0.919)} \quad (4)$$

Where X is the L_{w443}.

2.3 Bio-optical Technique (BOT)

Based on shipboard bio-optical data set collected from the central-west Florida shelf between 2000 and 2001 found that Reflectance model simulations indicated absorption due to cellular pigmentation is not responsible for the factor of ~ 3–4 decrease observed in $R_{rs}(\lambda)$ for waters containing greater than 10^4 cells L^{-1} of *Karenia brevis* (Cannizzaro et al., 2008). Instead, particulate backscattering is responsible for this decreased reflectivity. Measured particulate backscattering coefficients were significantly lower when *K. brevis* concentrations exceeded 10^4 cells L^{-1} compared to values measured in high-Chl (>1.5 mg m^{-3}), diatom-dominated waters containing fewer than 10^4 cells L^{-1} of *K. brevis.*

A classification technique for detecting high-chlorophyll, low-backscattering *K. brevis* blooms was developed. The technique proposed by Cannizzaro et al. (2008) was used to examine the backscattering coefficient at 551 nm ($b_{bp;551}$) estimated with the Quasi-Analytical Algorithm (QAA) developed by Lee et al. (2002) against $b_{bp;Morel}$ from the Case-I empirical algorithm by Morel (1988) (Equation 5),

$$b_{bp,Morel} = 0.3 \times Chl^{0.62} \times (0.002 + 0.02 \times (0.5 - 0.25 \times log_{10}Chl)) \quad (5)$$

Pixels with Chl-a < 1.5 mg m^3 are masked as black and because *K. brevis* blooms exhibit a lower backscattering efficiency compared to diatom blooms, the warm colors, therefore, ratio

$$b_{bp,ratio}(555) = \frac{b_{bp,QAA}(555)}{b_{bp,Morel}} < 1.0 \quad (6)$$

can be classified as dominated by *K. brevis* cells.

3. PRELIMINARY RESULTS OF RED TIDE DETECTION IN SOUTH OF CENTRAL OF VIETNAM COASTAL

3.1. Study area and remote sensing data

For the first step to detect red tide from remote sensing data in Vietnam, study area was selected in the southern central of Vietnam coastal waters, where red tide mostly happened annually. It covered from NhaTrang to Vung Tau, geographic location from 9°N to 13°N and 106.5°E to 111.5°E.

The MODIS Aqua Level 1A images were downloaded from ocean-color web (http://oceancolor.gsfc.nasa.gov/) when the red tide happing in July 2002, July 2003, August 2005, August 2006 and August 2009. Image processing is used SEADAS 6.4 on Ubuntu 11.04 operating system.

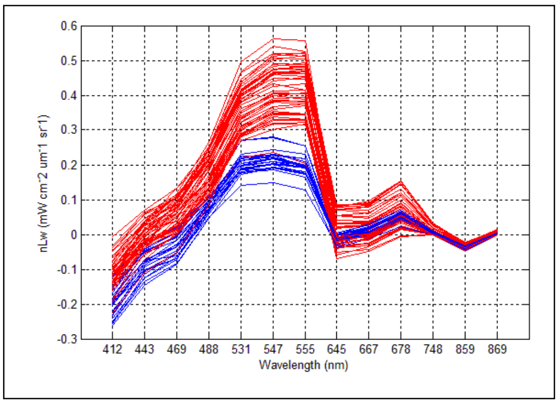


Figure 2: Spectral profile of MODIS image on 18th July 2002

3.2. Apply methods

In the condition of red tide, in-situ data is absent, cannot use empirical regression to get a suitable coefficients for detecting red tide model. Therefore, this study used two methods to detect bloom, Peak Shift (Equation 2) and Bio-optical (Equation 6). Fig. 2 shows the spectral profiles of MODIS image on 18th July 2002, which red line present where the pixel met Equation (2) condition, otherwise is in blue color. The pixels were selected randomly where Chl great and equal 20 (mg m^{-3}).

3.3. Analysis results

In 2002, both methods BOT and PS gave the similar results (Fig. 3) on bloom regions except the lower part in PS. In 16thJuly 2003 (Fig. 3f) where the Chl concentration is low, the results from PS and BOT were similar, but in 26th July 2003, when suck a up welling phenomenon happen (Fig. 3g), the result from BOT was quite different with PS, where BOT deleted blooms, PS does not. In 2005 (Fig. 3h) got the same results as 2003. In 2006 (Fig. 3i) and 2009 (Fig. 3j), the results shown the invert to 2003 and 2005. The BOT detected a very slight bloom's region, but PS showed a large blooms region.

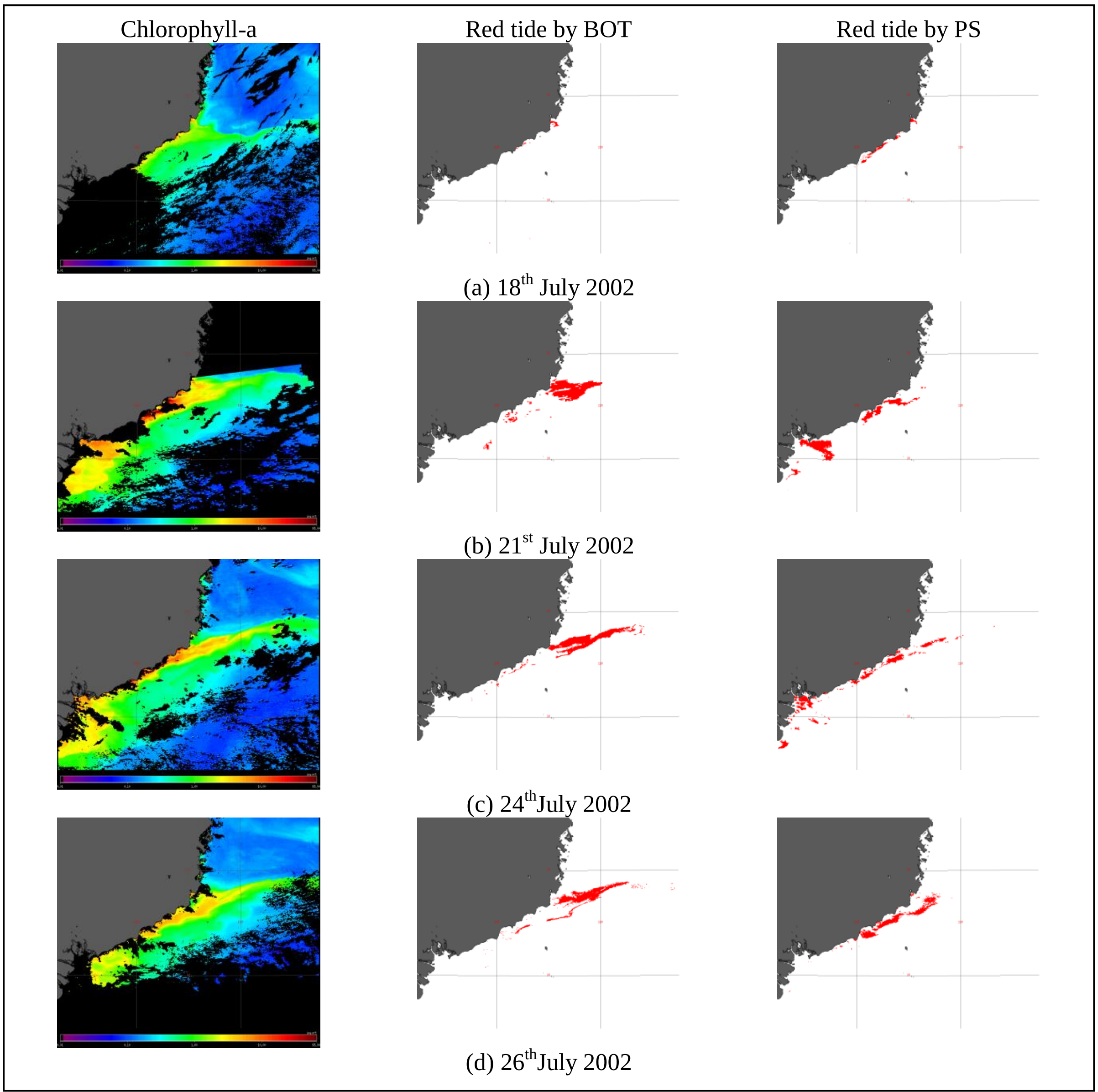
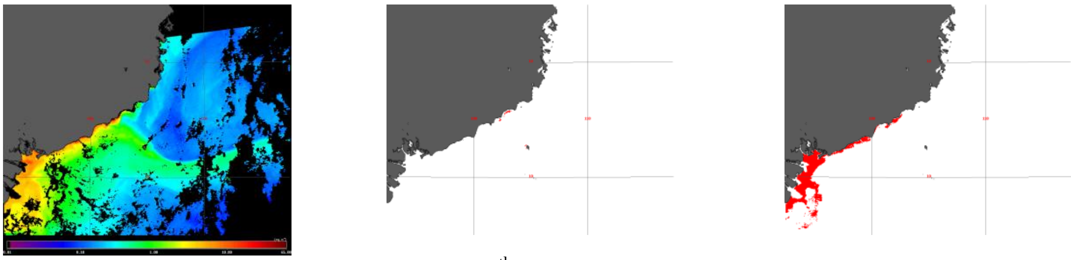
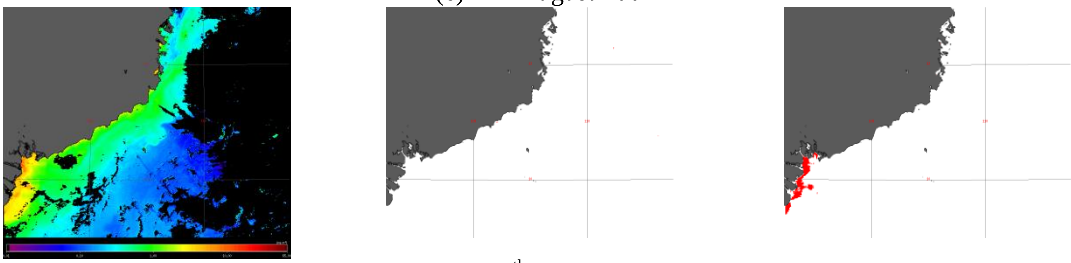


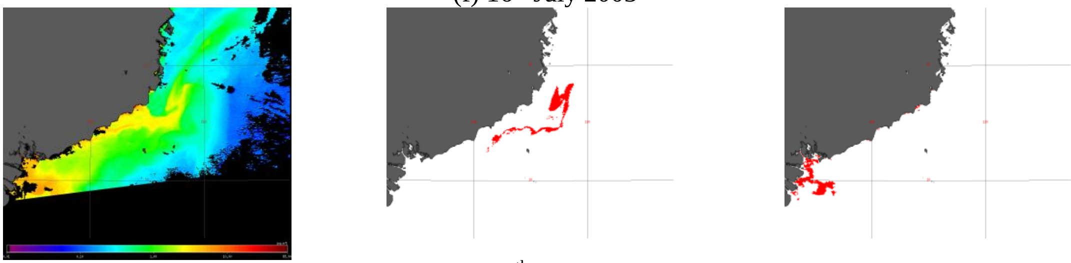
Figure 3. Red tide detection from MODIS data in Southern centre of Vietnamese waters in the period of 2002-2009. Chlorophyll-a distribution (Left), Red tide by Bio-optical Technique (Centre), Red tide by Peak Shift (Right)



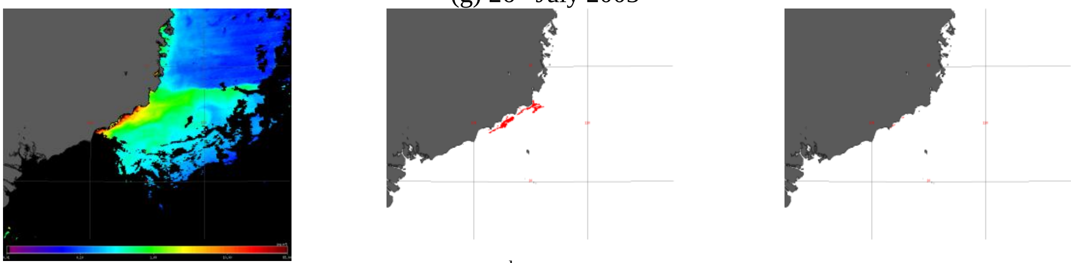
(e) 24th August 2002



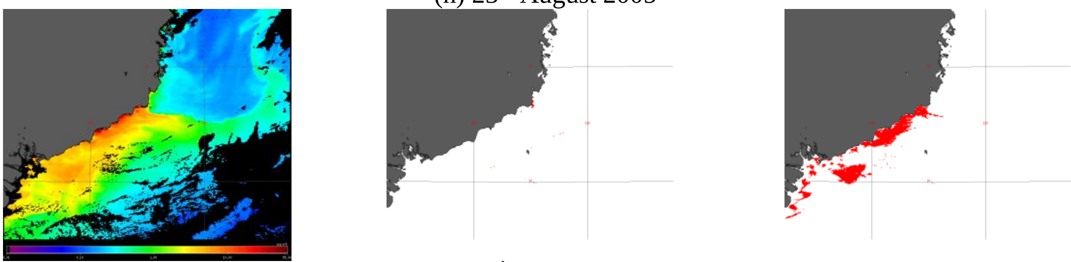
(f) 16th July 2003



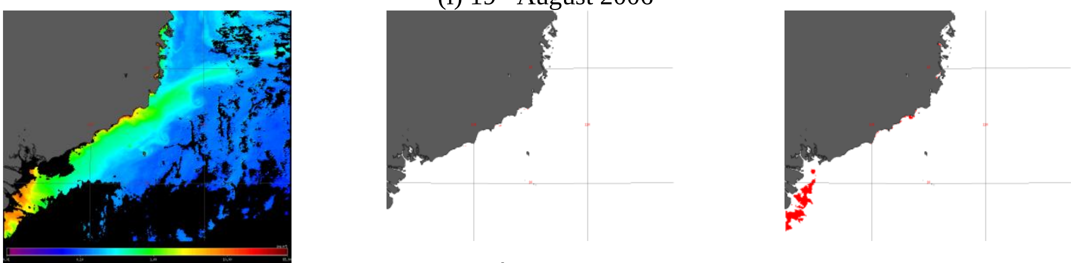
(g) 26th July 2003



(h) 23rd August 2005



(i) 19th August 2006



(j) 20th August 2009

Figure 3 (Cont.). Red tide detection from MODIS data in Southern centre of Vietnamese waters in the period of 2002-2009. Chlorophyll-a distribution (Left), Red tide by Bio-optical Technique (Centre), Red tide by Peak Shift (Right)

From the results, the PS method looked very sensitive in the region where high chlorophyll concentration, this also showed in spectral profile (Fig. 2) while BOT is not. This sensitive will be in trouble when meet the turbidity and CDOM water.

The blooms were detected mostly in upwelling region on South West monsoon (Doan et al., 2010), and resulted from the nutrient supporting of the depth water mass and the comfortable condition of algal blooms. The results in 2002 to 2005 are more reasonable of blooms than in 2006 and 2009, because the results might be affected by the suspended material sources from Mekong River in Southwestern monsoon in the period of 2006 - 2009.

The results of red tide detection have not had the validation part due to lack of in-situ bio-optic data in waters combining with red tide events. Therefore, it is necessary to have investigation of marine optics before, during and after algal bloom events for improving red tide detection results.

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