APPLICATION OF OCEAN COLOR REMOTE SENSING IN MARINE STUDY OF VIETNAM – STATUS AND POTENTIAL

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ABSTRACT: The remote sensing is powerful oceanographic tools not only for Integrated Coastal Zone Management (ICZM) but also for various areas of oceanography. Thank to effort of Government and local authorities as well as active support of international institutions, many projects on the applied oceanography had and have been caring out in coastal and offshore waters of Vietnam sea. One of the modern methods which has been used in these project is ocean color remote sensing technique. This paper will present some preliminary results obtain from application of these techniques in study of coastal and offshore environment of Vietnam sea.

KEY WORDS: Ocean colour remote sensing, MODAS, MODIS, EOF, MCC, Giovanni and PFEN websites.

INTRODUCTION: The remote sensing is powerful oceanographic tools not only for Integrated Coastal Zone Management (ICZM) but also for various areas of oceanography. Thank to effort of Government and local authorities as well as active support of international institutions, many projects on the applied oceanography had and have been caring out in coastal and offshore waters of Vietnam sea. One of the modern methods which has been used in these project is ocean color remote sensing technique. This paper will present some preliminary results obtain from application of these techniques in study of coastal and offshore environment of Vietnam sea.

Some modern techniques have been applied in these researches such as: Empirical Orthogonal Function (EOF) in study main structures in South China Sea, method of Maximum Cross Correlation (MCC) for extracting advection current system, application of ocean color images for studying the temporal and spatial variability of Sea Surface Temperature (SST), Chorophyll-a, Primary Production Total Suspended Solid (TSS) as well as monitoring on the Red Tide and Harmful Algae Bloom (HAB) .... have been introduced. These results are relative appropriate with surveyed data as well as previous calculated results on main hydrology features of South China Sea.

USED DATA AND METHODS:

- ***Empirical orthogonal functions (EOFs):*** were used to decompose our resulting SST maps into modes ranked by their variance. In their analysis or a set of AVHRR SST images, Lagerloef and Bernstein (1988) /3/created a covariance matrix of the SST images to decompose the EOF functions to study the SST patterns in Santa Barbara Channel. Kelly (1985 /2/; 1988/3/) used instead a singular value decomposition (SVD) method for the EOF computation which was found to be computationally more efficient than the direct covariance approach. In our research we used Kelly's SVD method /6/ for the EOF decomposition.

Used source for our EOF analyzing is MODAS images, with their spatial resolution is 1/8 ° in bitmap format. We can download them daily (1997-2004) from website of NAVY-USA http://www7320.nrlsc.navy.mil/ . By the special techniques we converted them from bitmap to digital data for all of images and then EOF analysis.

- ***PFEL data assess*** : using PFEL (Pacific Fisheries Environmental Laboratory) live assess server from one of website of NOAA http://www.pfeg.noaa.gov , we can collect monthly wind product – wind stress and their Curls in SCS.

- ***Maximum cross correlation (MCC)***: The computation method for deriving sea surface advective velocities consists essentially of identifying of the maximum cross correlation in a lagged matrix between two sub areas of a pair of sequence scenes .The first image is divided into continuous sub areas called template window. The size of this window is taken as [10 x 10] pixels. For the template, a large search window was identified in the second image as its center called search window.

The size of this second window is taken as [25 x 25] pixels. In the Cartesian coordinate system f(x, y) and g(x+p, g+q) denote a possible pair of similar pattern in two time lapsed images. Attention, in MCC method elapsed time between AVHRR image pairs are less than 24 h. The vector (p,q) represents a possible spatial displacement of the original pattern between the two image. The cross correlation matrix is formed as (Catia and other 2000 /1/)

$$\rho(p,q)=\frac{\mathrm{cov}\{f(x,y),g(x+p,y+q)\}}{\sqrt{\{\mathrm{var}[f(x,y)]\mathrm{var}[g(x+p,y+q)]\}}}$$

In order to increase "statistically searched number" of maximum cross correlation coefficient from search window, this one have been divided to sub-window that have same size of template window (i.e [11 x 11] pixels). They arrange not side by side but tiled form. This much, searched number (events of correlation coefficient) for each template window will be [(25-11) x (25-11)] = [14x14] events of correlation coefficient.

In tropical climate, the cover level of cloud is usually high. This thing will cause noise in AVHRR images and effect to accuracy level of surface advection current field

derived from the statistical MCC search. So that when calculation of correlation coefficient we have to eliminate pixels of "cloud" and also "land" in calculated matrix.

From this matrix, maximum cross correlation coefficient and corresponding xlag (pmax) and ylag (qmax) are found. Figure 1 shows the schematic of feature tracking using the above approach.

The MCC method indicates the actual flow during a specific period (average of two - time elapsed images) i.e., integrating tidal and wind influences.

The maximum cross correlation in the relative displacement (p,q) between the template and the search windows of the sequential scenes determine the advection velocity vector ; the magnitude of which is given by Catia and others /1/ as :

$$C = \frac{\sqrt{(p \max \Delta x)^2 + (q \max \Delta y)^2}}{\Delta t}$$

and direction of motion can be calculate as

$$\theta = \arctan\left[\frac{q \max \Delta y}{p \max \Delta x}\right]$$

RESULTS AND DISCUSSIONS:

1, EOF method for studying main hydrological structures in SCS: From the analytic results of Empirical Orthogonal Function of (1997 – 2004) MODAS image dataset, we interpreted the structural characteristics of sea surface temperature using 5 selected EOF main first components. These components accounted for 49.3%, 24.7%, 7.5% respectively, according to the common variance of the whole sample set.

EOF1 component is characterized for SST distribution pattern under the influence of North-East monsoon. It represents clearly the intrusion of the tongue of cold water from north-eastern (thought Taiwan strait) to south-western South China Sea

The EOF2 component is characterized for SST distribution pattern under the influence of South – West monsoon. It expresses the trend of forming a coastal colder SST area in the general warm font of SST (T ≈ 29 – 30° C). This coastal colder SST area was formed mainly due to the up-welling and other phenomena. visual observations of MODAS images also show that, this coastal colder SST area often existed in the waters of North of Central as well as coastal water in West of Tonkin Gulf in April and May every year, was formed under the influence of hot dry Foehn wind and caused the local heat loss in this region. In years with El Nino phenomena, this colder SST area was in Quang Binh, Quang Tri or Hue. In the South – West monsoon, it moved gradually to the South and usualy existed in Phan Rang – Phan Ri. Its main mechanism is that it was formed under the influence of South – West monsoon blowing parallel with the coast causing the upwelling phenomena in this region

The diagram in figure 3 exprresses the monthly temporal variability of EOF1 và EOF2. It shows the alternatives and the absolute reverse phases as well as the monsoonal predominance of these two components

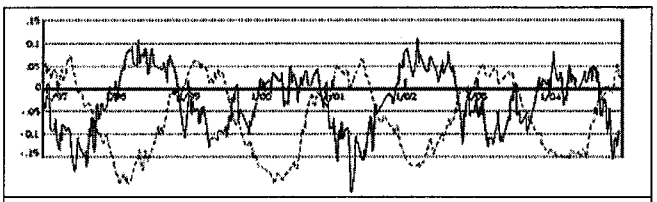

Figure 1: Temporal EOF1 (solid line) and EOF2 (dashed line) components

Besides, when analysing EOF1 component according to years with strong El Nino (1997-1998), with mean El Nino (2001-2002) và without El Nino (1999 - 2000), we found that El Nino phenomena also impacted on the temparature distribution field in the winter. In years without El Nino, the tongue of cold water intruded into the extreme South of South China Sea, whereas in years with El Nino, it was pushed gradually to the extreme North. It could be told that, El Nino impacts have raised the general thermal font of sea temparature of the whole South China Sea significantly, even in the winter. The EOF3 is characterized for SST distribution pattern under the influence of ENSO phenomena. This was expressed clearly during the analyses of EOF3 temporal variability with Southern Oscillation Index - SOI throught the close relationship between EOF3 and SOI (figure 4)

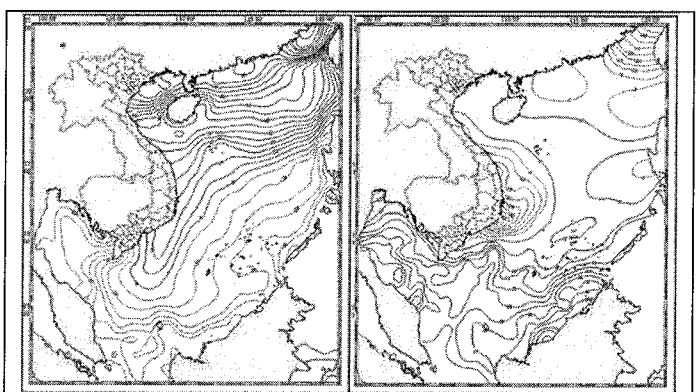

Figure 2: Spatial distribution of EOF1 and EOF2 components

The EOF3 component is characterized by the expansion of the tongue of cold water from the coastal upwelling in the south central of Viet Nam. In the time El Nino occurred (1997-1998; 2001 - 2002), at the end of South-West monsoon, the tongue of cold water expanded very far to the Spartly islands (in September)

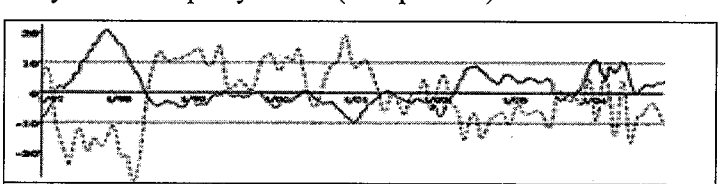

Figure 3: The relationship between temporal EOF3 (solid line) and SOI (dashed line)

2, Curl of wind tress and up-welling areas in South China Sea: by using PFEL (Pacific Fisheries Environmental Laboratory) live assess server from one of website of NOAA http://www.pfeg.noaa.gov for collecting monthly wind product – wind stress and their Curls. Base on hydrograph opinion, positive wind stress curl will caused upwelling event and negative values will

cause down-welling, we found 4 sub upwelling areas exist in SCS, in which 2 areas appear during south west monsoon (summer) and 2 others happen during North East monsoon (Winter) (Figure 6)

Publications of Land and Son (2000 /7/) , Tan and Ishizaka (2005) /9/ also found above rules base on observation data as well as sattelite data.

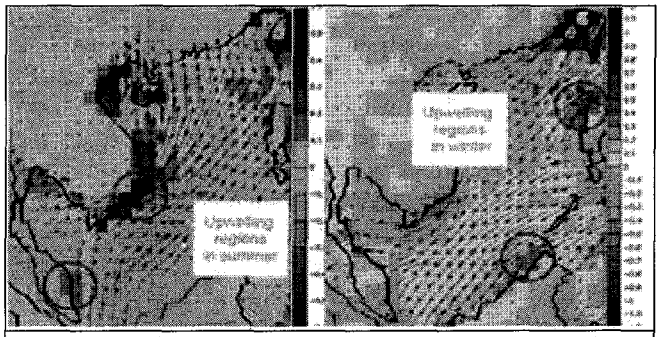

Figure4 : Curl of wind stress for detecting of up-welling areas in South China Sea.

3, MCC method for extracting advection surface current from AVHRR image pairs: The derived velocity vectors plotted on the AVHRR thermal infrared image pairs by MCC method in studied region (from Phu Yen to Vung tau) show that in this region exist a cyclone eddy with large scale in both monsoons : South West monsoon (SWM) and North East Monsoon (NEM) (figure 5). These cyclone eddies close to coast , during summer (or SWM), it is smaller and lies in coastal water of Ninh Thuan – Binh Thuan according to upwelling region. During winter (or NEM) this cyclone eddy enlarge to offshore as well as toward North side. The formation mechanism of cyclone eddy related to effect of cold water tongue from north side penetrate toward south side through Luzon strait. This strong cold current press close to coast, create surf water and down-welling phenomena in coastal water . In order to balance with offshore water mass, current will return toward offshore as well as North direction and forming this cyclone eddy.

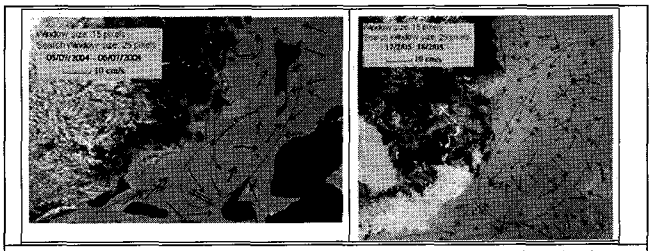

Figure 5 : The advection surface current field during SWM as well as NEM which extracting from AVHRR image pairs

The frequently existence of Southward cold water current along the coast of central Vietnam in both seasons (SWM as well as NEM) also have been recorded on the basis of observation data collected mooring buoy stations (V.V.Lanh and D.V.Hoan 2000) /6/.

These relatively coincide with results that was calculated by hydrographical method (the derived current field extract from oceanography data source of temperature, salinity and density - dynamical height method (Vo van Lanh and Tong Phuoc Hoang Son – 2002 /4 /).

4, Explanation the mass coral mortality by ocean colour images: During Mid October of 2005 a mass mortality of the corals and benthos occurred surrounding Con Dao Islands (South Vietnam) where is the recognized as one of the most famous marine parks of Vietnam. Results from the field survey in October 2005 showed that the mass mortality of corals focused only on the North-West of the islands whereas there was almost no death recorded in the South - East parts. Another record showed that the mass mortality happened mainly in the shallow waters (2 -3 m) while in the deeper waters (5-6 m), the amount of dead organisms was negligible. Based on field data it was assumed that an overlap between high water temperature (>30°C) and low salinity (<25‰) during short term was the impact causing the situation. We tried to explain this phenomenon based on the hydrographical view together with analyzing ocean color images.

Time series analysis of satellite data (Giovanni data) also showed that during October 2005, the concentration of chlorophyll-a and suspended matter (K490) increased drastically (chlorophyll-a increased 6 times, K490 increased 3 times compared with the monthly average value of the data series from 1998 – 2006). Mid October 2005 was a period of many natural disasters such as heavy, extended rain and flooding in Mekong delta. These indirect evidences (instead of sea water salinity) clearly show the effect of fresh water from Mekong water plume.

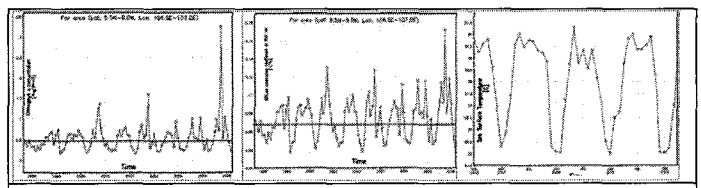

Figure 6: The monthly variability of Chlorophyll-a (left) and K490 (mid) and SST (right) show that extreme increasing of Chlorophyll-a and light attenuation coefficient – K490 as well as SST in October 2005

On the global scale, October 2005 was considered as one of the hottest months in history which may be further evidence of the effects of warmer water mass from Mekong river.

The distribution pictures of sea surface temperature, total suspended solid matter, Chlorophyll-a and Turbidity (obtained from MODIS images) showed more clearly the effects of the warm, fresh water tongue which carried high concentrations of suspended solid matter from the Mekong river system to the sea during October 2005. All of the picture show that this fresh, warmer water tongue only impacted the northwest of the island. It broke up the temperature structure of the cold water mass coming from northern side of South China Sea and impacted Con Dao island during the highest rainfall period of year (October).

Figure 7: The spatial variability of SST(left) and Chlorophyll-a (mid) and (right) Turbidity during 11st October 2005 show more clearly the effects of the warm, fresh water tongue with high turbidity from the Mekong rivers hit to NW Condao Island

The random coincidence of the extreme increase of sea surface temperature with lower reducing sea water salinity as well as high turbidity (mainly due to water plume from Mekong rivers) during 10-13th October 2005 is main reason causing mass mortality of corals and benthos in Con Dao Island.

5, Capacity building on the remote sensing in Vietnam: Ocean color remote sensing has been used to forecast fishery grounds, potential harmful algae blooms, visualize the effects of upwelling. In developing countries, where funding maybe limited, remote sensing may be one of the means for gathering the preliminary database. In order for the students to fully exploit the utility of remote sensing data and gain the ability to conduct independent research, students need lectures in optics physics complemented with field work and the ability to run remote sensing, GIS, and database software. Ocean colour data are also free for research purposes. Thus, for some, and especially those in developing countries, ocean colour data are one of a few means of data (albeit sea surface data) available to characterize an environment or process. A training to better understand optical theory and properties and the utility of ocean colour data and software will empower the staff at the Institute to conduct independent research in the waters of Southeast Asia, an area that has not been thoroughly investigated , preliminary because there is a lack of data. In April 2006, thank to the support of the POGO foundation, Drs. Joji Ishizaka from Nagasaki University (Japan) and Mati Kahru from Oceanography Script Institute (USA) trained 20 researchers from the Institute of Oceanography and outside institutions in Vietnam. A follow-up training project of Nippon – POGO have been preparing and will carry out in 2007. By mean of these projects, the knowledge as well as special skills of Vietnamese researchers have been improved and enhanced clearly. These are important human resources in applied oceanography in Vietnam in present time and near future.

CONCLUSION:

- The remote sensing is powerful oceanographic tools not only for Integrated Coastal Zone Management (ICZM) but also for various areas of oceanography.
- By mean of ocean colour remote sensing, main hydrological, dynamic structures of South China Sea have been found.
- Capacity building on the ocean colour remote sensing have been built step by step in Vietnam. These are important human resources in applied oceanography in Vietnam in present time and near future. Some study fields in Vietnam as monitoring Red Tide and HAB, forecast the fishery domain, study of upwelling phenomena and their ecological effects will use these techniques in owner researches.

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