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CZCS (Coastal Zone Color Scanner)에 의해 관측된 제주해역의 생물생산력 특성

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Biological productivity of Cheju Island area (East China Sea) observed by CZCS (Coastal Zone Color Scanner)

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Despite the high fish productivity, little has been known for the phytoplankton dynamics and primary productivity of the marine ecosystem adjacent to Cheju Island. The region is under the influence of different water masses with varying strength during the course of the year, which in turn drive the phytoplankton dynamics.

To the east of Cheju Island where Tsushima Warm Current passes, the phytoplankton biomass was very low throughout the year. On the other hand, to the west of Cheju Island, active production during spring through autumn due to the frequent runoffs from Changjiang River was observed. This feature contrasts to that of the Yellow Sea where there seems to be typical bimodal peaks in the annual growth of phytoplankton and primary production is kept low during summer by strong stratification.

Key words : Ocean Color, East China Sea, Productivity

INTRODUCTION

East China Sea has been known to fishermen as a very productive area for hundreds of years. There have been, however, a limited number of studies on the ecological characteristics of the area, which aim to elucidate the phytoplankton dynamics and primary productity of the marine ecosystem. Consequently, little is known about these properties. One of the few available estimates of primary productivity of the region (Nishimura, 1983), for instance, ranges 150 ~200gC/㎡/yr for both Yellow Sea and East China Sea. It is rather a low value compared with other continental shelf areas of the world (Walsh, 1988). It seems an underestimate considering the high fishing yields of these seas.

Nor are known the characteristics of phytoplankton dynamics, e. g., timing and duration of blooms. For the Yellow Sea, it has been suggested there are a spring and an autumn bloom as part of the annual cycle

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like other areas of the North Pacific. We do not know, however, details of the dynamics and spatial patterns. Less is known about for the East China Sea.

Here, I will review some of the available ocean color images by CZCS (coastal zone color scanner), which show characteristics of the phytoplankton dynamics of the region.

MATERIALS AND METHODS

Characteristics of CZCS

The characteristics of CZCS are described in literature (e. g. Robinson, 1983). The principles of ocean color remote sensing and processing the ocean color data were discussed by Gordon and Morel (1983). Since only three visible channels are available with CZCS and consequently empirical algorithm is used, it is difficult to assess quantitatively the effect of suspended sediments and CDOM (colored dissolved organic matter) on the estimate of pigments. While quantitative assessment of plant pigments by CZCS has been known quite successful, it is not so with Case 2 water, where constituents other than phytoplankton pigments affect the water color significantly. Readers are referred to the description of the methodological problems associated with ocean color analysis in Case 2 waters by Holligan *et al* (1989).

Data and processing

Level 1b LAC CZCS data have been used for this study. The raw data were provided from GSFC/DAAC, NASA. Images were processed using PC-SEAPAK packge (McClain *et al.*, 1992). In processing ocean color images, two fundamental problems have to be solved; atmospheric correction and pigment estimation algorithm.

The atmospheric noise comprises more than 90% of the signal which the sensor received and presents a difficult problem in interpreting the images. Due to its vicinity to the continent, the atmosphere of the Yellow Sea is under the strong influence of continental haze and the Yellow Dust from the GobiDesert (Fukushima, 1989).

Since the swath width of CZCS was about 1, 600 km wide, some of the scenes contain both the Yellow Sea area and rather clear water of the East Sea (Japan Sea) or upper Pacific region. Therefore it was possible to obtain estimates of the Angstrom exponents applying the Clear Water Radiance Method (CWRM) with multiple scattering model (Gordon *et al.*, 1988) and apply them to the entire scene. However, this assumption of homogeneous distribution of aerosol particles over the entire scene is not warranted, particularly in the marginal area of continent.

Therefore, after applying CWRM estimates to the Yellow Sea scene, the residual scene was carefully examined for any particular aerosol structure. In PC-SEAPAK this could be easily made by using ANGST module which implements Arnone and LaViolette (1984) method. Whenever CWRM was not available, Arnone and LaViolette method was used.

The in-water algorithm (relating water-leaving radiances to the pigment concentration) used here is by Gordon *et al.*, (1983) ;

$C1 = 1.13\,(Lw443/Lw550)^{-1.71}$

$C2 = 3.326\,(Lw520/Lw550)^{-2.439}$

if $C1 > 1.5$ and $C2 > 1.5$ then $C = C2$

otherwise $C = C1$

where C is pigment (chlorophyll a and phaeopigments) cncentration in mg/m^3

Image presentation

Accuracy of the above algorithm when applied to Case 2 water like the Yellow Sea is questionable. Therefore, images are presented in two types: RGB composites and false-color image of calculated pigments concentration. RGB composites are made from three channels (443, 520, 660 nm without atmospheric correction and 443, 520, 550 nm with atmospheric correction). Thus these are true color or semi-true color. In the RGB composites, the presence of phytoplankton pigments and CDOM is indicated by dark (black) color since these strongly absorb lights (particularly in red and blue region).

On the other hand, suspended sediments appear bright white or yellow since these particles reflect lights in all three channels. It should be noted that over-estimation of pigments by above in-water algorithm can be resulted simply by having high sediment load (which increases the reflectance in the 550 nm channel). Therefore, pigment images should be double-checked with corresponding RGB composites to verify that pigment values are due to real pigments rather than due to high sediment loads. Computed pigments values are presented using false-color, and color code is pre-sented in Figure 1.

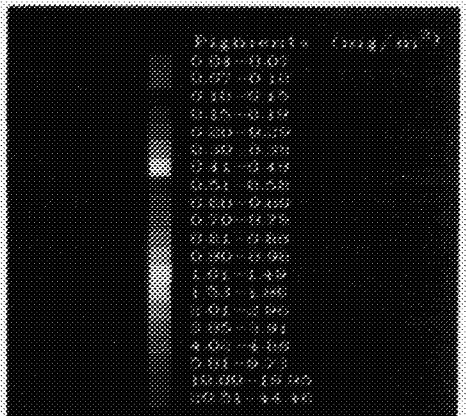

Fig. 1. Color code for falsecolorpresentation of pigment concentration.

SATELLITE IMAGES

The seas around Cheju Island are under quite different hydrographic conditions. It is possible to identify four notable water masses around the island (Lie, 1984) : Yellow Sea Cold Water, Tsushima Warm Current, runoff from the Changjiang River, and Coastal Waters along the coastal area of the Yellow Sea. These water masses influence the phytoplankton dynamics adjacent to Che-ju island with varying strength depending on the time of the year.

Figure 2a is a true color composite image of March 2, 1980. It is not corrected for atmospheric noise. In the image, suspended sediments appear bright yellow or greenish yellow. Two features are obvious from the image. Coastal Current along the Chinese coast carried huge amount of suspended sediments southeast most of which were resuspended from sediment deposit near the

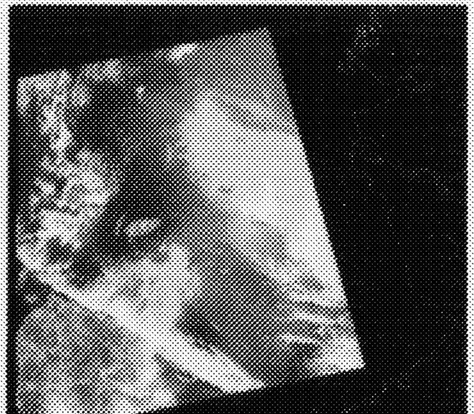

Fig. 2a. A true color composite of channel 1, 3, 4 of CZCS without atmospheric correction (March 2, 1980).

old mouth of the Yellow River. Even from this uncorrected image, it can be seen that the Yellow Sea is very turbid indeed. Another region of strong tidal mixing is the southern tip of Korean Peninsula (Mokpo area).

Although it appears that pigment value is high (Figure 2b), it is not real. This error is due to the inability of CZCS in distinguishing the pigments from sediments. In Figure 2c, a semi-true color composite with atmospheric correction is shown. Here, suspended sediments appear bright white or yellow. By comparison, it is obvious that the high pigment value in the false-color image is in fact due to the high sediment load. It should be noted that high turbidity corresponds with the pattern of computed stratification parameter (Lie, 1989)

During the spring after the water column becomes stabilized, spring bloom occur in the Yellow Sea and the East China Sea. High value of pigment in the central part of the Yellow Sea and around the Cheju Island (Figure 3a) was real as can be verified by composite of the same scene (Figure 3b). In the composite image, high pigment values correspond to dark (black) color indicating

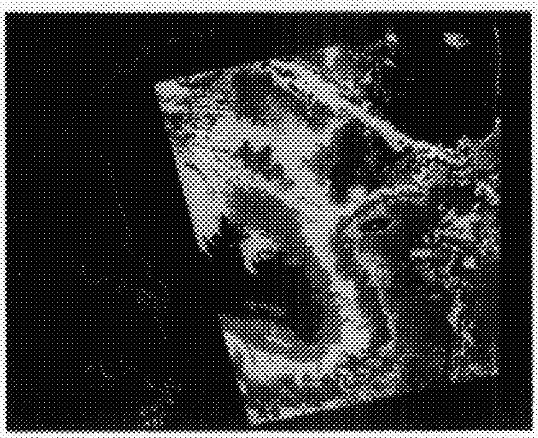

Fig. 2b. A false-color image of calculated pigment value (same date as 2a).

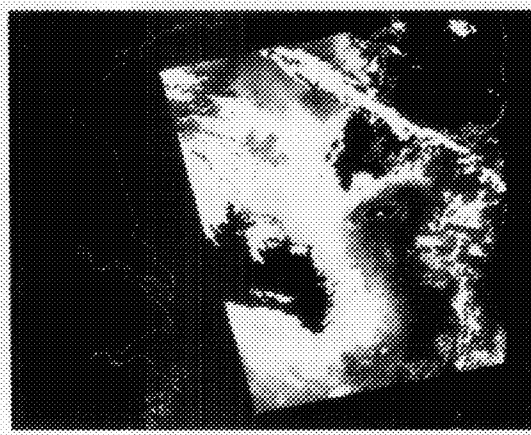

Fig. 2c. A semi-true color composite of channel 1, 2, 3 after atmospheric correction (same date as 2a).

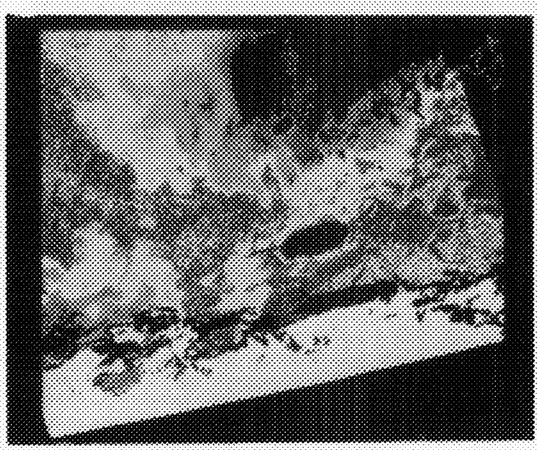

Fig. 3a. A false-color pigment image of May 2, 1980.

Fig. 3b. A semi-true color composite of the same scene as 3a.

phytoplankton pigments, except the Mokpo area where there were still very high sediment loads.

Around the end of May or early June, spring bloom ceased as stratification strengthened. In figure 4a, three aspects are noteworthy : 1) In the Yellow Sea, entire area except near-shore region with strong tidal mixing was stratified resulting in low pigment level; 2) weakening of Tsushima Warm Current forming fronts along the southern coasts of Korea and along the shelf break; 3) near the Changjiang River mouth, substantial production was sustained and extended to the west of Cheju Island. This trend continued on as the season progressed. Note that stratification in the Yellow Sea strengthened as in figure 5. On the contra-ry, active production was present in the East China Sea probably due to the runoffs from Changjiang River.

The continuation of active production seems to persist throughout summer in the vicinity of the Changjiang River mouth (Figure 6). This feature was observed repeatedly in 1981 and 1982 and is probably the typical pattern of the region (Yoo, 1994).

In the autumn as water column becomes destabilized, a second bloom occurred in the

Fig. 4. A false-color pigment image of June 4, 1980.

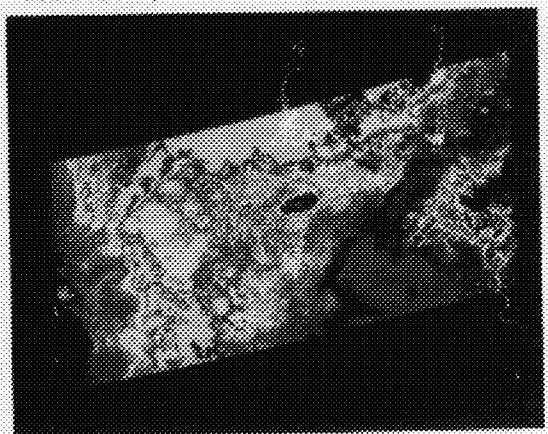

Fig. 6. A false-color pigment image of August 6, 1981.

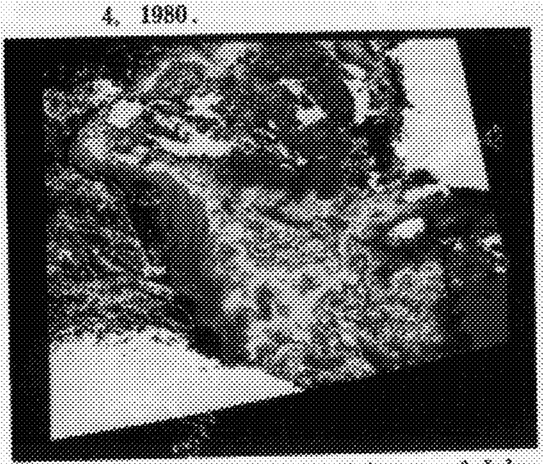

Fig. 5. A false-color pigment image of July 23, 1981.

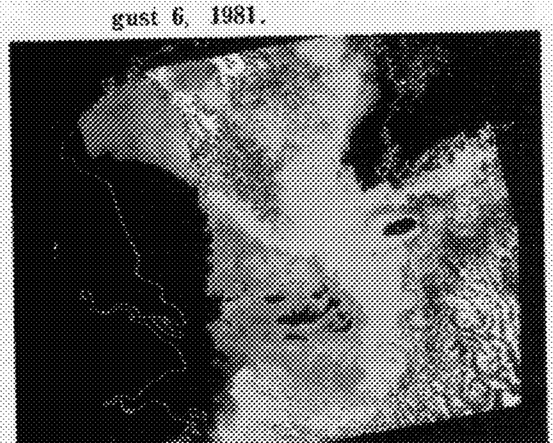

Fig. 7a. A false-color pigment image of October 2, 1980.

central Yellow Sea and west part of the East China Sea (Figure 7a). At the same time Coastal Current strengthened (Figure 7b). Coastal Current prevailed throughout the winter until March. In figure 8, Coastal Current was seen flowing south-eastward.

CONCLUSION AND SUMMARY

In the Yellow Sea, stratification appears to be the major controlling process of phytoplankton dynamics (Yoo, 1994). After the water column was stabilized, nutrients became limiting. This kept the phytoplankton biomass and productivity at low level until the stratification weakened in the autumn.

On the contrary, stratification did not inhibit the continual production in the East China Sea (the region west to Cheju Island) since river runoffs provided nutrients to the upper layer. The phytoplankton biomass was kept high even during the summer time. Thus the primary productivity of the region seems to be quite high indeed.

To the east of Cheju Island, however, the story is quite different. This region is under the influence of Tsushima Warm Current throughout the year. Primary productivity of the water mass is low as indicated by low pigment concentration (<0.1 -0.2 ㎎/㎥) all the year around. It is interesting to note that this hydrographic regime is exactly reflected in the structure of fish community (Yoo and Shin, 1994).

Although CZCS data revealed qualitative features of phytoplankton dynamics of the region, it fell short of quantitative assessment. This inability is expected to be remedied with the secondgeneration ocean color sensor, SeaWiFS (Sea-viewing Wide-Field-of-view Sensor), which has four additional channels and higher S/N ratio (Hooker *et al.*, 1992). These ad-ditional channels will allow a muchimproved algorithm for atmospheric correction as well as pigment assessment. SeaWiFS is scheduled to be launched in July, 1994.

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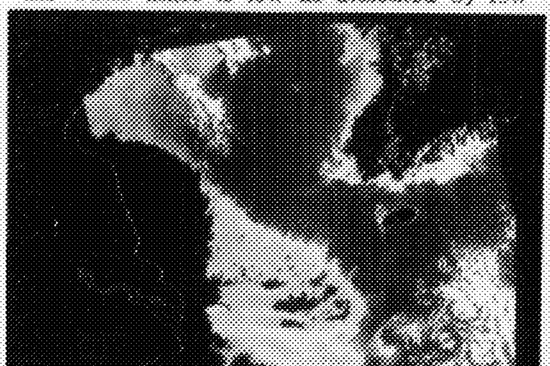

Fig. 7b. A semi-true color composite of the same scene as 7a.

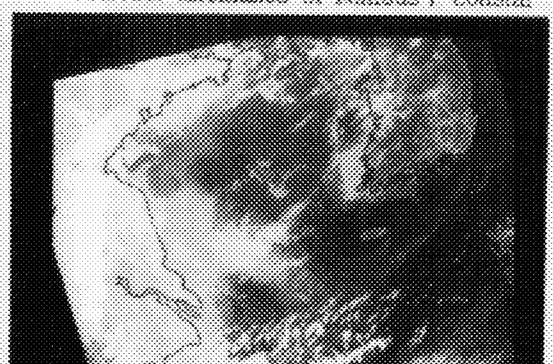

Fig. 8. A true color composite of November 18, 1980.

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요 약

제주해역 (동중국해)은 높은 어획량을 보이지만 식물플랑크톤 역학이나 생산력에 대해서는 잘 조사되지 않았다. 이 해역은 연중 다양한 수괴의 영향 아래에 있으며 식물플랑크톤의 역학도 이에 영향을 받고 있다.

제주도 동쪽 해역은 연중 대마난류의 세력 아래 있어 식물플랑크톤의 생산력이 낮다. 반면 서쪽 해역은 양자강 담수의 유입으로 봄에서 가을에 걸쳐 지속적인 생산이 일어나는 것으로 보인다. 이는 성층에 의해 봄, 가을 증식시기를 제외하면 생산력이 낮게 억제되는 황해와는 대조적인 것이다.