Estimation of Sea Surface Current Vector based on Satellite Ocean Color Image around the Korean Marginal Sea

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Abstract: One of the most difficult parameters to measure in the sea is current speed and direction. Recently, efforts are being made to estimate the ocean current vectors by utilizing sequential satellite imageries. In this study, we attempted to estimated sea surface current vector (sscv) by using satellite ocean color imageries of SeaWifs around the Korean Peninsula. This ocean color image data has 1-day sampling interval and spatial resolution of 1x1 km. Maximum cross-correlation method is employed which is aimed to detect similar patterns between sequential images. The estimated current vectors are compared to the surface geostrophic current vectors obtained from altimeter of sea level height data. In utilizing the color imagery data, some limitations and drawbacks exist so that in warm water region where phytoplankton concentration is relatively lower than in cold water region, estimation of sscv is poor and unreliable. On the other hand, two current vector fields agree reasonably well in the Korean South Sea region where high concentration of chlorophyll-a and weak tide is observed. In the future, with ocean color images of shorter sampling interval by COMS satellite, the algorithm and methodology developed in the study would be useful in providing the information for the ocean current around Korean Peninsula.

KEY WORDS: SeaWiFs, Ocean color, MCC, current vector

1. Introduction

Under the plan to launch a communication ocean meteorological satellite which is a multi-purpose geostationary orbit satellite in 2008, currently COMS & data processing software is under development in Korea. This communication ocean meteorological satellite is equipped with various sensors and will conduct real-time monitoring of the ocean and the atmosphere of the Korean marginal sea in geostationary orbit. It is anticipated that the sea surface temperature (SST) and ocean color data of this satellite data will greatly contribute to the understanding of physical and biological characteristics of the ocean. In this study, we have tried to estimate the ocean surface current vector from the ocean color images as an example of the study to attain dynamic information from simple information of image data of the physical property of the ocean such as the direction and speed of the ocean current, location of front, and distribution of eddies.

2. Method and Algorithms

Algorithms for SeaWiFs ocean color data processing: In this study, to process the SeaWiFS ocean color data, we have broken down the image processing stage into 2 stages. In the first stage, gappy pixels of the imagery is detected and in the second stage, the noise signal within the image is eliminated by using the imagery mapped with gapppy pixels.

In the first stage of image processing, we have mapped the partial data gap of pixel units, calculating the mean within the area by dividing the image into sub-areas. On the basis of this result, we have conducted the smoothing method of the image with 3x3 pixels to eliminate the noise within the image to enhance the consistency of the pattern between images within the range which does not greatly change the image structure. As a result, it was confirmed that the noise was effectively removed without deteriorating the quality of the raw data.

We have used the image processing algorithm which partially enhances the ocean color prior to estimating the surface current vector from the ocean color. The enhancement of image is a method of increasing or decreasing with a minimum value of '0' or a maximum value of '255' after calculating the minimum value or maximum value from the SeaWiFs ocean color data of chlorophyll-a which was observed. At this point, the image enhancement algorithm conducts image enhancement of two data from the search image and pattern image within the same range as the size of the search tile used for estimating not the entire raw image data but one current vector (Figure.1).

Maximum Cross-Correlation Method: The Maximum Cross-Correlation Method is a method which estimates the current speed in the direction that has the maximum correlation coefficient by calculating the correlation coefficient between SST images (Figure.1). And this method was first used in the aspect of geophysics on the movement of clouds (Leese et al., 1971). Another similar method was used on the moving condition of ice (Ninnis et al., 1986, Collins and Emery, 1988). There are also studies on the ocean of Emery et al. (1986), Kamachi (1989), Wu et al. (1990), and Kim and Ro (2000).

These MCC method uses two sequential images of the same resolution and determines the point where it has similar areas with the even smaller P(i, j) acquired from

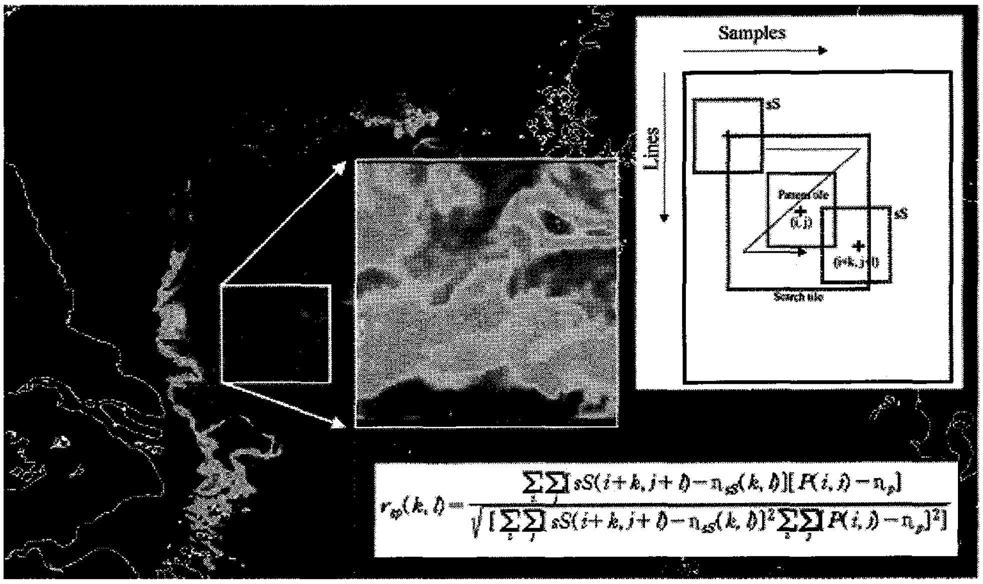

Figure 1. Algorithm of partial image enhancement for SeaWiFs data and algorithm for current vectors estimation

the sub-area(sS) inside the image and the first image by selecting partial image S(m, n) from the second image. Here, we call P(I, j), 'Pattern tile' and S(m, n), 'Search tile.' Pattern tile is included in the center of the same area as the Search tile in the first image. At this point, the correlation matrix between the Pattern tile and the Search tile is calculated with the following formula.

$$r_{sp}(k,l) = \frac{\sum_i \sum_j [sS(i+k, j+l) - \eta_{sS}(k,l)][P(i,j) - \eta_P]}{\sqrt{[\sum_i \sum_j [sS(i+k, j+l) - \eta_{sS}(k,l)]2 \sum_i \sum_j P(i,j) - \eta_P]2]}}$$

However, $\eta_{SS}(k,l)$ is the mean of the subarea(sS) within the Search tile which has the same size of arrangement as P(i,j). The calculation is done by calculating the correlation coefficient of the Pattern tile in relation to all the sub-areas (sS) within the Search tile. η_P value is the mean value on the Pattern tile. The value of k and l are values changing within the correlation coefficient included in P(i, j).

In the stage of developing the algorithm for this study, we have conducted research by setting the size of the pattern tile to 19x19. Through conducting repetitive research, we have set the Low limit critical value for estimating the information of the overall current pattern of the ocean being studied to 0.75.

3. Application example in Korean marginal seas

In this study, we have tried to estimate whether or not it is possible to estimate the ocean surface current vector from the SeaWifs ocean color data observed in intervals of approximately 1 day. The distribution of chlorophyll-a ocean color observed on SeaWifs is initially determined by the primary output of marginal seas around the Korean peninsula. The spatial distribution of this chlorophyll-a is greatly effected by the currents and tides of the ocean.

The surface current speed of Korean marginal seas estimated from SeaWifs ocean color data has the following characteristics according to each sea area. The general current field of the ocean surface has a huge difference from the current field calculated from sea surface height (SSH) in the mid-northern waters of the West Sea. In the case of the West Sea, the distribution of phytoplankton can be affected by the influence of the tides and there is a difference between two data due to the inaccuracy of the sea surface height (SSH) which appears in coastal regions. In the case of the East Sea, it was difficult to estimate the surface current vector from the SeaWifs data since the warm water region had a low concentration of phytoplankton compared to the cold water region. However, in the cold water region, it was comparatively easier to estimate the surface current vector, and its results matched well with the current field of the sea surface height (SSH). In the case of the South Sea, the estimation of the surface current vector was carried out satisfactorily compared to other seas by comparatively weak tides and high concentration of chlorophyll-a.

From the findings in the Korean South Sea in April of 2003 and 2004, the spatial distribution of the current is well-matched between the current vectors calculated from the sea surface height (SSH) and distribution structure of estimated current vectors from the ocean color. Among the findings during this period, We have compared the current vectors near the Jeju strait with the ADCP fixed point observed by National Oceanographic Research Institute (NORI) since both relatively correspond with each other (Table 1). If you look at the results of

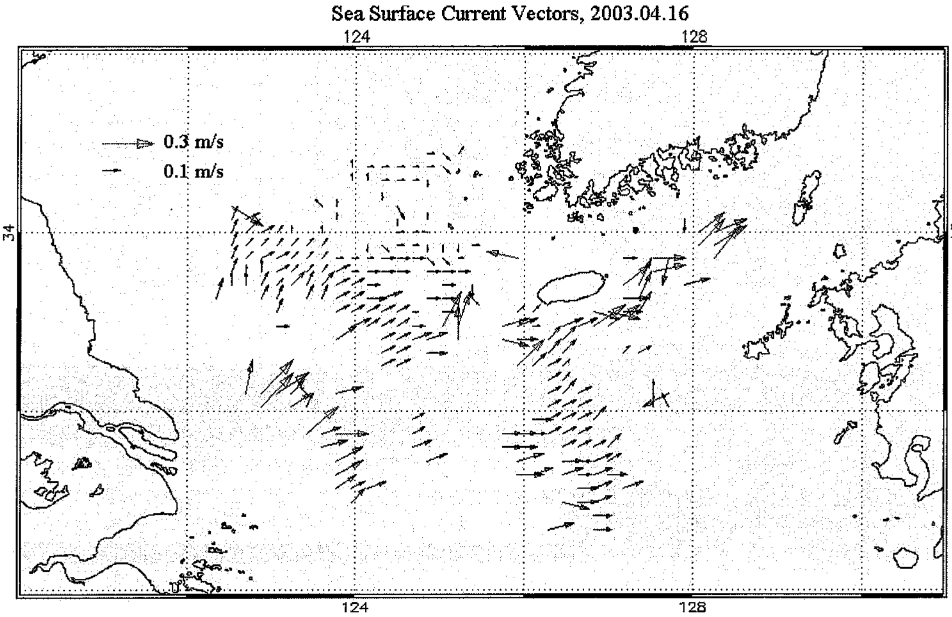

Figure 2. Estimated ocean current vectors by SeaWiFs Ocean Color (2003.105D,04:02 and, 2003.106D,04:40)

Table 1. Comparison between the estimated current vectors by SeaWiFs ocean color and observed data by ADCP.

	Long.	Lat.	Vel.(m/s)	Dir.(deg.)	Coeff.
2003.04					
SeaWifs	128.072	33.853	0.21	50	0.79
	128.072	34.001	0.19	58	0.77
	128.251	33.704	0.24	44	0.84
	128.251	33.853	0.22	64	0.87
	128.251	34.001	0.20	72	0.75
		mean	0.21	57	
ADCP	128.056	34.185	0.23	67	
	128.121	34.127	0.24	67	
	128.186	34.075	0.16	82	
	128.251	34.023	0.16	93	
		mean	0.20	77	
2004.04					
SeaWifs	127.780	33.848	0.09	31	0.90
	127.780	34.002	0.09	31	0.82
	127.966	34.002	0.09	32	0.73
	127.966	34.156	0.09	32	0.72
	128.339	34.156	0.15	61	0.75
	128.339	34.310	0.12	50	0.73
		mean	0.11	39	
ADCP	128.056	34.185	0.22	49	
	128.121	34.127	0.21	72	
	128.186	34.075	0.21	47	
	128.251	34.023	0.22	40	
		mean	0.21	52	

two current vectors in April 2003, and the ADCP observation results for the eastern sea of Jeju Island were similar to the current of 0.2 m/s from the satellite. The direction was similar with ADCP being 57° and the result by the algorithm of this study being approximately 77°. In April 2004, while there was a twofold difference between the current speed estimated from the ocean color data being 0.1 m/s and ADCP current speed being approximately 0.2 m/s, but the direction was relatively similar with them being 39° and 52°, respectively

4. Conclusions

In the satellite image data, various errors due to the reception condition of the receiving station or weather conditions are included in it. Therefore, in order to use this image data, a technology which eliminates noise is needed. In this study, we have conducted image processing by applying the smoothing method of 3×3 pixels to eliminate the noise in the image after calculating and mapping the mean from the gap data and marginal data of the satellite image.

In order to enhance the performance of estimating current vectors from the image processed satellite image data, we have developed an algorithm which enhances the image using the minimum value and the maximum value within the pattern tile and search tile. This algorithm displayed an enhanced performance compared to the existing current vector estimating method. It can also be used on both sea surface temperature (SST) and ocean colors capable of being used for estimating surface current vectors.

We could estimate the current vector field from the Seawifs color images which agrees reasonably well with the local current measurements. The preliminary result of this study seems promising in providing useful informations for the surface current around the Korean marginal seas. This method would also be utilized in forecasting the trajectory of the red tide frequently occurring in the South Sea

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