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Assessing Sea Surface Temperature in the Yellow Sea Using Satellite Remote Sensing Data

Kyoo-seock Lee* and Hee Sook Kang**
*Assistant Professor, Dept. of Landscape Architecture, Sung Kyun Kwan University
**Graduate Student, Dept. of Oceanography, Chungnam National University
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Abstract

The first Marine Observation Satellite(MOS) was launched by National Space Development Agency of Japan on February 19, 1987, and it is equipped with three sensors covering visible, infrared, and microwave region. One of them is Visible and Thermal Infrared Radiometer(VTIR) whose main objective is to detect the Sea Surface Temperature (SST). The objective of this study was to process the MOS data using Cray-2 supercomputer, and to assess the SST in the Yellow Sea. In order to implement this objective, the linear regression model between the ground truth data and the corresponding digital number of VTIR in MOS was used to establish the relationship. After testing the significance of the regression model, the SST map of the whole Yellow Sea was derived based on the model. The digital SST map representing the study area showed certain pattern about the SST of Yellow Sea in March and April. In conclusion, the VTIR data in MOS is also useful in investigating SST which provides the information about the Yellow Sea water current in the spring.

I. Introduction

Satellite remote sensing technique is useful in extracting the information from the large area which cannot be obtained using the aerial photography. Especially, if the area conerned is the sea whose data are relatively homogeneous, it can be applied usefully. So far the Advanced Very High Resolution Radiometer(AVHRR) of National Oceanic and Atmospherical Administration(NOAA) meteorological satellite has been used in deriving the SST. However, the area of sea nearby Korean peninsular has not been reported for the SST in using MOS VTIR data because collecting VTIR data has been begun recently. The VTIR is a radiometer intended to observe the earth using one band in the visible region and using three bands in the infrared region. The wavelength range of VTIR is close to that of NOAA AVHRR data(Table 1). The ground resolution of the VTIR is about 1Km in the visible band and about 3Km in the infrared band(Table 2).

Table 1. The Comparison of the Spectral Region Between AVHRR and VTIR

AVHRR		VTIR	
Channel	Wavelength(μm)	Channel	Wavelength(μm)
1	0.58 to 0.68	1	0.5 to 0.7
2	10.5 to 11.5	3	10.5 to 11.5
5	11.5 to 12.5	4	11.5 to 12.5

Table 2. Characterisitcs of the VTIR Sensor

Wavelength(μm)	0.5－0.7	6.0－ 7.0 10.5－11.5 11.5－12.5
IFOV(Km)	0.9	2.7
Swath Width(Km)	1500	

Therefore, the purpose of this study was to process MOS VTIR data using Cray-2 supercomputer and to assess the SST in the Yellow Sea of Korea. To implement this objective, the linear regression model between the ground truth data and the corresponding digital number of VTIR in MOS was used to establish the relationship. After testing the statistical significance of the regression model, the SST map of the whole Yellow Sea was derived based on the model. The study area, data acquisition, and data analysis methods were described in the following sections, and these are followed by results and discussion sections, and finally the conclusion drawn based on the results.

Ⅱ. Methods

1. Study Site and Data Acquisition

Fig. 1 shows the location of the study site. It covers the Yellow Sea between Korea and China. Three sets of MOS data were provided by the Maritime Police Office in the Ministry of

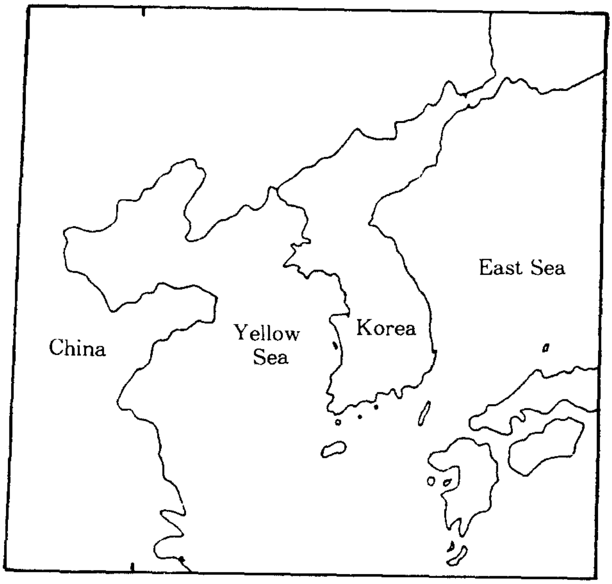

Fig. 1. The Location of the Study Area.

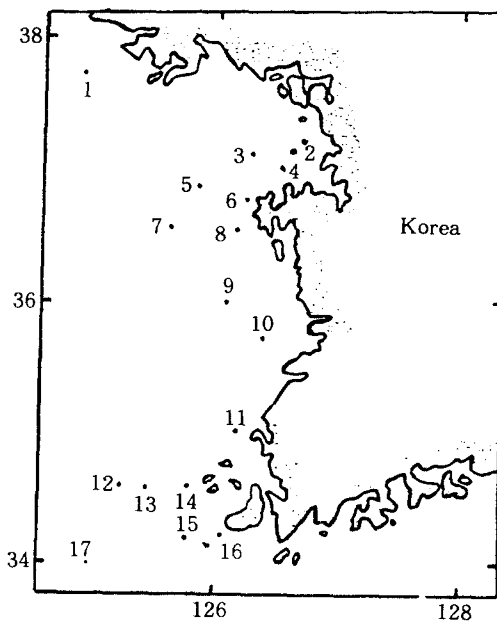

Fig. 2. The Location of Sample Points.

Internal Affairs in Korea whose dates are March 9, April 9, and 22 in 1988. There were significant amount of cloud coverings in Korean peninsular and the East Sea(Sea of Japan) on March 9, and some coverings in the middle Yellow Sea on April 24. The local passing time of MOS satellite was around 14:00 for all three dates.

The ground measurement data of SST were collected and provided by the Ministry of Transportation in Korea. Fig. 2 shows the location of sampling positions, and these all positions were located near the Korean peninsular. The data collection time of ground data was 9:00 to 9:30 a.m..

2. Data Analysis and Remote Access to Cray Supercomputer

Most of the data processing was done from IBM-PC compatible with 80386 processor and 80387 math-coprocessor connected to Cyber at System Engineering Research Institute(SERI), attached to Korea Institute of Science and Technology(KIST) by 1200 bps modem. The Cyber is connected to Cray Supercomputer locally within SERI. Later in this study, Cray access was made possible by Korea Research Environment Open Network(KREON), which is a nationwide network connecting research and educational institutes. The Institute of Space Science and Astronomy SUN 3/280 system was connected to SUN 3/160 system via KREON.

The location of all sample points were measured by latitude-longitude coordinate system based on Bessel datum. These coordinates can be reliable, because the sampling positions are located at the lighthouse sites administered by the Ministry of Transportation in Korea. However, the coordinate system of VTIR data were projected into the Lambert Conformal Conic(LCC) coordinate system. So, the coordinate transformation software was written in Cray system. In order to identify the sampling positions in the ground measurement data and VTIR data, the following procedures were adopted.

(1) The latitude, longitude coordinates of the ground data were converted into the LCC coordinate system.

(2) Based on these coordinates of the ground data, the coresponding row/pixel number of the VTIR data were derived.

(3) The corresponding digital number of row/pixel position and the ground measured SST data were regressed.

The VTIR data for bands three and four were extracted at each sample point, and the ground SST data were regressed using the polynomial regression model which was written in Cray system for this study. The R-square, F-test, and T-test were used to test the statistical signifi-

cance of the regression models. When investigating several orders of regression correlation coefficients, it was shown that the higher order, the more R-square value. However, the T-test for the coefficient was only significant in the first order. So, the first order linear regression model was selected to quantify the relationship between VTIR measurement data and ground measurement SST. Apart from the simple linear regression model, Multi Channel Sea Surface Temperature(MCSST) algorithm that utilizes a set of regression coefficients multiplying the channel 3 and channel 4 brightness values to determine the SST was used.
The multiple regression model used was as follows.

$$SST = a^*(\text{Band } 3 + b^*(\text{Band } 3 - \text{Band } 4)) + C$$

The detailed results were described in the following section.

Ⅲ. Results and Discussion

Table 3 shows the regression coefficients, R-square value, and F-test results of the model derived.

Table 3. Regression Coefficients Derived From the Model

Date	Channel	SST = a * DN + b	R-square	F_0 > (95%)
3. 9.	3	0.4857 * DN – 38.006	0.927	117.9 > 4.54
3. 9.	4	0.4978 * DN – 38.518	0.878	100.7 > 4.54
4. 9.	3	0.5802 * DN – 47.831	0.729	40.3 > 4.54
4. 9.	4	0.5140 * DN – 41.316	0.800	60.0 > 4.54
4. 24.	3	0.6154 * DN – 50.343	0.792	57.2 > 4.54
4. 24.	4	0.4390 * DN – 33.119	0.670	30.5 > 4.54

As we can see in Table 3, April 24 data had a poorer correlationship and the significantly different coefficient value between band 3 and band 4 compared with other data. This can be explained by the fact that there are cloud water vapors in the sampling positions on that date which can be shown in Fig. 3-3, the cartographic display of the Yellow Sea using the SST model based on the above regression equation in band 3 on April 24. March 9 data had also the significant amount of cloud covers in the middle part of Korean peninsular and the East Sea(Sea of Japan). However, the Yellow Sea portion was clear on this date as we can see in Fig. 3-1. So,

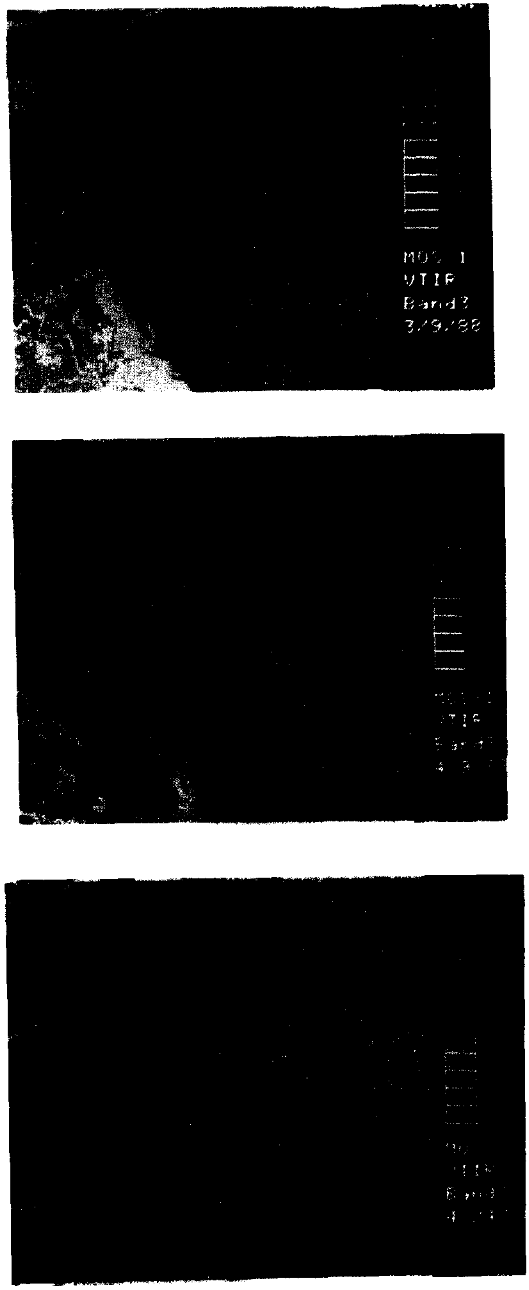

Fig. 3. The SST Maps Based on the Regression Model.

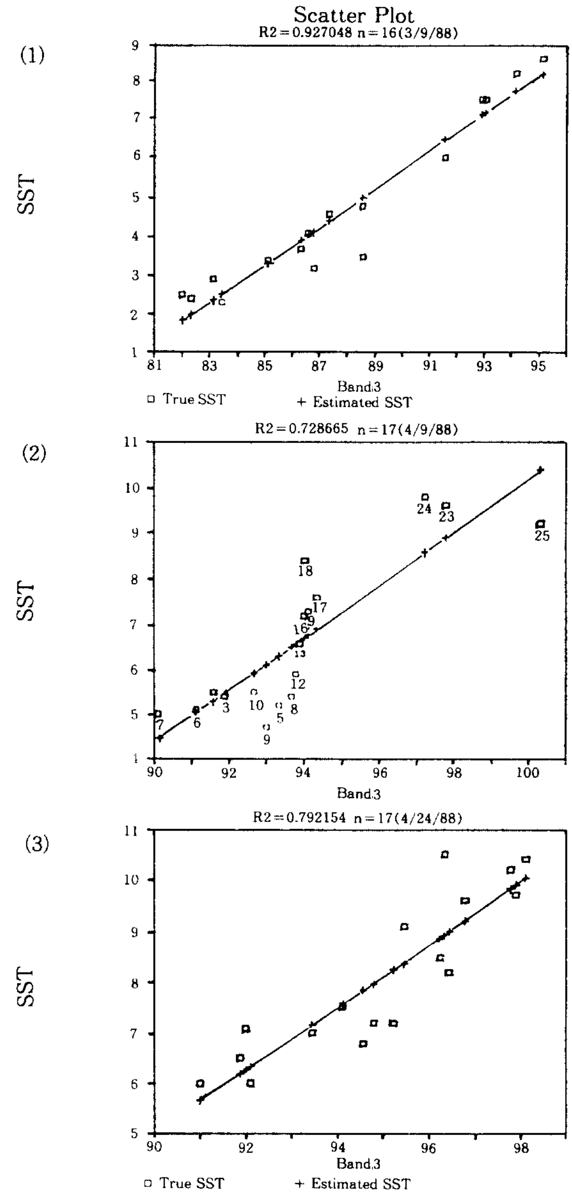

Fig. 4. The Scatterplots of the Regression.

the correlation was very high. Fig. 3-2 shows the eddie whose SST is lower than the surrounding area on April 9. It needs to be investigated more by comparing the data captured on around that date.

For April 9 data, the regression scatter plot does not fit the first order linear regression model which can be shown in Fig. 4-2. It may be due to the diurnal temperature variation because of the time difference between data collection(MOS, around 14:00) and ground measurement(09:30). Another reason could be due to the projection and coordinate transformation error between LCC and latitude, longitude coordinate system. Figs. 4-1, and 4-3 show the corresponding March 9, April 24 data scatterplot, respectively. Based on the first order regression model, March 9 data seem to be the best in establishing the relationship between the ground measurement data and VTIR brightness value.

Apart from the simple regression model, multiple regression approach was tested to know whether MCSST would be better than simple band approach in establishing the relationship. Table 4 shows the multiple regression coefficients, R-square value, and F-test results of the model derived.

Table 4. Multiple Regression Coefficients Derived From the Model

Date	SST=a(Ch. 3+b(Ch. 4))+c	R-square	F_0>(95%)
3. 9.	0.443 * (Ch. 3+2.618(Ch. 3−Ch. 4))−35.2	.953	33.7>4.54
4. 9.	0.512 * (Ch. 3−0.021(Ch. 3−Ch. 4))−41.1	.800	18.9>4.54
4. 24.	0.644 * (Ch. 3+1.270(Ch. 3−Ch.4))−53.3	.743	15.5>4.54

March 3 data also had the highest correlation in the multiple regression model, and April 24, the lowest one like the simple linear regression model. So, the comparison with Table 3 shows that MCSST approach is slightly better than the simple linear regression approach.

Ⅳ. Conclusions

The MOS VTIR data were used to figure out the SST map in the Yellow Sea based on the regression model between the ground data and VTIR data. One of the limitations of the model is that it was derived only from the sample points near Korean peninsular. Those from near China continent and the middle part of the Yellow Sea would increase the accuracy of the relative SST difference in the study area. Another limitation was that the digital number was used instead of the absolute radiance value in VTIR. Despite the above limitations, MOS VTIR data were useful in depicting the relative SST difference and displaying the SST map in the Yellow Sea. The application of VTIR data needs more study together with comparing the AVHRR data.

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