Environmental Information Processing of Closed Bay Area by Remote Sensing

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Abstract

In order to maintain the high quality of environment in a closed bay area we must measure the water qualitiy at closely located points in the area. But it is difficult to get all the measurement data at the same time due to availability of limited measurement devices. To overcome this problem we propose to use remote sensing technique together with some sea truth data. Applying regression analysis for the remote sensing data and sea truth data, we can obtain the distribution maps of water temperature, transperancy, chlorophyll-a, etc. Then we propose methods to remove the atmospheric scattering effect.

Introduction

The rapid growth of industry in Japan affected the serious damages for environment of the air and water quality. One of the damages would be river or sea water pollution. Many rivers or sea bays have become highly nutritious. As a result, the red tide appeared in the sea near bays in Japan in summer and many weak fish were killed. But the mechanism of red tide generation has not been clarified up to now so well.

In order to consider the cause of the red tide we have applied a remote sensing technique by taking into consideration that the remote sensing has advantages to obtain data in a wide range and at the same time. But we have found that the data by the multi spectral scanner include the pass radiance and random noise after data processing. Usually, in order to delete the pass radiance the data near the central part of scanning line have only been used and the remaining data have been omitted from the data processing. Since these data include a part of information about the object pixel. It is meaningful to use the data at the remaining part as much as possible. In this paper, we propose an algorithm to correct the pass radiance based on both the regression analysis and the physical modeling approach.

Study Area and Observation Data

The study area is shown in Fig.1 where the circuled points denote observation points of water qualities when the remote sensing data are measured. The items measured at these points are sea temperature, salinity, transparency, COD, DO, chlorophyl-a, SS, T-P, T-N, and water color. The remote sensing data were observed by airborne multi spectral scanner(MSS) and they were measured in summer for three years from 1980 to 1982.

Regression Analysis

Using the regression analysis for the sea truth data and remote sensing data, we have obtained the regression equations for several observation data. From these regression equations, we can estimate the water qualities in those study area from only the remote sensing data. In Tables 1-3 we show the regression equations. In 1980 we can see that the MSS data of channels 3, 5, and 7 are mainly effective to estimate the chlorophyl-a, transparency,

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Table 1. Regression equations in 1980 where cor.means multiple correlation coefficient and * and ** denote significant F-test for 1% and 5%, respectively.

items	regression equations	cor.	F
chlorophyl-a	$y=-0.35x_3+0.03x_3+0.63x_7-8.93$	0.99	**
transpareny	$y=0.24x_3+0.31x_5+5.36$	0.91	**
SS	$y=-0.13x_3+1.7x_5+2.31$	0.91	**
salinity	$y=-0.01x_3+0.04x_5-0.05x_7+18.3$	0.63	*
sea temperature	$y=0.035x_{11}+21.11$		*

Table 2. Regression equations in 1981.

items	regression equations	cor.	F
chlorophyl-a	$y=-0.46x_6+0.21x_7+24.83$	0.93	**
transparency	$y=0.60x_6+0.10x_7+8.11$	0.91	**
SS	$y=-0.23x_6+0.14x_7+8.51$	0.74	*
salinity	$y=-0.11x_6+0.05x_7+35.57$	0.92	**
sea temperature	$y=0.09x_{11}+12.13$	0.56	*

Table 3. Regression equations in 1982.

items	regression equations	cor.	F
chlorophyl-a	$y=-0.02x_5+7.57$	0.40	*
SS	$y=0.03x_7+0.01x_{11}-5.11$	0.61	**
T-P	$y=0.01x_7-0.01$	0.51	**

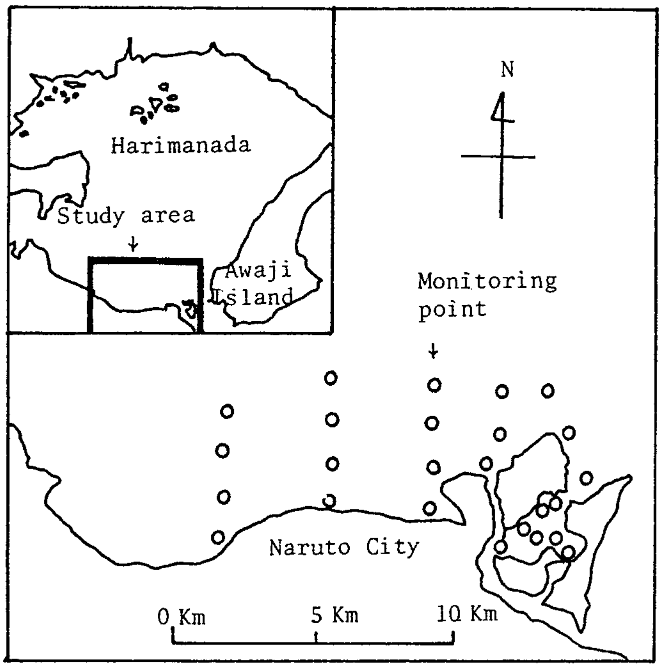

Fig.1. Study area for remote sensing.

SS, and salinity distributions. On the other hand, for the sea temperature the remote sensing data of channel 11 is effective. Similar results have been obtained for the regression equations in 1981 and 1982.

Table 4. Results for quadratic fitting where x ranges from 1 to 268.

channel No.	a	b	c	-b/(2c)
0 ch.	188.2	-1.135	0.004	129.03
1 ch.	148.7	-0.83	0.003	118.57
3 ch.	166.8	-0.943	0.003	131.00
5 ch.	123.0	-0.625	0.002	135.85
7 ch.	120.7	-0.470	0.002	138.29
9 ch.	131.8	-0.300	0.001	149.85
11 ch.	81.8	0.385	-0.001	146.73

Statistical Data Correction

During the data processing of the MSS remote sensing data, we have found that the MSS data have been affected heavily by atmospheric scattering effects. In order to see this, we will pick up the histogram of the MSS levels in the specific area where the observed data by the sea truth are almost equal and there is no object affecting a special effect to produce some biasness in MSS data, for example, a wide range of green grass at one side of the study area. From the histograms of CCT levels, we can find that the remote sensing data have some bias which makes the MSS levels larger near the end points for channels 0 to 10 than the data at the central part in the scanning lines. But the converse phenomena occurred for the channel 11. Therefore, in order to correct this effect we must make some correction model. From computational viewpoints, we fit quadratic curves for column line levels as follows:

$$y = a + bx + cx^2 \qquad (1)$$

where x denotes the column line and y is MSS level. Let Y be the observed MSS data and let M be the average value of column levels. Then the correction algorithm is given by

$$Y = k(y - Y) + M \qquad (2)$$

where k is some gain constant and usually it is equal to 1/2. Table 4 shows the regression curve of (1), from which we can see that for the lower channel, that is, for the higher frequency range the quadratic curve becomes more convex. Furthermore, the coefficient c for channel 11 becomes negative coefficients, that is, upper convex functions.

Atmospheric Scattering Model

In order to see the reason of distortion of MSS data stated above, we consider the atmospheric scattering model. We assume that the MSS observe three components, that is, the radiance reflectance L_r of the object pixel which is denoted by r, the radiant flex scattered from the sun light L_d the radiant flux L_n scattered from the terrain surrounding the object pixel with average reflectance n. Fig.2 shows these components where L denotes the radiance. The first component L_r is the quantity which reaches MSS after the sun light reflected at the object pixel and it will be decreased since the quantity reflected at the object pixel suffers from the absorption and the scattering of the atmosphere. The second component L_d is

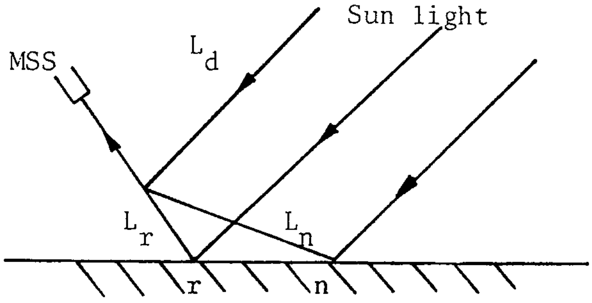

Fig. 2. Three components in MSS.

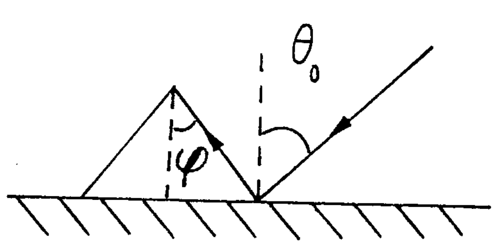

Fig. 3. The relation between MSS angle ϕ and solar zenith Θ_0.

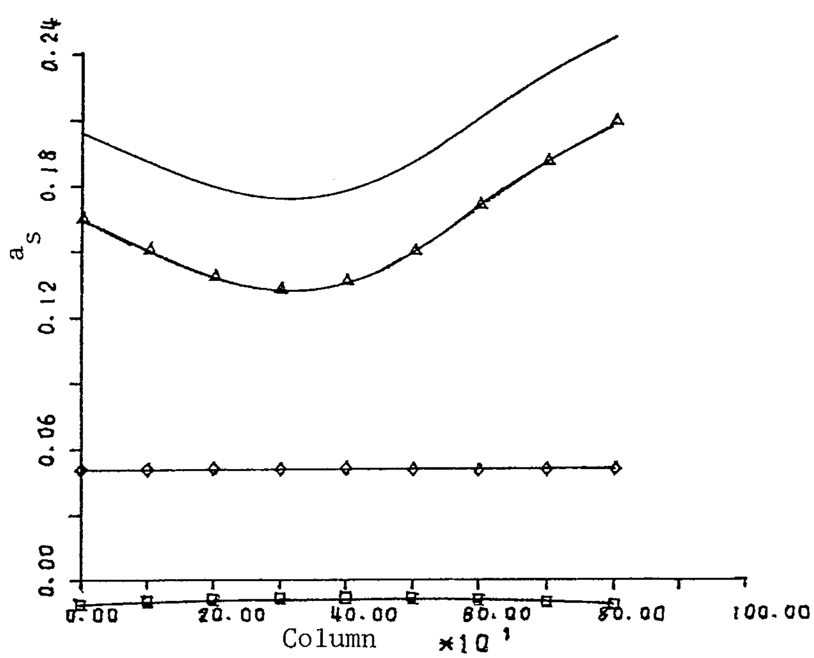

Fig. 4. Results for Θ_0=80°, B=0,061, and W=0.027.

the quantity which directly reaches MSS after the sun light scattered in the atmosphere. This quantity has nothing to do with the earth surface and it is useless when we want to acquire the information of the earth surface. The third quantity L_n is what is reflected from terrian surrounding the object pixel and subsequently scattered to MSS by the atmosphere. The quentity makes the data smooth when we acquire the information of the earth surface.

Based on the single-scattering approximation, that is, an assumption that a photon being scattered either leaves the top of the atmosphere or strikes the surface. J. otterman et al.[1] proposed the atmospheric model of Landsat. They assume that

1) the atmosphere is horizontally homogeneous,
2) the reflectance of the earth surface is constant,
3) the optical thickness of the atmosphere is small, and
4) the earth surface is Lambert plane.

But their model does not include any component concerning with the scanner angle. Thus, we propose another model [1]-[4] based on their model. Let a_s be the reflectivity observed by the airborne MSS and let F, B, and W be optical thickness of the forward scattering, the backward scattering, and the absorption, respectively. Furthermore, let θ_0 be the solar zenith angle and let $\mu_0 = \cos\theta_0$. When the scanner angle is ϕ, we propose the following scattering model:

$$a_s = r\,(1-(B+W)/\mu_0 + 2rB) - r\,(B+W)/\cos\phi + g\,(\cos(\theta_0+\phi))\,b/(2\mu) \quad (3)$$

where $g(\cdot)$ denotes the anisotropy of back scattering to the zenith from the direct beam. Thus, when we think only Rayleigh scattering,

$$g(\mu_0) = 3(1+\mu_0^2)/4. \quad (4)$$

Fig.3 shows the relation between the scanner angle and them simulation results of (3). In Fig.4, ——— denotes a_s and —◇—, —□—, and —△— show the first, second, and third term in the right hand side of (3), respectively. The columns of the horizontal axis are from 1 to 802 and column 1 shows ϕ = 40° and column 802 shows ϕ = -40°. From the simulation result, we can see that 1) the result by using (3) looks like quadratic form, 2) the second term does not change so much and its absolute value is small, which means that the quadratic form of the simulation result is affected mainly by the third term, that is, the path radiance, and finally, 3) the central axis movement of the quadratic curve is due to the land area effect where the high reflectivity by trees or grasses exist.

Conclusions

In this paper, we have proposed to correct the distortion of the remote sensing data from statistical and physical viewpoints. The result by using the physical model used here conformed to that of the statistical model. Thus, we can use each method independently to delete the pass radiance included in the method is more flexible than the physical modeling method since the correction parameters can be estimated by using the observed MSS data. But the statistical method cannot offer any physical meaning although the physical modeling method gives us the concrete meaning of the parameters and the correction method. The remaining problem is to apply the present method to correct the shadow area by the cloud.

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