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Abstract |

Establishing a global algorithm for water quality mapping from multi-dates images

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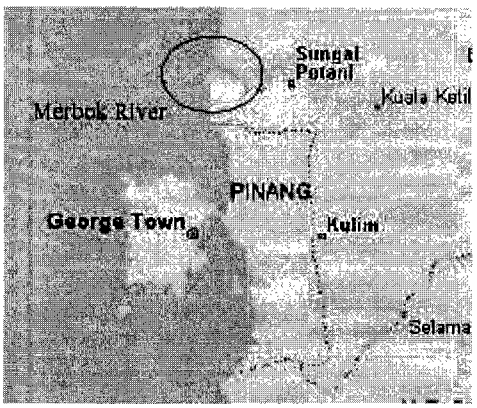
Introduction

Water quality assessment of ocean and inland waters using satellite data has been carried out since the first r satellite Landsat-MSS has been operational (Thiemann and Kaufmann, 2000). Many researchers used satellite investigations [Allee, et al., (1999), Forster, et al., (1993) and Ritchie, et al., (1990)]. However, in this study we emote sensing. A digital camera was used as a sensor to capture the images at altitude of 8000 feet. The main resent study is to update our proposed algorithm for mapping total suspended solids in marine environmen camera images from previous study (MatJafri, et al., 2002). We also attempted to develop a simple correction te airborne images acquired from different dates, locations, and different flying altitudes. Data from seven imag combined in the present analysis. This study also proposed a cheaper and economical alternative to overcome obtaining cloud-free scenes in the Equatorial region.

Study Area

In this study, a Kodak DC290 digital camera was used as a sensor and a Cessna 172Q aircraft was used a capture images of the study areas. The study areas were the Prai, Muda, and Merbok river estuaries, located witl 22' N to 5o 24'N and longitudes 100o 21'E to 100o 23'E; 5o 34' N to 5o 36'N and longitudes 100o 19'E to 100o 2 N to 5o 41'N and longitudes 100o 20'E to 100o 24'E, respectively. The images were captured from the altitude of October 2001 and 8,000ft on 9 March 2002 for Prai River estuary, 8,000ft on 20 January 2002 and 9 March River estuary, and also 8,000 ft on 5 May 2002, 25 October 2002 and 22 March 2003 for Merbok River estuary. T are shown in Figure 1. Water samples were collected from a small boat within the areas covered by the scenes with the airborne image acquisition and later analyzed in the laboratory.



(Source: Microsoft Corp., 2001.)
Figure 1. Study area

Optical model of water

A physical model relating radiance from the water column and the concentrations of the water quality constituen most effective way of analyzing remotely sensed data for water quality studies. Reflectance is particularly inherent optical properties: the absorption coefficient and the backscattering coefficient. The irradiance reflecta the water surface, R(l), is given by Kirk (1984) as

$$R(\lambda) = 0.33b(\lambda)/a(\lambda) \quad (1)$$

where λ = the spectral wavelength
b = the backscattering coefficient
a = the absorption coefficient

The inherent optical properties are determined by the contents of the water. The contributions of the individual the overall properties are strictly additive (Gallegos and Correl, 1990). For a case involving two water quality cc chlorophyll, C, and suspended sediment, P, the simultaneous equations for the two channels given by Gallie and can be expressed as

$$R(\lambda_1) = R_1 = 0.33\frac{(0.5b_{bw}(\lambda_1) + b_{bc}^*(\lambda_1)C + b_{bp}^*(\lambda_1)P)}{(a_w(\lambda_1) + a_c^*(\lambda_1)C + a_p^*(\lambda_1)P)} \quad (2a)$$

$$R(\lambda_2) = R_2 = 0.33\frac{(0.5b_{bw}(\lambda_2) + b_{bc}^*(\lambda_2)C + b_{bp}^*(\lambda_2)P)}{(a_w(\lambda_2) + a_c^*(\lambda_2)C + a_p^*(\lambda_2)P)} \quad (2b)$$

where
$b_{bw}(i)$ = backscattering coefficient of water
b_{bc}^* = specific backscattering coefficients of chlorophyll
b_{bp} = specific backscattering coefficients of sediment
$a_w(i)$ = absorption coefficient of water
a_c^* = specific absorption coefficients of chlorophyll
a_p^* = specific absorption coefficients of sediment
C = chlorophyll
P = suspended sediment

Regression Algorithm
TSS concentration can be obtained by solving the two simultaneous equations to get the series of terms R1 and F as

$$P = a_0 + a_1R_1 + a_2R_2 + a_3R_1R_2 + a_4R_1^2 + a_5R_2^2 + a_6R_1^2R_2 + a_7R_1^2R_2^2 + a_8R_1^2R_2^2 + \ldots \quad (3)$$

where aj, j = 0, 1, 2, ... are the coefficient for equation (3) that can be solved empirically using multiple regressior equation can also be extended to the three-band method given as

$$P = e_0 + e_1R_1 + e_2R_2 + e_3R_3 + e_4R_1R_2 + e_5R_1R_3 + e_6R_2R_3 + e_7R_1^2 + e_8R_2^2 + e_9R_3^2 \quad (4)$$

where the coefficient ej, j = 0, 1, 2, ... can also be solve empirically.

Data Analysis And Result
Seven sets of the colour images were selected for calibration analysis. Figure 2 shows the images that were usec

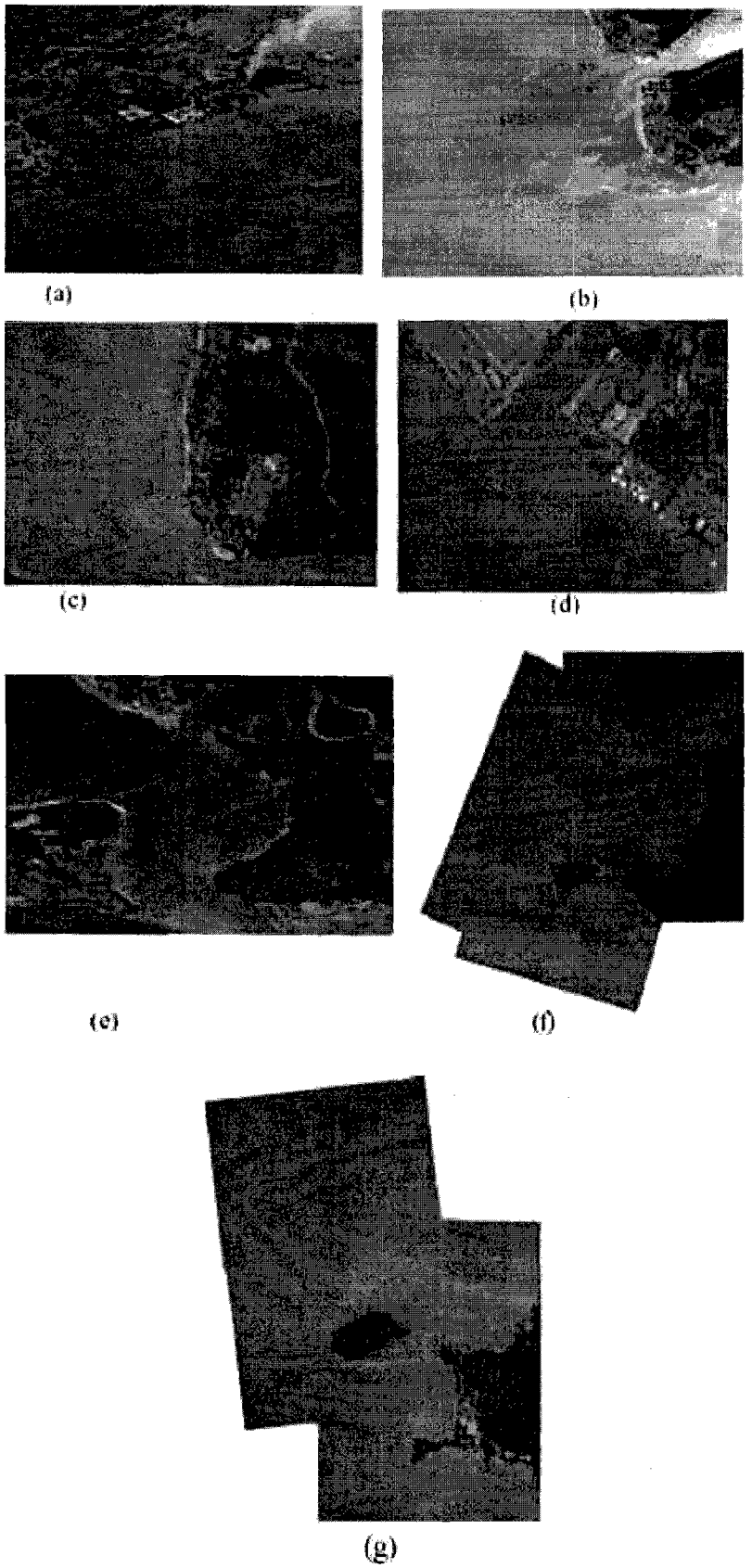


Figure 2. Images of the study ares: (a) the oblique image of the Prai River estuary captured on 28 October 2001 from altitude of oblique image of the Muda River estuary captured on 20 January 2002 from altitude of 8,000ft, (c) the vertical image of the Prai captured on 9 March 2002 from altitude of 8,000ft. (d) the vertical image of the Muda River estuary captured on 9 March 2002 f 8,000ft, (e) the oblique image of the Merbok River estuary captured on 5 May 2002 from altitude of 8,000ft, (f) the vertical imag

River estuary captured on 26 October 2002 from altitude of 8,000ft and (g) the vertical image of the Merbok River estuary captur 2003 from altitude of 8,000ft.

The colour images were separated into three bands, namely, red, green and blue bands for multispectral analysis Figure 2(a) was taken at an altitude of 3,000ft, while the rest were taken from altitude of 8,000ft. The image Figure 2(b) and Figure 2(e) were taken obliquely. The view angle correction was first performed to the oblique im for the angular dependence of image brightness. In this study, a contour map of the image brightness was plotte angle effect was removed based on the map. Then, the multi-date data were corrected to remove the difference effects between scenes using radiometric normalization technique. The vertical image of Figure 5(c) was s reference image and the average brightness of the chosen target; in this case, grass vegetation was noted. W reflectance of these targets did not change with time. This assumption is in accordance with the methods propc (1990). The average brightness values of grass in other images were then recorded. The difference from the r was used to correct for each scene. All the brightness values of the other five images of Figure 5 (a), (b), (d), were adjusted using this normalization technique. This normalization technique forced the images to h atmospheric conditions and the effects due to different camera altitudes have also been removed. The correcte then regressed with the sea-truth data to obtain all the coefficients of equation (4) in the proposed multi-date, r multi-altitude analysis. Image rectification was performed using second order polynomial tranformation equation.

The DN values corresponding to the water sample locations were extracted from all the images. The relationshi nd DN of the data set is shown in Figure 3. The coefficients values are listed in Table 1. Figure 4 shows algorithm produced high correlation coefficient (R) and low root-mean-square (RMS).

The TSS maps were generated using the proposed calibrated algorithm. The generated maps were then filtered t pixels average for removing random noise. Finally, the generated TSS maps were colour-code for visual interpret in Figure 5. This indicates the reliability of the calibrated proposed algorithm for TSS mapping using digital camer

Table 1. Correlation coefficients of equation (2)

Coefficients	ao	a1	a2	a3	a4	a5	a6	a7	a8	a9
Values	43.794	-2.021	-9.964	10.710	0.121	-7.278x10--2	0.279	-1.640x10-2	-0.141	-0.15

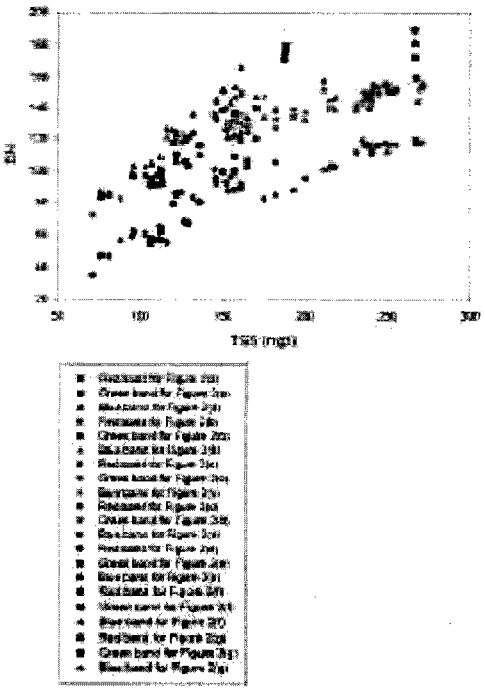


Figure. 3 TSS concentration versus digital number (DN).

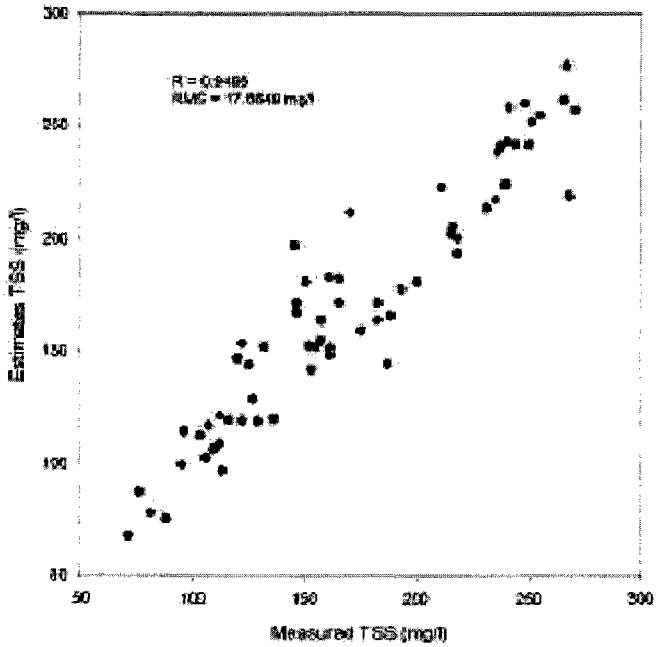
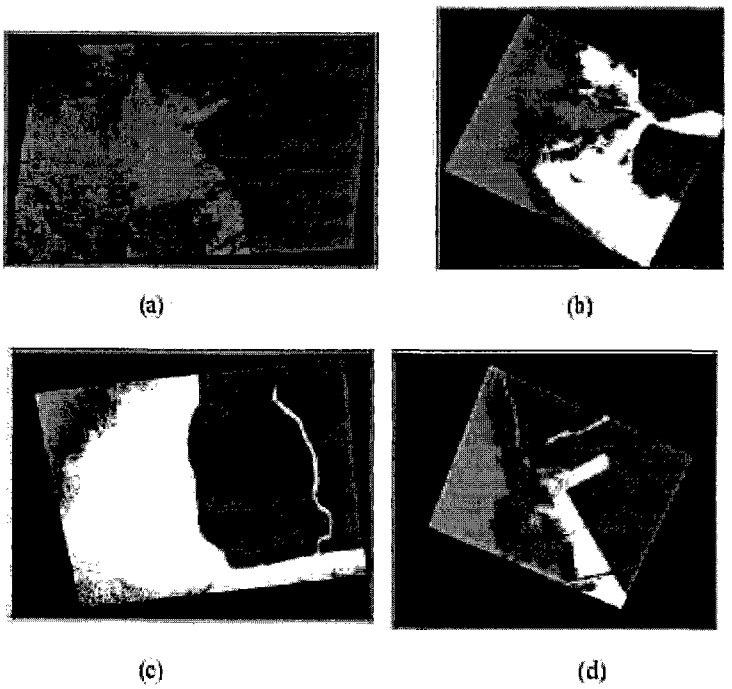


Figure 4. Measured versus estimated TSS concentration



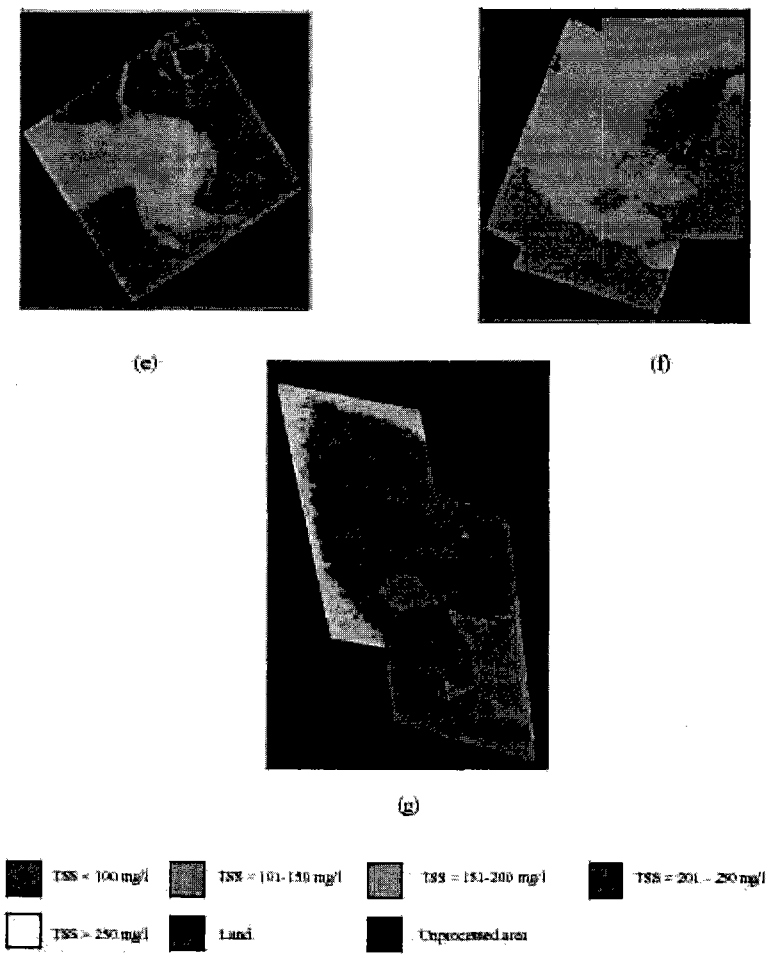


Figure 5. TSS map for the study area estimated using the proposed algorithm. Colour code:

Verification analysis

For the verification analysis, sea truth data were divided into two groups, half of the numbers of water sample selected for algorithm calibration and the another half of the numbers of water samples were radom selected analysis. The calibrated algorithm was produced high accuracy with R value of 0.9685 and RSM value of 13 verification analysis. Figure 6 shows the relationship of the measured TSS versus estimated TSS concentratio calibration analysis. Figure 7 shows the relationship of the measured TSS versus estimated TSS concentration analysis.

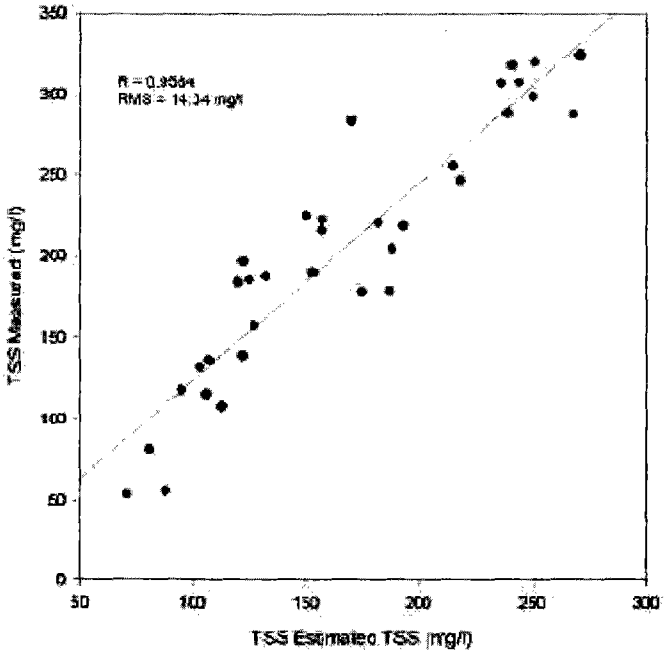


Figure 6. Measured TSS versus estimated TSS concentration for algorithm calibration analysis

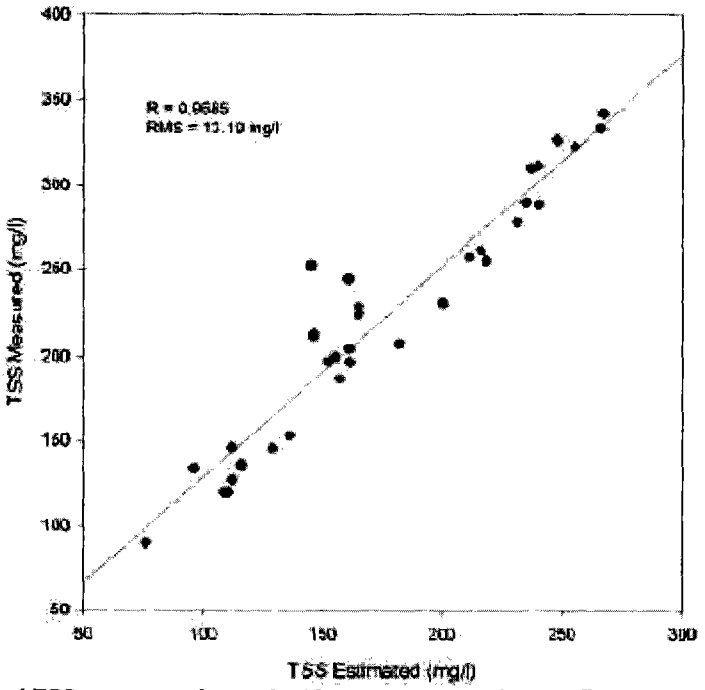


Figure 7. Measured TSS versus estimated TSS concentration for verification analysis Conclusion

This study gives a cheaper way to overcome the problem of difficulty of obtaining cloudfree scenes at the Eq Traditional water quality monitoring method based on water sample collection is time consuming and requires a cost. It is good for determined the water pollution for real time. The proposed algorithm is considered superior algorithms based on the values of the correlation coefficient, R=0.97 and root-mean-square error, RMS=15mg/l. that the TSS maps can be generated using digital camera imagery with the proposed algorithm.

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