Multispectral Assessment for Various Chlorophyll-a Content Water Body
-featuring 2006 Field Campaign using FieldSpec Pro-

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ABSTRACT

Water area are being called upon to sustain lager human populations than ever before. Also coastal zone is a dynamic transition area where oceanic processes and land processes interact. Detailed and repeating hyperspectral experiment is indispensable to know an effective wavelength range to assess high chlorophyll-a content water body using multispectral remotely sensed data. The spectral patterns through hyperspectral range in situ measurements were examined using FieldSpec Pro. DOC decreased in a largely conservative manner along salinity profiles, whereas chlorophyll-a peaked at intermediate regions of the mixing gradient. Green reflectance peaks were found between 550nm and 590nm. The NIR peak near 700nm was diagnostically useful for high concentrated chlorophyll-a, either when normalized for non-algal background scattering or through identification of peak position, which varied from about red region reflectance. We encountered the following range and spectral property : chlorophyll-a=50 to 250 μ g/m3; seston=35 to 186 μ g/L; DOC= 6.8 to 62.425 μ g/L.

1.Surface Water Biophysical Features

To accurate monitoring the spatial extent, organic/inorganic constituents, depth in rivers, lakes, reservoirs, and sea using remote sensing technique, it is important to first obtain an appreciation for the energy-matter interactions that may impact to perform water environmental remote sensing.

1.1. Radiance of water body

The goal of most water area remote sensing is to extract the radiance of interest from all the other radiance components being recorded by the sensor system. Most of path radiance is atmospheric noise and will be discussed this unwanted path radiance as a year 3rd step. The total radiance, (Lt) recorded by on-board sensor of satellite is one of functions of the electromagnetic energy from the four sources identified in Figure 1 (Bukata, et al., 1995) :

$$Lt = Lp + Ls + Lv + Lb$$

where

- Lp is the portion of the radiance recorded by a remote sensing instrument resulting from the downwelling solar(E sun) and the sky(E sky) radiation which never reaches the water surface.
- Ls is the radiance from the downwelling solar and sky radiation that reaches the air-water interface but only penetrates it millimeter or so and is then essentially reflected from the water surface.
- Lv is the radiance from the downwelling solar and sky radiation that actually penetrates the air-water interface, interact with the water and organic/inorganic constituents and then exits the water column without encountering the bottom.
- Lb is that portion of the recorded radiance resulting from the downwelling solar and the sky radiation that penetrates the air-water interface, reaches the bottom of the water body, is propagated back through the water column, and then exits the water column.

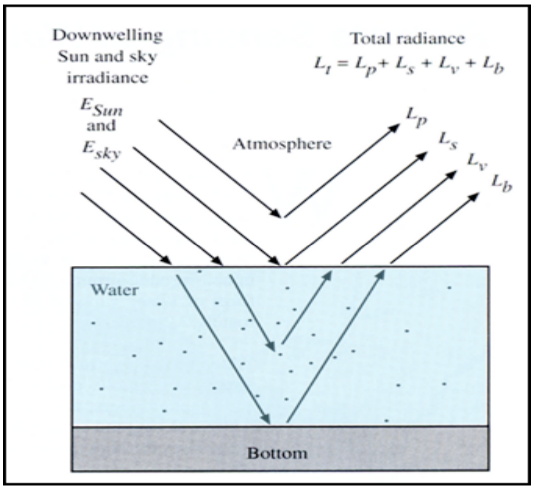

Fig. 1 Water bodies receive irradiance from the Sun and atmosphere.

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Chlorophyll-a の濃度変化がスペクトル特性におよぼす影響評価

2. Multispectral response feature of water bodies with Suspended Solid and Chlorophyll-a

Before conducting a remote sensing analysis on water bodies using satellite data, it is essential to understand how pure water selectively absorbs and/or scatters the incident, downwelling sunlight in the water column and also to consider how the incident light is affected when the water column is not pure, but contains organic and inorganic materials.

Pure water, which is essential for our human life, is free from organic and inorganic matter. Bukata summarized the absorption coefficient $\alpha(\lambda)$, the scattering coefficient $\beta(\lambda)$, and the total attenuation coefficient $c(\lambda)$ of pure water molecules at wavelength from 200nm – 800nm from various previous studies (Table-1)

2.1 Monitoring Suspended Solid

Most of natural water bodies, however, contain a variety of organic constituents. When natural waters contain a mixture of these materials, one of the most unwanted issues is to grasp quantitative information about these specific constituents from the remote sensing data. In situ spectral reflectance measurements of clear water and clear water with various levels of clayey/silty soil suspended sediment concentration from 0-1000mg/L is shown in Figure 2(a) and (b). The silty soil had approximately 10 % more volume reflectance at all wavelength when compared with the clayey soil. In both case, the peak reflectance shifted toward longer wavelengths in the visible region as more suspended sediments were added. Plate 1 shows field measurement of water bodies using the FieldSpec Pro.

2.2 Monitoring Chlorophyll-a

Chlorophyll-a introduced to pure water changes its spectral features, i.e., its color. Figure 3(a) show the spectral reflectance characteristics of clear water and the same water laden with algae consisting primarily of chlorophyll-a. Clear water reflected approximately 2-3% at the blue portion (400-500nm) and dropped gradually to less than 2 % at wavelength beyond NIR (700nm), as expected. Conversely, four pronounced scattering/absorption features of chlorophyll-a are evident in the algae-laden water. Figure 3(b) shows the spectral response as chlorophyll-a concentrations from 0-500mg/L. When both suspended materials and chlorophyll-a are present in the water body at the same time, a dramatically different spectral response is identified.

Table 1 Optical property of pure water derived from various sources by Bukata et. al., 1995.

Wavelength (nm)	Absorption $\alpha(\lambda)$ (m^{-1})	Scattering $b(\lambda)$ (m^{-1})	Total Attenuation $c(\lambda)$ (m^{-1})
250 – ultraviolet	0.190	0.032	0.2200
300 – ultraviolet	0.040	0.015	0.0550
320 – ultraviolet	0.020	0.012	0.0320
350 – ultraviolet	0.012	0.0082	0.0202
400 – violet	0.006	0.0048	0.0108
420 – violet	0.005	0.0040	0.0090
440 – violet	0.004	0.0032	0.0072
460 – dark blue	0.002	0.0027	0.0047
480 – dark blue	0.003	0.0022	0.0052
500 – light blue	0.006	0.0019	0.0079
520 – green	0.014	0.0016	0.0156
540 – green	0.029	0.0014	0.0304
560 – green	0.039	0.0012	0.0402
580 – yellow	0.074	0.0011	0.0751
600 – orange	0.20	0.00093	0.2009
620 – orange	0.24	0.0082	0.2408
640 – red	0.27	0.00072	0.2707
660 – red	0.310	0.00064	0.3106
680 – red	0.38	0.00056	0.3806
700 – red	0.60	0.0005	0.6005
740 – near-infrared	2.25	0.0004	2.2504
760 – near-infrared	2.56	0.00035	2.5604
800 – near-infrared	2.02	0.00029	2.0203

Plate 1 In-situ measurement of rich Chl-a content pond water using FieldSpec Pro Spectrometer derived specific hyper-spectral reflectance pattern at the VR and NIR region.

3. Results and Discussion

For this methodology, the following assumptions were verified:

1) The presence of suspended matter could be neglected in this flat terrain with low flow and less sediment transport.
2) Variations of spectral response can be only due to chlorophyll-a.
3) The dependence between chlorophyll-a and spectral variation was linear.
4) Strong chlorophyll-a absorption of visible blue(400nm-500nm) and red at approximately 680nm
5) Maximum reflectance peak around 550nm(visible green) was caused by relatively lower absorption of visible green by algae.
6) Prominent reflectance peak around 680-700nm was caused by an interaction of algae-cell scattering and a minimum combined effect of pigment and water absorption. These reflectance peaks above the baseline (absorption trough) can be used to accurately qualify chlorophyll-a amount.

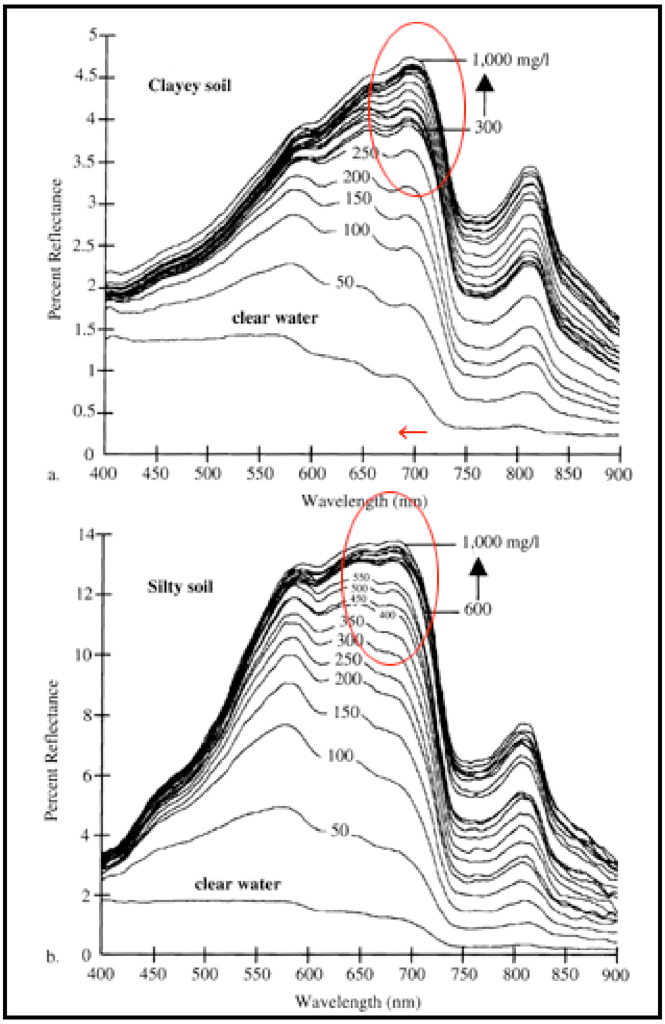

Fig. 2 Hyper-spectral reflectance measurements of clear water and clear water with various levels of clayey/silty soil suspended sediment concentration from 0-1000mg/L show specific differences in its reflectance peak pattern. The silty soil shows had approximately 10 % more volume reflectance at all wavelength when compared with the clayey soil. Reflectance increased in the 580-690nm region and in the NIR region as more minerals were suspended in the water body. In both case, the peak reflectance shifted toward longer wavelengths in the visible region as more suspended sediments. A water body with suspended sediment in it will generally appear brighter in satellite imagery than nearby water body without any suspended sediment.

4. Conclusion

However, it is often difficult to disentangle the information about the phytoplankton pigments in the satellite remote sensing data. Next assignments to be elucidated are 1) establish sophisticated atmospheric radiometric correction method applied to the satellite remote sensing data set and a complex multiple-component extraction methodology. Previous local algorithms are only suit data, a complex multiple-component extraction for the particular site, and can not usually be transported through space and time. Our final goal on this project is to establish the transportable and multiuse algorithm that will work most anywhere, anytime. This multiple algorithm will be applied to Landsat, Aster, and Terra Modis/Aqua data to produce maps of water environments.

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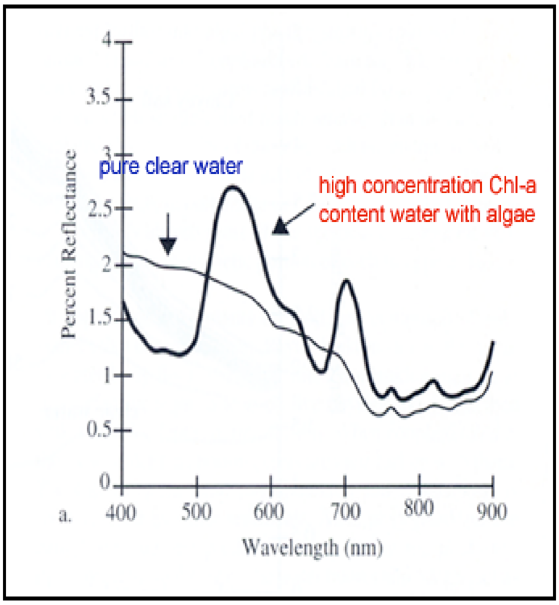

Fig. 3(a) Percent reflectance of clear and algae based chl-a content water derived from in situ spectral measurement using FiledSpec Pro shows significant decrease in the relative amount of energy in the visible blue and red wavelengths but an increase in visible green and NIR wavelength reflectance.

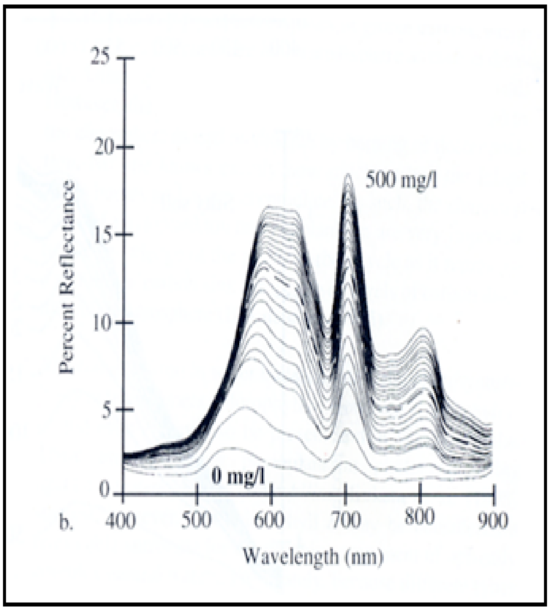

Fig. 3(b) Percent reflectance of rich algae based chl-a content water derived from in situ spectral measurement using FiledSpec Pro shows significant absorption in the relative amount of energy in the visible red but an increase in NIR wavelength reflectance. Simple ratio, RVI can be used effectively to estimate turbid level of water body.