NEAR-REAL TIME MONITORING OF COASTAL LAGOON TURBIDITY DISTRIBUTION USING MODIS DATA

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ABSTRACT:

We have been studying the turbidity estimation for Lakes Shinji and Nakaumi, Shimane Prefecture Japan using satellite sensors. Recently, we have developed a turbidity monitoring system for this area using near-real-time MODIS 250-m resolution band reflectance data which have been provided from Japan Aerospace Exploration Agency (JAXA). MODIS sensors on-board the Terra and Aqua satellites visit this area almost once or twice a day, so the limitation of sparse visit is solved to some extent (the limitation of cloud cover still remains). Since thin cloud and occasionally sand storm cover the ocean and/or lake areas, some threshold techniques are applied to remove the data or to issue warning flags. Empirical formulas adjusted for each lake (Lakes Shinji and Nakaumi) are used to estimate the turbidity from the Band 1 reflectance. The resulting turbidity distribution map is now published on our web site for general users. In this presentation, an outline of this system will be introduced.

1 INTRODUCTION

Many coastal lagoon areas in the world suffer from water quality deterioration due to close interactions between the lagoons and surrounding land areas. Turbidity is a basic water quality parameter which is related to many application areas such as ecosystem assessment and studying the impact to fishery. Remote sensing of turbidity has been studied by many researchers (*e.g.* Sakuno *et al.,* 2002; Oyama *et al.*, 2009). It has been shown that fairly good accuracy could be obtained using visible wavelengths, although some caution should be exercised for the effect of Chl-a absorption and CDOM concentration. One of the biggest issue of visible remote sensing of turbidity (and other water quality estimation using satellite remote sensing) is the limitation due to cloud cover. In particular, in the case of narrow water areas such as coastal lagoons, the situation is worse than the ocean since only high-spatial-resolution sensors having relatively long revisit days can be used for the monitoring.

More frequent observations are needed for continuous monitoring of water qualities at these areas. Although MODIS sensors onboard the Terra and Aqua has relatively low resolution compared to the size of the above-mentioned narrow water areas, they visit these areas almost once or twice a day. Therefore, the limitation of sparse visit is solved to some extent Though the limitation of cloud cover still remains, it is inevitable for any kinds of visible sensors.

In this study, MODIS reflectance data is used for the monitoring of turbidity for Lakes Shinji and Nakaumi, Shimane Prefecture Japan. Observation data are transfered automatically and converted to turbidity, then opened to the public via the Internet. Since the estimated turbidity are evaluated using the in-situ observation data, the accuracy for practical usage is confirmed.

2 TURBIDITY MONITORING SYSTEM

The flow of our turbidity monitoring system is shown in Fig. 1. The reflectance data of band 1 (645 nm) and band 2 (NIR 860 nm) obtained by MODIS is transfered to our processing site everyday automatically. In the processing of JAXA MODIS data, an atmospheric correction is applied to MODIS band 1 using the reflectance at clean ocean surface nearby the lakes (dark pixel assumption). Next, a simple geometric correction is first applied to both bands using a high land-water contrast reflectance of MODIS band 2. Then, the reflectance is converted to turbidity using empirically obtained relations. The obtained turbidity distribution map is now put on our web site for general users within one day after the original MODIS observation. Weather conditions are divided into several categories and rather good condition data is put on the web site. More sophisticated thin cloud and sand storm detection algorithm is now under study.

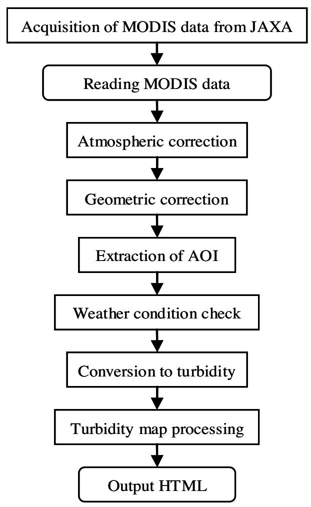

Figure 1: Flow chart of turbidity monitoring system.

3 GEOMETRIC CORRECTION

Although a geometric correction is carried out for the MODIS data provided by JAXA, relatively small correction errors up to several kilometers still remains at Lakes Shinji and Nakaumi area. Since a coarse geometric corrections carried out by JAXA, we investigated the remained small correction errors and we confirmed it is not necessary to to carry out further complicated geometric corrections, such as a rotation, a scale-down, or enlargement. Therefore, a simple geometric correction is applied using a template matching method.

First, an atmospheric correction is applied to MODIS band 1 using the reflectance at clean ocean surface nearby the lakes. Reflectance data at ocean area with the size of 2.5km x 2.5km nearby the lakes is used for obtaining a dark pixel value. Minimum reflectance in this area is subtracted from all the data. A template is prepared from the geometric data. This template is divided to three categories of land, water, and boundary area. Since the land-water contrast of band 2 is higher than that of band 1, band 1 reflectance data is used for this simple geometric correction. In this study, water, land, boundary are defined to be 1, -1, 0, respectively. Geometric correction is achieved where the product of the template and the data is minimized. The obtained results show that a geometric correction errors up to 60 pixels is automatically corrected by this method.

4 TURBIDITY ESTIMATION

It has been reported that the the reflectance becomes high when the suspended solid (SS) is high (Han, 1997). Water contains high SS shows high turbidity. Using this principle, turbidity can be monitored from the reflectance observation from the satellite sensors.

MODIS Band 1 (620 - 670 nm) reflectance data is used for this study at Lakes Shinji and Nakaumi. MODIS reflectance and the in-situ observation data are compared to obtain regression lines which are empirical equations to estimate turbidity.

In this study, 31 samples of in situ observation data are used during 2002 - 2005. Figure 2 shows the reflectance data, the in situ observation turbidity data, and the linear regression lines. Estimation equations are obtained as follows;

$$y = \begin{cases} 4.25x + 5.60 & \text{(Lake Shinji)} \\ 3.94x + 3.00 & \text{(Lake Nakaumi)} \end{cases} \qquad (1)$$

where y and x show turbidity and atmospherically corrected reflectivity, respectively. Different equations are obtained as the

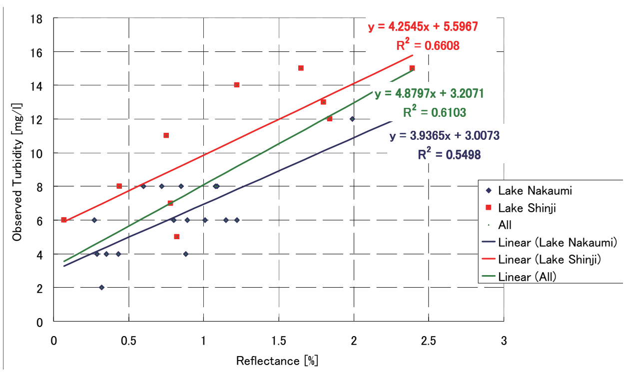

Figure 2: Correlation between MODIS reflectance and in-situ turbidity, and regression lines.

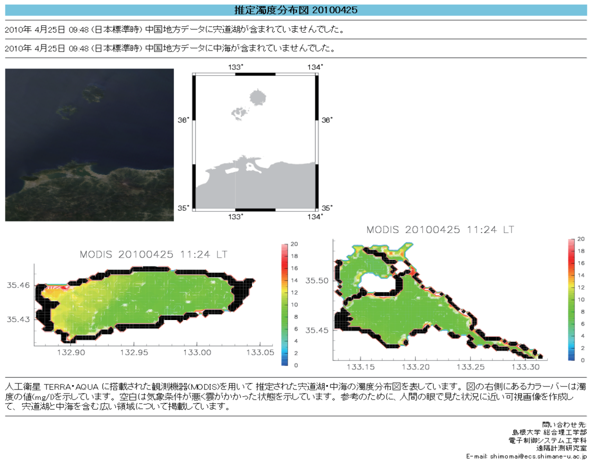

Figure 3: An example of web page output.

regression equation for Lakes Shinji and Nakaumi. This result suggests that the causes of the turbidity depends upon the components of SS. Detailed analysis on this matter is beyond the scope of this paper.

Estimated turbidity maps are automatically put on the web page as well as true color images of the same areas. Figure 3 shows an example of the web page output.

5 DISCUSSION

Estimated turbidity is tested by comparing with the in situ observation at continuous monitoring station data provided by Ministry of Land, Infrastructure, Transport and Tourism (MLIT). Data obtained during 2008 - 2009 are used for this comparison. Figure 4 shows the in situ observation turbidity and the turbidity estimated from MODIS reflectance data, when the weather condition is fine. It is suggested that reasonable precision is obtained for the turbidity estimated from MODIS observation data. More sophisticated algorithm for detecting thin cloud and sand storm is now under study.

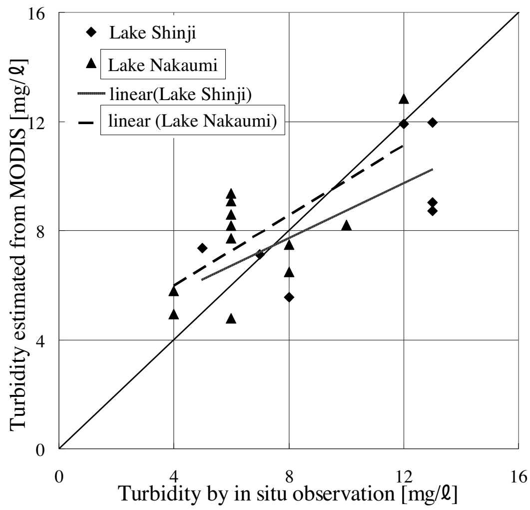

Figure 4: Comparison of the estimated turbidity with the in situ observation.

6 SUMMARY

We have developed a turbidity monitoring system for Lakes Shinji and Nakaumi area using MODIS 250-m resolution band reflectance data provided from JAXA. A simple geometric correction is applied to both bands using a high land-water contrast reflectance of MODIS band 2. Dark pixel assumption method is adopted for atmospheric correction. Empirical formulas adjusted for each lake are used to estimate the turbidity from the MODIS band 1 reflectance. It has been shown that the estimated turbidity values are in good agreement with in-situ observations. The obtained turbidity distribution map is now put on our web site for general users within one day after the original MODIS observation.

ACKNOWLEDGMENTS

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REFERENCES

Han, L., 1997. Spectral reflectance with varying suspended sediment concentrations in clear and algae-laden waters. *Photo. Eng. Rem. Sens.,* 63, 701–705.

Oyama, Y., Matsushita, B., Fukushima, T., Mtasushige, K., and Imai, A., 2009. Application of spectral decomposition algorithm for mapping water quality in a turbid lake (Lake Kasumigaura, Japan) from Landsat TM data. *ISPRS J. Photo. and Rem. Sens.,* 64, 73–85.

Sakuno, Y., Matsunaga, T., Kozu, T., and Takayasu, K., 2002. Preliminary study of the monitoring for turbid coastal waters using a new satellite sensor, "ASTER". *Proc. 12th International Offshore and Polar Enginerring Conference (ISOPE-2002)*, CD-ROM(Vol.II), 341–347.