MONITORING TURBIDITY AND SUSPENDED SEDIMENT CONCENTRATION OF COASTAL AND INLAND WATERS USING SATELLITE DATA

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1. INTRODUCTION

Water quality is an important factor affecting human health and ecological systems. Global water quality monitoring is included in the work plan activities (WA-07-01) of the Groups on Earth Observation (GEO) [1]. Operational remote sensing systems for monitoring of inland and coastal water quality are still lacking and need to be developed. In this paper, we describe our attempts in retrieving water turbidity and suspended sediment concentration of inland and near-shore coastal waters using remote sensing satellite data. The method involves the use of the quasi-analytical algorithm (QAA) [2] to retrieve the backscattering coefficient of water in the visible to near-infrared spectral regions from the satellite measured radiance. Simple procedures are used to correct for the atmospheric effects and reflection of skylight at the water surface [3], [4]. In-situ measurements of water reflectance, suspended sediment concentration and water turbidity were performed to establish the relation between water backscattering coefficient retrieved from reflectance, water turbidity and suspended sediment concentration. This relation is applied to convert the satellite measured water backscattering coefficient to water turbidity (in NTU) or suspended sediment concentration. The algorithms used to retrieve water turbidity and suspended sediment can be operationalized easily since all the required parameters can be derived from the satellite data. This method has potential to be developed into an operational system for global water quality monitoring using satellite data.

2. METHODS

The conventional ocean color satellites have sensors specifically designed for ocean applications. However such sensors usually have spatial resolution of about 1 km and are not suitable for inland and coastal applications. In this paper, we use data from high resolution satellites such as Landsat and SPOT. The method is also applicable to the land bands of MODIS with 250 m and 500 m resolutions. The satellite images are first converted to the top-of-atmosphere (TOA) reflectance, and then corrected for Rayleigh scattering and molecular absorption using routines in the 6S package [5], assuming a standard atmosphere with considerations of the spectral response of each spectral band of the sensor. In a previous work, we employed a simple aerosol and glint correction procedure by subtracting the reflectance of the near-infrared (NIR) band from the visible bands [3, 4]. This process assumed that the water was dark in the NIR band. However, we found that this assumption was not valid in inland and near-shore coastal waters with high turbidity due to scattering by suspended sediment in the NIR band. In this paper, we employ the reflectance in the 1.6 micron short-wave infrared (SWIR) band to perform atmospheric correction. After correction for atmospheric effects and surface glints, the water reflectance is converted to sub-surface remote sensing reflectance.

The sub-surface reflectance is related to the absorption coefficient a_i and backscattering coefficient b_{bi} at the *i-th* spectral band by the expression

$$r_{wi} = 0.33\frac{b_{bi}}{a_i + b_{bi}}$$

The absorption coefficient of water is approximated by that of pure water at the NIR band and hence the backscattering coefficient at the NIR band can be computed using the above equation and the NIR backscattering coefficient due to suspended particles can be obtained by subtracting away the backscattering coefficient due to pure water.

In order to relate the backscattering coefficient to the water turbidity value usually measured in the Nephelometric Turbidity Units (NTU) and the concentration of total suspended sediment (TSS), we performed laboratory controlled experiments using suspensions of soil particles in a water tank. A portable spectroradiometer (GER 1500) was used to measure the water reflectance and an NTU meter was used to measure the water turbidity. The TSS concentration was obtained by using the filtration method. Water backscattering coefficient was retrieved from the reflectance measurements and correlate with the NTU and TSS. The relations obtained was applied to the satellite measurements to obtain a turbidity map (in NTU) in coastal and inland waters.

3. RESULTS AND CONCLUSIONS

The water turbidity (in NTU) was found to be linearly related to the backscattering coefficient of water in the controlled water tank experiments for different types of soil (Fig. 1). Despite the different types of soil used, the same linear relation seems to be applicable to all the soil types tested.

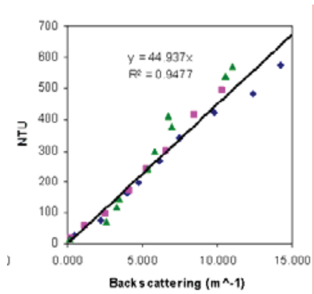

Fig. 1: Relation between backscattering coefficient and turbidity (NTU) for various types of soil

A SPOT-4 satellite image of Singapore and surrounding area was used to derived the water turbidity map of the coastal sea and river waters (Fig. 2). The NTU values were validated using in-situ measurements in an inland reservoir.

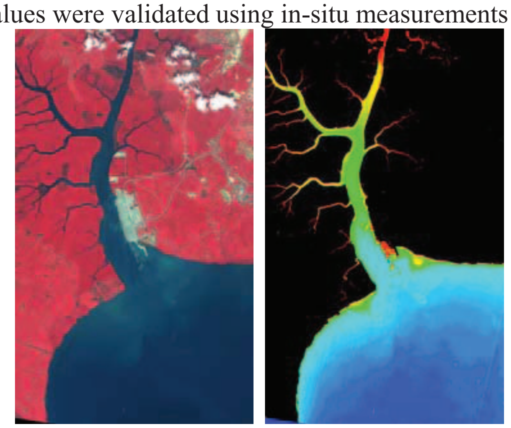

Fig. 2: A sub-scene of a SPOT-4 satellite image (left) and the turbidity map (right, in rainbow color scheme) of a coastal area north of Singapore.

Our results indicated that water turbidity map can be derived from high resolution satellite data such as those acquired by the SPOT and Landsat satellites. This method can also be applied to the land bands of MODIS. The method does not require the availability of external data and hence can be used for routine operational applications to monitor water turbidity, which is an indicator of water quality.

4. REFERENCES

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