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Spectral Angle Mapping (SAM)-based Anomaly Detection in Ocean Environments using the GOCI

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Abstract - The Geostationary Ocean Color Imager (GOCI) is the world’s first ocean color remote sensor platform operated on a geostationary orbit. This sensor platform receives ocean color data around the Korean Peninsula every hour, eight times a day. Therefore, GOCI can be utilized to observe subtle changes and to detect anomalies in ocean environments in real time. We have attempted to develop a spectral angle mapping (SAM)-based anomaly detection method. SAM is a method to directly compare test spectrum vectors to a predefined reference spectrum vector. The experimental result showed that the proposed method can efficiently detect the anomalies (e.g., the red tide) on the ocean area.

Keywords: GOCI, Spectrum Angle Mapping, Anomaly Detection

1. Introduction

Over the last few years, the harmful algae or red tide has been found to occur often in the sea around the Korean Peninsula [1]. Humans and marine organisms can be damaged by these anomalies therefore a quick response system to cope with ocean disasters needs to be developed [2]. However, it is difficult to simultaneously monitor the vast ocean areas. Geostationary Ocean Color Imager (GOCI) [3], the world’s first geostationary ocean color remote sensor platform, can be a great solution to monitor and detect ocean anomalies because it observes the ocean color around the Korean Peninsula every hour, eight times a day [4]. Here, we developed an ocean anomaly detection method based on the spectral angle matching (SAM) scheme [5].

GOCI was equipped with six visible spectral bands and two near-infrared bands. The wavelengths are 412, 443, 490, 555, 660, and 680 nm for the visible band and 745 and 865 nm for the near-infrared band. The ground sampling distance (GSD) is 0.5 km, and the coverage is 2,500 km × 2,500 km, centered at 36°N and 130°E. The instantaneous field of view (IFOV) of GOCI corresponds to the field of view (FOV) of the slot area due to GOCI’s two-dimensional complementary metal-oxide semiconductor (CMOS) and 1,413 × 1,430 effective-pixel arrays. A raw data observed by GOCI is composed of 16 (4 × 4) slots.

The raw data with 16 slots are received from the GOCI platform to the ground data acquisition system (GDAS) via the satellite communication channel. The raw data are transmitted via L-band (i.e. center frequency is 1687.2MHz and bandwidth is 6MHz) using the quadrature phase shift keying (QPSK).

These slots that arrive the ground GDAS are agglomerated into a scene like a mosaic after the geometrical correction. This scene consists of 31,648,395 pixels (5,567 width and 5,685 height). Eight scenes are generated for each eight spectral band and we refer to these eight scenes as a GOCI level 1 scene. The GOCI level 2 scenes such as the chlorophyll concentration (CHL), the total suspended matter (TSS), and the normalized water-leaving radiance (nLw) are derived from a GOCI level 1 scene by applying various ocean color algorithms. In this paper, we used the nLw spectrum vector that consists of nLw values for each eight band to detect ocean color anomalies.

2. Methodology

In general, nLw tends to be relatively high in the blue-wavelength range of 390 to 430 nm for the normal ocean color (Fig. 1a). On the other hand, different spectrum vectors can be drawn when the anomaly occurs. For example, nLw decreases in the blue-wavelength range when the red tide occurs (Fig. 1b).

Fig.1 An example of the comparison for GOCI-derived nLw spectrum vectors between (a) the normal ocean color and (b) the anomaly.

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To detect the anomaly in the GOCI-derived ocean color data, we employed the spectral angle mapping (SAM) [5] calculated by

\[
\text{Spectrum Angle}(t, r) = \frac{\sum_{i=1}^{n} t_i \times r_i}{\sqrt{\sum_{i=1}^{n} (t_i)^2} \times \sqrt{\sum_{i=1}^{n} (r_i)^2}}
\] (1)

where \(t\) and \(r\) are the test and the reference spectrum vectors respectively, and \(i\) means the wavelength index. Here, a \(r\) is predefined by the representative anomaly (e.g., red tide). Then each \(t\) in the GOCI-derived ocean color data is compared with \(r\). The value of spectrum angle become close to 1, as two vectors are similar.

3. Experiment

![Fig.2 (a) Natural color data derived from GOCI at 12:30 on 2 August 2013 and (b) the spectrum angle map (i.e. the anomaly detection result) calculated from the reference spectrum vectors (Fig. 1b)](image)

Shown as Fig. 2, we applied the proposed method to ocean color data derived from GOCI at 12:30 on 2 August 2013 to detect the ocean color anomaly. The \(nL_w\) spectrum vector shown as Fig. 1b was set to a reference spectrum vector. \(nL_w\) spectrum vectors in the GOCI-derived ocean color data were set to the test spectrum vectors. Fig. 2a indicates the natural color data and Fig. 2b is the spectrum angle map (i.e. the anomaly detection result). In Fig. 2b, we can find out that anomaly (i.e. the probability of red tide) occurs in the region printed in red.

4. Conclusions

Prompt response is required to cope with ocean disasters (e.g., the red tide and the oil spill) because humans and marine organisms can be damaged by these ocean anomalies. To automatically detect ocean disasters, we developed a spectral angle mapping (SAM)-based anomaly detection system using the GOCI ocean color data. We validated that the ocean anomalies can be efficiently detected by the proposed method. For the future work, we are planning to develop a real time anomaly detection system using the high temporal resolution of GOCI.

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Selected References