

Marine Disaster Detection Using the Geostationary Ocean Color Imager (GOCI)

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Abstract

Recently, harmful algae (e.g., red tide) has damaged human and marine ecosystems. To address this, a response system should be developed to quickly cope with these ocean disasters. However, it is difficult to simultaneously monitor the vast ocean areas. Here, a marine disaster detection system can be developed through a convergence between the satellite-based ocean color remote sensing and the marine sensor network. The system architecture is divided into two steps: first, the system detects ocean anomalies in real-time using the satellite-based techniques, and secondly, the detected disaster information is transferred to the ships via the marine sensor networks. In this paper, we only focused on the first step and the second step is reserved for future work. Although the polar orbit satellite-based ocean color sensor platforms (e.g., MODIS, MERIS, and SeaWiifs) can be used to simultaneously monitor the vast ocean areas, they are unsuitable for capturing subtle changes on a geographically equivalent area. On the other hand, the Geostationary Ocean Color Imager (GOCI), the world's first ocean color remote sensor platform operated on a geostationary orbit, receives ocean color data around the Northeast Asia region every hour, eight times a day. Therefore, GOCI can be more effectively utilized to observe subtle changes and to detect anomalies in ocean environments in real-time. In this paper, we attempted to build a system to monitor marine disasters by detecting ocean anomalies using the ocean color data derived from GOCI. This system directly compares the test spectrum vectors (i.e. anomaly candidates) to a predefined reference spectrum vector (i.e. a target anomaly) through the cosine similarity. The experimental result showed that the proposed system could efficiently detect the disasters (e.g., the red tide) on the ocean environments.

Keywords: Marine Disaster, GOCI, Cosine Similarity

1. Introduction

Over the last few years, harmful algae or red tide has been found to occur often in the sea around the Northeast Asia region [1]. Humans and marine organisms can be greatly damaged by these anomalies; therefore, a quick response system to cope with ocean disasters needs to be developed [2]. Figure 1 shows the system architecture for marine disaster detection. The system can be devised by converging satellite communication and marine sensor network techniques. First, ocean disasters can be detected using the satellite-based ocean color remote sensing; the detected disaster information is then received through the satellite. Second, the received disaster information is transferred to the ships via the marine sensor networks. Thus, it becomes possible to cope with the ocean disasters in real-time. In this paper, we only focused on the first step and the second step was reserved for future work.

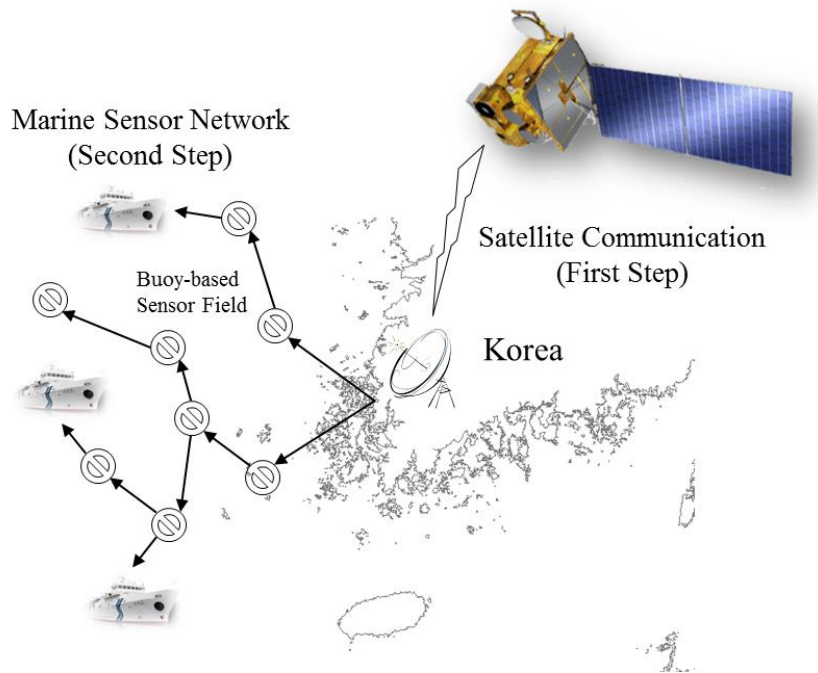


Figure 1. A Marine Disaster Detection System Architecture. (First Step) Ocean Disasters are Detected and Transferred using the Satellite-based Techniques (Second Step). The Disaster Information is Transferred to the Ships via the Marine Sensor Networks

There were some challenges to achieving our goal: 1) Simultaneous monitoring for the vast ocean areas, and 2) High frequency monitoring for an equivalent area. The satellite-based ocean color sensor platforms (e.g., Moderate Resolution Imaging Spectroradiometer (MODIS) [3], Medium Resolution Imaging Spectrometer (MERIS) [4], Sea-Viewing Wide Field-of-View Sensor (SeaWiifs) [5] etc.) were designed to observe the global ocean color data. These sensor platforms can be usefully exploited to simultaneously monitor the vast ocean areas, but it is difficult to capture the subtle changes on a geographically equivalent area using these programs because they only revisit the area after a few days.

Geostationary Ocean Color Imager (GOCI) [6], the world's first geostationary ocean color remote sensor platform, can be a great solution to monitor and detect ocean disasters in real-time because it observes the ocean color around the Northeast Asia region every hour, eight times a day [7-8]. Here, we developed an ocean anomaly detection system based on spectral angle mapping (SAM) [9]. SAM is a method to directly compare test spectrum vectors to a predefined reference spectrum vector. We designated a predefined reference spectrum vector as an anomaly (i.e. ocean disaster), and then differentiated the anomalies from normal test spectrum vectors (i.e. ocean disaster candidates).

The remainder of this paper is organized as follows. Section 2 describes the GOCI and section 3 explains the data and materials used to achieve our goal. In section 4, we describe a method to detect the ocean anomalies. In section 5, we show our experimental results. Finally, discussions and conclusions about our work are provided and future research is suggested in section 6.

2. GOCI, The World's First Geostationary Ocean Color Remote Sensor Platform

Table 1. General Specifications of GOCI

Volume Size(mm³)	1,000 × 760 × 896
Weight	83.3kg
Power	125W
Digitization	12bits
Spatial resolution	0.5km @ point of 130°E, 36°N
Observation period	1hour (8 times a day)
Field of regard	Local Area (2,500km × 2,500km, Center: 130°E, 36°N)
Mission life time	7.7 years

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. Other specifications of GOCI [6] are shown in Table 1.

The raw data with 16 slots are received from the GOCI platform to the ground data acquisition system (GDAS) via the satellite communication channel, and then the data are converted from analogue to digital in the GDAS as shown in Figure 2. The raw data are transmitted via L-band (i.e. center frequency is 1687.2MHz and bandwidth is 6MHz). The transmitted data are received at the GDAS with about -90dBm through the L-band 9m Gregorian Antenna installed in the Korea Ocean Satellite Center (KOSC) at Korea Institute of Ocean Science and Technology (KIOST), which is the main operator of GOCI. The received data are amplified by the low noise amplifier (LNA) as much as -40dBm, then amplified again by the down converter (D/C) as much as 23dBm. Here, D/C conducts the frequency translation as 70MHz to digitalize the analog satellite data. The translated data are digitalized by the quadrature phase shift keying (QPSK) in the Modem/BB.

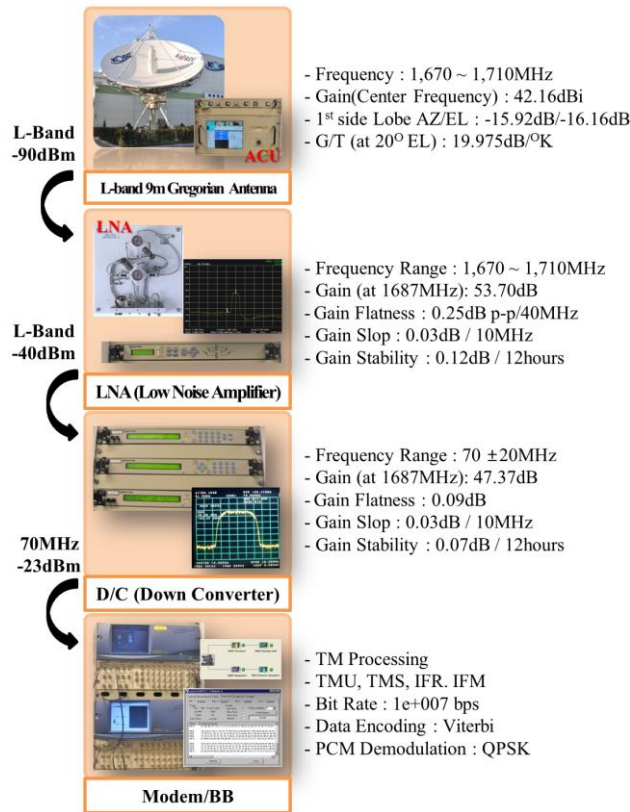


Figure 2. A flow Diagram of the Ground Data Acquisition System (GDAS) Process. GOCI Data are Converted from Analogue to Digital in the GDAS

3. Data and Materials

16 slot-raw data 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. In this paper, we used GOCI level 2 scene (e.g., nL_w and R_{rc}) spectrum vectors that consist of the values for each eight band in order to detect ocean color anomalies. We attempted to detect the red tide blooms on the coasts around East China Sea (Figure 3a) using a nL_w anomaly and green algae blooms on the west coast around Yellow Sea of Korea (Figure 3b) using a R_{rc} anomaly.

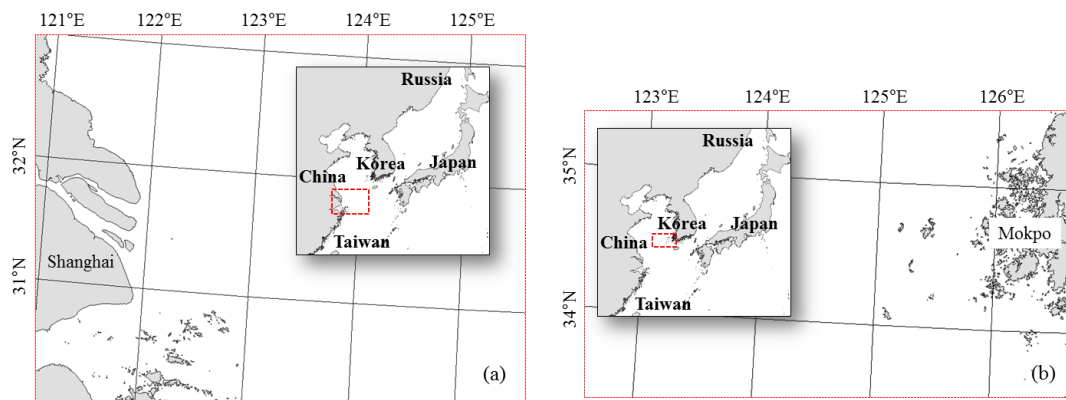


Figure 3. Maps of the Coasts Around East China Sea (a) and Yellow Sea of Korea (b)

In general, nL_w tends to be relatively high in the blue-wavelength range of 390 to 430 nm for the normal ocean color around East China Sea (Figure 4a). On the other hand, different spectrum vectors can be drawn when the red tide-related anomaly occurs. For example, nL_w decrease in the blue-wavelength range and relatively increase in the red-wavelength when the red tide occurs, as shown in Figure 4b. We designated this red tide-related spectrum vector as an nL_w anomaly. Similarly, R_{rc} tends to be relatively low in the near infrared (NIR) range of 700 to 900 nm for the normal ocean color (Figure 4c), while high for the green algae-related ocean color (Figure 4d), around Yellow Sea of Korea.

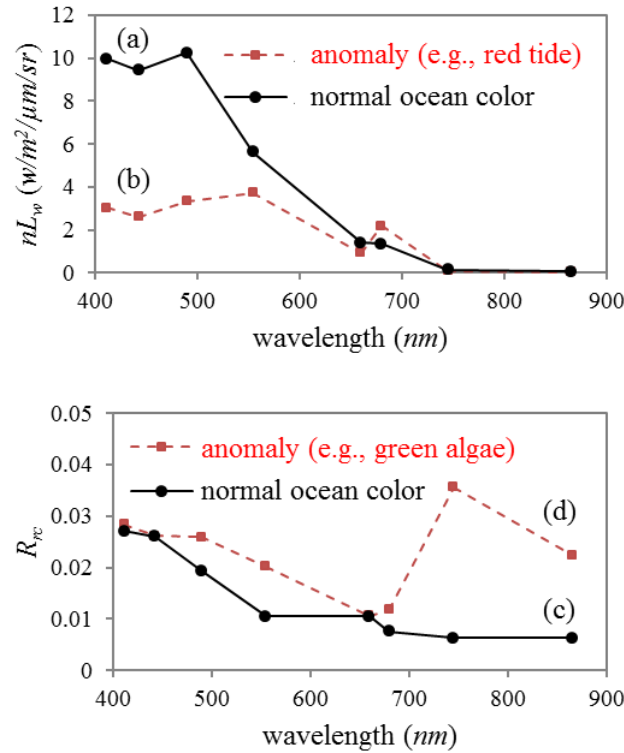


Figure 4. Examples of the Comparisons for GOCI-derived nL_w Spectrum Vectors between (a) the Normal Ocean Color and (b) a Red Tide-related Anomaly in the East China Sea Coast, and GOCI-derived R_{rc} Spectrum Vectors between (c) the Normal Ocean Color and (d) a Green Algae-related Anomaly in the Yellow Sea Coast of Korea

4. Methodology

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

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

where t and r are the test and reference spectrum vectors respectively, and i means the wavelength indices (0, 1, ..., 7) that indicate (412, 443, ..., 865). n is the number of wavelength bands of GOCI (i.e. 8). This method uses the cosine similarity to compare t with r .

Figure 5 shows a flow diagram to detect ocean anomalies from GOCI-derived ocean color data. Here, r is predefined by the representative anomaly (e.g., red tide) then

compared with all anomaly candidates, $T=(t^0, t^1, \dots t^{m-1})$. If the spectral angle result is larger than a threshold for detection, $thres$, we determine that an ocean disaster is detected.

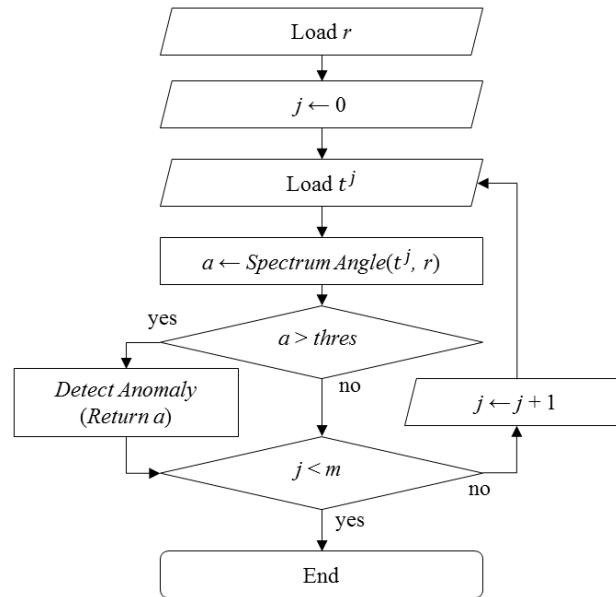


Figure 5. A Flow Diagram to Detect Ocean Color Anomalies. r is a Reference Spectrum Vector. $T=(t^0, t^1, \dots t^{m-1})$ is a Test Spectrum Vector St (i.e. GOCI-Derived Ocean Color Data) where m is the Number of Elements in T . $thres$ is a Threshold for Detection

5. Experimental Results

5.1. Red Tide Detection

We applied the proposed method to ocean color data derived from GOCI at 11:30 on 11 July 2013 to detect the red tide blooms. The nL_w spectrum vector shown as Figure 4b was set to a reference spectrum vector, r , in order to find out the probability of red tide occurrences. We set to the test spectrum vectors, T as the nL_w spectrum vectors in the GOCI-derived ocean color data around the Shanghai coast corresponding to the Figure 3a. A threshold for the red tide detection, $thres$, was determined as 0.98 through the empirical experiments.

The experimental result is shown in Figure 6. Figure 6a indicates the natural color scene that is composed of red (680 nm), green (555 nm), and blue (412 nm) color data derived from GOCI. Yellow-colored areas indicate the turbid coastal waters and white-colored areas indicate the clouds. Figure 6b is the spectrum angle map result (i.e. the red tide-related anomaly detection result). In the Figure, we can find out that anomalies (i.e. the probability of red tide occurrences) are detected in the region printed in red. It is regarded that the probability of red tide occurrences increases as the colors are closer to dark red.

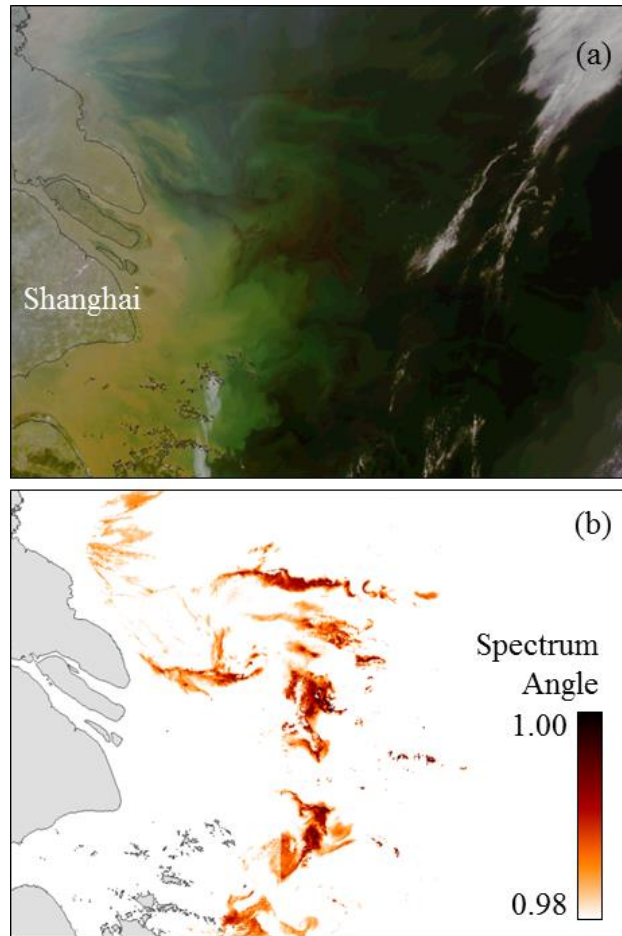


Figure 6. (a) Natural Color Image Derived from GOCI Data at 11:30 on 11 July 2013 and (b) the Spectrum Angle Map (i.e. the Red Tide-related Anomaly Detection Result) Calculated from the Reference Spectrum Vectors (Figure 4b) with a Threshold for Detection, $thres = 0.98$. The Probability of Red Tide Occurrences Increases as the Colors are Closer to Dark Red in the Spectrum Angle Map Result

5.2. Green Algae Detection

We also applied the proposed method to ocean color data derived from GOCI at 11:30 on 19 July 2011 to detect massive green algae. The R_{rc} spectrum vector shown as Figure 4d was set to the r to find out the probability of green algae occurrences. We set to the T as the R_{rc} spectrum vectors in the GOCI-derived ocean color data around Mokpo coasts on the Yellow Sea of Korea corresponding to the Figure 3b. A threshold for the green algae detection, $thres$, was determined as 0.91 through the empirical experiments.

The result is shown in Figure 7. Figure 7a indicates the natural color scene derived from GOCI, which was observed on a clear day without clouds. Figure 7b is the spectrum angle map result (i.e. the green algae-related anomaly detection result). The figure shows that the probability of green algae-related occurrences increases as the colors are closer to dark green. In particular, it seems that there is nothing to indicate massive green algae in the natural color scene, while we found out that some green algae are scattered throughout the sea in the spectrum angle map result because they can be mainly characterized by R_{rc} spectrums in the NIR range.

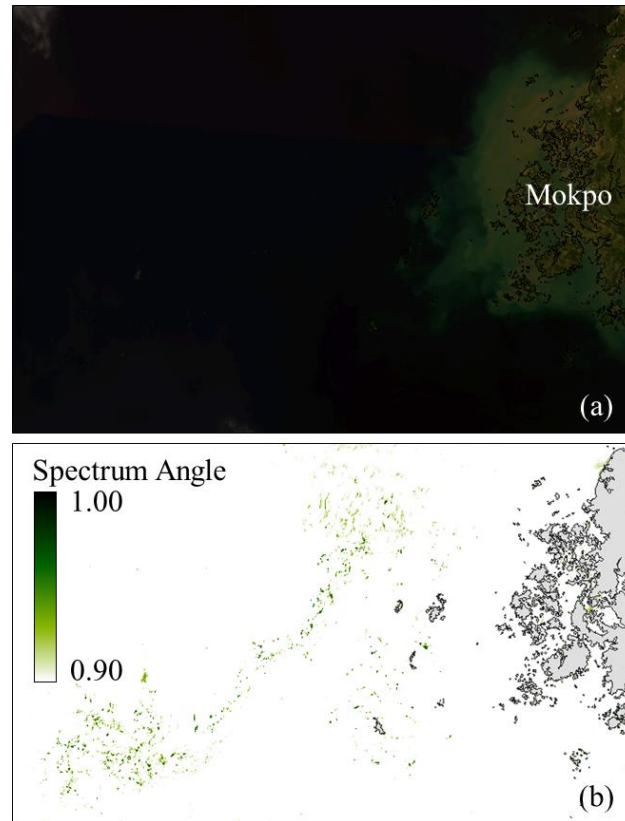


Figure 7. (a) Natural Color Image Derived from GOCI Data at 11:30 on 19 July 2011 and (b) the Spectrum Angle Map (i.e. the Green Algae-related Anomaly Detection Result) Calculated from the Reference Spectrum Vectors (Figure 4d) with a Threshold for Detection, $thres = 0.91$. The Probability of Green Algae Occurrences Increases as the Colors are Closer to Dark Green in the Spectrum Angle Map Result

6. Conclusions

Prompt response is required to cope with ocean disasters (e.g., the red tides and the green algae) because humans and marine organisms can be greatly damaged by these ocean anomalies. Convergence between satellite-based techniques and marine sensor network can be a solution to resolve this challenge. In this paper, therefore, we developed a spectral angle mapping (SAM)-based anomaly detection system using the GOCI ocean color data in order to automatically detect ocean disasters. We validated that ocean anomalies can be efficiently detected by the proposed method. The probability of red tide and green algae occurrences was estimated by our method on the coasts around the East China Sea and the Yellow Sea of Korea, respectively.

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