A Method for Red Tide Detection and Discrimination of Red Tide Type (Spherical and Non-Spherical Shapes of Red Tide) Through Polarization Measurements of Sea Surface

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Abstract

A method for red tide detection and for discrimination of red tide type (spherical and non-spherical shapes of red tide type) through polarization measurements of water leaving radiance is proposed. There are a variety of shapes of red tide types, in particular, spherical and non-spherical shapes. Polarization characteristics of spherical and non-spherical shapes of red tide types are different each other resulting in discrimination can be done through polarization measurement. Through laboratory based experiments with Chattonella Antiqua containing water and just water as well as Chattonella Marina and Chattonella Globossa containing water, it is confirmed that the degree of polarization of non-spherical shape of red tide is greater than that of spherical shape of red tide. Also it is confirmed that the polarization measurements is effective for discrimination between spherical and non-spherical shapes of red tide at the coastal areas of the Ariake sea in Kyushu, Japan in comparison to insitu data of red tide with research vessel.

Keywords: Red Tide, Remote Sensing Reflectance, Polarized Radiance, Polarization Camera.

1 INTRODUCTION

Due to red tide contaminations, water color is changed by an algal bloom. In accordance with increasing of phytoplankton concentration, sea surface color changes from blue to green as well as to red or brown depending on the majority of phytoplankton (Dierssen et al, 2006) so that it is capable to detect red tide using this color changes [1].

MODIS ocean color bands data is used for red tide detection. An iterative approach (Arnone et al., 1998 [2]; Stumpf et al., 2003 [3]) for sediment-rich waters, based on the Gordon and Wang (1994) algorithm [4], is used to correct for the atmospheric interference in the six ocean color bands in turbid coastal waters to obtain water leaving radiance, which are then used in the band-ratio algorithm (O'Reilly et al., 2000 [5]) to estimate Chlorophyll in unit of mg m^{-3}. Also suspended solid is estimated with two bands algorithm (visible minus near infrared bands data). The multi-channels of red tide detection algorithms (in the formula of $C=(R_i-R_j)/(R_k-R_l)$ where R_i, R_j, R_k and R_l are the reflectivity derived from bands *i, j, k* and *l*.) are proposed. Also learning approaches based on k-nearest neighbors, random forests and support vector machines have been proposed for red tide detection with Moderate Resolution Imaging Spectroradiometer: MODIS satellite images (Weijian C.,et al.,2009) [6].

Satellite based red tide detection does work under a fine weather condition but not under cloudy and rainy conditions obviously. Furthermore, revisit period of fine resolution of radiometer onboard satellite orbits are longer than typical red tide propagations so that it is not enough observation frequency if only remote sensing satellite is used for red tide detections. Therefore satellite-and ground-based red tide monitoring system is proposed [7]. In the ground based red tide monitoring system, green colored filtered camera and polarization camera are featured for detection of red tide and discrimination of red tide types [8].

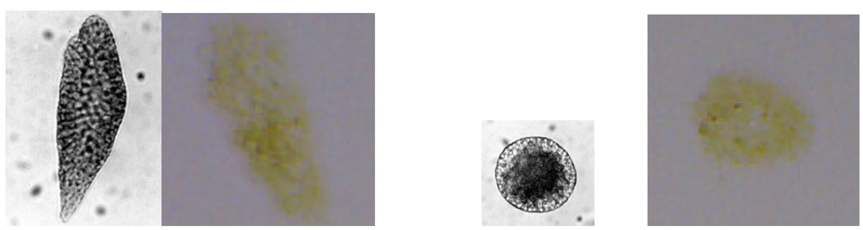
In this paper, a method of which polarization film attached camera images are used for correction of polarization influence on the band-pass filter attached camera images is proposed. Furthermore, an attempt is made for red tide specie discrimination between spherical and non-spherical shapes using ground based polarization camera images.

The second chapter describes the proposed method followed by experiments for validation of the proposed method and system. Then a possibility of red tide detection with polarized radiance measurements is discussed followed by concluding remarks.

2. THE PROPOSED METHOD

2.1 Polarization Measurements for Discrimination of Phytoplankton Types

An attempt is made for red tide specie (phytoplankton type) discrimination between spherical and non-spherical shapes based on polarization measurements. There is a demand of phytoplankton type identification. There are so many types of phytoplankton. Not only pigment, but also shape, size are different each other. Shape of phytoplankton is concerned. For instance, Chattonella Antiqua (ellipsoidal) and Chattonella Globosa (spherical) has the different shape each other as is shown in Figure 1.



(a) Chattonella Antiqua (b) Chattonella Globosa (c)Chatonella Marina
FIGURE 1: Different type and shape of Chattonella

Size of Chattonella Antiqua is around 50-130 μm x 30-50 μm so that it might show polarization characteristics while Chattonella Globosa does not have any polarization characteristics because it has a spherical shape. Accordingly, polarization radiance reflected from the Chattonella Antiqua is different from that of Chattonella Globosa. In order to confirm this fact, polarization measurement of the sea surface is conducted.

2.2 Experiment in Laboratory

An experiment for discrimination of red tide type between spherical and non-spherical shapes of red tide with polarization measurements is conducted. Outlook of the experiment set-up is shown in Figure.2. Figure 3 shows acquired polarization images for both Chattonella Antiqua contaminated water and just water together with a portion of DP (Degree of Polarization: equation (1)) image and its histogram (ellipsoidal portion of DP image).

$$DP=(Rp-Rs)/(Rp+Rs) \qquad (1)$$

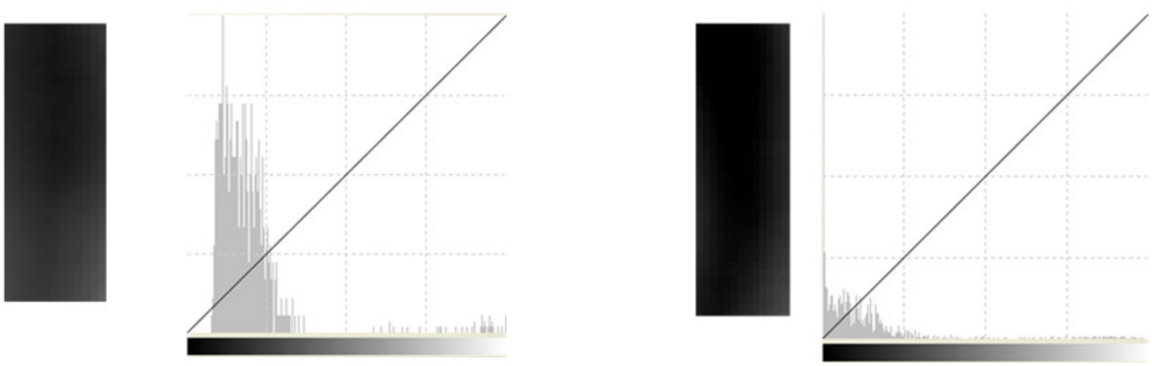
where Rp, Rs denotes radiance of p and s polarization, respectively.

Averaged DP of Chattonella Antiqua contaminated water is 32 while that of just water is 20. As is shown in Figure 1, the shape of Chattonella Antiqua looks like a football and size of Chattonella Antiqua is relatively large so that DP of Chattonella Antiqua contaminated water is greater than that of Chattonella Marina (spherical shape) and Chattonella Globossa (much small spherical shape) as well as just water. Also DP of Chattonella Marina contained water is measured. The averaged DP is 24 so that it is confirmed that it is possible to discriminate between Chattonella Antique and Marina using polarization measurements.

Through these laboratory based experiments, it is permissive to estimate existence of red tide and also discrimination between non-spherical and spherical shapes of red tide type can be done with polarization measurements of sea surface.

FIGURE 2: Chattonella Antiqua containing water and Chattonella Marina containing water and experimental set-up with polarization camera.

(a) DP of Chattonella Antiqua containing water (b) DP of just water



(c) DP image and its histogram of Chattonella Antiqua contaminated water (d) those for water

FIGURE 3: Degree of polarization of Chatonnella Antiqua contaminated water (DP=32) and just water (DP=20)

3. EXPERIMENTS

3.1 Intensive Study Area

Figure 4 shows the locations for the ground-based red tide monitoring system stations. Five stations are situated at the seashore of the Ariake Sea in Kyushu Island, Japan where red tide appears almost every year.

Water quality measuring instruments gather the information of chlorophyll-a, suspended solids, water turbidity, hue information of water color, salinity, water temperature, conductivity of the water, etc. On the other hand, weather robot gathers air temperature, relative humidity, atmospheric pressure, wind direction and wind speed, etc.

(a) Locations of red tide monitoring stations **(b) Location of the Ariake Sea**

FIGURE 4: Locations of the proposed red tide monitoring system stations (Red circle) ©Google.

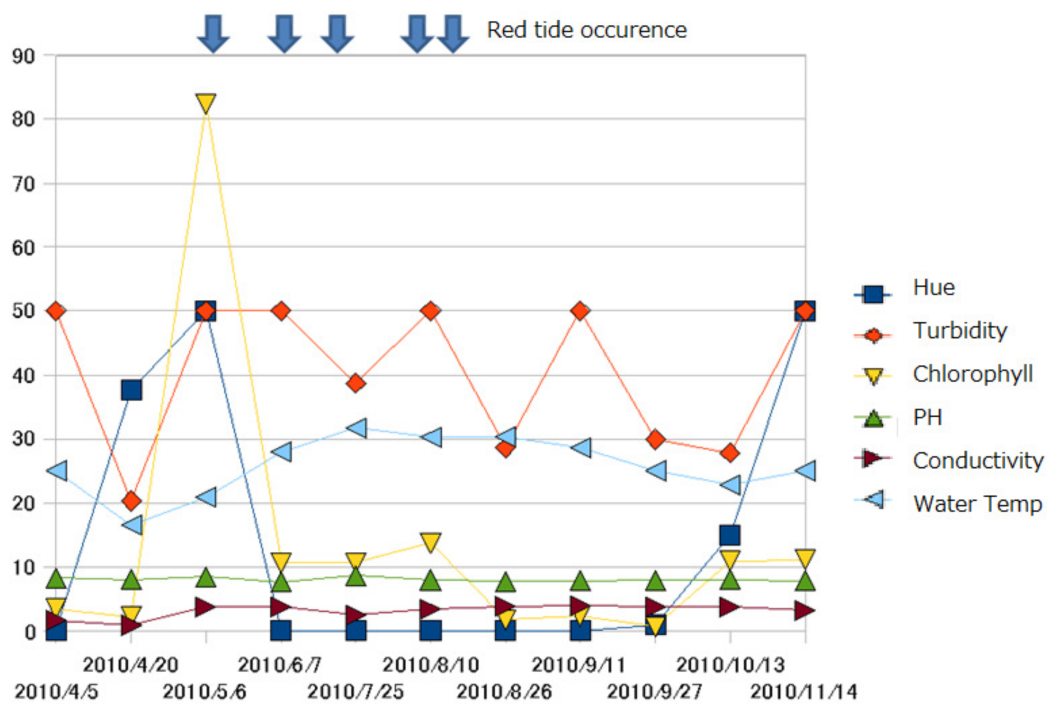


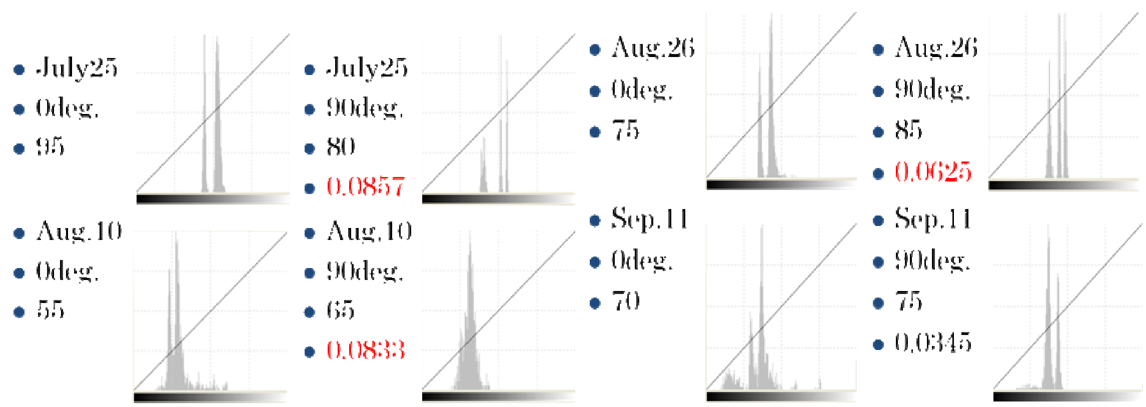
FIGURE 5: Red tide occurrence and measured data for 8 months in 2010.

3.2 Measured data

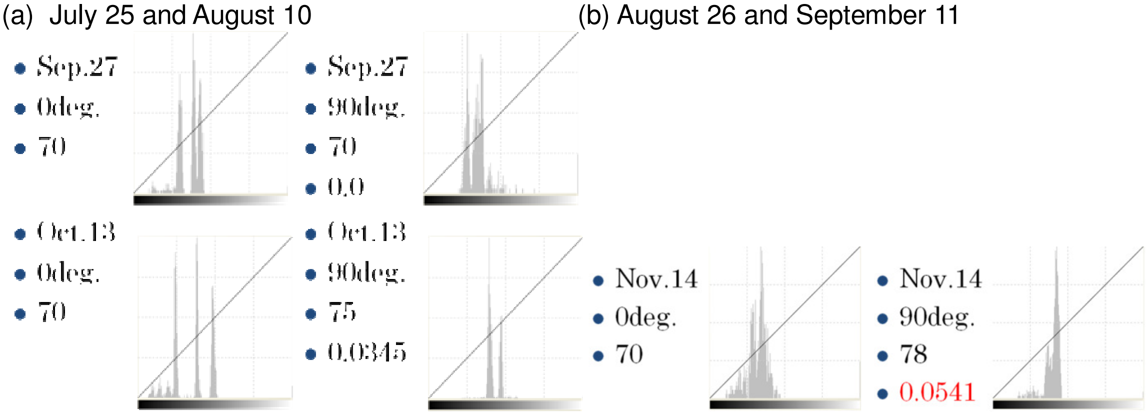
Figure 5 shows hue, turbidity, chlorophyll, PH, Conductivity, water temperature measured at the Nanaura station for the period from the begging of April 2010 to the middle of November 2010. In the summer time, sever Chattonella Antique occurred. Other than that, there are so many red tide events in the period as follows,

May 21: Heterosigma:10, Skeletonema spp.:7125
June 25: Heterosigma:100, Skeletonema spp.:6450
July 5: Chattonella Antiqua:480, Chattonella spp.:130
July 20: Skeletonema spp.:88000
August 2: Cript: 18000
August 10: Chattonella Antiqua:1080
August 17: Thalassiora spp.:6000, Skeletonema spp.:7250, Chattonella spp.:1400
November 22: Akasiwo sanguinea: 640
These events are reported by SPAFPC with the date, red tide type and the number of red tide a litter of sea water.

In the same period, polarization camera data are acquired. Figure 6 shows the Histograms of the acquired p and s polarized photos of the sea surface of Nanaura test site of the Ariake sea (From the top, Acquisition date, p or s polarizations, average of the histogram and DP which appear the bottom of the 90 degree of polarization data). Example of the acquired natural color, 0 degree of polarization and 90 degree of polarization of photos are shown in Figure 7. These photos are taken at Nanaura test site on August 10 2010. In particular, the Ariake sea was covered with Chattonella Antiqua of red tide almost entirely.



(a) July 25 and August 10 (b) August 26 and September 11



(c) September 27 and October 13 (d) November 14

FIGURE 6: Histograms of the acquired p and s polarized photos of the sea surface of the Nanaura test site of the Ariake sea (From the top, acquisition date, p or s polarizations, average of the histogram and DP which appear the bottom of the 90 degree of polarization data).

(a) Natural photo

(b) 0 degree of polarization photo

(c) 90 degree of polarization photo

FIGURE 7: Example of the acquired natural color, 0 degree of polarization and 90 degree of polarization of photos which are taken at the Nanaura test site on August 10 2010.

3.3 Summarized Results

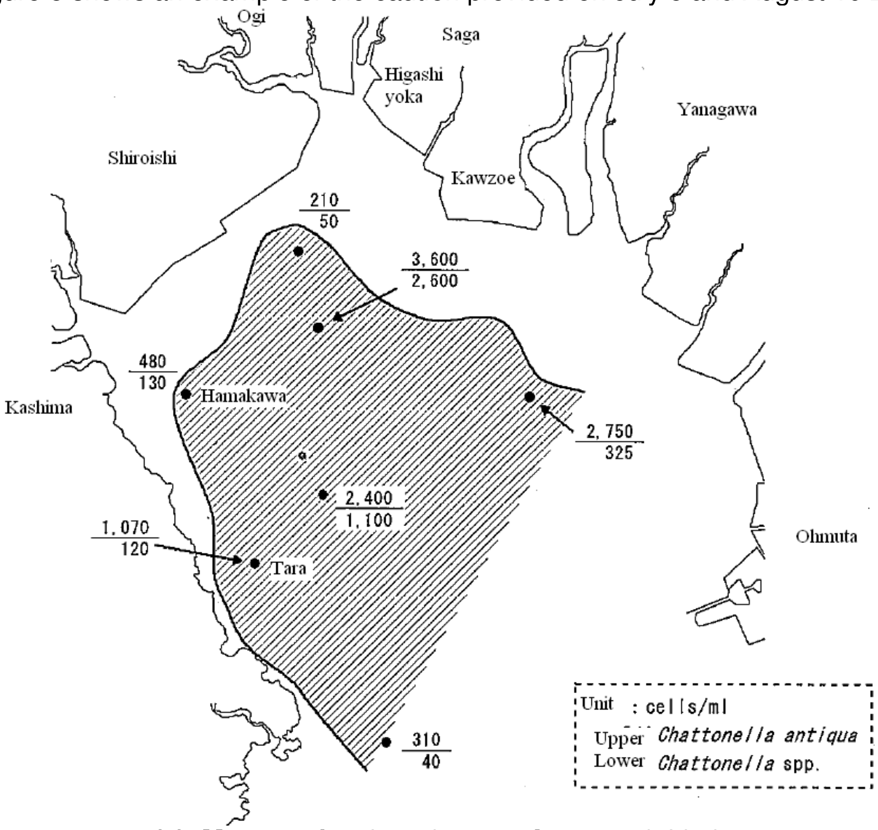
Calculated DP is summarized as follows,

July 25: DP=0.0857, August 10: DP=0.0833, August 25: 0.0625, September 11: 0.0345, September 27: 0.0, October 13: 0.0345, November 14:0.0541

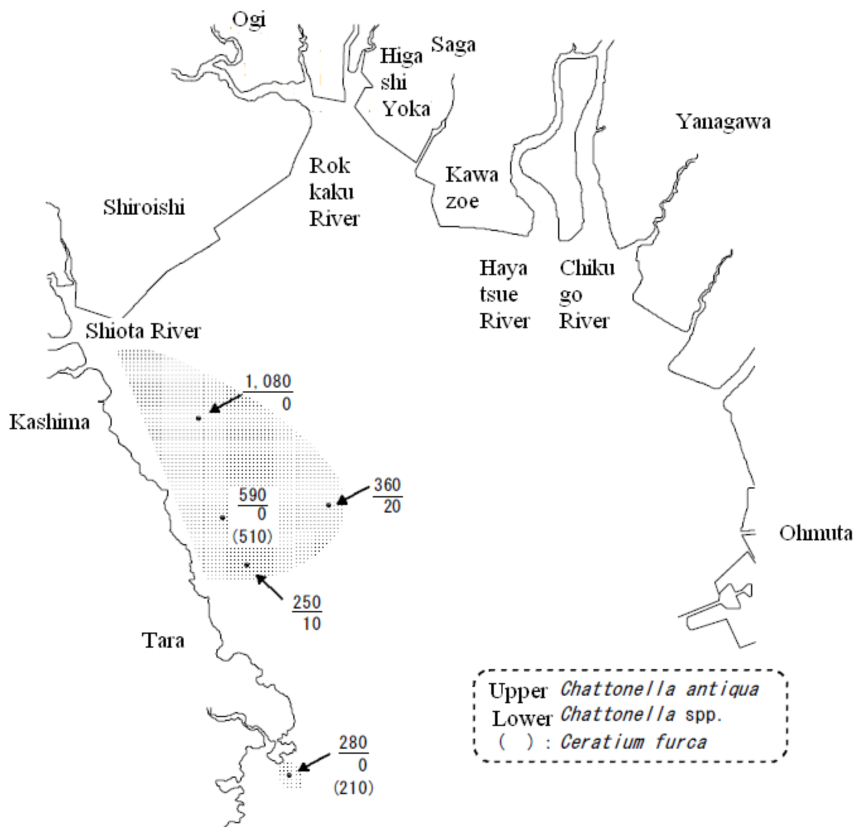
Relation between red tide measured by Saga Prefectural Ariake Fisheries Promotion Center: SPAFPC and the calculated DP is as follows,

May 21: Heterosigma:10, Skeletonema spp.:7125
June 25: Heterosigma:100, Skeletonema spp.:6450
July 5: Chattonella Antiqua:480, Chattonella spp.:130
July 20: Skeletonema spp.:88000→DP=0.0857
August 2: Cript: 18000
August 10: Chattonella Antiqua:1080→DP=0.0833
August 17: Thalassiora spp.:6000, Skeletonema spp.:7250, Chattonella spp.:1400→DP=0.0625
September 11, September 27, October 13→DP=0.0345, 0.0, 0.0345
November 22: Akasiwo sanguinea: 640→DP=0.0541

SPAFPC picked sea water up from their research vessel and then red tide type is identified and the number of red tide is counted by using microscopic instrument. They used to provide caution of red tide to fisherman together with suffered area map including red tide type and the number of red tide. Figure 8 shows an example of the caution provided on July 5 and August 10 2010.



(a) Measured at 8:15-9:45 on August 10 2010



(b) Measured at 13:30-15:30 on July 5 2010

FIGURE 8: SPAFPC provided red tide caution with red type and the number of red tide

SPAFPC uses their research vessel so that they cannot measure red type and the number of red tide near to coastal areas while the proposed red tide monitoring system allows measurements in particular in coastal area so that these can be used complementally.

4. CONCLUSIONS

The proposed polarization characteristics based method for red tide detection is validated in both of laboratory basis as well as field experiment basis. It is confirmed that Degree of Polarization: DP of red tide contained water is greater than that of just water in laboratory basis. Meanwhile a strong relation between insitu measurement data provided by Saga Prefectural Ariake Fisheries Promotion Center and the measured DP proposed in this paper is also confirmed with field experimental data which are acquired at the Ariake Sea in Kyushu, Japan where red tide occurs almost every year. The proposed method requires polarization film attached camera so that it is quit cheap and easy to equip. Furthermore, red tide type discrimination with polarized radiance measurements is attempted. Through a comparison of DP between Chattonella Antiqua containing water and water from water supply, it is confirmed that the former is greater than the later. Non-spherical shape of red tide can be discriminated with the other types of red tide (Spherical shape).

5. ACKNOWLEDGEMENT

This research is founded by the Ministry of Education, Culture, Sports, Science and Technology, MEXT Japan so that the authors would like to thank to staff of the space utilization promotion program under the MEXT. Also the authors would like to thank to Dr. Kawamura and Dr. Matsubara of Saga Prefectural Ariake Fishery Promotion Center for their valuable comments and suggestions together with Associate Professor Dr. Katano of Institute of Lowland and Marine

Science, Saga University for his nice discussions and providing the Chattonella Antique and marina containing water.

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