Tropical Algal Bloom Monitoring by Sea Truth, Spectral, and Simulated Satellite Data

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ABSTRACT

This research assesses the potential of using remote sensing ocean colour measurements in algal bloom monitoring by the simulation of 9 different types of ocean colour and high resolution visible sensors. After 2 years of research, the results suggest that large scale (500m to 1km) algal blooms may be detected from the ocean colour measurements. The GLI sensor onboard the upcoming ADEOS-II satellite provides the highest spectral capability in bloom type differentiation. In terms of the combination of spectral and spatial capability, the results show that the ENVISAT MERIS sensor provides the best combination. The high resolution mode (300m) of MERIS is expected to be a very powerful tool in the coastal area as smaller scale algal blooms (150m-300m) can also be detected.

1. INTRODUCTION

Phytoplankton are algae, microscopic plants that float in the surface waters of the sea, lakes, and rivers. In the ocean they constitute the base of the marine food web. Algal blooms are biological phenomena referring to the situation whereby there is a high cell concentration of phytoplankton. As phytoplankton is the base of marine food web, algal blooms are thus related to the ocean primary production. The identification and monitoring of these blooms are often considered as a viable means to locate new fishing grounds. Thus algal bloom monitoring has a positive social economical impact. However, not all algal blooms are beneficial to humans. Often the terms 'Harmful Algal Bloom (HAB)' or 'Red Tides' are used to describe algal blooms which causes negative impacts (e.g. toxic effects) to humans (Hallegraeff and Maclean, 1989).

Traditionally algal bloom monitoring is carried out through regular *in situ* ship borne water sampling programmes. However, these sampling programmes are discrete point measurements and can not provide sufficient spatial and temporal coverage to monitor these complex dynamic phenomena. Remote sensing technique has potential to be an important complementary tool for such monitoring. In this research, we attempt to assess this potential. This work was done by acquiring a two year time series of *in situ* sea truth data (parameters include water temperature, setchi reading, chlorophyll A, total suspended solids, dissolved organic matter, phytoplankton and zooplankton species count and identification under microscope) as well as simultaneously acquired spectral data taken from a hand held spectrometer. The spectral data is used to simulate 9 different types of past, present, and future satellite ocean color and high resolution visible data. The sensitivity of using these different data in terms of algal bloom monitoring is studied.

2. ALGAL BLOOM CLASSES

In this research, 7 algal bloom classes were studied. These classes were *Trichodesmiun* (fig.1), chain-forming diatom, "mixed diatom and high dinoflagellates bloom", "mixed diatom and low dinoflagellates bloom", *Cochlodinum*, small armoured dinoflagellate, and dinoflagellates from Manila Bay. Among the 7 classes, 6 of them were collected in the Johor Strait, Singapore and one class was from the Manila Bay, Philippines. 2 reference sea water classes were used for comparison, one from Johor, and the other from the Manila Bay.

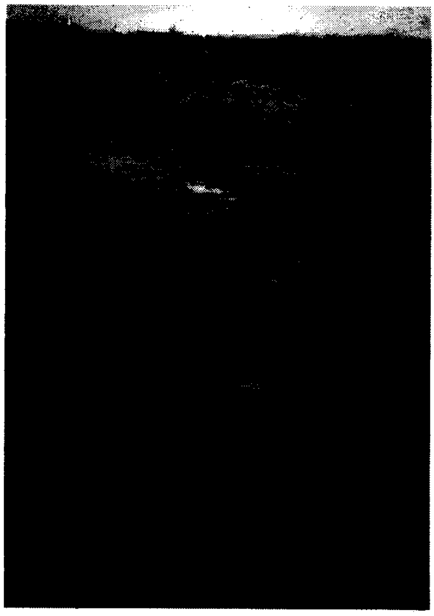

Fig. 1: This photograph shows the patches of *Trichodesmiun* bloom found off Bedok coast, Singapore on 31st July 1997.

3. SIMULATION OF SATELLITE DATA

In this research, 9 types of satellite data (GLI, MERIS, MODIS, OCTS, SEAWIFS, CZCS, TM, SPOT, AVHRR) were simulated from the original spectra collected during the field work. The simulation was done by the integration of the spectrometer reflectance

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data into the desired band and bandwidth. Fig. 2 illustrates the original spectra of the *Trichodesmiun* bloom. It can be seen that these spectra are very different from the clear sea water spectra (fig. 3). As shown in fig. 2, the 2 chlorophyll A absorption bands at 443nm and 660nm showing clear absorption characteristics. Another clear trough is found at band 490nm corresponding with pigment absorption. At 520nm band a peak is observed since this band is sensitive to red tides. A further peak is observed at 625nm band. This 625 band is sensitive to the sediments.

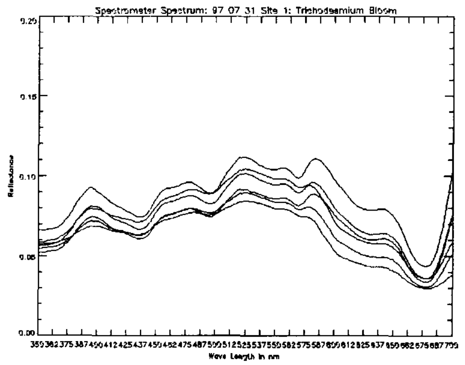

Fig. 2: Typical spectra of the *Trichodesmiun* bloom between the range 350nm to 700nm.

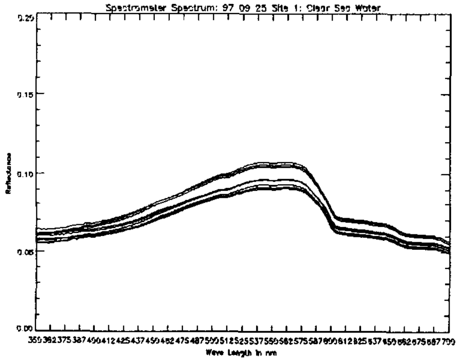

Fig. 3: Typical spectra of the reference sea water sample taken at Johor Strait, Singapore.

4. SPECTRAL ANALYSIS

In order to extract useful information from multi-spectral data, different combinations of reflectance difference and reflectance ratio of the available bands were tested. In addition, Principal Component Analysis (PCA) was also implemented. These analyses were combined to assess the spectral sensitivity of different satellite sensors in differentiating algal bloom types. Due to the large amount of results, only limited examples of simulated GLI data are shown. Fig.4 illustrates a scatter plot of all the 9 classes based on the reflectance ratio between band 565nm/545nm .vs. band 545nm/520nm. It can be seen from the figure that with the combination of these 2 sets of bands, 5 classes can be unambiguously differentiated. Other classes can be further separated out from the combination of other bands or principal components. As such, an algorithm can be proposed which utilises band manipulation and combination to achieve the highest possible discrimination (fig. 5).

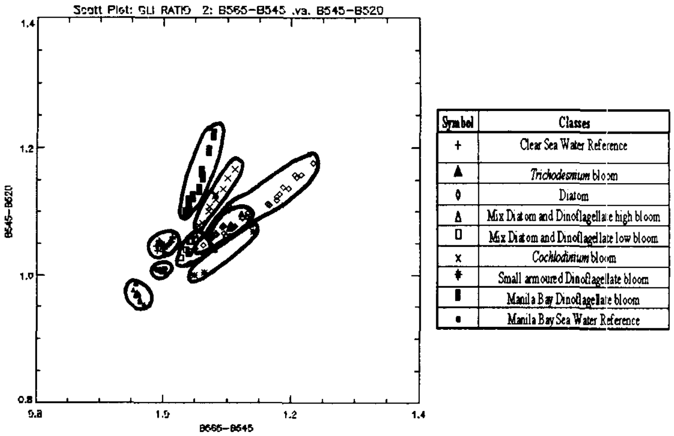

Fig. 4: Scatter plot of the 9 classes by their band ratio using simulated GLI data. The X axis is the reflectance ratio between band 565nm and 545nm. The Y-axis is the reflectance ratio between band 545nm and 520nm.

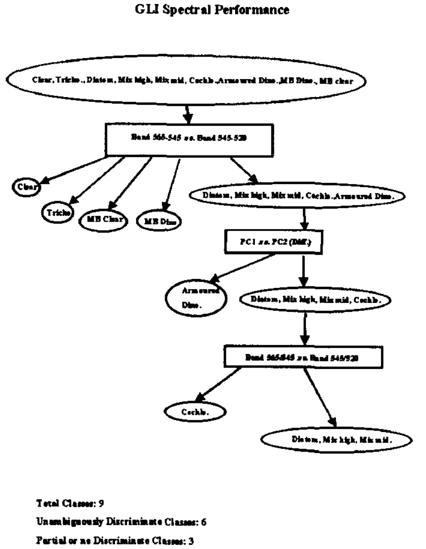

Fig. 5: Spectral analysis suggest a proposed algorithm for the GLI sensor which utilises the combination of spectral bands to achieve separation of different bloom classes.

5. SPATIAL ANALYSIS

In many situations, algal blooms may be of sub-pixel scale. This analysis assesses such situations and study the extent to which satellite data can detect these sub-pixel blooms. In most situations, it is not necessary to discriminate all bloom classes in one satellite image since it is unlikely for all different species of blooms to happen at the same time and at the same location. Very often the requirement is just to discriminate the bloom areas from ambient sea water. The spatial analysis was done by first generating a series of simulated data with different proportions of sea water and bloom cover. As such, a series of scatter graphs based on different proportions of bloom are generated. Figs. 6a-6c illustrate the situation of using GLI sensor to discriminate the *Trichodesmiun* bloom from sea water. It can be seen from fig. 6a that if a GLI pixel (1000m by 1000m) is completed covered by the *Trichodesmiun* bloom (▲), it can be easily separated from the sea water (+). When the bloom area reduced to 49% (fig. 6b), the bloom cluster (▲) moves towards the sea water (+) but it is still possible to separate the 2 classes. When the *Trichodesmiun* bloom covers 25% of a pixel, the separation becomes impossible (fig. 6c).

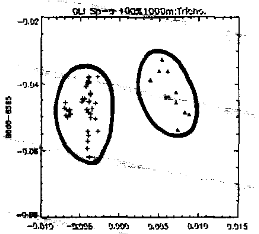

Fig. 6a

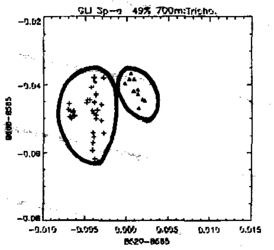

Fig. 6b

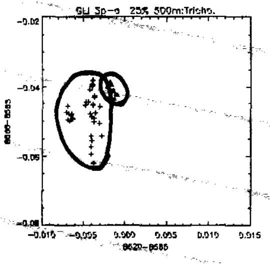

Fig. 6c

Fig.6 : Scatter plots showing the separation of sea water and *Trichodesmiun* bloom under different bloom coverage. 6a:100%,6b:49%,6c:25%.

	Trichodesmium		Diatom		*Cochlodinium*		Manila Bay Dinoflagellates	
GLI (1000m)	√	49% 700m	√	49% 700m	√	49% 700m	√	25% 500m
GLI/TM band (250m)	x	x	√	51.8% 180m	√	51.8% 180m	√	16% 100m
MERIS (1200m)	√	44.4% 800m	√	44.4% 800m	√	44.4% 800m	√	25% 600m
MERIS (300m)	√	44.4% 200m	√	44.4% 200m	√	44.4% 200m	√	25% 150m
MODIS (1000m)	√	44.4% 667m	√	44.4% 667m	√	44.4% 667m	√	25% 500m
OCTS (700m)	√	51% 500m	√	51% 500m	√	51% 500m	√	18.4% 300m
SEAWIFS (1130m)	√	51% 807m	√	51% 807m	√	51% 807m	√	18.4% 484m
CZCS (825m)	√	51% 589m	√	51% 589m	√	51% 589m	√	18.4% 353.6m
TM (30m)	x	x	√	51.8% 21.6m	√	51.8% 21.6m	√	16% 12m
SPOT (20m)	x	x	√	56.25% 15m	√	56.25% 15m	√	100% 20m
AVHRR (1000m)	x	x	x	x	x	x	x	x

Table1: Summary and comparison of the spatial sensitivity of different sensors/resolution modes.

Table 1 summarises the spatial sensitivity of different sensors/modes in detecting different types of blooms. It can be seen that the discrimination between sea water and algal bloom depends both on the spatial resolution and the spectral bands. For example, GLI normal resolution mode (1000m) can differentiate all the 4 types of algal blooms from sea water. However, under the high resolution mode (250m) (TM spectral bands), *Trichodesmiun* bloom can not be discriminated. In general, all the ocean colour sensors, i.e. GLI normal mode, MODIS, MERIS, OCTS, SEAWIFS, and CZCS can discriminate all the studied algal bloom types from sea water.

The broad band visible sensors, i.e., GLI TM mode, TM, and SPOT can only separate certain bloom types (i.e. diatom, *Cochlodinium*, and Manila Bay dinoflagellates) from sea water. Though only certain bloom types can be separated (table 1), these broad band sensors have the advantage of detecting very small scale blooms (10m-20m) from the ambient sea.

6. CONCLUSIONS

This research suggests that it is possible to monitor different algal blooms by satellite ocean colour data from a series of simulation data. Large scale (500m to 1km) algal blooms can be detected from the medium resolution satellite ocean colour measurements. To a certain extent, the bloom types may be identified. The GLI sensor provides the highest spectral capability. In terms of the combination of spectral and spatial capability, the high resolution mode (300m) of MERIS is expected to be the best as smaller scale algal blooms (150m-300m) can also be identified. The high resolution broad band visible sensors (e.g. TM and SPOT) are found to be capable in differentiatomg certain bloom types from the ambient sea water. Though the identification of the bloom species is not possible, suspicious bloom areas of very small scale (10m-20m) can be located which provides a first warning of bloom location and scale.

7. ACKNOWLEDGEMENTS

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8. REFERENCES

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