Regional sea water chlorophyll distribution derived from MODIS for near-real time monitoring

S. C. Liew and A. W. C. Heng
Centre for Remote Imaging, Sensing and Processing (CRISP)
National University of Singapore, 10 Kent Ridge Cresent, Singapore 119260
{crslsc, crshwca}@nus.edu.sg

Abstract: Ocean color products derived from remote sensing satellite data are useful for monitoring the sea water quality such as the concentrations of chlorophyll, sediments and dissolved organic matter. Currently, ocean color products derived from MODIS data can be requested from NASA over the internet. However, due to the bandwidth limitation of most users in this region, and the time delay in data delivery, the products cannot be use for near-real time monitoring of sea water chlorophyll. CRISP operates a MODIS data receiving station for environmental monitoring purposes. MODIS data have been routinely received and processed to level 1B. We have adapted the higher level processing algorithms from the Institutional Algorithms provided by NASA to run in a stand-alone environment. The implemented algorithms include the MODIS ocean color algorithms. Seasonal chlorophyll concentration composite can be compiled for the region. By comparing the near-real time chlorophyll product with the seasonal composite, anomaly in chlorophyll concentration can be detected.
Keywords: MODIS, chlorophyll, algal bloom, ocean color.

1. Introduction

Ocean colour data from remote sensing satellites provide rich information on the spatial distribution of phytoplankton abundance and other useful parameters such as the concentration of dissolved organic matter and suspended sediments in the surface ocean waters. The MODIS instruments on board the NASA's Terra and Aqua satellites have eight ocean color bands in the visible spectral region, with 10 nm bandwidth and 1 km spatial resolution. Algorithms for performing atmospheric correction and retrieving the various ocean colour parameters from MODIS data have been developed by the MODIS ocean science team. Temporal variations in the distribution of these parameters can be investigated with the availability of regular data acquisition. Data sets can be combined to provide useful information on seasonal variations. The averaged data sets provide the seasonal baseline chlorophyll concentration. Sudden onset of high phytoplankton population (indicated by an increase in chlorophyll concentration) may be detected by comparing the daily chlorophyll map with the seasonal mean chlorophyll distribution.

2. Seasonal charts for regional chlorophyll-a distribution

The Centre for Remote Imaging, Sensing and Processing (CRISP) receives daily data from the Moderate Resolution Imaging Spectroradiometer (MODIS) on board the TERRA and AQUA satellites. The raw data are processed daily into Level 1B radiances.

Furthermore, the daily MODIS data from the TERRA satellite are processed using the Institutional Algorithm, PGE09 Version 4.2.2 (release date: 18 Dec 2002) to extract the chlorophyll-a distribution. This module applies atmospheric correction to the Level 1B data to obtain normalized water leaving radiances at the 7 MODIS ocean viewing bands: 412 nm, 443 nm, 488 nm, 531nm, 551 nm, 667 nm and 678 nm. The MODIS chlorophyll-a is computed using an empirically derived algorithm This algorithm, due to Clark [1], relates the chlorophyll-a concentration (Chl-a) to the water leaving radiance, L_{wn}, from MODIS bands 9 (443 nm) and 12 (551 nm):

$$\log_{10}(Chl) = -1.40 \log_{10}\left(\frac{L_{wn}(443)}{L_{wn}(551)}\right) + 0.07 \qquad (1)$$

To obtain an averaged synoptic view of the chlorophyll-a distribution over the region, we combine data from multiple temporal passes over the region into monthly charts. An example of such a chart is shown in Fig. 1.

These charts are generated for the region between latitudes 30^0N and 25^0S and longitudes 70^0E and 140^0W, covering an area approximately 7800 km by 6100 km. A grid is generated such that there are 24 rows per degree latitude or a total of 1320 rows between latitudes 30^0N and 25^0S. This number was chosen to be consistent with MODIS Ocean Level 3 equal-area sinusoidal grid [2]. This makes the grid size to be approximately 4.64 km.

The data from each pass are filtered to retain only the "good" quality values, indicated in the quality flag (http://modis-ocean.gsfc.nasa.gov/qualfilter.html). The charts show the averaged chlorophyll-a values between 0.01 mg/m^3 to 10.0 mg/m^3 on a logarithm scale.

We use simple averaging to obtain the averaged chlorophyll values. The values of chlorophyll concentration, C, (not the logarithm of C) at each grid point are summed and divided by the total number of

observations. We also compute the standard deviation. Thus, for each grid point, we have the averaged concentration, C_{avg} and the standard deviation, *s*.

3. Detecting Chlorophyll Anomaly

The processed chlorophyll values for each day are put into the same grid as for the seasonal charts and filtered to retain only the "good" values. A chlorophyll anomaly event is defined as one where the daily chlorophyll value is significantly higher than the averaged value for the month. Each daily chlorophyll value is compared with the averaged value for the month and the number of standard deviations that it differs is plotted on a chart, such as the example shown in Fig. 2. As seen in Fig.2, it is possible to flag areas with higher than the average chlorophyll concentration. In this particular example shown, chlorophyll anomaly was detected on 11 August 2003, off the southern coast of Southern Sumatra where the chlorophyll concentration was more than 5 standard deviations higher than the August mean value. Unfortunately, we cannot be sure that the increase appeared only on that day concerned. It is because there was no data on the previous day or the next day for this location due to cloud covers. Clouds and sun glint are two severe restrictions to data availability over this region.

4. Conclusions

Regional chlorophyll distribution can now be derived from MODIS direct broadcast data. The monthly averaged values can be used to flag areas where the chlorophyll concentration is unusually high. These monthly averaged values can also be used to study the seasonal variations of chlorophyll concentration.

References

[1] Dennis K. Clark (1997) MODIS Algorithm Theoretical Basis Document Bio-Optical Algorithms – Case 1 Waters.

[2] Janet W. Campbell, John M. Blaisdell, and Michael Darzi (1995) SeaWiFS Technical Report Series Volume 32, Level-3 SeaWiFS Data Products: Spatial and Temporal Binning Algorithms.

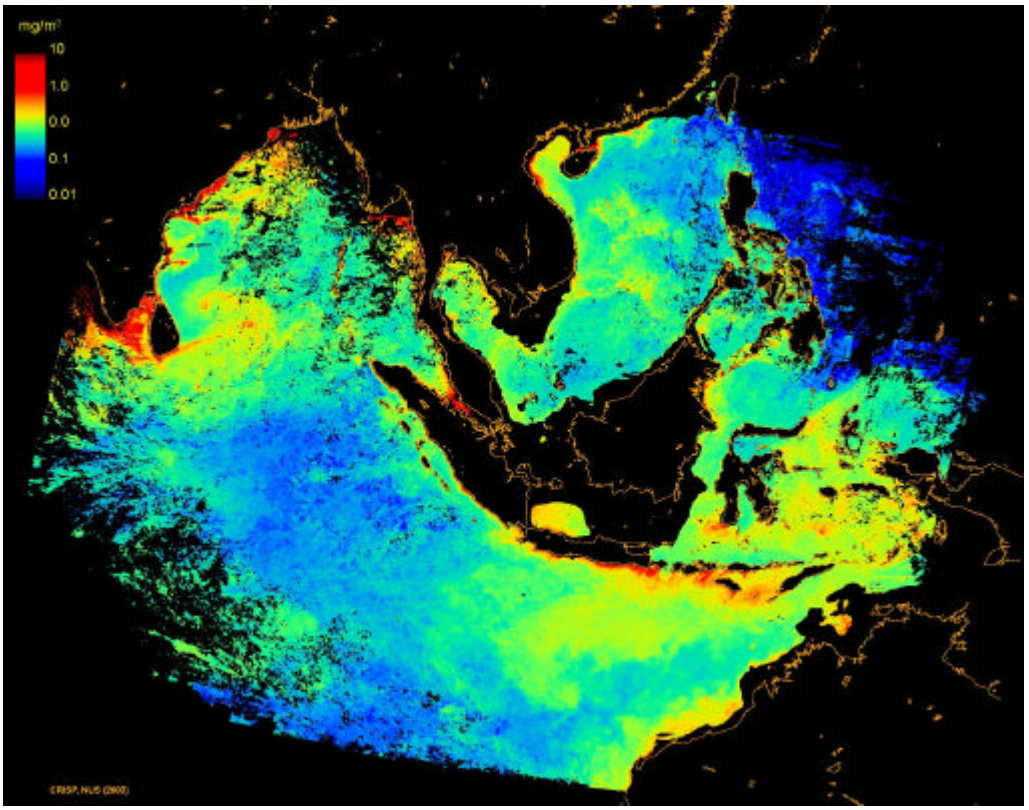

Fig. 1. Chlorophyll-a distribution in the Southeast Asian waters for the month of August 2002. The colour bar is shown, with chlorophyll concentration ranging from 0.01 to 10 mg/m^3.

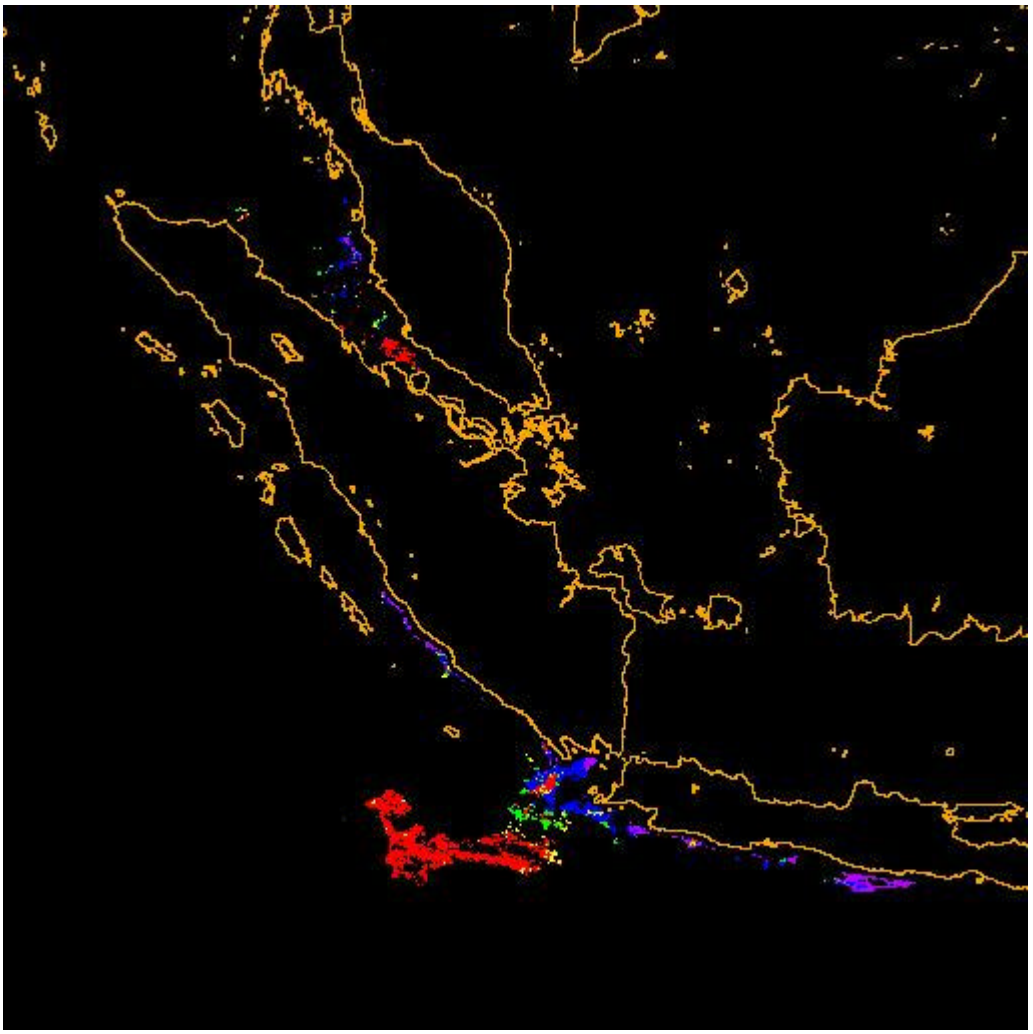

Fig 2. Areas with higher than the averaged chlorophyll on August 11 2003. Purple areas are 1 standard deviation from the average, blue -2 standard deviations, green – 3 standard deviations, yellow- 4 standard deviations and red – 5 and more standard deviations.