Multispectral Remote Sensing Algorithms for Particulate Organic Carbon (POC)

Young Baek Son[a], Wilford D. Gardner[b], Alexey V. Mishonov[c], and Mary Jo Richardson[b]

[a] Nagasaki University, Nagasaki, Japan 852-8521

[b] Department of Oceanography, Texas A&M University, College Station TX 77843-3146

[c] National Oceanographic Data Center (NODC), 1315 East West Highway, Silver Spring, MD 20910

I. INTRODUCTION

POC plays a key role in the transport of carbon in the ocean through the biological pump. While CO_2 and DOC move with the water, POC can settle through the water column, across isopycnals, scavenging or aggregating other particles and transporting carbon and associated elements to deeper waters. Thus, POC is a key component in the ocean's role in sequestering and isolating carbon from the atmosphere. Because POC is produced/cycled on day-to-week time scales, a synoptic picture can only be obtained employing remote sensing techniques.

We have developed remote sensing algorithms for particulate organic carbon (POC) by matching in-situ POC measurements in the Gulf of Mexico with matching SeaWiFS remote sensing reflectance. Data on total particulate matter (PM) as well as POC collected during nine cruises in spring, summer and early winter from 1997-2000 as part of the Northeastern Gulf of Mexico (NEGOM) study were used to test algorithms across a range of environments that may be related to Case I versus Case II waters. Finding that the remote-sensing reflectance clearly exhibited a peak shift from blue to green wavelengths with increasing POC concentration, we developed a maximum normalized difference carbon index (MNDCI) algorithm which uses the maximum band ratio of all available blue-to-green wavelengths, and provides a very robust estimate over a wide range of POC and PM concentrations (R^2=0.99, N=58). The algorithm can be extrapolated to areas in the vicinity of the area of shipboard sampling for more detailed spatial and temporal studies.

II. DATA and METHODS

NEGOM Program

Location : North East Gulf of Mexico

Cruises : 9 seasonal cruises from 1997 – 2000

CTD Stations 100 per cruise from 20 m to 1000 m

Samples : POC filtered from Niskin bottle samples at 60 stations per cruise

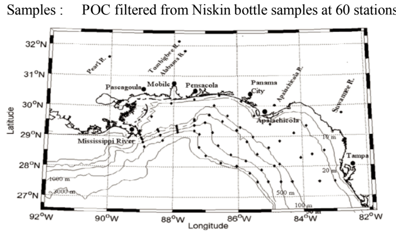

Figure 1. Bathymetry and POC sampling stations in the Northeastern Gulf of Mexico (NEGOM Program) from November 1997 to August 2000 (60 POC stations)

Empirical Approach for algorithm development

Compare POC data with synchronously obtained satellite-derived ocean color data (+/- 3 hrs).

Process daily Level 1 data from SeaWiFS ocean color data .

Process Level 2 data for all eight SeaWiFS wavelengths include: normalized water-leaving radiance, *Lwn* (or remote-sensing reflectance, *Rrs*).

For comparing SeaWiFS and POC data we:

1) calculated the average value of each SeaWiFS-derived parameter at station locations. Data were gridded and smoothed using 3×3 pixel median filtering to reduce noise and fill small gaps.

2) used least-squares analysis for multiple and linear regressions between POC and ocean color parameters.

POC maps using bottle data

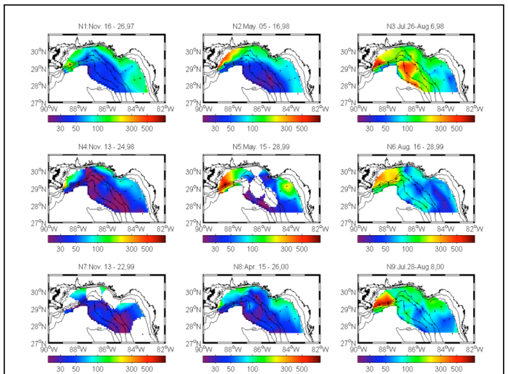

Figure 2. Surface POC concentration (mg·m^{-3}) contoured from bottle samples collected at ~60 stations during each NEGOM hydrographic cruise.
Fall - Cruises N1/N4/N7, Spring - N2/N5/N8, and Summer - N3/N6/N9, 1997 - 2000.

Fall and early spring - elevated POC concentrations confined to the inner shelf.

Late spring and summer - elevated POC concentrations extended to outer shelf and upper slope. Maximum concentration was 780 mg·m^{-3}.

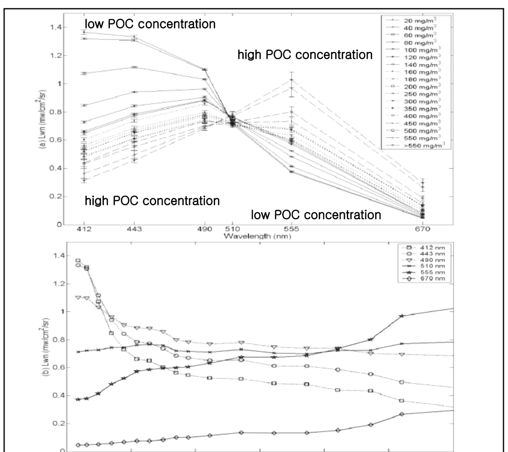

Figure 3. (a) Normalized water-leaving radiance (*Lwn*) versus 6 SeaWiFS wavelengths averaged over areas with 18 different binned ranged of POC (< 20 to > 550 mg m^{-3}) from all nine NEGOM cruises. Error bars are one standard deviation from the mean. As POC concentration increased, the peak in radiance shifted from the shorter wavelengths (412 and 443 nm, violet-blue band) to longer wavelengths (555 nm, green band) (Fig. 3a). This shift was used in developing the Maximum Normalized Difference Carbon Index, similar to what is used to quantify land vegetation. Radiance variation as function of POC concentration is minimal at 510 nm. (b) *Lwn* versus averaged POC concentration from (a) at six spectral wave-bands.

POC maps using MNDCI algorithm

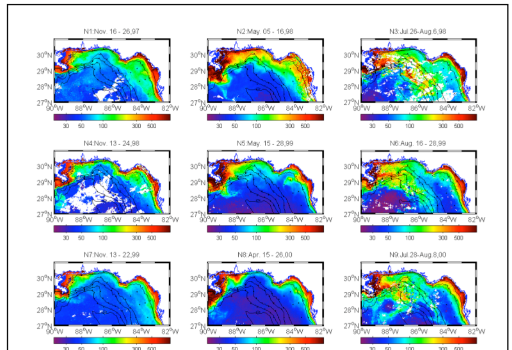

Figure 5. Estimated POC concentration (mg·m^{-3}) in the Northeastern Gulf of Mexico using the Maximized Normalized Difference Carbon Index estimate of POC (Figure 4b) at the 60 POC sampling stations. POC estimates are well correlated with in situ data at all POC concentrations (compare with Figure 2).

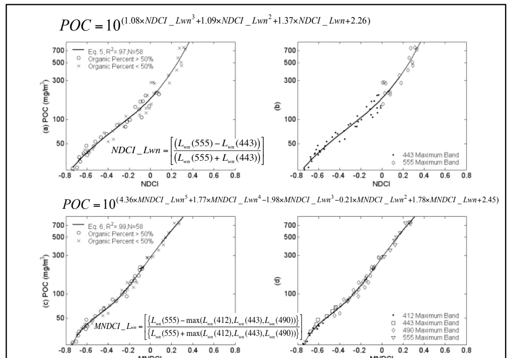

Figure 4. A least-squares fit regression between POC and (a) NDCI and (b) MNDCI. The NDCI uses two wavelengths, while the maximum NDC I uses wavelengths between 412 and 555 nm.

III. CONCLUSIONS

* Spectral radiance is highly dependent on POC concentration.

* The radiance peak shifts significantly from violet-blue wavelengths to green wavelengths as POC concentration increases.

* Therefore, using multiple wavelength radiances provides more reliable estimates of POC over a wide range of concentrations.

* The best estimates for POC concentrations were achieved using the Maximum Difference Carbon Index algorithm (R^2=0.99).

* Furthermore, the accuracy of the MNDCI algorithm was not significantly different when used in waters with either high or low percentage of the total particulate matter being POC, suggesting that the algorithm will be accurate in Case I through Case II waters.

* This algorithm clearly reproduces seasonal cycles and spatial distribution in the Gulf of Mexico at much greater resolution than is possible using shipboard sampling and will be important for interpreting POC cycling in the dynamic waters of the Gulf of Mexico.