Development of Carbon Data Products for the Coastal Ocean using SeaWiFS and MODIS-Aqua

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Objectives

• Apply SeaWiFS and MODIS-Aqua measurements to study Carbon fluxes and Ecosystem processes within coastal ocean waters of the U.S. Middle Atlantic Bight (MAB) and Gulf of Maine (GoM).
• Development and validation of algorithms to retrieve Colored Dissolved Organic Matter (CDOM), Dissolved (DOC) and Particulate Organic Carbon (POC) using SeaWiFS and MODIS-Aqua.

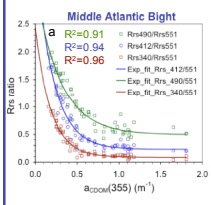
Approach

•Algorithm Development - In order to develop empirical algorithms for POC, CDOM and DOC, the CDOM absorption coefficient (a_{CDOM}) and POC were each correlated with in situ radiometry (remote sensing reflectance, Rrs, band ratios), and DOC was then derived from a_{CDOM} through the a_{CDOM} to DOC relationships (Mannino et al. 2008).

•Satellite Validation – The validation protocols described by Bailey and Werdell (2006) were applied with the exception that 3x3 1km pixel arrays centered on the field station locations were analyzed. The statistical parameters applied include the mean and standard deviation of the absolute percent difference (APD), root mean square error (RMSE), and the R^2 and slope values from linear regression analyses of the validation match-ups for each satellite sensor (Bailey and Werdell, 2006; Garcia et al., 2006; Mannino et al. 2008).

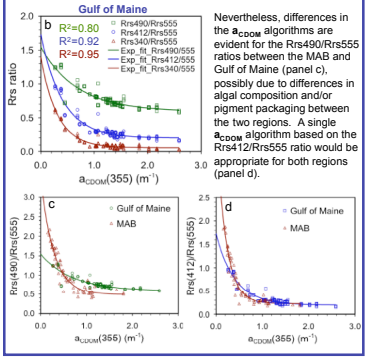
CDOM Algorithms

Figure 1. Empirical band ratio algorithms for a_{CDOM}. Data shown are derived from in-water radiometry and lab measurements of a_{CDOM} from the southern MAB and western Gulf of Maine.



Exponential one-phase decay models yield excellent curve fits for multiple band ratios, including Rrs ratios of UV (e.g., 340nm and 380nm) to 551 or 555nm bands (panels a & b). However, current ocean color satellite sensors do not have UV capability. The band ratio with Rrs(412nm) would be appropriate, but atmospheric correction issues for the 412nm band compels us to use the 490nm band ratio.

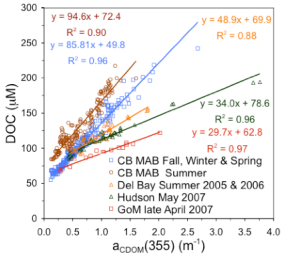
$a_{CDOM}(355) = \ln[(Rrs490/Rrs551 - 0.494)/2.7]/-3.37$
Mean APD = 19 ± 14%



Nevertheless, differences in the a_{CDOM} algorithms are evident for the Rrs490/Rrs555 ratios between the MAB and Gulf of Maine (panel c), possibly due to differences in algal composition and/or pigment packaging between the two regions. A single a_{CDOM} algorithm based on the Rrs412/Rrs555 ratio would be appropriate for both regions (panel d).

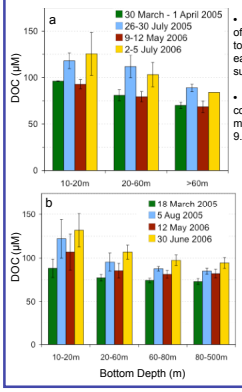
DOC Algorithms

Figure 2. Cross-system variability and interannual consistency of a_{CDOM}-DOC relationships. CB MAB = region between Chesapeake Bay and Delaware Bay mouths and the continental slope sampled from 2004-2007; Del Bay = Delaware Bay mouth and plume region; Hudson = Hudson River and Plume; GoM = western Gulf of Maine.



• The amount of DOC for each unit of a_{CDOM} increases from north to south, which suggests differences in source materials, such as more colored terrestrial DOM exported to the GoM due to absence of large estuaries where the DOM can be degraded. Note the much higher a_{CDOM} values for the GoM than the MAB in Fig. 1.
• Remarkable interannual consistency for the CB MAB and Del Bay.
• Seasonal variability of the a_{CDOM}-DOC relationship in the CB MAB and Del Bay is due to the concomitant accumulation of DOC from net community production and photooxidation of CDOM between spring and fall.
• Need further field sampling during seasonal shifts in a_{CDOM}-DOC.

Figure 3. Surface DOC in the southern MAB from (a) field measurements and (b) MODIS-Aqua demonstrating the seasonal Net community production (NCP) of DOC.



• The seasonal NCP of DOC ranges from 12 to 34 µM between early spring and summer.
• Satellite to field data comparisons yield mean APD for DOC of 9.3 ± 7.3%.

POC Algorithms

Figure 4. Development and evaluation of POC algorithms for the southern MAB. Matchups of POC values derived from in-water AOP (radiometry) and in situ lab measurements for (a) published POC algorithms and (b) exponential curve fits. Panel c shows the in-water derived exponential decay algorithm. Stram_1 and Stram_4b represent Algorithms 1 and 4 from Stramska & Stramski (2005); Gardner_str from Gardner et al. (2006) except Cp computed as function of Lwn443/Lwn555 from Stramska & Stramski (2005).

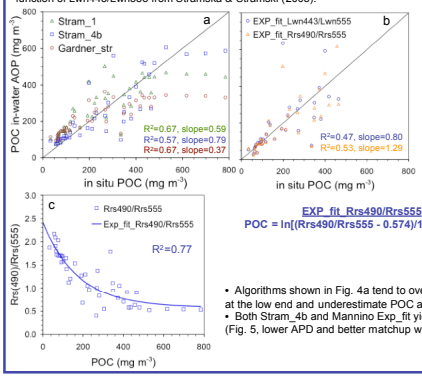
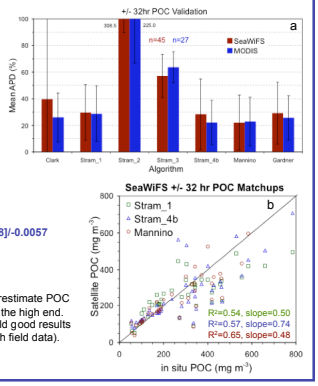


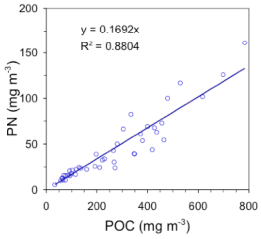
Figure 5. Validation of POC algorithms for the southern MAB. Clark (unpublished); Stram_1, Stram_2, Stram_3 and Stram_4b represent Algorithms 1-4 from Stramska & Stramski (2005); Mannino from Exp_fit in Fig. 4c); Gardner from Gardner et al. (2006). APD = Absolute Percent Difference between *in situ* POC and satellite-derived POC.



EXP_fit_Rrs490/Rrs555
POC = ln[(Rrs490/Rrs555 - 0.574)/1.8]/-0.0057

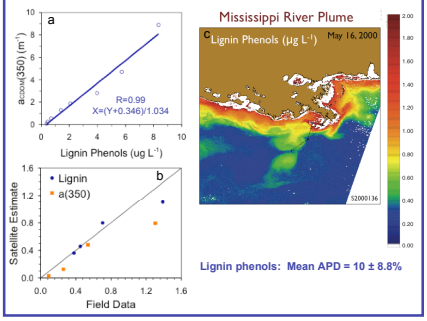
• Algorithms shown in Fig. 4a tend to overestimate POC at the low end and underestimate POC at the high end.
• Both Stram_4b and Mannino Exp_fit yield good results (Fig. 5, lower APD and better matchup with field data).

Figure 6. Correlation of POC and particulate nitrogen (PN) in the southern MAB will permit satellite-retrieval of PN using a POC algorithm.



Terrestrial DOM from Space

Figure 7. Satellite retrieval of dissolved terrestrial organic matter (lignin phenols) from a_{CDOM} algorithm. (a) Field-based relationship of $a_{CDOM}(350)$ with lignin phenols (Hernes & Benner 2003), (b) matchups of satellite and field data for $a_{CDOM}(350)$ and lignin phenols, and (c) SeaWiFS image of lignin phenol product for the Mississippi River plume.



Lignin phenols: Mean APD = 10 ± 8.8%

References

Bailey, S. and P.J. Werdell. 2006. RSE, 102: 12-23.
Garcia, V.M.T. et al. 2006. IJS, 27: 1539-1562.
Gardner, W.D., A.V. Mishonov and M.J. Richardson. 2006. DSRII, 53: 718-740.
Hernes, P. and R. Benner. 2003. JGR, 108, C9, 3291, doi:10.1029/2002JC001421.
Mannino, A., M.E. Russ and S.B. Hooker. 2008. JGR, doi:10.1029/2007JC004493, in press.
Stramska, M. and D. Stramski. 2005. JGR, 110, C10018, doi:10.1029/2004JC002762.

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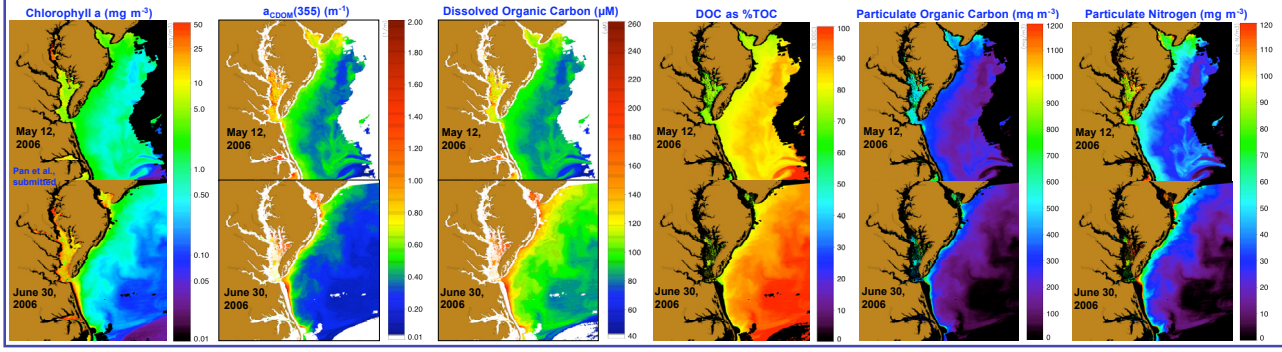
Figure 8. New satellite products for the southern MAB obtained from the MODIS-Aqua high-resolution processing with SWIR and NO_2 atmospheric corrections.



• Biogeochemical products demonstrate expected gradients of high to low concentrations from nearshore to offshore.

• Higher levels of chlorophyll, CDOM, POC and PN are observed in spring than in summer along the continental margin.
  • Elevated nutrient levels in spring promote phytoplankton blooms and accumulation of biomass.
  • Higher CDOM results from the riverine/estuarine discharge of terrigenous organic matter.

• The higher concentrations of DOC in summer are due to the release of DOC from Net Community Production that promotes the accumulation of semi-labile DOC from late spring to summer.
• Spring to summer decrease in $a_{CDOM}(355)$ is due to photooxidation.

• Elevated levels of Chl a, CDOM, DOC, POC, and PN in the bay plumes and along the coast on June 30th were due to 300yr flood level precipitation in these watersheds throughout the month of June.