Satellite-derived Distributions of DOC and CDOM in the U.S. Southern Middle Atlantic Bight

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ABSTRACT

Dissolved organic carbon (DOC) in the ocean constitutes a major global carbon reservoir. In coastal ocean waters, distributions of DOC vary seasonally and interannually due to multiple source inputs including *in situ* primary production, contributions from adjacent ocean waters, and terrigenous, anthropogenic and estuarine-derived organic matter entering the coastal ocean from rivers and bays, and removal processes such as advection, microbial remineralization and photooxidation. Chesapeake Bay, as one of the largest and most productive estuaries in the world, can influence the carbon cycle of the adjacent continental margin through contributions of carbon and nutrients. We conducted several cruises in 2005-2006 between the mouth of Chesapeake Bay and continental slope waters within the U.S. Middle Atlantic Bight (MAB) to examine the impact of Chesapeake Bay and adjoining watersheds on distributions of DOC, particulate organic carbon and chromophoric dissolved organic matter (CDOM). One of our objectives is to apply our *in situ* data to develop algorithms to retrieve CDOM and DOC from MODIS and SeaWiFS observations. In order to develop empirical algorithms for CDOM and DOC, we correlated the CDOM absorption coefficient (a_{CDOM}) with *in situ* radiometry (reflectance band ratios) and then correlated DOC to reflectance band ratios through the a_{CDOM} to DOC relationships. Our results demonstrate that we can retrieve a_{CDOM} through empirical relationships similar to those described by D'Sa and Miller (2003) and Johannessen et al. (2003). Because of seasonal differences between the DOC to a_{CDOM} relationship, at least 2 seasonal algorithms for DOC will be required (winter-spring and summer). Our analyses indicate that DOC and a_{CDOM} can be retrieved from coastal ocean waters with MODIS-Aqua to within ~10% and ~20% on average, respectively. With accurate satellite retrievals of DOC and a_{CDOM}, we will be able to apply satellite observations to investigate interannual and decadal-scale variability in surface a_{CDOM} and DOC concentrations within the MAB and quantify the DOC reservoir.

OBJECTIVES

- Develop algorithms to retrieve a_{CDOM} and DOC with MODIS and SeaWiFS observations.
- Apply algorithms and *in situ* data to examine the impact of Chesapeake Bay and adjoining watersheds on the seasonal and interannual distributions of DOC & CDOM to the continental margin.
- Contribute to the modeling activity to derive carbon budgets for the U.S. Eastern Continental Shelf

METHODS

In situ Radiometry

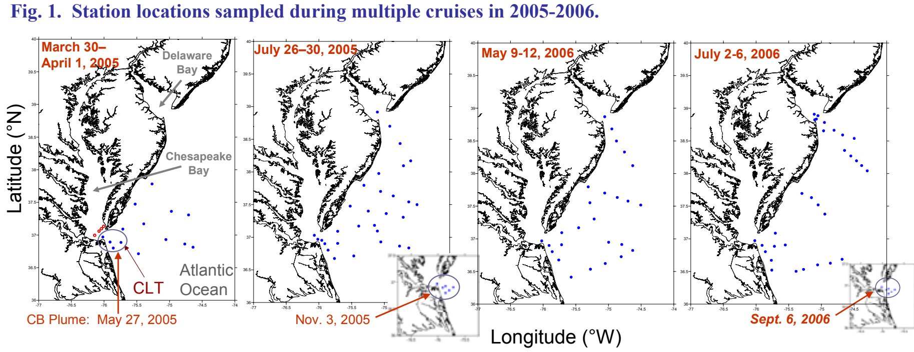
The instrumentation is based on the PRR-800 series manufactured by Biospherical Instruments (San Diego, CA). The in-water profiler, which measures downward irradiance, Ed(ϐ), as well as upwelling radiance, Lu(ϐ), is floated away from the ship to avoid ship perturbations. All radiometers have 19 channels spanning the UV (320 nm) to near infrared (865 nm) with intermediate channels selected to match existing satellite sensors. All the radiance products are corrected for self-shading effects. Separate extrapolation intervals are used for the blue-green and red parts of the spectrum, because the attenuation in the red is significantly different. The quadrature sum of uncertainties gives values <4.5% in the blue-green wavelengths and <5% in the red. Assuming half of the total uncertainty budget is apportioned to the satellite sensor, the allowed uncertainty in the *in situ* data is ~3.5%.

CDOM Absorption, DOC & Other Measurements

Seawater collected from Niskin bottles is filtered (through GF/F filters) directly into sample containers for analysis of DOC and CDOM absorption. Particles are collected on 25 mm GF/F filters for analysis of POC/PN and HPLC pigments (Van Heukelem & Thomas 2001). DOC is analyzed in triplicate (S.D. <2%) by high temperature combustion oxidation using a Shimadzu TOC-V. The Sargasso deep sea water reference (Hansell Lab) is used daily to verify the accuracy of DOC and maintain an analytical error to within 5%. Absorption spectra of CDOM (after filtration through 0.2 µm Nuclepore or Supor filters in the lab) are collected with a UV-Visible spectrophotometer (250-800 nm) using UV oxidized Milli-Q water as the blank and reference (Mitchell et al. 2003).

FIELD CAMPAIGN

Fig. 1. Station locations sampled during multiple cruises in 2005-2006.



CLT - station near the Chesapeake Light Tower (~25km offshore), an AERONET site recently equipped with a SeaPRISM.

Fig. 2. Vertical distributions of dissolved organic carbon (DOC) at select stations from the March 30-April 1 and July 26-30, 2005 cruises. During Spring, the water column was well mixed vertically from the inner-shelf to the continental slope except for the Chesapeake Bay mouth & plume region as exemplified by DOC distributions. By Summer, thermal stratification isolates the surface ocean layer from deeper water, yielding higher DOC in the surface layer due to ecosystem productivity.

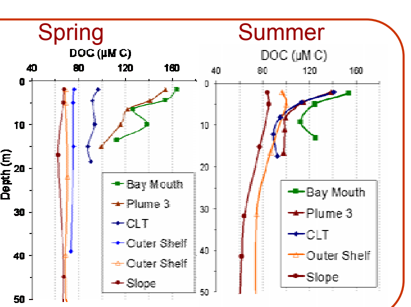
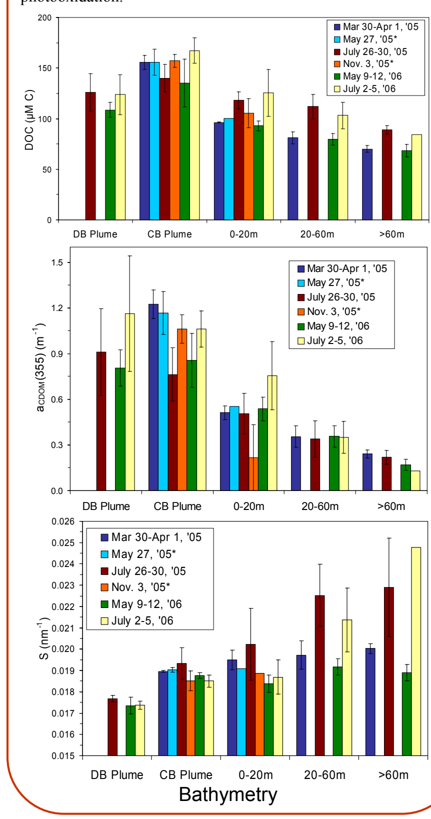


Fig. 3. Seasonal and interannual variability in surface DOC, a_{CDOM} and CDOM spectral slope (S) across the continental margin of the Southern MAB. Except for the Delaware (DB) and Chesapeake Bay (CB) Plume regions, DOC increases from Spring to Summer across each bathymetry region. Both DOC and a_{CDOM} decrease from the bays to the continental slope. S increases from Spring to Summer across the shelf to values more consistent with marine CDOM. The shift in S can be attributed to greater solar intensity and a stratified water column in summer that promotes photooxidation.



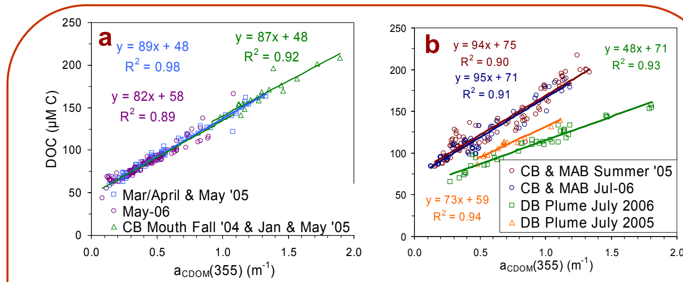


Fig. 4. Seasonal variability and inter-annual consistency of the DOC to a_{CDOM}(355) relationship derived from field measurements collected between the Chesapeake Bay mouth and the continental slope. The DOC to a_{CDOM}(355) relationship in a) winter-spring and b) summer are highly correlated and consistent for 2005-2006. Our results indicate that at least 2 DOC algorithms are required (Winter-Spring & Summer) and possibly algorithms for transitional periods (late Spring to early Summer and Summer to Fall). Panel c shows the relationship applied to estimate DOC from satellite-derived a_{CDOM}(355) (see Fig. 5). Results are similar for other a_{CDOM} wavelengths.

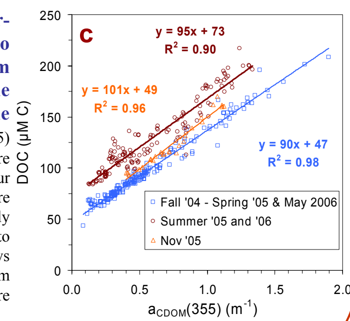


Fig. 5. CDOM algorithms derived from *in situ* measurements of a_{CDOM}(355) and reflectance band ratios (Rrs) collected on the 2005 cruises. Several non-linear and linear curve-fitting routines model the *in situ* data very well (following a least squares approach), especially the a) exponential one-phase decay model and the b) linear regression model applied to log-transformed data. Similar relationships can be derived for other a_{CDOM} wavelengths.

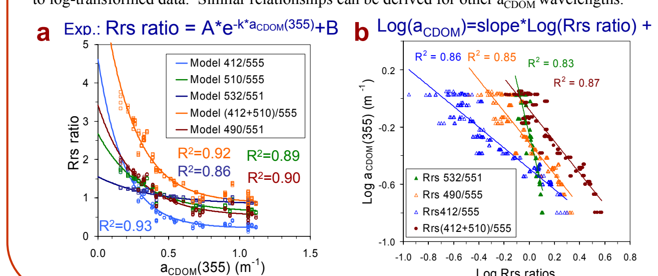
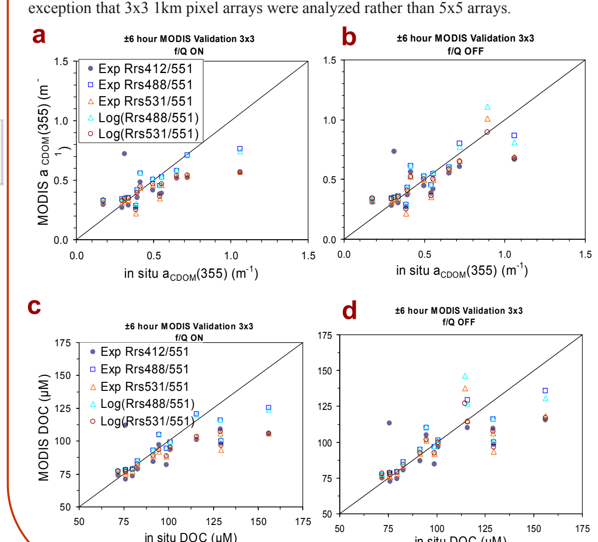


Fig. 6. Validation match-ups of a_{CDOM}(355) and DOC *in situ* measurements versus data derived from MODIS-Aqua: a) a_{CDOM}(355) with BRDF f/Q correction, b) a_{CDOM}(355) without BRDF, c) DOC with BRDF, d) DOC without BRDF, e) a_{CDOM}(355) mean absolute percent difference (APD) and f) DOC mean APD evaluated for 5 algorithms. The validation protocols described by Bailey and Werdell (2006) were applied with the exception that 3x3 1km pixel arrays were analyzed rather than 5x5 arrays.



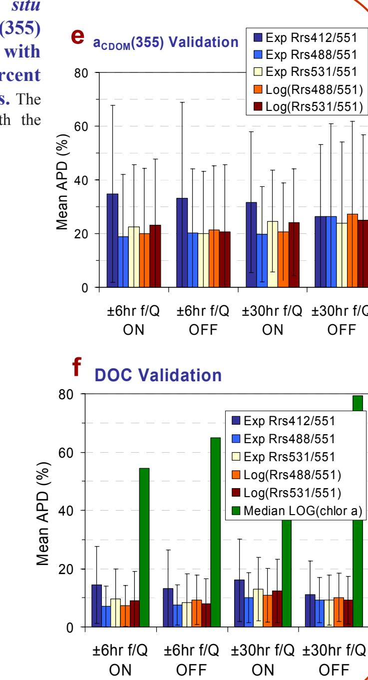
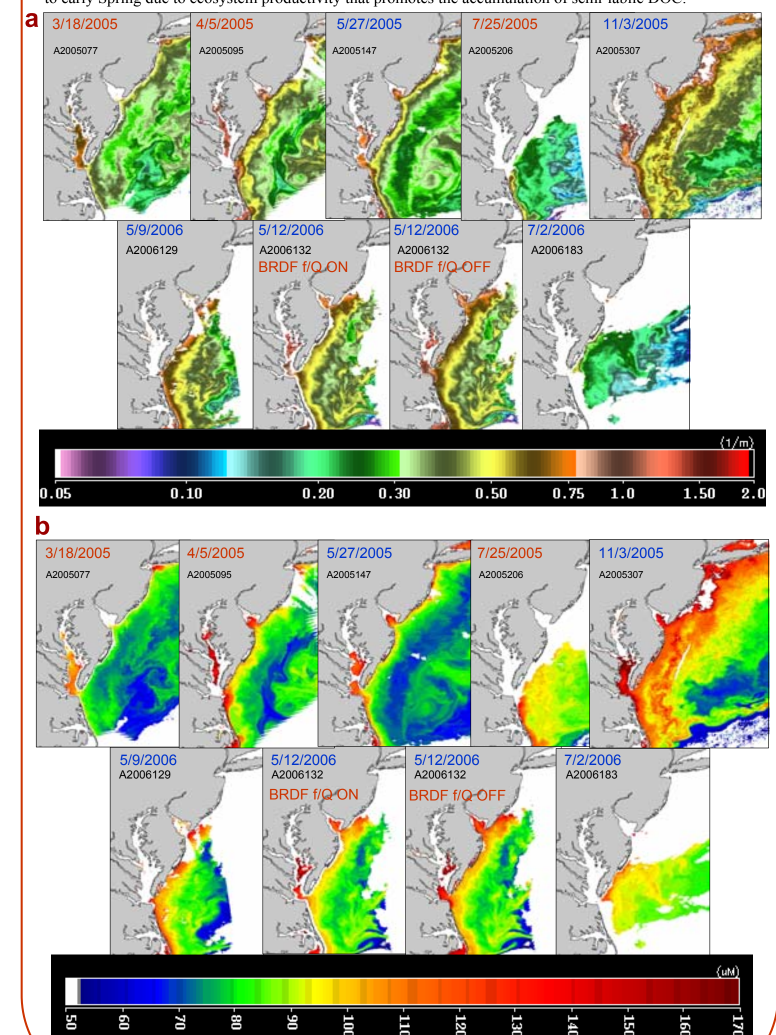


Fig. 7. MODIS-Aqua derived a) a_{CDOM}(355) and b) DOC products using the exponential decay Rrs488/551 ratio algorithm. Significant variations in a_{CDOM}(355) and DOC occur along the continental margin from Spring to Summer and Summer to Fall. a_{CDOM}(355) decreases from Spring to Summer, due to photooxidation and possibly from lower inputs of terrigenous DOM as a result of reduced river discharge. From Summer to Fall, storm events vertically mix the water column and introduce CDOM into surface waters. Much higher DOC are observed in Summer compared to early Spring due to ecosystem productivity that promotes the accumulation of semi-labile DOC.



SUMMARY & CONCLUSIONS

- Meteorological variability & ecosystem productivity result in seasonal & interannual variability in coastal ocean DOC and a_{CDOM}.
- DOC and a_{CDOM} can be retrieved from coastal ocean waters with MODIS-Aqua (~10% and ~20% mean APD, respectively).
- Satellite retrieval of DOC requires 2 or more seasonal algorithms due to the variable DOC versus a_{CDOM} relationships.
- Satellite observations can be applied to quantify the entire DOC reservoir for the southern MAB during winter-spring.

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