Remote sensing retrievals of colored dissolved organic matter and dissolved organic carbon dynamics in North American estuaries and their margins

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Objectives:
- Dissolved organic carbon (DOC) and the colored component of dissolved organic matter (CDOM) are key indicators of coastal water quality and biogeochemical state; however, the application of space-based remote sensing for monitoring CDOM variability and the assessment of DOC exchanges along highly dynamic terrestrial-aquatic interfaces and ecosystems have been scarce.
- Two significant factors in limiting such assessments and applications are the coarse spatial resolution of most existing ocean color sensors and the seasonal and regional dependence of most existing algorithms.
- In order to respond to the challenges of satellite retrievals of CDOM and DOC in optically complex coastal waters, this study develops and validates new CDOM and DOC algorithms that are broadly applicable to different estuarine and coastal regions over different seasons and a wide range of in-water condition.
- Full-resolution (300-m) MERIS imagery was used to develop the new algorithms that were evaluated, for the first time, across estuarine systems using satellite and in situ match-ups spanning different seasons and multiple years.
- Results were compared with 1-km resolution MODIS retrievals.
- The authors used multi-spectral remote sensing reflectance ($R_{rs}$) to retrieve both CDOM absorption ($\alpha_{CDOM}(\lambda)$) and the CDOM absorption spectral slope in the 275–295 nm spectral range ($S_{275–295}$), then obtained DOC concentrations from a tight relationship between the DOC-specific CDOM absorption and $S_{275–295}$, an approach allows for a broader application across coastal regions and temporal scales.
- The study region included the Chesapeake and Delaware Bay estuaries, the adjacent coastal waters of the Middle Atlantic Bight, and the northern Gulf of Mexico.
- The data were collected from July 2002 to September 2013 and included the impacts of Tropical Storm Lee in October 2011.

New Science:
- The application of the new algorithms allowed, for the first time, the capture of the impact of tidal exchanges on carbon dynamics along wetland estuary interfaces and highlights the finding that tides have a strong influence on retrievals of carbon distribution and dynamics from ocean color observations.
- The algorithms also resolved spatial gradients, seasonal variability, and year-to-year changes in estuarine carbon amount and quality associated with marsh carbon export, riverine inputs, and extreme precipitation events.
- The algorithm data across the different estuarine and coastal environments and across different seasons and over multiple years resulted in relative errors of 29% (N = 17), 9.5% (N = 14), and 18% (N = 32), for $\alpha_{CDOM}$ (300), $S_{275–295}$, and DOC, respectively which are comparable to those reported for satellite retrievals of CDOM and DOC products in less optically complex offshore waters.
Significance:

• DOC represents over 80–90% of the total organic carbon in the coastal ocean, playing a critical role in a broad range of climate-related biogeochemical cycles.

• Characterized as “the great modulator” in aquatic ecosystems (i.e., the variable that modifies the influence of other variables), DOC and the colored component of dissolved organic matter, CDOM, affect processes such as estuarine ecosystem metabolism, nutrient uptake, the balance between autotrophy and heterotrophy, acidity, bioavailability and toxicity of trace metals and contaminants, photochemical release of biologically labile organic compounds, photoproduction of trace gases, and phytoplankton activity.

• Assessing the impact of estuaries on carbon budgets has been difficult due to the tremendous heterogeneity of estuarine systems and the large uncertainties in scaling up in situ observations, as well as the bio-optical complexity characterizing these highly dynamic nearshore environments and the coarse spatiotemporal resolution of most ocean color sensors.

• The new algorithms discussed in this study are shown to capture variability not only across a larger spatial domain or multiple systems but, more generally, across a wider range of conditions even within a smaller region, or within the same estuary.

• These findings highlight that high spatial resolution multi-spectral observations, similar to or better than the full resolution MERIS, are critical for resolving biogeochemical processes in estuarine-coastal systems from space.

• In addition, high temporal resolution (1–3 h) ocean color observations, for example from a geostationary platform, are necessary for capturing highly dynamic diurnal processes and biogeochemical exchanges in estuaries and their margins.

• Advanced remote sensing tools are urgently needed for monitoring and understanding the resilience, responses, and feedbacks of estuarine and coastal ecosystems to ongoing anthropogenic disturbances and global environmental change.
Comparison of $a_{\text{CDOM}}(300)$ between (a) MODIS-A and (b) MERIS for February 2011 over the Chesapeake Bay.
MERIS monthly composites of the distribution of DOC in the Chesapeake Bay and adjacent coastal waters in 2009.
(a)–(c) CDOM optical properties and DOC in the Chesapeake Bay derived from MERIS in October 2011, after the passage of Tropical Storm Lee. (d)–(f) Differences in CDOM optical properties and DOC between October 2011 (influenced by extreme precipitation) and October 2009 (not influenced by extreme weather event).