Estimating Photochemical Contributions to Coastal Carbon Cycles from Remote Sensing: BLC

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Ocean Optics and Biology

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Summary

This work seeks to evaluate the significance of photochemical reactions on carbon cycles in the South Atlantic Bight and North American coastal waters using satellite ocean color data and parameterized photochemical efficiency spectra. Most photochemistry in the ocean is driven by colored dissolved organic matter (CDOM). Photo-induced changes in biologically labile organic carbon (BLC) is modeled using laboratory determined spectral photochemical reaction efficiencies (i.e. apparent quantum yields: AQY) from water samples taken in the vicinity of Sapelo Island, GA, USA. The variable spectral shapes of BLC AQYs determined in different samples reflects the NET result of simultaneous photochemical production and destruction of biologically labile compounds. Different AQY spectral shapes have a dramatic effect on remote sensing models of in situ photochemical BLC dynamics.

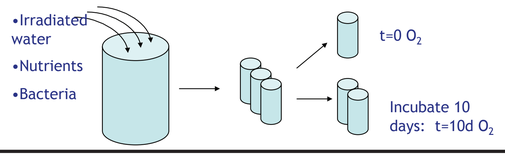
① Background and Question

Previous reports of the role of sunlight on bioavailability of DOC to heterotrophic bacteria have been variable. A review by Mopper and Kieber in 2002 *(In: Biogeochemistry of Marine Dissolved Organic Matter, ed. Hansell and Carlson)* reported 61 studies done in fresh and seawater that showed 40 positive and 21 zero or negative bacterial growth responses in pre-irradiated water relative to dark controls. The magnitude of response ranged from -90% to +560% with a general trend of fresh and nearshore waters exhibiting a large positive effect and offshore and blue water exhibiting a zero or smaller negative effect. None of these studies examined the spectral efficiency of these DOC alterations in detail. This begs the question...

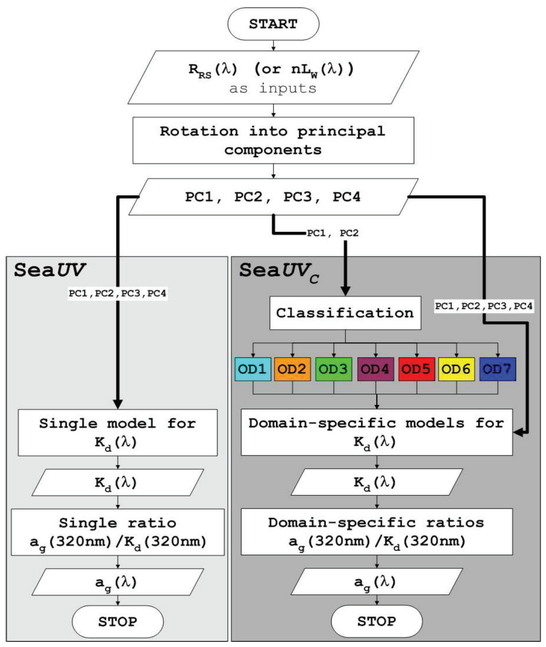
Can spectral efficiency studies provide a quantitative understanding of these variations so that the role of photochemistry in biological lability of DOC can be more accurately Modeled?

② Approach

0.2um filtered seawater was exposed in quartz cells using an Atlas Solar Simulator and long-pass optical filters to generate 14 unique light fields. Bacteria isolated in the original filtration were inoculated and dark O2 consumption over 10 days was used as a proxy for DOC consumption.

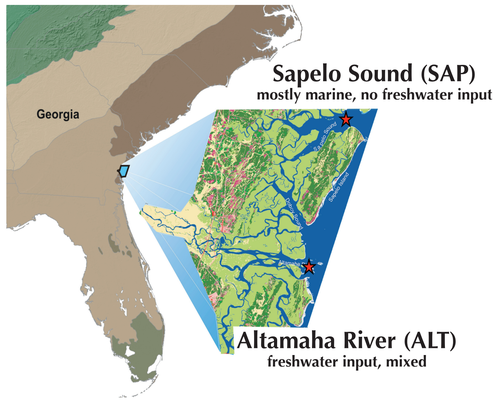


③ SeaUV Model (flowchart)



④ Examining BLC Production, Quantum Yield Spectra, & Production Model

Study Site: Sapelo Island, GA



Cutoff Filter Results: Percent Change relative to Dark controls

	295 nm	305nm (full solar spectrum)	320nm (UV-A and visible)	425nm (visible only)
ALT	31%	151%	146%	129%
SAP	-2%	9%	5%	8%

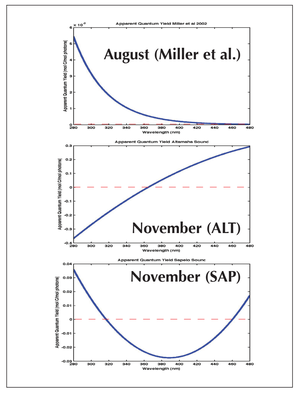
Calculating Photochemical Rates

$$d[P]/dt = \sum_{\lambda} E_{o\lambda}\,(1 - 10^{-a_{\lambda}l})\,\Phi_{\lambda}$$

RATE — LIGHT AVAILABLE — LIGHT ABSORBED — QUANTUM YIELD

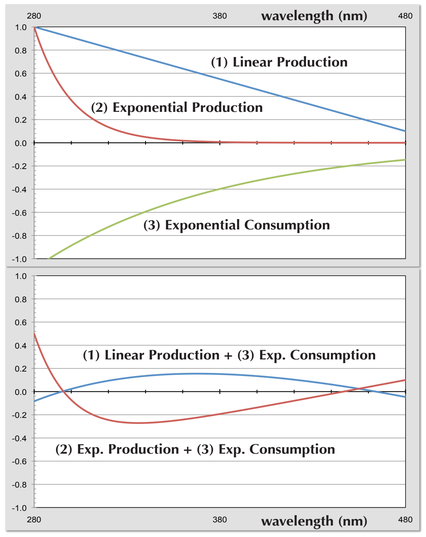
$$\Phi = \frac{\text{moles of product formed}}{\text{moles photons absorbed}}$$

Experimental AQYs for BLC

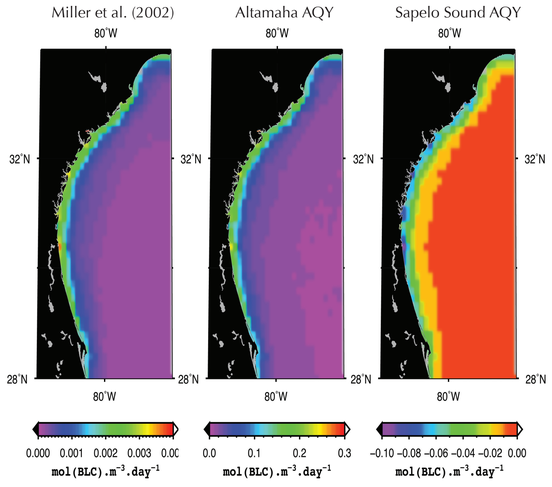


The variable shapes are easily explained when it is understood that some of the same DOC involved in increasing BLC can be photochemically oxidized to CO and CO2 which results in a loss of labile carbon. Both of these reactions go on at the same time. The AQY spectra for BLC, determined by community bacterial respiration of all available compounds, represents a NET production or destruction of labile carbon.

BLC is a NET Measure

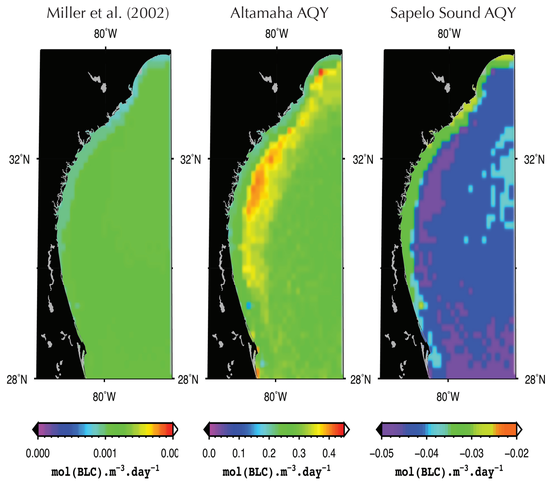


Surface BLC Production



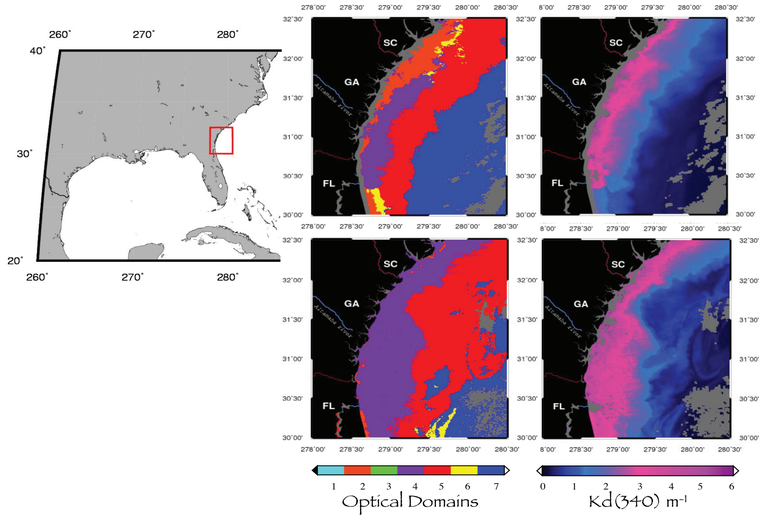
The result of using these three AQY spectral shapes to calculate BLC photoproduction in the South Atlantic Bight. (November. 10-yr SeaWiFS climatology, SeaUVc, and the STAR irradiance model)

Depth Integrated BLC Production



⑤ Application of the SeaUV/SeaUVc Model to Photochemistry

example of SeaUVc application



Some details for application of SeaUV/SeaUVc to photochemistry

Our SeaUV algorithm was applied to SeaWiFS or MODIS monthly binned ocean color in order to retrieve K_d (UV) (+/-11% error) for UV attenuation and a_g(UV) for photochemical calculations. Data were obtained for 10 years (September 1997 until September 2007) and processed to remove outliers.

Monthly climatologies are generated for the period of August 1996 to December 2003 from TOMS reflectivity data and were used to correct E_d (UV) for cloud cover from modelled solar irradiation generated with the STAR model over the spatial area considered.

⑥ Conclusion and Future Work

The spectral efficiency of photochemical BLC formation in the coastal ocean exhibits high spatial and seasonal variability.

Simultaneous production and destruction of biologically available products lead to many possible AQY shapes for NET production of BLP from CDOM.

Shape of AQY is critical in accurate determination of BLP production and greatly affects vertical distribution and depth integrated rates.

There is a need to greatly improve understanding of AQY variations for BLC.

Remote sensing can be used to make large scale estimates of the role of photochemistry in biogeochemical cycles but is only as good as our ability to define the algorithms that drive photochemical production.

Acknowledgments

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