Improving the Accuracy of the SeaUV Algorithms in Dark Marine Waters

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Award Number: N000140610219

LONG-TERM GOALS

Our long-term objective is to develop a robust set of algorithms for the global ocean to provide accurate surface UV attenuation and CDOM retrieval from remotely sensed ocean color for use in optical, photochemical, and photobiological investigation.

OBJECTIVES

The central objective of this project is to generate new, high quality optical data sets for a variety of darker coastal systems to be used in evaluating SeaUV algorithms and retraining them for accurate use in the highly variable optical conditions typical of nearshore waters.

APPROACH

Previous ONR funding in our lab produced two improved and ready-to-use algorithms (SeaUV and SeaUV$_C$) detailed in Fichot (2004) and Fichot et al. (2008). These algorithms are used for estimating $Kd(320\text{-}490)$ and $a_g(320)$ from measurements of spectrally resolved remote sensing reflectance, $Rrs(\lambda)$. Our general approach for this project is to collect new in situ optical data sets for inshore and dark waters, apply the SeaUV algorithms to this new data set for evaluation of current predictive capability, and incorporate these new data into the training data set for evaluation of improved predictive capability using new 'dark trained' algorithms. The final product will be a single model that will predict Kd(UV) and $a_g(\lambda)$ from ocean color in optical domains ranging from the clear open ocean to the dark waters found in close proximity to the coast. We will then apply these trained algorithms to independent data sets where possible for validation.

Approach to Fieldwork: We collect simultaneous *in situ* measurements of Lu(λ), $Kd(\lambda)$ and $a_g(\lambda)$ in the dark waters found along the coast of Georgia, focusing efforts around the UGA Marine Institute (UGMI) on Sapelo Island, GA. Past ONR funding has provided the Satlantic® instruments to collect high quality UV-Vis data for use in the SeaUV algorithms: a Satlantic® MicroSAS ocean color buoy (2 sensors for below-surface multispectral visible upwelling radiance: wavebands = 412, 443, 490, 510, 555, 670 and 683nm) is deployed adjacent and coincident with a Satlantic® Micropro free fall profiling radiometer (2 sensors for below-surface multispectral UV-Vis downwelling irradiance: wavebands = 305, 325, 340 380, 412, 443, 490, 555nm) and a reference radiometer (2 sensors for above-surface multispectral UV-Vis downwelling irradiance: wavebands = 305, 325, 340 380, 412, 443, 490, 510, 555, 670 and 683nm).

Report Documentation Page	*Form Approved* *OMB No. 0704-0188*

1. REPORT DATE **2008**	2. REPORT TYPE	3. DATES COVERED **00-00-2008 to 00-00-2008**

4. TITLE AND SUBTITLE **Improving the Accuracy of the SeaUV Algorithms in Dark Marine Waters**	5a. CONTRACT NUMBER
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **University of Georgia,Department of Marine Sciences,Athens,GA,30602**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**6**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

Figure 1. Typical deployment of Satlantic ocean color buoy in dark waters around Sapelo Island [picture of the buoy afloat in still brown water at the end of its conducting Kevlar tether; its above-water reference irradiance sensors ride about 0.5 meter above the air-water interface on a black PVC post and its in-water radiance sensors point down about 5 cm below the water surface at each end of a black PVC spar]

Water samples for spectrophotometer determination of $a_g(\lambda)$ are collected with all survey optical data. We seek out opportunities to deploy our Satlantic systems in as many inshore and near-coastal waters as possible using "cruises of opportunity" in order to supplement the southeastern US data set, thus adding potentially different optical domains to the training set.

Approach to Data Analysis: The new Lu(λ) data collected in dark coastal waters is fed into the SeaUV and SeaUVc models and $Kd(\lambda)$ and $a_g(\lambda)$ estimates are compared to *in situ* data with statistical analysis following that of Fichot et al. (2008). The new 'dark water' data sets are added to the SeaUV training set, the model retrained, and estimates re-evaluated for performance in all optical domains. As we accumulate sufficient UV data to make the approach statistically valid, we evaluate the use of data subsets to train type-specific versions of SeaUVc. For example, we are examining the effectiveness of constraining the training set to include only spectral data with Lu(412) values from highly absorbing water and exploring the development of algorithms specific for use in near shore systems. As new data, both from different seasons (and terrestrial flow patterns) and from different locations are obtained, we will explore how these new sets effect both specific and overall performance of the SeaUV algorithms. A continued statistical examination of both the "blue water" and the "dark water" accuracy is repeatedly performed as the training set is seeded with more dark water data.

Approach to Validation and Prediction: This involves mining existing optical databases and seeking out other sources of optical data sets (unpublished with collaboration) for 'dark' water to provide an independent test of SeaUV performance and future incorporation into the SeaUV training set.

WORK COMPLETED

- We published the SeaUV/SeaUVc in Remote Sensing of Environment (Fichot et al, 2008).

- Miller and Fichot continued work on publications resulting from ONR funding with a paper that uses the SeaUV/SeaUVc model to calculate global depth resolved CO photochemistry accepted in RSE (Fichot & Miller, 2008a) and another using the model to evaluate the global variability of CDOM almost ready for submission (Fichot & Miller, 2008b).

- We analyzed new optical data from Sapelo Island and evaluated SeaUV/SeaUVc in dark waters.

- We began design efforts for new configurations of optical gear with Satlantic.

- We brought a new graduate student into the program and began the long, steep learning curve that leads to high-level work relating ocean optics, remote sensing, and photochemistry.

- We continued to refine, comment, and generally detail the steps in using the SeaUV algorithms and related programs to increase usability by others following Fichot's departure from UGA.

RESULTS

A survey of DOC, CDOM and water leaving radiance was completed and data analyzed in the dark waters surrounding Sapelo Island GA in conjunction with a GCE-LTER (Georgia Coastal Ecosystem – Long Term Ecological Research) project sampling effort. Figure 1 shows sampling sites and Figure 2 shows the relation between $a_g(320)$, representing a general proxy for CDOM spectral absorbance, and DOC and our subsequent SeaUV based estimates for DOC using $Lu(\lambda)$ spectra for the same sites. This is possible due to the strong correlation between DOC and $a_g(320)$.

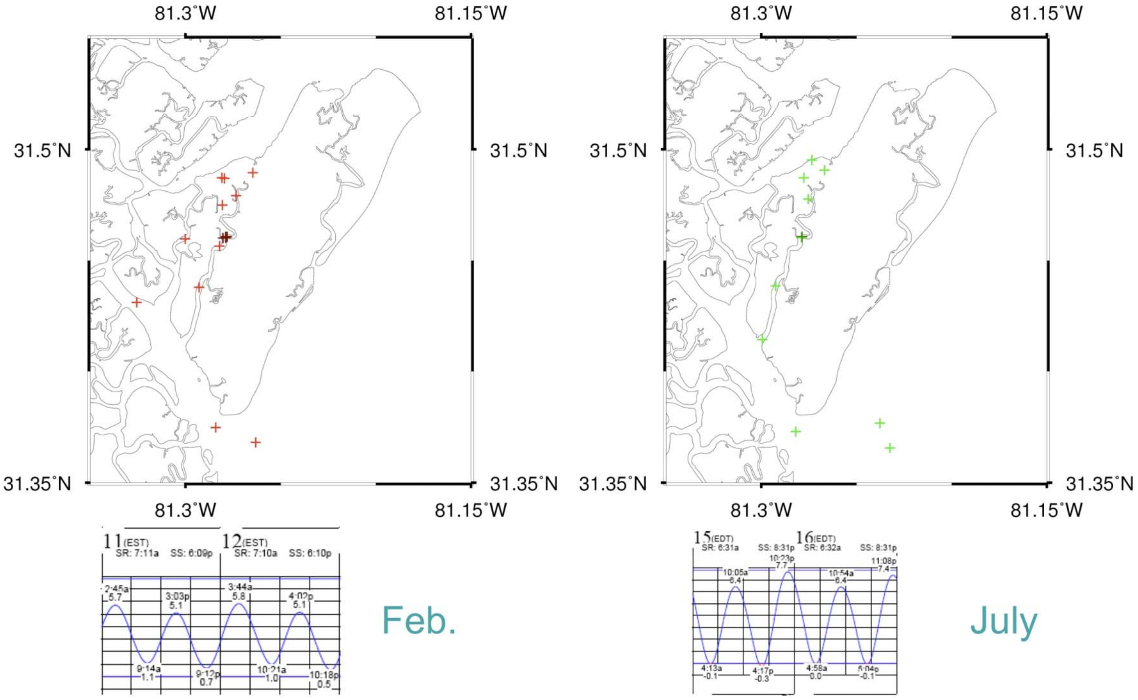

Figure 2. Sampling sites around Sapelo Island, GA [A map of the Georgia coast with red and green crosses showing location of optical measurement and water collection. February (left) and July (right) samples show all but three points are in the tidal creeks and adjacent sounds.]

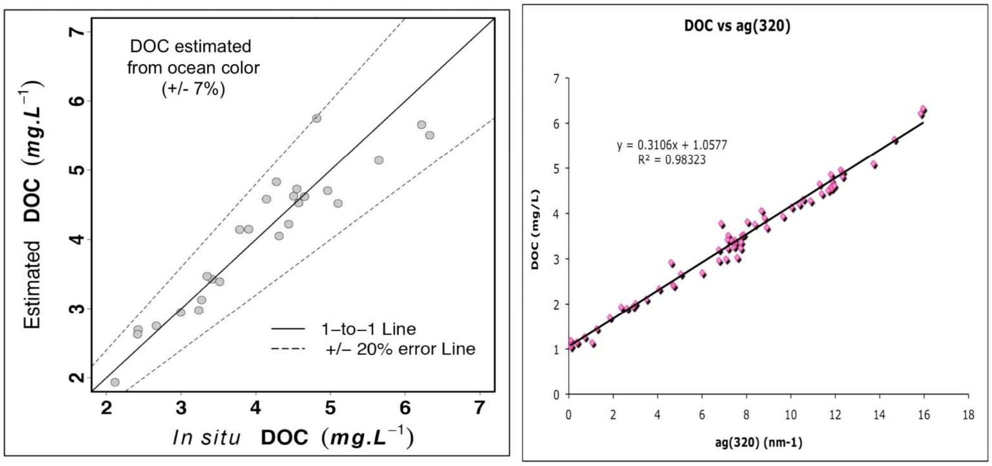

Figure 3. Linear correlation between ag(320) and DOC and subsequent modeled estimated vs. measured DOC concentrations using Lu spectra collected at the same location. [two panels: left shows the scatter of points around a one-to-one line relating model-estimated (y-axis) and in situ (x-axis) DOC concentrations(mg/liter) will all points falling within the plus or minus 20% error envelope shown by a dotted line. The right panel shows the linear correlation between ag(320) (x-axis) and DOC (mg/liter)(y-axis) with a slope of 0.3106, a y-intercept of 1.0577 and an R-squared value of 0.98323.]

The strong correlation between DOC and CDOM in samples from different seasons is somewhat surprising but may prove extremely useful in predicting organic carbon flow in these dark waters. The ability of our "dark" retrained global model to predict CDOM (and consequently DOC) is more accurate than it was before retraining the global SeaUV models with these new 'dark water' data sets. However, there is a great deal of improvement to be had. We expect that a 'dark water only' trained version of the SeaUV/SeaUVc model will result in increased accuracy for these coastal areas but many, many more 'dark water' data points will be needed to reach a level of statistical validity that allow application with confidence.

This year represents a transitional period from our previous award period that focused on algorithm development and global applications of the SeaUV models to a renewed emphasis on fieldwork. The previous cycle funded Cedric Fichot, an expert in this field, as technical support and involved no student support or fieldwork. This year Cedric left UGA and returned to graduate school at the University of South Carolina to pursue a PhD. The recruitment of a good new student to take on the project has been more or less successful but may see some shifting of personnel as the project proceeds. While Cedric remains in close contact, we are still learning the intricate details of fine-tuning the algorithms while gearing up for a renewed field effort. Results have been many but slow during this year and we have made progress. However, the specific details of some of this progress are difficult to articulate (new student training, gathering background, gaining familiarity with new computer programs, etc.) in the format of a progress report.

IMPACT / APPLICATIONS

The SeaUV/SeaUV$_c$ model has proved to significantly improve our ability to estimate UV optical properties and CDOM dynamics in the ocean and is applicable to all marine environments including both optically shallow and deep situations, areas of high productivity and particle loads, open ocean, coastal and estuarine waters. New work on dark, coastal waters will improve this performance to a level that detailed variability of dynamic inshore areas can be better observed. Understanding of the variability in CDOM will produce better models for photochemical distributions. Better quantification of CDOM will allow better corrections for CDOM in chlorophyll algorithms and characterization of the UV light field in the ocean. Associated algorithms developed for use with SeaUV that account for cloud affects on modeling UV scalar irradiance in the ocean will prove useful to all fields studying the biogeochemical role of UV in the ocean.

RELATED PROJECTS

This ONR project to refine and apply SeaUV/SeaUVc to the evaluation of UV optics and CDOM dynamics in dark waters will benefit from collaboration with a funded NASA project (Miller, PI) to use these same models to examine photochemical carbon cycling in the south Atlantic bight off the coast of the S.E. United States. A newly funded Georgia Sea Grant (NOAA) project to examine relations between ocean color and DOC in dark water for carbon export models will also be synergistic with this project.

REFERENCES

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PUBLICATIONS

Fichot C. G., S. Sathyendranath, and W. L. Miller. (2008) SeaUV and SeaUVC: Algorithms for the retrieval of UV/Visible diffuse attenuation coefficients from ocean color. Remote Sensing of Environment, 112:1584-1602.