Ocean Color Studies at ICESS

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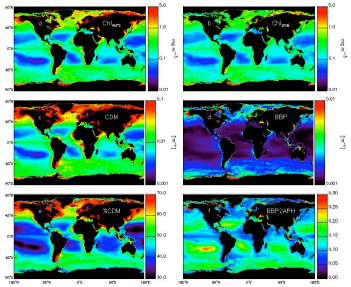
ABSTRACT

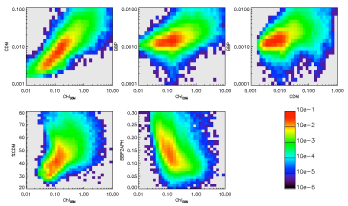
We are using ocean color technology in conjunction with oceanographic field work and laboratory research to address a number of significant interdisciplinary science issues. Ocean color data from sensors such as MODIS, SeaWiFS, and future VIIRS yield important information on the spatial and temporal variability of ocean biology and biogeochemistry, and our goal is to develop *and apply* ocean color products. Our research includes algorithm development, data merging, global analysis of optical properties, dynamics of chromophoric dissolved organic matter (CDOM), and application of CDOM data to problems in ocean circulation and the biogeochemical cycling of trace gases. Our NASA-funded projects at the moment include remote-sensing-analysis projects employing MODIS and legacy SeaWiFS data, and field work (at the time-series sites off Bermuda and the Santa Barbara Channel, and in the global ocean as part of the CLIVAR/Carbon repeat hydrography project. Some of the students working on these projects have been supported by NASA fellowships.



Global Distribution and Correlation of Ocean Color Properties
(Siegel, Maritorena, Nelson, Behrenfeld)

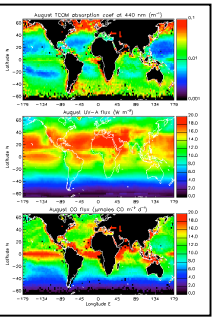
On the left is a figure showing averaged values of major ocean color products derived from the GSM model (chlorophyll, CDOM, phytoplankton optical absorption (APH) and particulate backscatter BBP) and the traditional band-ratio algorithm (chlorophyll). Obvious N/S hemispheric differences in the distributions of CDOM are evident, as are patterns in BBP/APH ratios. These results are providing insight into phytoplankton growth and photoadaption processes and is yielding a novel view of global phytoplankton ecology.

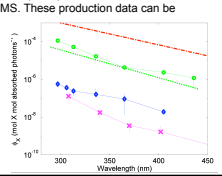
The figure on the right shows the frequency distribution of relationships between the different ocean color retrievable parameters. The traditional view of ocean color holds that all these properties should be correlated. They are, but the nature of the correlation is more complex than a simple function with some error. Multi-dimensional views of ocean color are allowing us to further understand these relationships in the context of phytoplankton growth and ecology.



CDOM-mediated photochemistry in the ocean
(Nelson, Siegel, Toole, collaborators)

Ocean photochemical processes play an important role in the cycling of trace gases related to the earth's radiation budget. We are using ocean color and other remote sensing data to estimate the penetration of UV radiation into the ocean and its absorption by CDOM, which acts as a photosensitizer. These data are convolved with laboratory (literature) quantum yield spectra to estimate (for example) the rate of photoproduction of CO or COS or the rate of photolysis of DMS. These production data can be used to estimate the atmospheric fluxes of the gases in question. The example on the far right shows an estimate of carbon monoxide flux from the ocean using GSM CDOM estimates and the Lubin UV data sets. Selected quantum yield spectra are also shown.

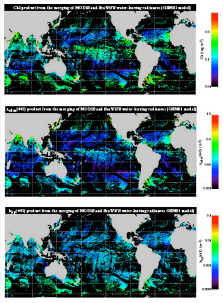


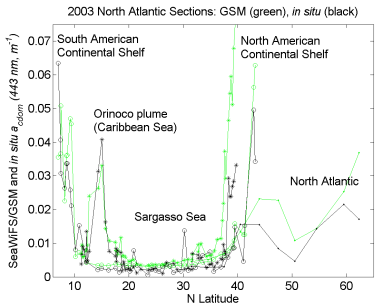


Data Merging and Validation
(Maritorena, Siegel)

An important ongoing effort is focused on development of accurate geophysical products from ocean color data. In addition to development of the traditional algorithms for chlorophyll, we are developing and validating the Garver-Siegel-Maritorena (GSM) ocean color model which retrieves CDOM absorption coefficient spectrum and the particulate backscatter coefficient as well as chlorophyll concentration. At right is an example of a comparison between in situ and satellite-derived CDOM.

A related effort is development of methods for successful merging of data from different platforms. In this example MODIS and SeaWiFS ocean color data are merged using GSM as an optimization tool.

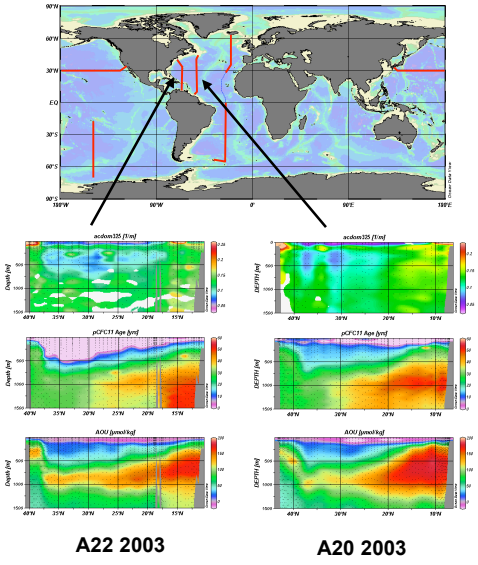


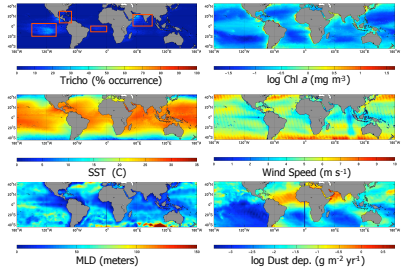


GLOBAL CDOM Survey Project: Siegel, Nelson, Carlson

One of our main interdisciplinary projects is a study of distribution and dynamics of chromophoric dissolved organic matter (CDOM) in the world ocean. In addition to development and validation of ocean color products and application of these data sets to other studies here listed, we are using the data sets we are gathering to estimate water mass renewal rates in (for example) the North Atlantic subtropical mode water. CDOM is the first example of a semi-conservative ocean tracer in the deep ocean that can also be quantified using remote sensing. This work may lead us toward better ocean circulation and biogeochemistry understanding and modeling. So far we have participated in six major ocean transects in conjunction with the CLIVAR/Carbon Repeat Hydrography study, which is in part a repeat of the WOCE survey grid.

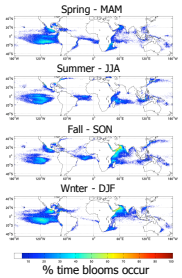
UCSB Global CDOM Survey





***Trichodesmium* algorithm development and application**
(Westberry, Siegel, Subramaniam, Mahowald)

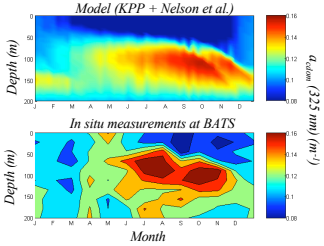
Our group has also worked on developing improved algorithms for detecting blooms of the colonial cyanobacterium *Trichodesmium*, an important nitrogen fixing species in the tropical ocean. Recent collaborative efforts have multiplied the amount of available in situ data but the patchy distribution of the blooms prevents their accurate assessment. New insights into the distribution of *Trichodesmium* blooms will allow accurate estimation of the contribution of *Trichodesmium* blooms to the nitrogen budget of oligotrophic waters and a better understanding of the factors that encourage or limit them.



Mixed Layer Modeling
(Klamberg, Siegel, Nelson, Doney)

We are using a simple conceptual model of CDOM dynamics (involving microbial production and solar radiation – linked destruction) in the upper water column to model the seasonal cycle of CDOM abundance in surface waters of the North Atlantic Subtropical Gyre. The simple model does a good job reproducing the seasonal cycle at Bermuda but interannual variability is likely linked to remote processes such as mode water formation. We are continuing to pursue this line of research.

Upper Ocean CDOM Distribution at BATS
Monthly averages (1995-2000 baseline)



(Selected) Recent Publications

Behrenfeld M.J., Boss E., Siegel D.A. (2005), Carbon-based ocean productivity and phytoplankton physiology from space. Global Biogeochem. Cycles 19 : GB1006.

Maritorena S., Siegel D.A. (2005) Consistent merging of satellite ocean color data sets using a bio-optical model. Remote Sensing of Environment 94: 429-440.

Nelson N.B., Siegel D.A., Yoder J.A. (2004) The spring bloom in the northwestern Sargasso Sea: spatial extent and relationship with winter mixing Deep-Sea Res. II. 51 (10-11): 987-1000.

Nelson, N.B., C.A. Carlson, and D.K. Steinberg (2004). Production of chromophoric dissolved organic matter by Sargasso Sea microbes. Mar. Chem. 89: 273-287.

Nelson, N.B. and D.A. Siegel (2002). Chromophoric DOM in the Open Ocean. In: Biogeochemistry of Marine Dissolved Organic Matter, eds. D.A. Hansell and C.A. Carlson. Academic Press, San Diego.

Otero M.P, Siegel D.A. (2004) Spatial and temporal characteristics of sediment plumes and phytoplankton blooms in the Santa Barbara Channel. Deep-Sea Res. II 51: 1129-1149.

Steinberg, D.K., N.B. Nelson, and C.A. Carlson. Production of Chromophoric Dissolved Organic Matter (CDOM) in the Open Ocean by Zooplankton and the Colonial Cyanobacterium *Trichodesmium* spp.(2004) Mar. Ecol. Prog. Ser. 267: 45-56.

Siegel, D.A., S. Maritorena, N.B. Nelson, and M.J. Behrenfeld. Independence and interdependencies among global ocean color properties: reassessing the bio-optical assumption. J. Geophys. Res., in press.

Siegel, D. A., S. Maritorena, N. B. Nelson, D. A. Hansell, and M. Lorenzi-Kayser (2002). Global distribution and dynamics of colored dissolved and detrital organic materials, J. Geophys. Res., 107: 3228, doi:10.1029/2001JC000965

Toole D.A., Siegel D.A. (2004) Light-driven cycling of dimethylsulfide (DMS) in the Sargasso Sea: Closing the loop. Geophys. Res. Lett, 31: L09308.

Toole DA, Kieber DJ, Kiene RP, Nelson, N.B. (2003) Photolysis and the dimethylsulfide (DMS) summer paradox in the Sargasso Sea. Limnol. Oceanogr. 48: 1088-1100.

Westberry, T., D.A. Siegel, and A. Subramanian. An improved bio-optical model for the remote sensing of Trichodesmium spp. blooms. J. Geophys. Res., in press.