A Simulation Analysis of the Time-Dependent Roles of Phytoplankton and CDOM in Effecting the 3-Dimensional Structure of Inherent Optical Properties on the West Florida Shelf

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LONG-TERM GOAL

Construction and validation of coupled physical/ecological/bio-optical models of phytoplankton and colored dissolved organic matter [CDOM] on continental shelves to predict both the time-dependent, spatially-heterogeneous inherent optical properties [IOP] of subsurface waters and the consequent hyperspectral water leaving radiances [L_w] at the surface.

OBJECTIVES

Using the West Florida shelf [WFS] as a test case, where extensive field data have been obtained in the ONR HyCODE [Hyperspectral Coastal Ocean Dynamics Experiment], ONR FSLE [Florida Shelf Lagrangian Experiments], NOAA/EPA ECOHAB [Ecology and Oceanography of Harmful Algal Blooms], MMS NEGOM [NorthEastern Gulf Of Mexico], NSF DOTGOM [Details Of *Trichodesmium* Gulf Of Mexico], and state-supported MOTE projects, my objective is to couple a model of nine functional groups of competing microalgae to ones of both physical forcing at different regional/local scales and of the consequent bio-optical signals sensed by aircraft and satellites for prediction of three-dimensional IOP and their surface L_w over time.

Thus far, 38 graduate students [*Ault, Black, Boehme, Burghart, Callahan, Cannizzaro, Cattrall, Conmy, Darrow, DelCastillo, Dixon, Drake, Havens, He, Hemme, Ivey, Jolliff, Lenes, Lester, Li, Liu, Masserini, McIntyre, Merkt, Milroy, Mehlan, Murasko, Nababan, Neely, Penta, Remsen, Richardson, Rutherford, Serebrennikova, Siegel, Stovall-Leonard, Sutton, Virmani*], under the supervision of collaborating faculty at USF, have been involved in the data acquisition and analysis necessary for such model construction and validation.

These studies focus on a control volume, bounded by ADCP arrays (*Bryan Black, Yonggang Liu, Eric Siegel*) which extends between the 10-m and 50-m isobaths, along the Florida coast from Tampa Bay to Charlotte Harbor (Fig. 1). The study site was usually sampled at monthly intervals, with continuous underway measurements out to the shelf-break of temperature, salinity, CDOM and chlorophyll fluorescence (*Jenifer Boehme, Robin Conmy, Carlos DelCastillo*), from June 1998 to September 2002. At discrete stations, additional data have been collected on hydrography (*Bill Hemme, Jyotika Virmani*), NO_3, NO_2, NH_4, urea, PO_4, SiO_4 (*Kellie Dixon, Howard Rutherford, Julia Serebrennikova*), Fe (*Michael Callahan*), DOP, DON (*Rachel Merkt, Leslie Melahan*),

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14. ABSTRACT
Construction and validation of coupled physical/ecological/bio-optical models of phytoplankton and colored dissolved organic matter [CDOM] on continental shelves to predict both the time-dependent, spatially-heterogeneous inherent optical properties [IOP] of subsurface waters and the consequent hyperspectral water leaving radiances [Lw] at the surface.

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DIC, DOC, chlorophyll (*Danyelle Ault, Merri Beth Neely*), phaeopigments, PN, PC, PP (*Sue Murasko*), del^{15}N of DON and PN (*Julie Havens*), and counts of all dominant phytoplankton (*Judy Drake*) and mesozooplankton (*Kristen Lester*) species, as well as benthic microflora (*Bill Richardson*), in relation to events of Saharan dust supply (*Chris Cattrall*).

Upstream boundary conditions of the coupled models on the West Florida shelf are derived from NEGOM quarterly surveys of hydrographic, nutrient, HPLC pigment, and CDOM properties (*Bisman Nababan*) in May, August, and November 1998-2000, taken between Tampa Bay and the Mississippi River delta (Fig. 1).

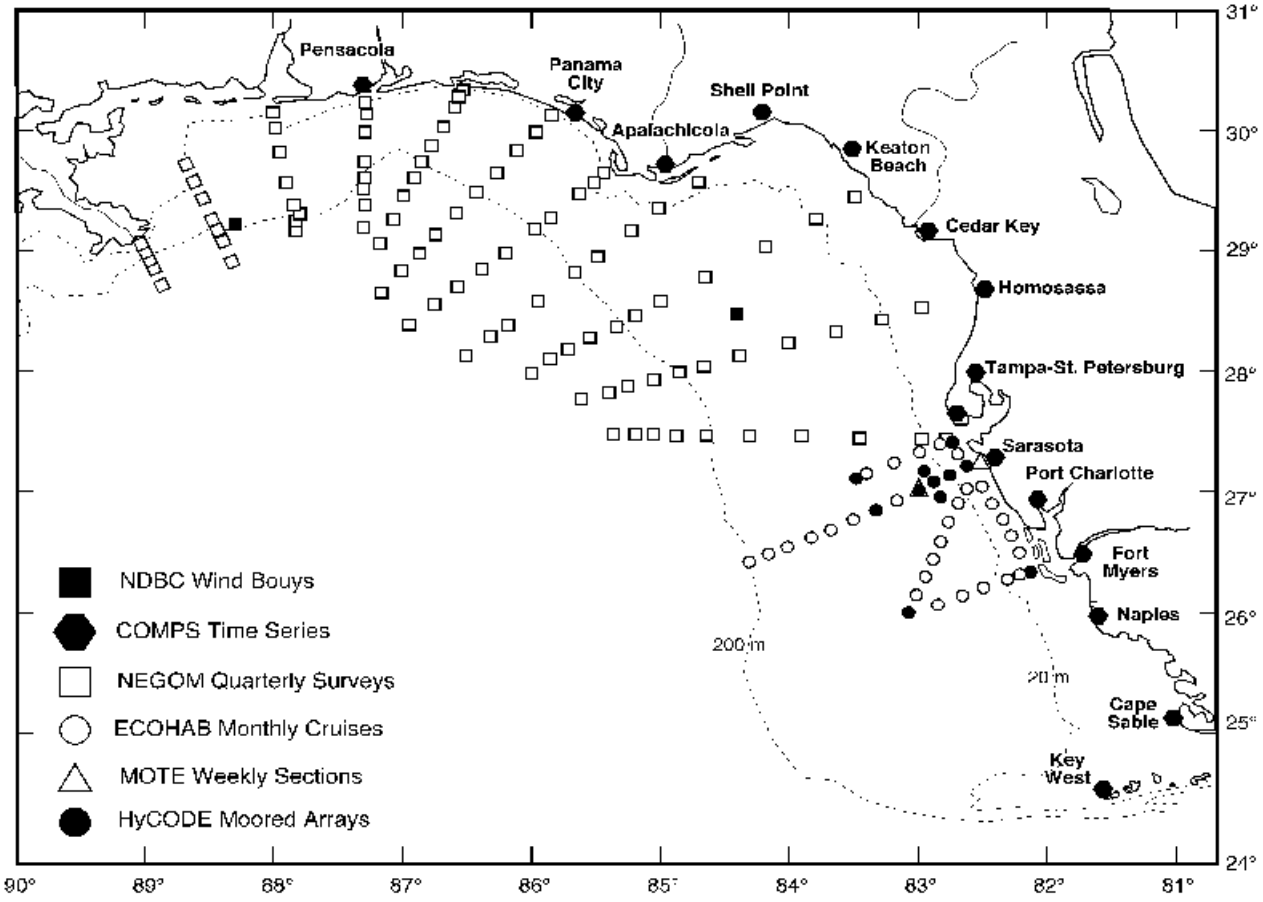

Figure 1. Station locations of the NEGOM (G), ECOHAB (F), and MOTE (Δ) surveys of the West Florida shelf in relation to HyCODE moorings (M), COMPS time series of sea level (◆), and NDBC buoys (■) during June 1998-September 2002. The FSLE tracers during 2000 and 2001 were released within the HyCODE/ECOHAB control volume.

Additional interior ADCP arrays within the control volume (Fig. 1) during 2000-2001 supported a suite of moored optical sensors. On supplemental cruises at 2-month intervals, other discrete measurements of turbidity, and spectral dependence of absorption, backscatter, water-leaving radiance, and light attenuation were made. Finally, during three FSLE experiments in July,

November 2000 and April 2001, SF_6 dispersion, nutrient tracer (*Rob Masserini*), and bio-optical studies (*Jen Cannizzaro, Jim Ivey*) were conducted in relation to aircraft overflights, underway sampling (*Scott Burghart, Drew Remsen, Tracey Sutton*) of plankton particles [OPC, LS] and images [SIPPER] by the towed USF HRS [High Resolution Sampler], and multi-beam bathymetric and side-scan sonar surveys (*Michelle McIntyre*) of the bottom.

APPROACH

A traditional Nutrient-Phytoplankton-Zooplankton model with one state variable each to represent the plant and animal communities of oceanic waters is incapable of addressing bio-optically complex regions of the coastal zone. Competing functional groups of plankton on the WFS can all generate separate pigment stocks of >5.0 ug chl l^{-1}, i.e. spectrally-averaged attenuations of >0.09-0.29 m^{-1} depending upon packaging effects of cell size, in the water column and the sediments. In this subtropical habitat, diatoms, microflagellates, toxic dinoflagellates, nitrogen-fixing cyanophytes, and benthic microflora each form episodic blooms, whose changing color signals are derived from physical supply of nutrients, aggregation processes, and differential losses of the algal populations. Riverine supply of terrestrial CDOM and plankton release of marine CDOM, as well as local resuspension of debris, further complicate interpretation of remotely-sensed L_w.

With this ONR goal of specification of IOP and L_w over time and space, one thesis (*Jason Jolliff*) now involves coupling of the Princeton Ocean Model [POM] at USF (*Ruoying He, Zhenjiang Li*) to a CDOM photolysis model (GCSOLAR) and our most recent plankton model (Walsh et al., 2002b). It utilizes daily estuarine boundary conditions, derived from USGS stream flow data and river CDOM end member data (*Antoya Stovall-Leonard*), to explore the impact of terrestrial CDOM - both upon the spectral attenuation of light, i.e. the water leaving radiances, and possible photolysis yields of labile nitrogen - in relation to phosphorus supplies to the WFS during 1998-2000. Other plankton models, driven by POM, involve the optical signals generated by red tide, *Karenia brevis* (*Scott Milroy*), and the nitrogen-fixer, *Trichodesmium erythraeum* (*Jason Lenes*), whose grazing losses are estimated from the field data.

The suite of pelagic state variables of these coupled 3-d models are small and large diatoms, toxic and edible dinoflagellates, *Trichodesmium*, coccolithophores, autotrophic microflagellates, and coccoid cyanophytes, based upon previous 1-d models (*Brad Penta*). Since chlorophyll biomass within the upper 0.5 cm of sediments can be 2-4 fold that of the overlying water column, with a five-fold seasonal variation on the WFS, the benthic microflora are another state variable (Darrow et al., 2002). A combination of NEGOM, FSLE, ECOHAB, and HyCODE data constrains 3-dimensional estimates (*Brian Darrow*) of benthic contributions to remotely sensed optical signals.

WORK COMPLETED

To provide a numerical synthesis of these diverse data sets, we first completed retrospective simulation studies of the plankton sources of IOP and L_w over the last 45 years on the WFS (Walsh and Steidinger, 2001), with the initial 3-d model focused on the 1979-1980 red tides (Walsh et al., 2002a). In the absence of CDOM, the shade-adapted, migrating *K. brevis* of a mature red tide were

excluded from surface layers, but their simulated spatial fields matched observations of alongshore transport and landfall in 1979, as well as vertical movement in 1980.

The next 3-d model (Walsh et al., 2002b) considered the consequences of massive upwelling of slope water nutrients and river discharge of CDOM to the WFS after the 1998 El Nino. In one case of 1) no light-limitation by CDOM, 2) only three phytoplankton groups (diatoms, *K. brevis*, and microflagellates), 3) slope-water supplies of nitrate and silicate, and 4) selective grazing stress by copepods and protozoans, the diatoms won. In the real world, the above data set confirmed that diatoms were indeed the dominant phytoplankton in 1998, with only a small red tide of *K. brevis* observed. However, a large red tide of *K. brevis* formed in a second model case, when estuarine supplies of CDOM favored the slow growth of these photophobic, ungrazed dinoflagellates.

To account for all the sources of surface color in the WFS, we must now add explicit representation of other atmospheric and estuarine sources of nitrogen; phosphorus; sediment microflora; labile CDOM; iron; and diazotrophs, i.e. the subjects of the present POM-driven, bio-optical models of Jason Jolliff, Scott Milroy, Jason Lenes, and Brian Darrow.

No data were submitted by this project to national archives.

RESULTS

Thus far, we have published five reviewed papers and three more have been submitted. A special volume of *Continental Shelf Research* (Kirkpatrick and Walsh, 2003) is now being prepared. More than 10 of the graduate students are presenting talks and posters on 21-25 October 2002 at the 10^{th} International Conference on Harmful Algae, whose proceedings will also be published.

IMPACT/APPLICATIONS

Once these coupled models of IOP and L_w are validated with the extensive observations made during 1999-2001 at the WFS site, we would apply them to other ongoing ONR field studies.

RELATED PROJECTS

With support from N000149810158, Bob Weisberg is providing ADCP data for the offshore boundary conditions of Scott Milroy's thesis on the optical signal and transport of red tides within the HyCODE/ECOHAB control volume, between Charlotte Harbor and Tampa Bay. With support from N000140110041, Paula Coble is providing CDOM data for the inshore boundary conditions of Jason Jolliff's thesis on the spectral attenuation of light and possible photolysis yields of labile nitrogen from terrestrial CDOM, between the Mississippi River and the Florida Keys. With support from N000149615024, Kent Fanning and Rik Wanninkhof are providing nutrient and SF_6 validation data from the FSLE cruises for Brian Darrow's thesis on the 3-dimensional optical consequences of phytoplankton/sediment microflora succession on the WFS. With support from N000149710006, Ken Carder is using remote sensing algorithms to provide initial conditions of Jason Lenes's thesis on the role of Saharan dust deposition and nitrogen-fixation by *Trichodesmium* in the nitrogen

economy of the WFS. Finally, with support from N000149615020, Tom Hopkins is providing corroborative HRS data for Kristen Lester's thesis on the role of zooplankton in WFS bloom initiation and termination within the control volume.

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