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

John J. Walsh
College of Marine Science, University of South Florida,
140 Seventh Avenue South, St. Petersburg, FL 33701
Phone: (727) 553-1164 Fax: (727) 553-1189 E-mail: jwalsh@seas.marine.usf.edu

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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.

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.

Thus far, 5 USF graduate students, under my direct supervision for their Ph.D. studies, have been involved in the data acquisition and analysis necessary for such model construction [Darrow, Jolliff, Lenes, Milroy] and validation [Lester]. Their studies focus on a control volume, bounded by ADCP arrays, which extends between the 10-m and 50-m isobaths, along the Florida coast

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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 timedependent spatially-heterogeneous inherent optical properties [IOP] of subsurface waters and the consequent hyperspectral water leaving radiances [Lw] at the surface.

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from Tampa Bay to Charlotte Harbor. 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, from June 1998 to September 2002. At discrete stations, additional data have been collected on hydrography, NO_3, NO_2, NH_4, urea, PO_4, SiO_4, Fe, DOP, DON, DOC, chlorophyll, phaeopigments, PN, PC, PP, and counts of all dominant phytoplankton and mesozooplankton species. Upstream boundary conditions of the WFS coupled models are derived from NEGOM quarterly surveys of hydrographic, nutrient, HPLC pigment, and CDOM properties in May, August, and November 1998-2000, taken between Tampa Bay and the Mississippi River delta.

WORK COMPLETED

The last year of the award involved synthesis of this project. Gary Kirkpatrick and J.J. Walsh agreed to serve as guest editors of a special volume of *Continental Shelf Research* on the results of the ECOHAB/HyCODE programs. Furthermore, a physical oceanographic nowcast/forecast model for west Florida shelf sea level and circulation, driven by winds, tides, freshwater influxes, and used to force the ecological ones, is now available at Bob Weisberg's site: http://comps.marine.usf.edu.

For example, our first coupled biophysical model (Walsh et al., 2003) of 1) wind- and buoyancy-driven circulation, 2) three phytoplankton groups (diatoms, *K. brevis*, and microflagellates), 3) slope-water supplies of nitrate and silicate, 4) selective grazing stress by copepods and protozoans, and 5) nutrient regeneration by the sediment biota was able to replicate the observed nutrient fields and the small red tide found in 1998, with a case of light-limitation of the phytoplankton by estuarine supplies of colored dissolved organic matter (CDOM), which did not decay in the model. The carbon to silicate ratio of the model's fecal pellets was not fixed, like the Redfield ratio of the silicieous phytoplankton, but instead changed due to dissolution of particulate silicon in the sediments - a stratagem developed in our previous 1-d numerical study (Darrow et al., 2003). Here, within the model's sediment layer (Walsh et al., 2003), the bioturbation coefficient, K_b, was a function of bottom water temperature, from the coupled USF version of the Princeton Ocean Model (POM).

When the CDOM was allowed to decompose via photolysis (GCSOLAR) in a second 3-d simulation study of the 1998 events (Jolliff et al., 2003), the allocthonous CDON supply of "new" nitrogen provided only a minimal source for growth of WFS phytoplankton and matched the observed color signals (Fig. 1) of shipboard discrete and satellite sampling programs. Indeed, based on freshwater influxes from Tampa Bay and Charlotte Harbor in 1998 and 1999, once the red tides of *K. brevis* initiated, the measured estuarine supplies of total dissolved nitrogen (DON + NO_3 + NH_4) then provided <3% of the daily nitrogen demands of ~1 x 10^5 cells l^{-1}, if all of the DON were labile and diluted into a volume of coastal water between the 10-m isobath and mouths of Tampa Bay and Charlotte Harbor.

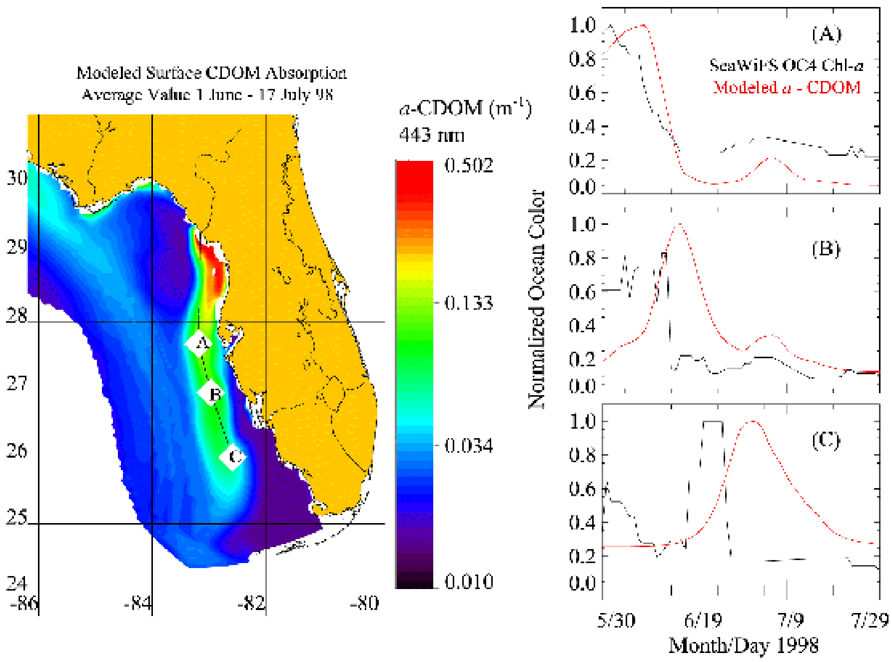

Figure 1. The average surface CDOM absorption over the WFS for the period 1 June 98 - 17 July 98 shows the southward dispersal of the Suwannee River plume. At right, a time series (5 May 98 - 29 July 98) for locations along a transect through the river plume shows the variability in the modeled surface CDOM normalized by the highest value modeled for that location during the time period (red). Similarly, 7-day composite SeaWiFS chlorophyll-a values for the corresponding pixel locations are presented (black) as values normalized by the highest value observed during that time period. Values were interpolated when cloud cover obscured retrieval.

A third 3-d numerical study (Milroy et al. 2004) of the role of zooplankton in nutrient cycles of the WFS found that the larger 1999 red tide could be replicated with no source of ammonium from the herbivores. If the benthos and the zooplankton are not major sources of recycled nitrogen for WFS phytoplankton blooms, whence their nutrition and consequent large optical signal? At small red tide levels of ~1 x 10^5 cells l^{-1} of *K. brevis*, or a biomass of ~1 ug chl l^{-1}, fish and manatee kills ensue within Florida waters. The nutrient sources to fuel larger blooms of ~10 ug chl l^{-1} of these ichthyotoxic dinoflagellates had thus remained unknown, since initial release of DON from nitrogen-fixation by *Trichodesmium*, as well as estuarine phosphorus and CDON loading, can only support the small initial red tides (Walsh and Steidinger, 2001; Lenes et al., 2001).

Our recent budgets of the organic nitrogen and phosphorus contents of dead fish, co-occurring with *K. brevis* and *Trichodesmium* at convergence fronts, suggest a positive feedback mechanism of decomposing fish that can promote large WFS red tides (Walsh et al., 2004). Interannual variations of bloom size and their color signal then depend on the relative strength of the negative feedback of indiscriminate grazing pressure, exerted by diatom-raised copepods on *K. brevis*, during intrusions of the Loop Current on the WFS (Walsh et al., 2003).

No data were submitted by this project to national archives.

RESULTS

Thus far, we have published eight reviewed papers and four more have been submitted. A special volume of *Continental Shelf Research* (Kirkpatrick and Walsh, 2004) is now being prepared.

APPLICATIONS

Once these coupled models of IOP and L_w are validated with the extensive observations made during 1999-2002 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. 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. 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 and off Barbados. 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.

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