An AUV-Based Investigation of the Role of Nutrient Variability in the Predictive Modeling of Physical Processes in the Littoral Ocean

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LONG-TERM GOALS

Our long-term goal is to explore and test the potential effectiveness of low-level nutrient concentrations (nitrate, nitrite, and ammonia) as descriptors of geophysical fields and tracers of physical processes in oligotrophic coastal waters, with particular attention to adapting our laboratory sensor of these nutrients for use in an AUV. The nutrient data are to be incorporated into prognostic physical-biogeochemical models in a feedback mode.

OBJECTIVES

Objective 1: Better Definition of the Nature of NH_3-enriched Zones in Oligotrophic Coastal Waters. This objective is a follow-on to the FSLE 5 (April, 2001) cruise on the West Florida Shelf in which zones containing boluses with maxima in NH_3 and injected SF_6 (a conservative tracer) remained "co-located" as both drifted in the same direction. FSLE = Florida Shelf Lagrangian Experiment.

Objective 2: Improved Understanding of the Fate of NH_3-enriched Zones in Oligotrophic Coastal Waters. Work on this objective is and will be designed to evaluate the reasons why the NH_3 in these waters is not rapidly consumed by NH_3-preferring phytoplankton (McCarthy et al., 1977) and why the co-location with SF_6 persisted for several days.

Objective 3: Modeling of Processes Affecting NH_3-enriched Zones in Oligotrophic Coastal Waters. The dispersion of NH_3 and SF_6 tracers is to be modeled using a nested 1-km grid within the present POM of the West Florida Shelf.

Objective 4: Improvements to the AUV-version of our Nutrient Sensor.

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14. ABSTRACT
Our long-term goal is to explore and test the potential effectiveness of low-level nutrient concentra-tions (nitrate, nitrite, and ammonia) as descriptors of geophysical fields and tracers of physical proc-esses in oligotrophic coastal waters, with particular attention to adapting our laboratory sensor of these nutrients for use in an AUV. The nutrient data are to be incorporated into prognostic physical-biogeochemical models in a feedback mode.

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APPROACH

Objective 1: The approach was two-fold. First was an effort to use the dispersion/dilution of the conservative SF_6 injected in FSLE 5 to separate and quantify the effects of physical dilution and internal chemical reaction on the suite of NH_3 maxima co-located in the same region. The second aspect was (and will be) another field study, FSLE 6, in the same coastal waters as FSLE 5. FSLE 6 data will broaden and constrain our understanding of variations of NH_3- and other coastal nutrient maxima. The cruise will be in a different season (November) from FSLE 5, with improvements in SF_6-injection and/or monitoring techniques and in software. For example, an attempt will be made to monitor SF_6 and NH_3 at different depths during continuous surveys with a towed pumping system. Key individuals: K. Fanning and R. Masserini of USF (ammonia/nutrient determinations), R. Wanninkhof and K. Sullivan of AOML-NOAA (SF_6 injection and measurement), and J. Patten of the Center for Ocean Technology (COT) at USF (software design).

Objective 2: During the FSLE 6 field study an important focus will be ancillary biological and nutrient measurements (chlorophyll, phaeopigment, phosphate, etc.) in order to elucidate the state of the biota in and around any high-nutrient patches of coastal water that are found. The key individuals involved in Objective 1 are involved in Objective 2 along with D. Ault, a USF biological oceanographer.

Objective 3: To model the fate of nutrient (e.g., NH_3) maxima, the present version of the USF POM -- forced by wind stresses, surface heat fluxes, and river inflows (He and Weisberg, 2001) – was to be combined with nutrient-phytoplankton-zooplankton models having many state variables to represent the plant and animal communities of the bio-optically complex regions of the coastal zone. Key individuals involved are all from USF: J. Walsh, R. Weisberg, B. Darrow

Objective 4: This work involves re-design of the signal- and peak-detect circuitry and other aspects of the AUV-sensor to improve sensitivity. Key individuals involved are: R. Masserini and K. Fanning (USF Marine Science) and R. Carr of USF-COT.

WORK COMPLETED

Objective 1: Linked evaluations of the SF_6 and NH_3 data provided insight into the usefulness of NH_3 as a tracer in oligotrophic coastal waters. In FSLE 5, the co-located regions containing boluses with upper SF_6 maxima and NH_3 maxima had been surveyed in a zig-zag pattern over ~ 5 days. Since normal sea-water contains no SF_6, calculations of the dilution functions within the SF_6-enriched zone in FSLE 5 were reasonably straightforward because the maximum SF_6 values within the region were determined each day. For the second aspect of this objective, custom software was designed to make the data acquisition and processing for continuous FSLE surveys on surface waters as close to real time as possible in order to maximize the effectiveness of nutrient surveys by ship or AUV.

Objective 2: none yet

Objective 3: Various approaches to modeling coastal processes were related to the fate of nutrient maxima on the West Florida shelf. The USF POM model was combined with 3-d biochemical models for (1) red tide generation and (2) the consequences of upwelling and riverine discharge as well as with a 1-d model for the sinking and regeneration of a coastal phytoplankton bloom.

Objective 4: To improve AUV nutrient sensor detection limits by maximizing the signal-to-noise ratio, two principal steps were planned: (1) synchronize the digitization of the detector signal with the timing of the light pulses from the flash lamps and (2) reduce the electronic noise in the sensor.

RESULTS

Objective 1: Two SF_6 dilution functions with time were obtained for FSLE 5, one describing dilution plus SF_6-loss across the air-sea interface and one describing SF_6 dilution alone after correction for the gas exchange. The first was used to estimate the SF_6 concentrations in high-NH_3 surface boluses sampled later in the experiment on the assumption that they were the same boluses as sampled earlier, with only dilution occurring between samplings. The estimates were compared to actual SF_6 concentrations in the boluses. Whenever an actual SF_6 concentration in a bolus was within 10% of a concentration estimated from a bolus that was sampled earlier, the two boluses were considered the same, and the second sampling was considered a "re-visit" of the earlier bolus. Fourteen "pairs" of samplings of NH_3 maxima were obtained (arrows in Fig. 1). Note the generally SE drift of all boluses with NH_3 maxima during FSLE 5. The second dilution function was used to estimate the declines in NH_3 concentration that should have occurred to each NH_3 maximum between samplings due to dilution, and these were compared to the declines that were actually measured. The fact that the predicted declines were markedly greater than the actual declines in 12 of the 14 pairs (black arrows in Fig. 1) indicates that ammonia *production* was occurring in the surface water. *This production is the reason why the region with boluses of high NH_3 survived and tracked the co-located region with high SF_6.* Ammonia consumption by phytoplankton may have occurred, but it was more than counterbal-anced by ammonia production. Thus ammonia in oligotrophic coastal waters can be considered as an effective label or tracer for coastal waters, and, under certain conditions, fairly close to conservative. The FSLE 6 field study next November will further define the conditions under which this characteristic exists. For the second aspect of this Objective 1, the custom software we designed samples nutrient data peaks during surveys, calculates concentrations, merges them with time-stamp and GPS-position data, and prepares preliminary surface distribution maps in near-real time. Data analysis will be greatly enhanced, and the results will permit rapid modifications to at-sea sampling and much greater accuracy in mapping high-nutrient surface patches.

Objective 2: None yet

Objective 3: See Walsh et al. (2002a, 2002b) and Darrow et al. (2002)

Objective 4: The following steps have been accomplished. A 64 MHz analog to digital converter has been added to synchronize light pulses with digitization of emitted fluorescent light. The analog section has been redesigned to eliminate discrete component peak detection. This new design utilizes an input op-amp for filtering, and a high-speed differential driver straight to the analog-to-digital converter. Peak detection, power estimation, integration and other filtering can now be performed in the digital domain, allowing great flexibility in signal processing. Also, all of the grounds have been rerouted and separated. Presently we are incorporating the electronics with the actual analytical system to determine gain requirements and the appropriate mathematical filters to apply to the waveform to minimize noise while optimizing and maintaining high-speed peak detection capability.

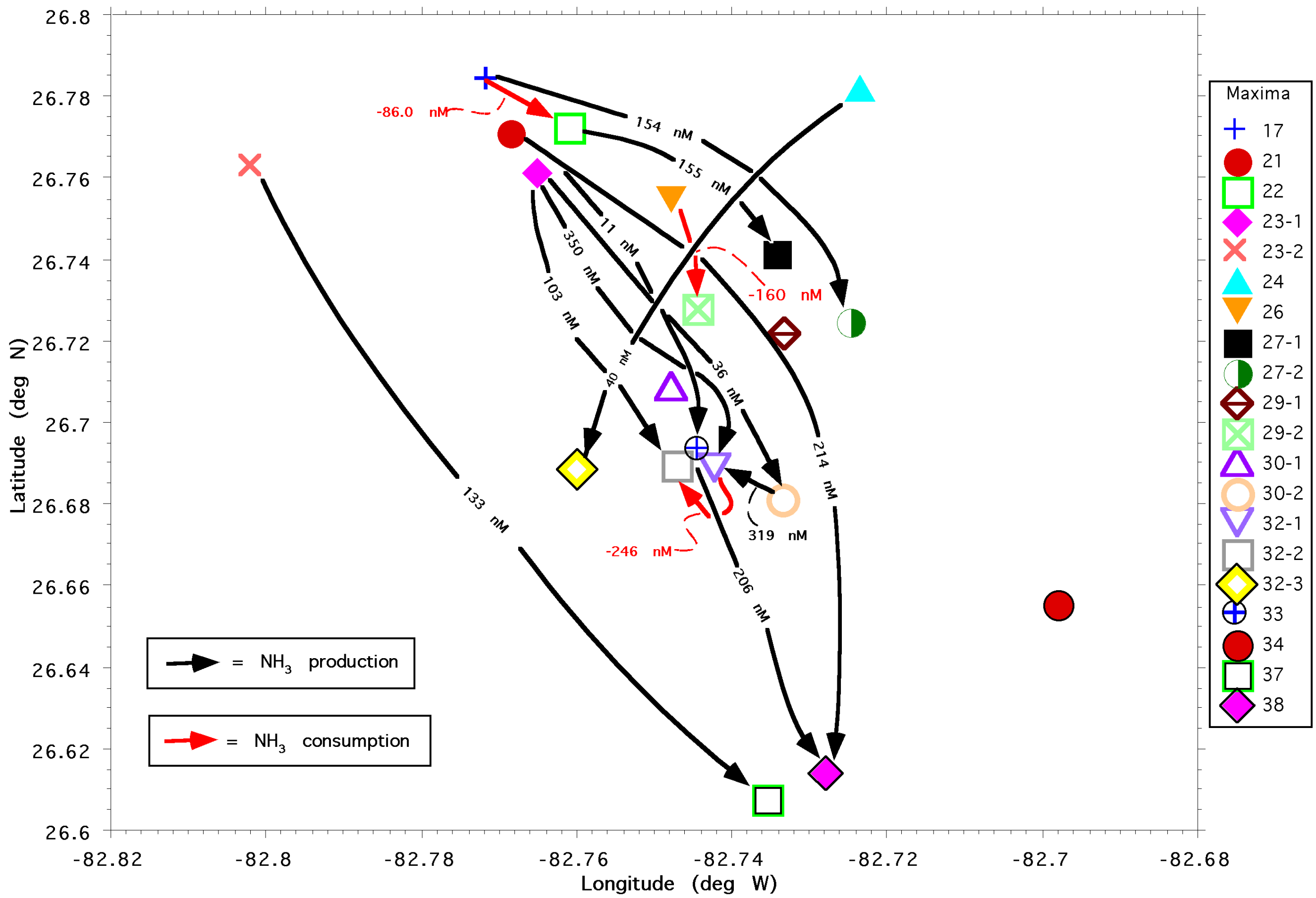

Figure 1. Differences between actual ammonia concentrations and predicted ammonia concentrations in the upper three meters when ammonia maxima were revisited and re-sampled during the FSLE 5 experiment in coastal waters of the West Florida Shelf in April, 2001. [Ammonia maxima sampled later in the experiment were matched to NH_3 maxima sampled earlier, using their respective SF_6 concentrations as a guide. SF_6 concentrations at the maxima were also used to predict the theoretical declinse in maximum NH_3 concentrations that should have occurred due to mixing alone. These theoretical declines were subtracted from the actual measured declines to estimate the NH_3 changes due to water-column reactions. The results are indicated as labels on the arrows between the earlier and later samplings of the same NH_3 maxima.]

IMPACT/APPLICATIONS

Nutrient concentration distributions obtained by the laboratory and AUV-versions of our nutrient sensor package can reveal differences in surface water types that will be useful for applying hydrostatic models to compute flows within the POM grid cells of the coastal ocean. This will have applications to SF_6 studies, to prediction of red-tide distributions, and to estimates of tempo-spatial variance of parameters related to CDOM as well to using naturally occurring nutrient pulses to track coastal water masses, especially when salinity variations are too small to be useful.

TRANSITIONS

The data generated by our high-sensitivity nutrient sensor (e.g., Fig. 1), as well as ancillary nutrient data that we provide for hydrocast nutrients on the West Florida Shelf for ECOHAB, are utilized for the generation and calibration of a variety physical-biological-chemical models of computer processes. Once the models replicate the observations of nutrient features interacting with physico-chemical processes on the West Florida shelf, we would anticipate possibly applying them to other ONR field studies: COBOP at Lee Stocking Island in the Bahamas and LEO-16 on the New Jersey shelf. In addition, we expect to conduct similar nutrient studies in oligotophic waters elsewhere.

RELATED PROJECTS

As already mentioned, J. Walsh (N000149910212) is developing models of plankton succession on the West Florida shelf. Forty-years of shelf nutrient, plankton, and physical data are being used along with our data to validate models, based on existing circulation and nutrient-cycling models. With support from N000149810158, Bob Weisberg, (http://ocg6.marine.usf.edu/) is applying a primitive equation model to observed West-Florida-shelf current fields. It is an adaptation of the POM with topography-following vertical sigma coordinates and horizontal orthogonal curvilinear coordinates. Far-field shelf-break forcing is also being examined. It will provide boundary values for the modeling of nutrient/SF_6 data, and the resulting nowcasts and forecasts can be calibrated by our measured distributions. With support from N000140110041, Paula Coble (http://www.marine.usf.edu/mfl/index.html) is providing CDOM data related to 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 N000149710006, Ken Carder is using remote sensing algorithms to provide initial conditions of models of 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 on the role of zooplankton in WFS bloom initiation and termination within the Control Volume on the West Florida Shelf where FSLE studies 3-5 were performed and FSLE 6 will be performed.

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