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A System for Improved Prediction of Ocean Optical Properties

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LONG-TERM GOALS

(i) Improving algorithms to obtain in-water optical properties from space-born ocean color satellites.

(ii) Improving our understanding of the link between physical and biological processes in the ocean and hence our ability to model the evolution of optical properties.

ABSTRACT

A system is proposed that will measure oceanic optical properties from a variety of platforms and will allow for improved quantification of their relationships to parameters retrieved from ocean-color remote sensing and in-situ oceanic processes (i.e. the dynamics of particulate and dissolved matter). Improvement will come primarily from increase in optical data currently limited in space and time (e.g. weighed heavily towards the summer in the Atlantic). The system involves a variety of sampling platforms including profiling floats, in-line samplers on ships and bottom mounted tripods. The data collected will be used to improve models describing the evolution of optical properties in time (e.g. describing sediment dynamics in the bottom boundary layer and ecosystem dynamics near the ocean's surface). Improvement in models will come from having a large amount of quality optical data to constrain models with (by tuning the models to agree with the data and exploring disagreement for processes that are poorly represented), or alternatively provide data for model validation. Improvement in models will allow for better prediction of underwater light fields, visibility and transmission of optical communication. In addition, data collected with profiling floats will allow for improved modeling of sub-surface optical properties (measured with the floats) from surface optical properties (measured using from space).

APPROACH

In this proposal we requested instrumentation that will improve our ability to model the evolution of optical properties through measurements of quality optical data on a variety of platforms, and linking these measurements to physical and biogeochemical processes in models. The Boss lab at the

University of Maine has been funded by the office of Naval Research to study several problems, among them:

1. The impact of particle dynamics in the bottom boundary layer on optical and acoustical properties.

2. The integration of optical properties into an ecosystem model to: a. improve the representation of the underwater light-field, b. add constraints on the model parameters and c. prepare the model for the phase in which ocean color remote sensing data could be assimilated into it.

3. Link physical features and optics (e.g. dynamics near straits and their impacts on optics).

In the first two problems, in-situ measurements are used to improve predictive model. In the first case it is in construction of an optical model for the aggregate-particles (e.g. Boss et al., 2009) to be included in a sediment transport model while in the other it is in the construction of the optical model for the components of the ecosystem model (e.g. Fujii et al., 2007).

In addition, we have been funded by the National Ocean Partnership Program, to improve the state-of-the-art of profiling floats for the whole oceanographic community (six profiling floats are funded), by, among other tasks, improving the integration of optical sensors to the floats, assess a variety of sampling modes, and evaluate the usefulness of the data for calibration and validation of remote-sensing ocean color.

Our approach here consists of:

1. Obtain data that will be used to train and test ecosystem models in a variety of open-ocean environments.

2. Increase matchup data between in-situ optical measurement and ocean color remote sensing for the purpose if improving algorithms that invert ocean color data to in-situ optical properties (see Fig. 1 for recent density and geographical distribution of data used to develop ocean color algorithms).

3. Increase the data available on observed optical variable in a variety of environments that are currently poorly sampled.

These approaches will enhance our ability (and that of the community through posting of the data in public databases) to predict surface and sub-surface optical fields.

The deployment platforms we have experience with and that we will enhance are:

1. Bottom moored tripods – provide for high (temporal) frequency measurements with a wide variety of optical instruments (one depth, near bottom).

2. Profiling floats – provide depth resolved profiles of a few optical properties together with CTD and oxygen with frequency varying from several times a day to ten days (each float can provide ~300profiles).

3. In-line pumped systems – provide high (spatial) frequency measurements with potentially a wide variety of optical instruments along the track of a vessel (one near-surface depth) by sampling waters pumped to the vessel.

Each of these deployment strategies is intended to resolve different processes but all have a common goal: improve our ability to predict how optical fields will evolve in time (e.g. for prediction of diver visibility and underwater electromagnetic communication). Our past research using these platforms has documented a variety of poorly explored phenomena. For example, we were able to demonstrate, using an in-line system we developed (Slade et al., 2010), that the beam-attenuation coefficient may be a better predictor of phytoplankton biomass than chlorophyll (Behrenfeld and Boss, 2006). With a float equipped with two optical sensors we were able to show that optical variables have shorter temporal de-correlation scales than physical variables implying the need for higher frequency sampling to resolve their variability. In addition, the float sampled for three months an eddy where particles at all depths were at significantly higher concentrations then outside the eddy (Nov.-Jan. of 2006). The particle source or responsible process has not be identified as of yet (Boss et al., 2008ab). Finally, the measurements by this float challenge a long held hypothesis that phytoplankton in the North Atlantic are light limited until stratification sets in; We observed positive net growth starting in December and at a rate similar to that during the spring (Boss and Behrenfeld, 2010). With our tripod sampling system we were able to explain the tight relationship observed between sediment mass and optical properties such as attenuation and scattering at a variety of angles (Boss et al., 2009a), as arising from aggregation (Boss et al., 2009b). We are working on including these findings and a more realistic aggregation model into the community sediment transport model (Hill et al., 2011) which will improve our ability to predict in-water optical properties and their evolution given specific physical forcing (wind, waves) and sediment properties.

WORK COMPLETED

We have 6 profiling floats under production at Teledyne-Webb. Two profiling floats will be used as part of the ONR DRI. The other floats will be deployed in the coming year in the Atlantic and Indian Oceans in conjunction with cruises of opportunities associated with optical research conducted by colleagues.

An ac-S was purchased which has been rotating on and off the R/V Tara collecting surface optical properties throughout the world ocean. An in-line system is being built with DURIP funds for an upcoming ONR DRI in Vietnam (with an AC-S for particulate optical properties and a capillary waveguide system for dissolved optical properties). With DURIP funds we purchased a bb2f instrument (measuring two wavelength of backscattering and CDOM fluorescence) which we deployed at MVCO as part of the OASIS effort. At the time of writing, data has been streaming in with little interruption for the past two weeks.

RESULTS

The instrumentation purchased in this effort is already assisting in our sampling on-board the Tara and in the OASIS experiment at MVCO.

IMPACT/APPLICATIONS

Instrument purchased through this grant were used in the 2011 Optics Classes taught at the Darling Marine Center this summer, exposing students to the latest optical technology.

RELATED PROJECTS

Flocculation, Optics and Turbulence in the Community Sediment Transport Model System: Application of OASIS Results - an ONR funded proposal to E. Boss, J. Trowbridge, P. Hill and T. Milligan. Equipment from this DURIP grant is providing instrumentation used in that proposal.

Shelf-Slope Physical/Biological Response to Monsoonal Wind Forcing and Riverine Inflow- 4D Sampling with Towed Profilers and Autonomous Gliders off Vietnam – an ONR funded proposal to C. Lee, L. Rainville, B. Jones and E. Boss. Equipment from this DURIP grant is providing instrumentation used in that proposal (2 profiling floats and the in-line system).

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