Bio-optical Dynamics And The Forecasting of Bio-optical Variability in The Sea

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LONG-TERM GOAL

Research on oceanic bio-optical processes and the prediction of ocean bio-optical properties requires coupled physical-biological-chemical models with the capability of real data initialization and assimilation. The goal is to develop and prove such models, focusing specifically on the bio-optical component. Ultimately, this research is directed towards the understanding of optical and biological processes in the sea, their variability and their response and sensitivities to local and remote forcings.

OBJECTIVES

The scientific/technical objectives of this project are i) to develop the bio-optical model component of the Harvard Ocean Prediction System (HOPS); ii) to apply the bio-optical model to the study of real ocean dynamical processes which govern the variability of bio-optical properties and associated effects on biogeochemical and ecosystem dynamical processes; iii) to initiate the development of a predictive capability for nowcasting and forecasting bio-optical variability in the coastal ocean and the deep sea, and iv) to develop data assimilation capabilities for satellite ocean color and other bio-optical data.

APPROACH

The approach is to construct interdisciplinary models in order to study the physical, biological (ecosystem), chemical and optical dynamics, their interactions and dependencies. Ecological, bio-optical and biogeochemical processes are highly non-linear and span a wide range of interactive spatial and temporal scales.

Both historical and real-time data sets are being used to guide the construction of idealized examples and carry out dynamical studies with realistic fields. Dr. Jeff Dusenberry, the lead scientist on this project, has been developing protocols for calibrating a bio-optical component of a coupled physical-biological model. A simulated annealing based protocol is being developed using available mooring time-series data. Sensitivity analyses are conducted to better understand sources of variability in biological and optical properties in the sea, and the responses of such properties to model parameter values and initial conditions. Data driven simulations in the New England Bight region are used to further our understanding of physical-biological interactions and their effects on horizontal, vertical, and temporal variability in biological and optical properties. Predictive capabilities are developed and tested by carrying out simulation experiments in real-time.

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WORK COMPLETED

A new simulated annealing based calibration protocol has been developed and tested using data from the Biowatt mooring time-series (Fig. 1) (Dusenberry et al., 1999b). This method offers distinct advantages over the methodology used previously, including the specification of a covariance (or correlation) matrix for parameter values. This is important when attempting to quantify model sensitivities to parameter values. Because of numerous local minima in the cost function (defined as the misfit between model predictions and observations), an ensemble based simulated annealing algorithm was used.

Data driven three-dimensional simulations in the New England Bight region have been initiated (Fig. 2). Physical and biological model initialization was based on data collected during the PRIMER and CMO experiments, augmented with historical data sets and climatologies as necessary.

The biogeochemical/ecosystem model component, including the bio-optical model component which was developed under this project (Dusenberry et al., 1999a), has also been successfully ported to several other ongoing studies, including studies in the Gulf of Cadiz, Massachusetts Bay, and the Gulf of Maine.

RESULTS

One significant result from the calibration of the bio-optical model to the Biowatt mooring time-series was the need to include a variable carbon to chlorophyll ratio for the phytoplankton component, with the value of the ratio affected by acclimation to ambient light levels. Without incorporating this variability, it proved difficult to obtain parameter estimates consistent with *a priori* knowledge. This demonstrates the sensitivity of model results to accurate and reasonable estimates of phytoplankton growth rates, which may differ somewhat from chlorophyll-specific photosynthesis rates.

Interesting preliminary results from the New England Bight simulations demonstrate significant biological variability in the shelf-break region as well as variability induced by tidal mixing in relatively shallow waters. Mesoscale advective events involving biological patchiness can result in what might appear to be local bloom events, when observed from the perspective of a fixed mooring. Realistic fully-dimensioned simulations should thus aid in the interpretation of real ocean observations which are taken from fixed moorings.

IMPACT/APPLICATIONS

Coupled optical-biological-physical models comprise an important investigative tool for studying both biological and physical processes in the world's oceans. From a management perspective, such models are valuable not only as predictive tools, but as an aide for designing efficient sampling strategies.

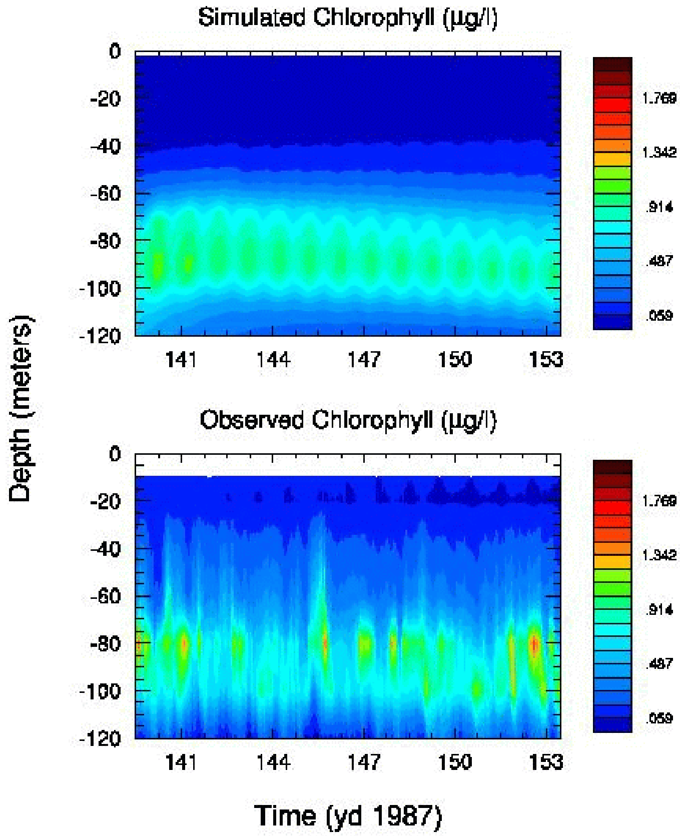

Figure 1 - Simulated and observed chlorophyll distributions from the Biowatt mooring data set based model calibration.

TRANSITIONS

The bio-optical modules of HOPS are expected to make transitions with new releases of HOPS to the community. HOPS is currently being used at Naval Research Laboratories, the Naval Postgraduate School, the Jet Propulsion Laboratory (NASA), SACLANT Undersea Research Centre, and universities in the United States, Japan, Greece, Italy, Turkey and Israel.

RELATED PROJECTS

We are collaborating with Prof. T. Dickey at UCSB to work with the Biowatt and Coastal Mixing and Optics (ONR) projects. These analyses will be used to develop predictive capabilities in both the open ocean and coastal regions.

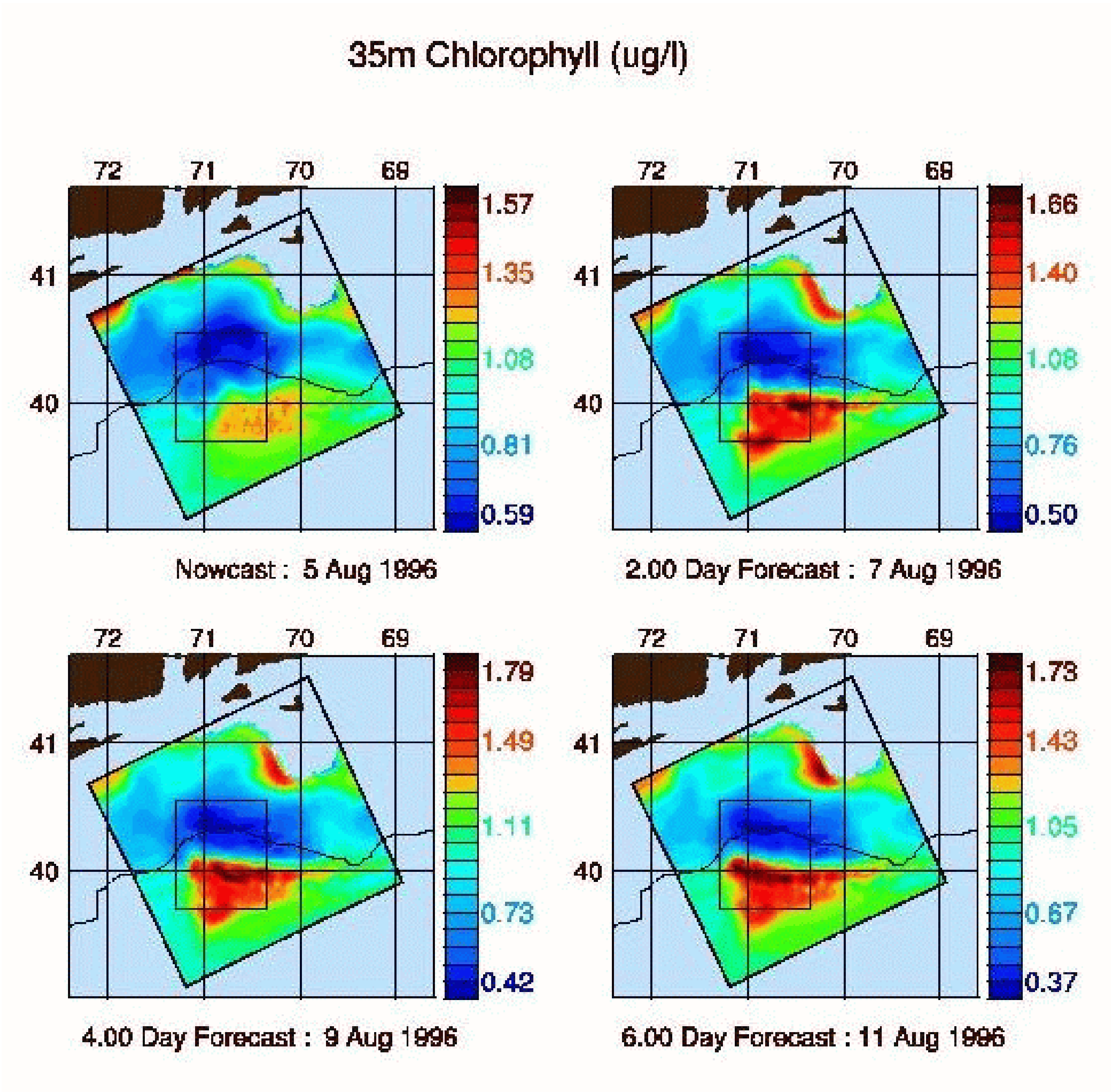

Figure 2 - Simulated chlorophyll fields at a depth of 35m for the New England Bight simulation.

The bio-optical models are being used in two other projects as well: the Littoral Ocean Observing and Predictive System (LOOPS) project (ONR) and the Atlantic Fisheries Management and Information System (AFMIS) project (NASA). These simulations are being conducted in the Gulf of Maine and in Massachusetts Bay, and complement the New England Bight research quite well.

REFERENCES

Dusenberry, J. A., C. J. Lozano, L. A. Anderson and A. R. Robinson. 1999a. The Harvard Ocean Prediction System bio-optical model component. *In prep.*

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