Use of a Circulation Model to Enhance Predictability of Bioluminescence in the Coastal Ocean

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LONG-TERM GOALS

The long-term objective is to contribute to the development of the components of limited area, open boundary, coastal nowcast/forecast systems that will resolve the time and length scales of the relevant ocean dynamics in shallow coastal environments.

OBJECTIVES

Our objective is to develop the technology and methodology to optimize limited spatial and temporal bioluminescence (BL) sampling for maximum impact on short-term (2-3 days) BL forecasts.

APPROACH

The BL forecasts will be conducted by assimilating limited BL observations into an advective-diffusive tracer model with the velocities and diffusivities from nested, data assimilating coastal circulation models of the Monterey Bay area (named ICON model due to NOPP sponsored project "Innovative Coastal-Ocean Observing Network" (ICON) and with a finer-resolution sub model of the ICON model (frsICON) around the upwelling front at the north of the Monterey Bay, Shulman et al., 2002a, Shulman et al., 2002b). Data sets to be used include ongoing observational efforts by Dr. Haddock in Monterey Bay, as well as the AOSN-II experiment planned for August 2003. A significant enhancement to the hydrodynamic model will be the inclusion of tidal forcing.

Modeling activities will be undertaken in conjunction with the high-resolution bioluminescence observational program being conducted by Dr. Haddock in the Monterey Bay area. During each of the three oceanographic seasons typical in this area, Haddock will use AUVs to measure BL along 5 radial sections covering the Bay over 6 subsequent days (one section will be sampled twice). These observations will be made during three typical oceanographic seasons through two full sets of seasonal cycles. A planned AUV upgrade will provide velocity data, as well as the temperature, salinity, and BL data. This coincident sampling of the BL and physical variables will allow crucial testing of our techniques, which would not be possible without data sets collected on comparable spatial and temporal scales.

Research is being performed in collaboration with Drs. I. Shulman and J. Kindle of NRL; S. Haddock of MBARI; J. Paduan and L. Rosenfeld of NPS.

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14. ABSTRACT
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WORK COMPLETED and **RESULTS**

This is a new effort started in July of 2002.

We are in the process of: 1) analyzing atmospheric and hydrodynamic conditions during the first MBARI cruise in August of 2002; 2) acquiring necessary input data for the circulation model runs during the period of the first cruise.

The proposed research is a part of the ONR's "Autonomous Ocean Sampling Network" (AOSN-II) adaptive sampling study in the Monterey Bay. We have been participating in development of objectives as well as in design and planning of the AOSN-II experiment.
This grant has also facilitated ongoing synthesis and modeling of bioluminescence data collected in Monterey Bay during the 2000 MUSE experiment. One example of Dr. McGillicuddy's efforts in this capacity is the assessment of the space/time hydrodynamic connectivity between survey transect data collected during the field campaign. The oceanographic relationship between two cross-shore survey tracks occupied on year days 242 and 245 was studied using a hydrodynamic model and numerical particle tracking software. Three-dimensional velocity fields were extracted from Dr. Shulman's ICON model for the region. Based on the Princeton Ocean Model, this model assimilates CODAR data and represents the most realistic representation of the flow field available for interpretation of the MUSE observations. The particle tracking software, DROG3DDT, is a component of the suite of finite element models developed by Prof. Daniel Lynch and colleagues at Dartmouth College (see http://www-nml.dartmouth.edu/circmods/gom.html). In order to facilitate use of the particle tracking code, a finite element mesh was generated consisting of a set of nodes that coincide with those in the ICON grid. Velocity fields from the ICON model, temporally averaged between days 242 and 245, were then simply mapped onto the finite element mesh.

Our approach to examining the potential connections between transects 242 and 245 involves tracking particles both forward and backward in time (Figure 1). Particles deployed along transect 242 are advected forward in time for three days in order to determine the extent to which they impinge upon the second transect occupied on day 245. Conversely, particles on transect 245 are advected backward in time to assess the source regions for the water sampled along that line.

Transect 242 cuts across a highly sheared region in which strong currents offshore are directed to the south-southeast. Just inshore, a coastal jet flows along the coast to the northwest. Sluggish currents are present close to the coast, with velocities of 10 cm/sec or less. Particle trajectories bespeak the complex hydrodynamic structure in this area. Although the three particles closest to the coast do not stray far from their release points in three days, those farther offshore transit large distances in the strong currents. Particles in the coastal jet tend to get entrained into the southeastward flow offshore due to an eddy-like structure lying in between the two current systems.

Transect 245 juts out directly into a northward flowing current at the mouth of Monterey Bay. Thus, backward advection of particles from the offshore two-thirds of the transect simply translates the line upstream. Even the relative spacing of particles from the outer half of the particles remain intact as they transit more than 30 km in three days. Particles released closer to shore are influenced by the counterclockwise circulation within the Bay. Thus the origin of water sampled in the nearshore portion of transect 245 appears to be further south and east within the Bay itself.

Based on this analysis, it appears that transects 242 and 245 sampled entirely different water masses.

This finding has important implications with respect to coupled physical-biological modeling of the bioluminescence data collected during MUSE. Observed fluctuations in bioluminescence arise from a complex mixture of biological processes and hydrodynamic transport. Without explicit resolution of gradients in the distribution of light-producing organisms on the appropriate space and time scales, it is not possible to distinguish between the effects of population dynamics and advection in creating the observed patterns. Future studies of this type would benefit from improved space/time resolution on "oceanographic" scales.

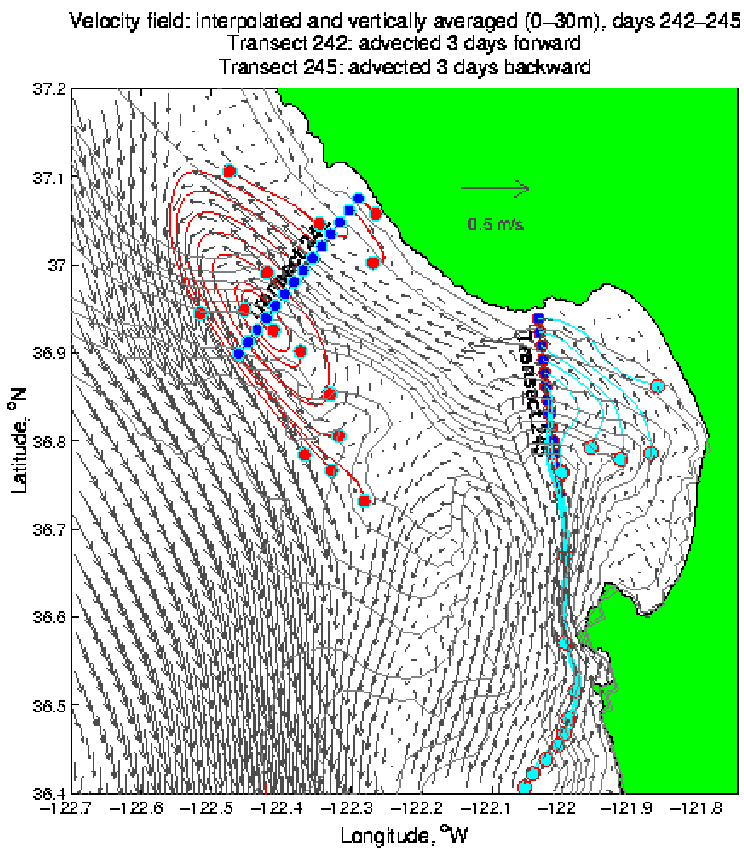

Figure 1. Particle trajectories based on velocities averaged in the upper 30 m for days 242-245. Release locations are shown in dark blue, and endpoints for particles from transect 242 and 245 are red and light blue, respectively. Particles from transect 242 are advected forward three days, and those from transect 245 are advected backward three days. Velocity vectors and bathymetric contours are overlayed.

IMPACT/APPLICATIONS

Prediction of the bioluminescence potential is critical for numerous naval operations, including preventing detection of covert operations involving submarines, Swimmer Delivery Vehicles and AUVs, and – conversely - in aiding detection of enemy incursions. In most cases, only limited in situ sampling of BL is possible immediately prior to, or during, these activities. The proposed research will provide technology and recommendations for optimizing this sampling and for use of these limited BL observations for short-term BL forecasts by tracers with the use of circulation model predictions.

TRANSITIONS

ICON model outputs will be used by AOSN II group for testing optimal sampling schemes and for optimizing the trajectories and control theory used for AUVs.

RELATED PROJECTS

ONR's "Autonomous Ocean Sampling Network II (AOSN II) Experiment".
Coordination with a joint effort of the Harvard, MBARI, WHOI, NPS, Princeton, CalTech, JPL, NRL, and USM groups in designing and building an Adaptive Coupled Observation/Modeling Prediction System in the Monterey Bay.

ONR's, "High-Resolution Measurements of Coastal Bioluminescence; Improving short-term predictability across seasons", MBARI.
Modeling activities will be undertaken in conjunction with the high-resolution bioluminescence observational program being conducted by Dr. Haddock in the Monterey Bay area.

NRL's "Coupled Biophysical-dynamics Across the Littoral Transition (CoBALT)."
CoBALT Pacific West Coast model predictions and COAMPS products are used for open-boundary and surface forcing in the Monterey Bay area models (ICON and frsICON models).

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