Front-Resolving Observational Network with Telemetry

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LONG-TERM GOALS

The goal of this National Ocean Partnership Program is to develop an autonomous network of ocean sensors that telemeter their physical and biological data to shore in real-time with cutting edge communication technologies. With additional remotely sensed data (satellite measurements of temperature and color and shore-based high-frequency radar (CODAR) measurements of surface currents), these data streams will be assimilated into physical and biological models to predict the 4-dimensional properties of a limited coastal region. The accuracy of the assimilated products will be tested with data from a series of high-resolution ship surveys. Additional measurements of turbulence and other small-scale properties will be used to aid the eddy diffusivity parameterizations used in the data assimilation model.

OBJECTIVES

The objectives of the URI component of the FRONT project are to produce maps of SeaWiFS-derived phytoplankton chlorophyll distributions, sea-surface temperature (SST) and surface currents for the data assimilation model. The URI group will also undertake regional surveys of the hydrographic fields at several times during the project.

In addition to these data products, we will examine the variability of SeaWiFS-derived phytoplankton chlorophyll distributions and its coupling to physical processes in the FRONT region. We will compare pigment fronts with thermal fronts and other collected in situ data sets to examine the biophysical coupling. We will attempt to understand the mechanism(s) of formation and the dynamical significance of mid-shelf SST fronts.

APPROACH

Using SeaWiFS ocean color images, maps of phytoplankton pigment (chlorophyll) in and near our study site will be produced. These images have been processed using NASA's software processing package, SeaDAS. Thermal images covering the same time-period and the same study area are available from the URI Satellite Archive. The annual cycles of chlorophyll and sea-surface temperature patterns and their distributions will be used to study the variability and co-variability between chlorophyll, sea surface temperature and other collected data sets as part of this project.

CODAR stations will be established to measure surface currents in a region where SST fronts occur. We will analyze concurrent AVHRR SST images for the occurrence of fronts within the range of CODAR. The CODAR-derived velocities will be combined with SST to estimate the rate of change of horizontal SST gradients (frontogenic tendency) due to the action of the horizontal deformation field.

Several high-resolution hydrographic frontal surveys over periods of several days will be used to characterize the frontal structure over a wide range of time scales and hydrographic conditions. This data will aid the interpretation of data collected by the moored array.

WORK COMPLETED

CODAR HF surface current mapping radars at three sites (Block Island, RI; Misquamicut Beach, RI; and Montauk Point, NY) have been operational since June 2000. Coverage has been almost continuous since the deployment, providing a record of surface currents of greater than 2 years duration. This long record, along with ADCP observations obtained at the FRONT site by Dan Codiga (UCONN), have allowed us to investigate the seasonal variability in the coastal jet that has been observed coincident with the location of surface thermal fronts in the region. A manuscript (Ullman and Codiga) based on this work has been prepared and submitted to JGR. In collaboration with UCONN workers, we are posting real-time CODAR maps on the web (available at the FRONT web site at http://nopp.uconn.edu .

To determine the distribution patterns of ocean color (phytoplankton chlorophyll) fronts in our NOPP study area, the frontal edge-detection algorithm was applied to two full years (2000 and 2001) of daily images of Version-3 processed SeaWiFS data. Monthly mean probabilities of phytoplankton chlorophyll were calculated from this time-series. The chlorophyll fronts are being compared to the thermal fronts derived from the AVHRR over the same time period. Together with D. Ullman, we are currently preparing a manuscript which will be submitted to peer-review journal within the next few weeks.

We conducted 5 hydrographic surveys (September 2001 to May 2002), each lasting several days, of the front south of Long Island using an undulating towed body. The towed body was equipped with a CTD, fluorometer, transmissometer and oxygen sensor. We obtained profiles down to 50 m and with a horizontal resolution of 500 m or shorter at the mid-depth. Over 40 transects across the frontal area were completed (Kirincich and Hebert, 2002) and this data, along with the shipboard ADCP data is the basis of Mr. Kirincich’s MS thesis.

RESULTS

The approximately 2-year record of CODAR and ADCP currents clearly shows the presence of a strong coastal jet during summer in the FRONT region. The jet axis is roughly aligned with a zone of high surface thermal front probability that is also observed during that season (Ullman and Cornillon, 1999). The jet is weak or absent altogether during the winter months. Analysis of the depth-averaged momentum balance shows that the cross-isobath balance on seasonal time scales is essentially geostrophic, and the pressure gradient term in this balance has been partitioned into steric (buoyancy-driven) and non-steric (i.e. wind-driven) components. The steric component of the depth-averaged pressure gradient is responsible for the mean downshelf (southwestward) current. The seasonal variability of the jet is forced by the combined variability of the steric component, which intensifies somewhat during summer, and the non-steric component, which is strongest in winter. The non-steric across-shelf pressure gradient in winter is due to sea level sloping down towards shore and appears to be associated with upwelling-favorable winds during this period.

The transport associated with the jet in the FRONT region (approximately 0.07 Sv in summer) is significant in relation to the 0.38 Sv south of Nantucket Shoals between the 40m and 120m isobaths determined by Beardsley et al (1985). Beardsley et al (1985) detected no annual variability in the flow over the middle and outer shelf. The results of this study suggest that the dynamics over the inner shelf is significantly more variable on seasonal time scales.

The observation that the downshelf flow over the southern New England shelf weakens significantly in winter suggests a mechanism for the observation by Ullman and Cornillon (2001) of enhanced cross isobath transport during winter in the Nantucket Shoals region. Wind stress in winter along the entire northeast coast is towards the southeast. In the FRONT region, this is an upwelling-favorable wind stress that retards the buoyancy-driven downshelf flow. Over the shelf north of Nantucket Shoals the wind stress in winter is downwelling favorable due to the 90° coastline bend. We speculate that north of Nantucket Shoals the wind-driven and buoyancy-driven components of the flow are both downshelf in winter, with the result that there may be an alongshelf convergence of flow at Nantucket Shoals. This is consistent with the observation of cold plumes of inner shelf water emanating from Nantucket Shoals and extending to nearly the shelfbreak (Ullman and Cornillon, 2001).

For the 2-year SeaWIFS time series, a strong frontal band was found during the second (April-May-June) and third (July-August-September) quarters (Figure 1). This band runs just offshore and parallel to the Long Island coastline and is the most intense from east of Block Island to the southeastern tip of Long Island. During both quarters this frontal band curls northward between Block Island and the eastern tip of Long Island. The location of these chlorophyll fronts and the predominant occurrence between the months of April-September coincides with a dominant thermal frontal band in the same location. This good correspondence seems to suggest that there is close coupling between the physics and the biology in regards to the formation of chlorophyll and thermal fronts in our study region.

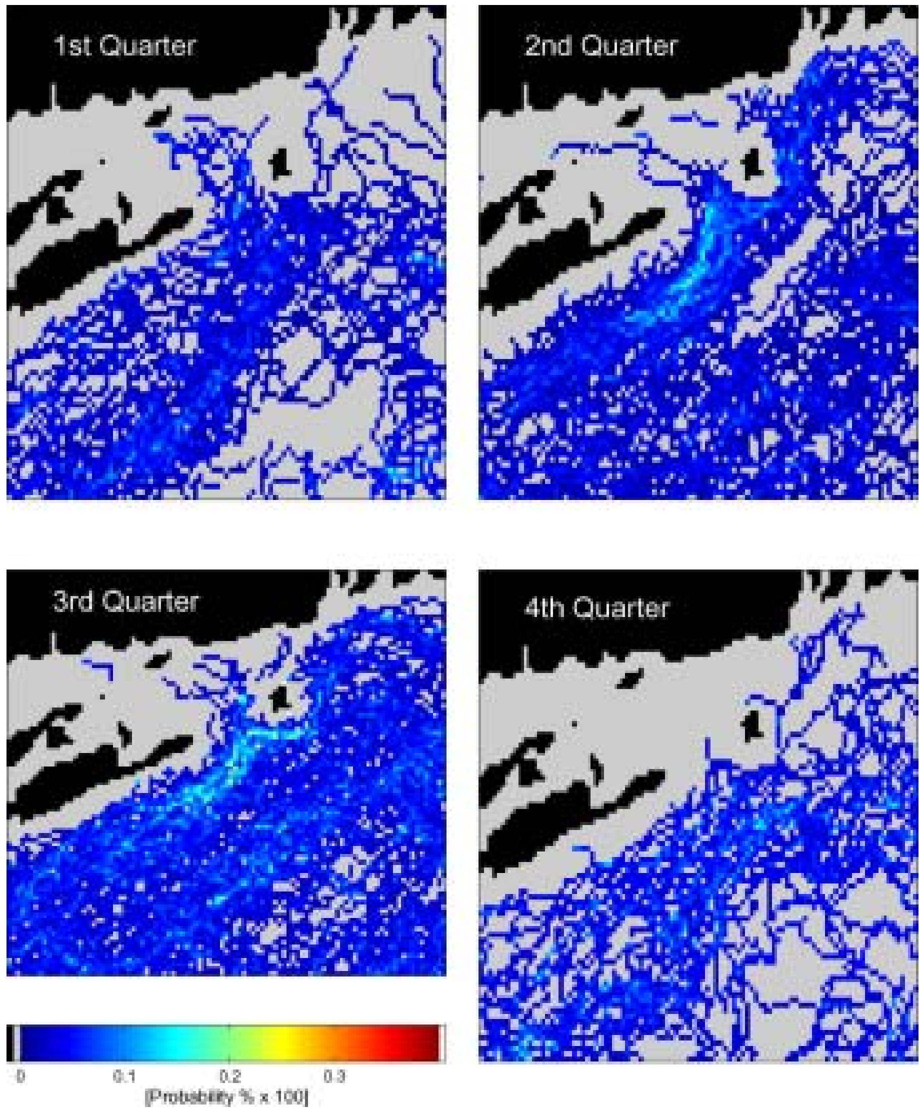

Figure 1. Mean quarterly chlorophyll frontal probability for the two year time-series (2000 and 2001) derived from SeaWiFS images. [A dominant chlorophyll frontal band is observed parallel to Long Island in the 2nd and 3rd quarters. A second, weaker frontal band is visible further offshore during the 1st, 3rd and 4th quarters.]

A second, albeit less intense, chlorophyll frontal band is observed further offshore during the first, third and fourth quarters. The northward curl characteristic of the dominant nearshore frontal band is also visible during the first quarter but absent in the fourth. These results will be submitted for publication in the next few weeks.

The initial CTD surveys using our undulating towed body illustrated the richness of structure in both the physical and biological properties of the frontal region in our study area. Analysis of the CTD and ADCP data is presently underway. In April 2002, a coastal jet flowing along the front was the dominant feature of the area circulation. Evidence for convergence and upwelling at the front exists in across frontal de-tided velocities as well as transmissivity measurements.

IMPACT/APPLICATIONS

Remotely-sensed data (surface currents, sea surface color and sea surface temperature) along with in situ data are being used to address the processes responsible for coastal frontal features and the dynamics occurring at these fronts. As well, this data is assimilated into a numerical model of the region and used for validation and testing of the model and data assimilation schemes.

TRANSITIONS

Several of the PIs from URI and UCONN (Ullman, O'Donnell, Edwards) are presently working with the U.S. Coast Guard to test the utility of real-time CODAR velocity fields in the prediction of trajectories of drifting objects for search and rescue operations.

RELATED PROJECTS

This is a cooperative project with many other institutions. Reports by O'Donnell (UCONN), Levine (NUWC) and Rice (SSC-SD) with the same title describe our other partners' work.

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