

## **FRONT: 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 is 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

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dynamical significance of mid-shelf SST fronts. The turbulence (microstructure) measurements will be used to examine the best way to parameterize the mixing processes for the modelling work.

## **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.

Measurements of conductivity microstructure obtained on a towed body will be compared to turbulence measurements from an AUV operated by Dr. Edward Levine (NUWC). Estimates of mixing rates will be investigated in context of the larger hydrographic fields, especially in the vicinity of the fronts.

## **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 with almost continuous coverage during this period. The original real-time processing that was implemented upon installation assumed that antenna patterns were ideal. Subsequent measurement of these patterns indicated distortions from ideality that were severe in one case. We have therefore undertaken and completed a reprocessing of the archived raw data (10 minute averaged cross-spectra) using the measured patterns. Analysis of the resulting 1.5 year time series of CODAR-derived velocity is now underway. The fact that two of the sites (Misquamicut and Montauk) measure radial velocity along a common baseline has allowed estimation of the accuracy of the CODAR velocity retrievals. This has confirmed the need to utilize the measured antenna patterns in the processing. 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>).

During the past year we have been processing real-time SST images provided by the University of Miami satellite group. These images are manually navigated and are then passed through the URI declouding algorithm. The images are posted on the web at the FRONT web site.

Using updated and reprocessed SeaWiFS data, the frontal edge-detection code has been run on daily chlorophyll images starting from summer 2000. Then the results are averaged for each month. This processing routine is currently being performed on all available images for the year 2000. If time permits, this will also be done for the years 1998 and 1999, thus expanding the time-series of mean monthly chlorophyll fronts for a total of 3 years. Maps of the chlorophyll gradient for the summer months in 2000 have also been produced. As with the chlorophyll frontal maps, this will also be done for the remaining months in 2000 and possible retroactively.

A towed body, the Acrobat, was obtained along with the necessary ancillary equipment. During a test cruise last year, the tow cable parted at the termination and the towed body and CTD were lost. We received a replacement system and have recently completed two days of cross-frontal surveys. The towed body is equipped with a CTD, fluorometer and transmissometer. We will be adding a Seabird oxygen sensor for the next surveys. With the present configuration, we can obtain profiles down to 40 m and with a horizontal resolution of 500 m or shorter at the mid-depth. We plan to use new wings that should allow us to profile deeper. We are working with the Acrobat manufacturer to improve the flight control software and, possibly, increase the horizontal spatial resolution by 20%.

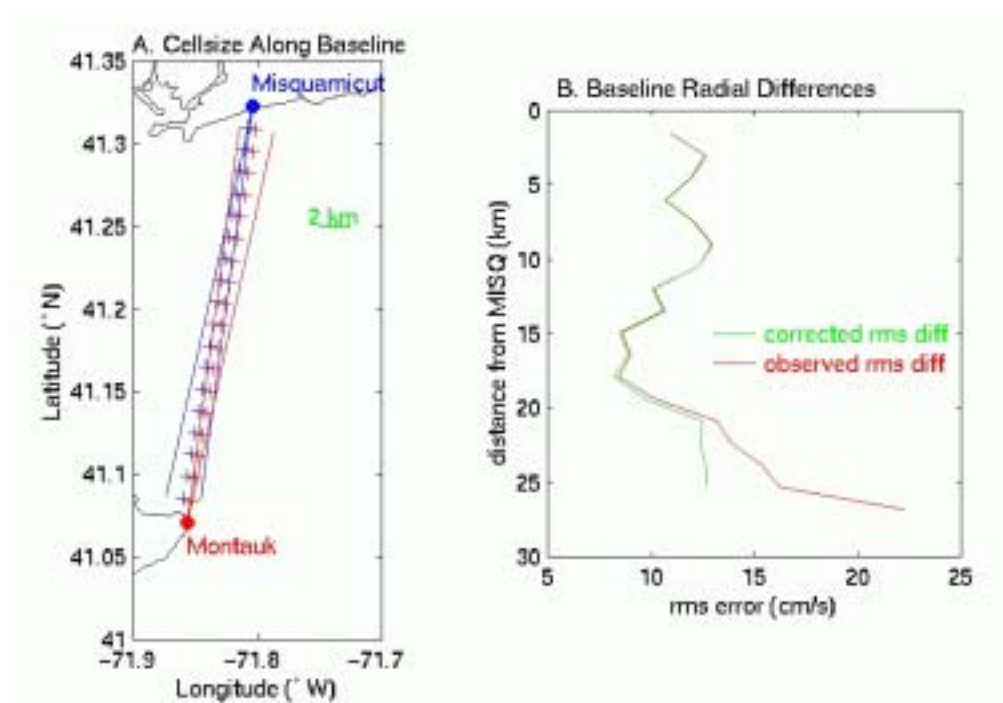
## RESULTS

Although the two CODAR radars covering a baseline measure radial velocity in the same direction, differences arise due to the presence of horizontal current shear combined with range-dependent radar cell size (Figure 1a). Observed radial velocity rms differences are large (20-25 cm/s) just north of Montauk Pt. (Figure 1b, red curve) where tidal model results show large tidal current shears (Chris Edwards, UCONN). After accounting for this source of error, the corrected differences (Figure 1b, green curve) are approximately uniform along the baseline with a value of approximately 12 cm/s. Assuming uncorrelated errors at the two sites this corresponds to a rms radar error at each individual site of 9 cm/s, representing our best estimate of the radial velocity uncertainty.

Monthly maps of mean chlorophyll frontal distributions for summer (June-July-August) 2000 are shown in Figure 2. The highest probability of chlorophyll fronts in all months is in an area adjacent to Long Island. In August, this frontal zone moves further offshore and is caused by higher chlorophyll levels extending further offshore at this time than during the prior 2 months. Another area with a higher probability of chlorophyll fronts is located between the eastern tip of Long Island and Block Island during June and July. Clearly, there is variability not just in the distribution patterns of chlorophyll fronts, but also in the zones of highest chlorophyll frontal probability. How this varies on a seasonal basis is currently being examined.

The mean monthly chlorophyll gradients for the summer of 2000 are generally higher nearshore than offshore (Figure 2). Also, August shows the largest spatial extent of high chlorophyll gradients. From June to July moderate gradients are evident in the entire study area but by August they seem to have been pushed back inshore again by a wedge of low chlorophyll waters coming from the southeast (possibly due to shelf break activity). Comparisons between maps of chlorophyll gradient and thermal distribution patterns are underway.

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.



**Figure 1. A).** Map showing the radar cell sizes for the Misquamicut and Montauk CODAR stations. The cell sizes increase with range from the site, so that large differences between the spatial scale of averaging at the two sites occur near the ends of the baseline. **B).** Observed rms differences between Misquamicut and Montauk radial velocities as a function of distance from Misquamicut (red curve). The observed differences become large in the vicinity of Montauk, where large horizontal current shears are known to occur. After correction for the effect of shear, the differences (green curve) are approximately uniform along the baseline (approximately 12 cm/s).

## IMPACT/APPLICATIONS

Monthly maps of chlorophyll frontal probabilities and chlorophyll gradients will provide information on the seasonality of biological activity in this region. Together with contemporaneous maps of thermal front activity and thermal gradients, details on the variability and co-variability between pigments and SST can be obtained. Furthermore, this kind of comparison will provide information on the spatial and temporal variability of coupling between biological and physical activity in the study site.

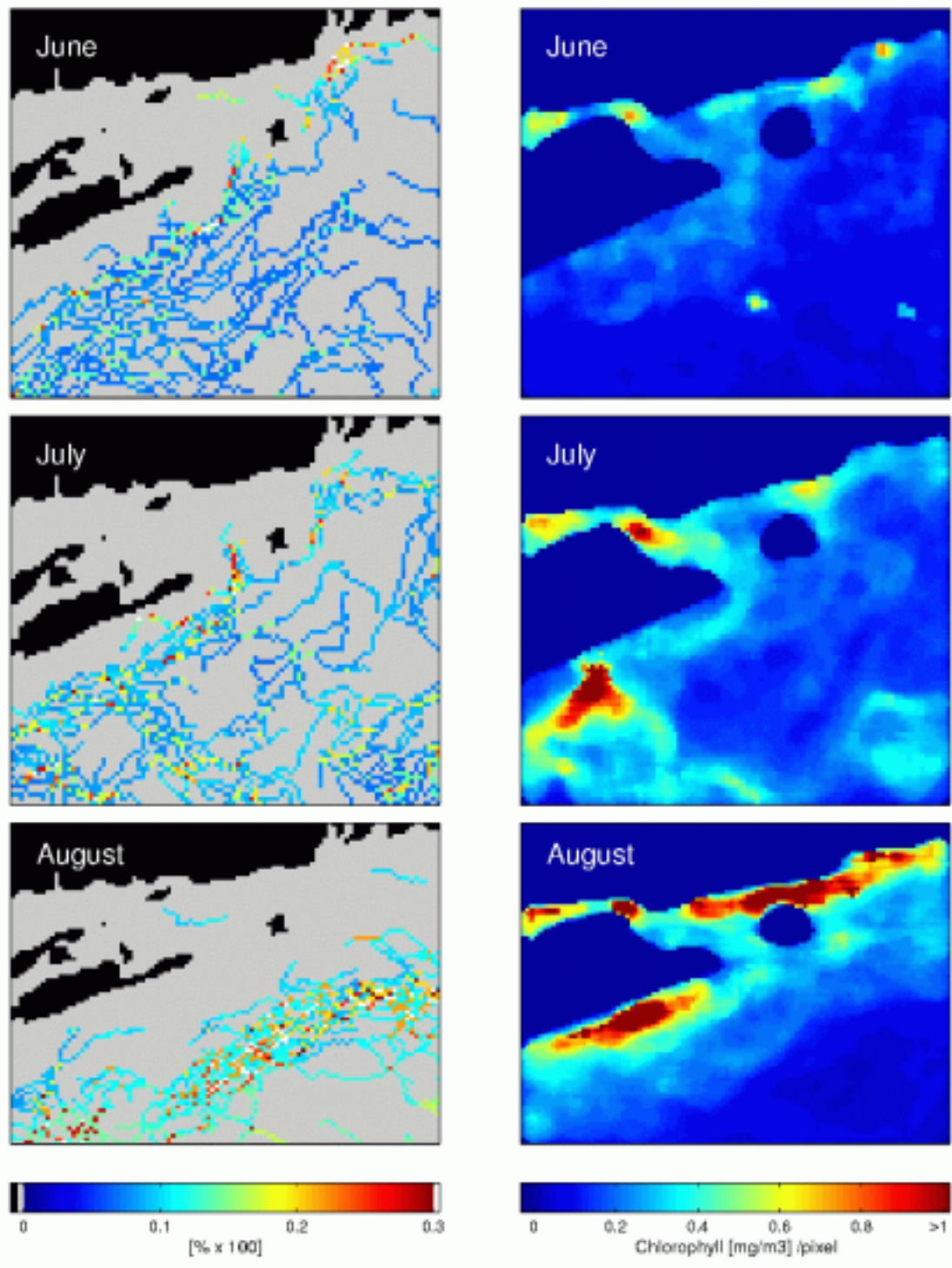
The eddy parameterizations based on the coastal microstructure measurements will be available for testing in dynamical models of the coastal ocean.

## 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.

## **PUBLICATIONS**

Ullman, D.S. and P.C. Cornillon, Continental Shelf Surface Thermal Fronts in Winter off the Northeast U.S. Coast, *Continental Shelf Research*, **21**, 1139-1156, 2001.



*Figure 2. (Left panels) Mean monthly chlorophyll frontal probability for June, July, and August 2000 derived from SeaWiFS images. [The highest probability of chlorophyll fronts in all months is in an area adjacent to Long Island. In August, this frontal zone moves further offshore.] (Right panels) Mean monthly chlorophyll gradients for the same months. [Gradients are higher nearshore than offshore and August shows the largest spatial extent of high chlorophyll gradients.]*