Regional Variability and Predictability in the Upper Ocean

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LONG-TERM GOALS

Our long-term objectives are to understand the dynamics of upper ocean physical processes and air-sea exchange and to see that understanding integrated into operational Navy strategies. Of particular interest is understanding the variability of the upper ocean on vertical scales from tens of centimeters to hundreds of meters, and on horizontal scales of meters to tens of kilometers, and the role that spatial-temporal variability in the atmospheric forcing plays in setting those scales.

OBJECTIVES

Our objective for this project is to improve our understanding of variability in the upper ocean encountered by mine warfare forces and to determine if local observations will lead to improved predictions that can be used to the advantage of the Navy.

APPROACH

Our approach is to pursue our research objectives in large part by participation in fleet exercises. These exercises have been MIREM (Mine Warfare Readiness Effectiveness Measuring) Programs, exercises focusing on the performance of Navy systems in the upper ocean and/or atmospheric boundary layer in the littoral environment. We conduct enhanced environmental monitoring during exercises. We place small, non-intrusive instruments on ships operating in the exercise region to collect time series of the surface meteorological forcing and upper ocean structure. We also deploy easily deployable/recoverable buoys equipped with meteorological sensors and upper ocean temperature, salinity, optical, surface wave, and current sensors. The marine boundary layer observations provide complete and highly accurate air-sea flux measurements; and the moored observations, together with Battlespace Profiler (BSP) data we obtain from the minesweepers after the exercise, document the variability in the ocean.

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Using telemetry, we work to provide high quality *in-situ* measurements to the METOC (MEtorological and OCeanographic) support for the exercise for their combination with all other data collected in stride during the exercise. We later use the internally recorded data in an environmental reconstruction and retrospective analysis of the exercise. This retrospective analysis would focus on quantifying the environmental variability seen in the upper ocean, examining the predictability of this variability and exploring how the environment may have impacted performance of operational systems used in the exercise. We couple our work with that of the METOC support for the mine warfare forces and with the Surface Warfare Development Group (SWDG) as they plan, carry out and analyze results from exercises.

WORK COMPLETED

A large part of our effort during the first year went towards becoming familiar with the ONR and Navy groups and activities that we would be working with during the next three years. This included travel to various ONR and Navy meetings and workshops, as well as providing scientific briefings to WHOI visitors. In the second year of the project we participated in GOMEX 99-2/MIREM-9. Our objective for this project was to assist the Surface Warfare Development Group and the Office of Naval Research in observing, documenting and improving our understanding of the marine environment encountered in the exercise area. We deployed an oceanographic buoy to monitor surface winds as well as the vertical temperature and salinity (and thus sound speed) profiles during the exercise.

In the third year of the project we developed a small, portable, moored coastal observatory that uses acoustic, inductive, satellite and radio telemetry to report surface meteorology (wind, radiation, barometric pressure, humidity, temperature, precipitation), wave, current, and full water column temperature, salinity, and diver visibility data in real-time. The incorporation of telemetry, wave data, optical (visibility) data, and full water column capability was motivated by feedback garnered from operators at post MIREM-9 briefings. This new system was deployed during Kernel Blitz 2001/MIREM-16 off Camp Pendleton, CA in March 2001, providing data in real time that was used for METOC support of the exercise as well as a high quality data set for post-exercise analyses. To provide additional operational testing of telemetry components the system was also deployed in support of the ONR sponsored CBLAST initiative off Martha's Vineyard, MA in August 2001. Based on the practical experience gained during these two deployments we have recently begun design work on a new surface buoy platform to use with the system. Compared to the prototype buoy the new platform will be easier to deploy, more maintainable, and offer better mounting positions for the meteorological instrumentation.

At the beginning of the third year, Joe LaCasce replaced Steve Anderson as the SECNAV/CNO Institution Scholar on the project. He is working on the on the predictability portion on of the project.

RESULTS

Telemetered results from the moorings were published on web sites once per hour during the experiments. During Kernel Blitz, ONR and fleet participants could visit the site (http://flux.whoi.edu/kb01) to get near real time information about conditions. The results from the Kernel Blitz 2001 deployment are also reported in a WHOI Technical report that will be distributed to SWDG and COMINEWARCOM METOC staff. In contrast to MIREM-9 in the Gulf of Mexico, there was significant temporal variability on a range of timescales during Kernel Blitz. Figure 1 shows contours of soundspeed at the WHOI mooring site during the deployment period. The dominant signal near the surface is due to diurnal heating. The semi-diurnal fluctuations near the bottom are tidally driven. The most striking feature of the dataset is an intrusion of cold, salty water along the bottom that continued throughout the experiment and produced the thickening of the dense bottom layer seen in Figure 1. The interface between warm surface water and cold bottom water supports internal waves. At the beginning of the experiment, high frequency (greater than 48 cycles per day) internal wave energy is present at 45 m depth. By the end of the experiment that energy was found shallower than 15 m depth. This high level of variability, on a range of time scales from weeks to minutes, presents a challenge to our ability to forecast environmental conditions. It illustrates the need for both continued enhancements to our observational efforts and the use of the consequently expanding datasets to improve modeling efforts.

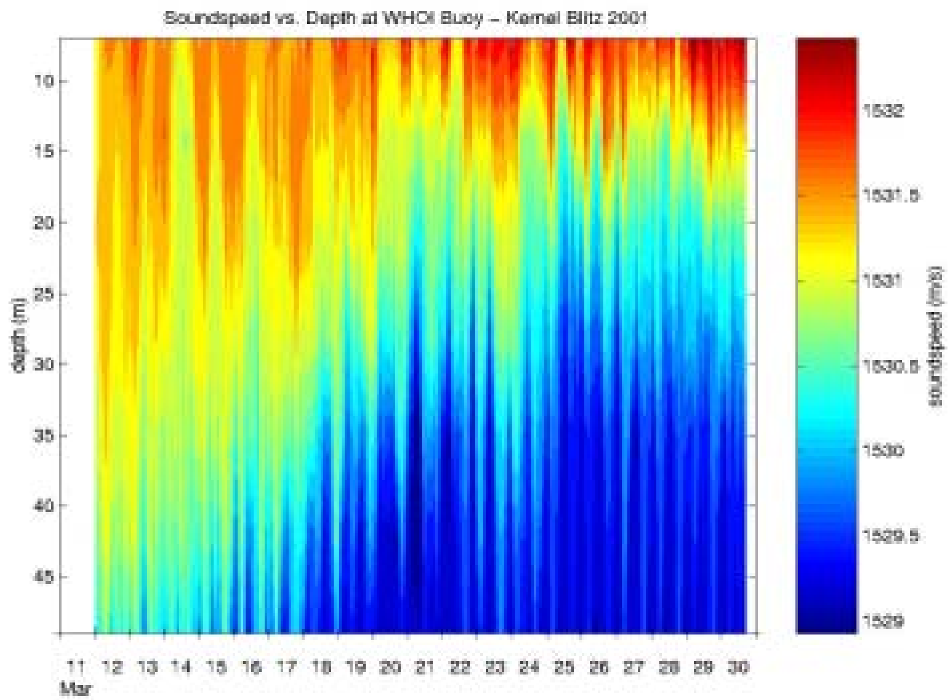

Figure 1. Soundspeed at the WHOI mooring site during Kernel Blitz 2001. In addition to significant diurnal and semi-diurnal variability near the surface and bottom, the soundspeed profile steepened sharply over the source of the experiment due to seasonal heating at the surface and an intrusion of cold, salty water along the bottom.

The primary focus of LaCasce's work is on Eulerian and Lagrangian predictability. The former concerns predicting currents at one location at a given time if currents are known at another point or points at the same or earlier times. The latter pertains to predicting where a free-floating object will drift, depending on the flow character. In this project, our concerns are on whether observations at a site remote to a naval operation, for example, a planned landing site, can yield good predictions for the site of the operation and how mines and mine-like objects will drift. The approach has centered on using so-called "two-dimensional turbulence" models. These employ simplified geometries and very high resolution to capture small-scale processes rather than parameterize them. The model results are then used to explain actual oceanic data.

Two turbulence models have been used, a ``periodic" one for interior regions and a basin model for semi-enclosed seas. The solutions generally possess waves and random flow. Predictability is characterized using model velocity records and simulated drifter trajectories. The models suggest that waves (Rossby waves, coastally trapped waves, etc.) produce long-range coherences and so are fundamental to predictability. An additional analytical study was conducted focused specifically on baroclinic waves in basins. A new set of modes was found which owe their existence to coupling with coastal Kelvin waves; these dominate the low frequency response under certain conditions.

The Eulerian statistical measures used with the models can be applied directly to current meter data, and a large set of data has been collected from diverse regions. Initial results are encouraging: a similar spatial degradation of velocity coherence is seen in the data and in one of the turbulence models (upper panels of Figure 2). Note in particular the degradation of the meridional velocity correlation with separation and the large scales of zonal correlation. A much larger data, shipboard ADCP records, has a potentially large payoff, since the instrument is wisely used.

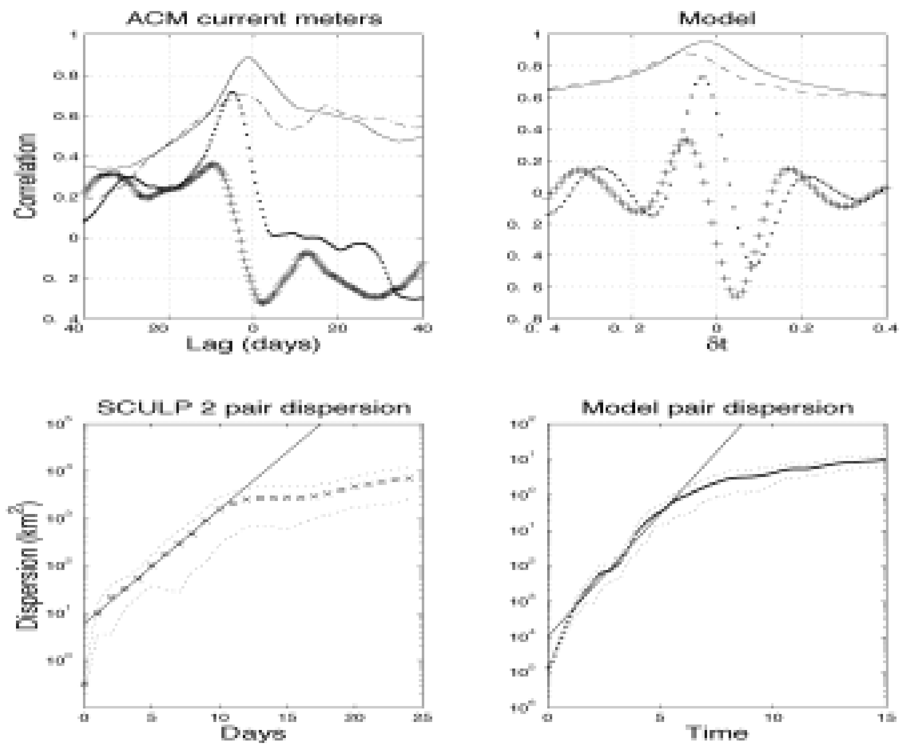

Figure 2. (upper left) Lagged velocity correlations from 26°N in the North Atlantic. Dot/pluses represent meridional velocities from the same latitude separated by 35 and 75 km respectively; the solid/dashed line are zonal velocity correlations. (upper right) Lagged velocity correlations from a spectral 2-D turbulence simulation, from points at the same "latitude" separated in "longitude". The dots and solid line are for nearer observations and the pluses and dashed lines are for more separated observations. (lower left) Dispersion of pairs of drifters from the Gulf of Mexico, showing mean square distance as a function of time. (lower right) Dispersion of pairs of drifters in a 2-D turbulence simulations, driven by large scale forcing.

In terms of Lagrangian predictability, tracks of surface drifters deployed in the Gulf of Mexico are being examined. The focus has been "relative dispersion" or two-particle statistics, which measures how quickly two initially close drifters on average separate in time (and is the most direct measure of predictability). The results suggest among other things that particle separations grow exponentially in time initially (lower panels of Figure 2), as one finds with chaotic flows. This is the clearest indication of exponential stretching from *in-situ* oceanic data to date.

The similarities between the predictability characteristics in turbulence models and in oceanic data suggest that the models are of value in understanding the data. If so, simplified predictability algorithms may be had. These would be of specific value to such activities as designing observational strategies and search and rescue.

IMPACT/APPLICATIONS

During Kernel Blitz 2001 we located our shoreside operations alongside ONR advanced technology operators at the Army Reserve Center on Camp Pendleton. As part of the ONR Detachment we participated in Distinguished Visitor day and had the opportunity to brief visitors and operational Navy personnel on our observing efforts and the high variability that was evident in the telemetered data. We spread the word about the availability of the real-time data by attending the pre-sail MCM brief on the USS Tarawa and visiting the North Island METOC staff. Throughout and following the experiment, the web site did see traffic originating from Navy installations involved in the exercise.

TRANSITIONS

One potential transition at the completion of this project might be the adoption of a moored observing system as a "Battle Space Buoy", that the Navy could deploy in stride, like the Battle Space Profiler, to monitor the environment in real-time during operational activities. In a future exercise we hope to increase our interaction with MCM units by locating our shoreside operations with the squadron METOC staff. Such interaction is critical to demonstrating and improving the utility of the high quality environmental information that such a system provides.

RELATED PROJECTS

A related project is the ONR Coupled Boundary Layers Air-Sea Transfer (CBLAST) DRI (http://www.whoi.edu/science/AOPE/dept/CBLASTmain.html) . Pilot experiments were carried out in the summer of 2001. The pilot experiment provided allowed testing of our telemetry development and at the same time a valuable additional data source for CBLAST. As with our Kernel Blitz efforts, the results from our portion of the pilot experiment were updated hourly on a web site (http://flux.whoi.edu/cblast).

Mooring data from the Kernel Blitz deployment has been provided to researchers from Scientific Solutions, Inc. for use in an ONR sponsored model validation effort. Researchers from NRL Ocean Optics Code 7333 used our visibility data for comparison purposes on their web site during the exercise (http://www7333.nrlssc.navy.mil/ocolor/Exercises/kernal_blitz2001/kbindex.html).

PUBLICATIONS

Jason Gobat, Robert Weller, Bryan Way, and Jeffrey Lord, 2001. “A compact coastal ocean observing system,” Proceedings of Oceans 2001. Honolulu, HI.

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