

# **New England Shelfbreak Front “Primer” Experiment Analysis Results**

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## **LONG TERM GOALS**

Our goal is to understand propagation of low frequency sound (10-1000 Hz) from the continental slope to the continental shelf including the effects of ocean processes and bathymetric features that are associated with the shelf-break. This understanding is key to achieving accurate sonar prediction in a shelf-slope littoral environment.

## **SCIENTIFIC OBJECTIVES**

The acoustics objectives of the Shelfbreak PRIMER study, which took place in the shelf-slope transition region just south of New England, are: 1) to determine the effects of the daily, seasonal, mesoscale and finescale oceanic variability of the shelf-break region on the transmission of sound from the slope to the shelf, 2) to understand the detailed relation between the oceanography and the acoustics, particularly in terms of standard acoustics variables as propagation loss, coherence, etc., and 3) to create tomographic maps of the ocean thermal structure in the shelf-break region. Studies of the local bottom acoustic properties were also pursued in collaboration with U. Rhode Island personnel. We additionally pursued oceanographic studies as part of our PRIMER work, with emphasis this year on the nonlinear internal wave field, which is of great importance to acoustics.

## **APPROACH**

Our overall approach was to make detailed, simultaneous measurements of the physical oceanographic and acoustic fields during both summer and winter conditions. We then relate these measurements to each other and to various quantities of interest using both standard acoustics models and newly developed theory and algorithms.

## **WORK COMPLETED**

The field work component of the shelf-break front PRIMER experiment was completed in FY97. This work included two intensive three-week experiments, one in July 1996 (summer) and one in February 1997 (winter). Each of the two experiments successfully employed a suite of observational techniques including an acoustic tomography array consisting of multiple transceivers/sources and two vertical hydrophone arrays (VLA's) straddling the shelfbreak front, several high-resolution, three-dimensional surveys of the frontal region with a SeaSoar, a shelf-to-slope hydrographic section, and moored arrays

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of ADCP", current meters, and thermistors. The resultant data were of high quality, and our FY98 efforts consisted entirely of the reduction and analysis of this vast data set.

During FY97 and FY98, we reduced both our summer and winter acoustic and oceanographic data to usable form. The winter oceanographic data reduction is described in the WHOI Technical Report "Preliminary acoustic and oceanographic observations from the winter PRIMER experiment" by A. Newhall et al. [1]. The summer data analysis, focusing on the acoustic paths leading to the northeast VLA receiver, is described in detail in the MIT/WHOI Ph.D. thesis "Analysis of acoustic propagation in the region of the New England continental shelfbreak" by B. Sperry [2]. (The data for the acoustic path to the northwest VLA are being worked on by NPS, in a previously agreed upon division of labor.) A propagation loss analysis of the summer, winter and spring (a purely SeaSoar cruise) data has been documented in a manuscript "Spatial and temporal variations in acoustic propagation characteristics at the New England shelfbreak front" by A. Newhall et al, which is being submitted to IEEE JOE. The analysis of the acoustic pulse distortion incurred by summer oceanographic conditions is documented in a manuscript "Small and large scale propagation effects near a shelfbreak front" by B. Sperry et al., which also is being submitted to IEEE JOE. In FY98, we participated in work on inverting acoustic shot signals for bottom geoacoustic properties, which is documented in the JASA article "Tomographic mapping of sediments in shallow water" by G. Potty et al [3] (JASA, in press). Additionally, we pursued some oceanographic issues of great interest to coastal acoustics. In particular, we examined the non-linear internal wave field on the continental shelf, using the copious thermistor string, ADCP and SeaSoar data collected. This work is documented in "Observations of nonlinear internal waves on the New England continental shelf during summer shelfbreak PRIMER" by Colosi et al. [4]. Finally, we have interacted, via the PRIMER grant, with another very similar coastal shelfbreak study off the Korean coast. This work is documented in "Effects of the Korean littoral environment on low-frequency acoustic propagation " by P. Abbott et al, which is being submitted to IEEE JOE for publication.

## RESULTS

Having had the data in hand for over two years now, we have been able to make progress on a number of topics, as we shall now describe. In the thesis work by Sperry, three major topics were treated: 1) the details of acoustic pulse propagation across the slope and shelf, 2) the array coherence degradation expected due to slope and shelf oceanography, and 3) inversion of acoustic data for coastal oceanographic properties. Regarding pulse propagation effects, the relative importance of the bottom, mesoscale oceanography (fronts, eddies) and internal waves were studied. It was found that, due to the warm "foot of the front" thermal layer, the bottom was effectively shielded and thus sound propagated upslope with a minimum of bottom interaction effects. The shelf-break front and non-linear internal waves both provided strong mode coupling, which drastically affected acoustic pulse shapes and amplitudes. Using a new variant of the coherence called the "modal phase structure function," the effects of the ocean mesoscale structure on horizontal array spatial coherence have been studied. It was found that a coherence length of 30 lambda is predicted for low frequencies in shallow water, in good agreement with the experimental results obtained by W. Carey. This work is currently being extended to fully coupled calculations, the standard pp\* coherence measure, and to include the effects of internal waves and buried river channels. Turning to the inversion of the acoustic data for oceanographic properties, we have examined inverting mode one leading edge arrival data for both the M2 internal tide and mesoscale oceanography thermal content. These inversions were modestly successful, but unless one can devise a method for inverting the fully coupled modal arrival structure, not just the mode one leading edge data, it appears that shallow water tomography in highly energetic coastal

regions may not be so useful. (A fully coupled mode approach is being pursued by C.Chiu of the Naval Postgraduate School.)

Based on the SeaSoar data from spring, summer, and winter, coupled with the bottom property determination by Potty et al., we have been able to model mesoscale oceanography effects on acoustic propagation loss over a seasonal cycle at the shelf-break PRIMER site. Interesting effects include the previously mentioned shielding by “foot of the front,” the seemingly porous ducting of sound by ocean finestructure in the front, and the sudden creation of a near surface acoustic duct by the wind driven advection of very cold, fresh water seaward across the front. Concerning the Korean study, we have shown that careful placement of sources and receivers, even in a complex coastal oceanographic environment, can result in greatly improved performance of Naval systems.

The oceanographic study of the internal wave field showed very clearly both the structure and variability of the non-linear internal wave field. These are important to know, since these non-linear internal waves have a strong effect on acoustics, producing large fluctuations.

## **IMPACT/APPLICATIONS**

The data sets collected in PRIMER are presently the most complete ones available for showing the detailed effects of coastal oceanography on acoustic propagation, and thus on Navy acoustics-based systems. We have already learned many lessons from these data. Representative examples are the extension of the foot of the front (in some regions), the time and length scales for coastal oceanography (which are of direct use in array processing/coherence studies) and the ubiquity and importance of non-linear internal waves. We have also recommended, based on the data we have seen, that coastal physical oceanography models (which can be used as input to acoustics models) try to incorporate the statistics of many coastal oceanographic processes rather than realizations, as these statistics are both more useful acoustically and more realistic to try to measure.

## **TRANSITIONS**

We feel that the work we have done here has important implications for the modeling of coastal oceanography and acoustics, as well as for the sampling of potential battlespace environments, *a priori* and in real time. Optimization of these efforts needs to be based on previous, realistic high resolution looks at representative coastal environments, and the shelfbreak PRIMER experiment gave us one such look.

## **RELATED PROJECTS**

Two closely related projects to PRIMER are the SWARM and STRATAFORM projects in which this P.I. has participated. The SWARM project focused on the non-linear internal wave field, which was also important in PRIMER. The STRATAFORM project concentrated on coastal stratigraphy issues, with a large component being in the Mid-Atlantic Bight. We are using remnant riverbed data from STRATAFORM in the coherence theory formalism that we have developed under PRIMER's auspices.

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