Shelfbreak PRIMER Data Analysis: Acoustic Propagation And Ocean Tomography

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LONG-TERM GOAL

My long-term research goals are:

1. The characterization of meso to internal-wave-scale oceanographic processes that influence broadband sound transmissions in a coastal environment. Central to the characterization are the formulation of accurate forward relations and the quantification of the sensitivities and variability of the various observable acoustic quantities to environmental differences and changes.
2. The development and improvement of high-resolution tomographic inverse techniques for measuring the dynamics and kinematics of meso and finer-scale sound speed structure and ocean currents in coastal regions.

OBJECTIVES

The field work of the Shelfbreak PRIMER field study was successfully completed in FY97. The data analysis phase of the experiment has begun in earnest. In close coordination and collaboration with the other Shelfbreak PRIMER investigators, my objectives are to address the following acoustic and oceanographic issues through follow-on data analysis and modeling:
1. To determine the effects of seasonal and mesoscale variability of the shelf-break frontal thermal structure on the transmission of sound from the fixed sources on the slope to the vertical line hydrophone arrays (VLAs) on the shelf.
2. To relate the temporal and spatial variability of the acoustic propagation with the ocean variability in the frontal zone.
3. To obtain 2D and 3D tomographic maps of the frontal region for use in the physical oceanographic description.
4. To test plausible hypotheses of shelfbreak frontal dynamics by combining acoustic tomography, SeaSoar, thermistor-string, ADCP and current-meter data in dynamically-constrained data inversions.

APPROACH

The experimental approach involves detailed and simultaneous measurements of physical oceanographic and acoustic properties during the contrasting summer and winter seasons. These measurements are being related to physical and acoustical modeling studies

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In the acoustic propagation analysis, my focus is on the transmissions of the pulse signals from the moored sources to the NW VLA (i.e., one of the two VLAs on the shelf), whereas Lynch at WHOI is focusing on the transmissions to the NE VLA. My analysis entails coupled-mode and ray acoustic propagation modeling using the high-resolution hydrographic measurements. The modeling results are compared to the omni-directional and ray and modal beamformed data for the quantification of the temporal and spatial fluctuations in the intrinsic acoustic variables such as magnitudes, phases, arrival times, mode patterns and ray geometries, and how these acoustic fluctuations are related to the shelf- slope ocean processes.

In the inverse tomographic analysis, my approach is to use hybrid ray-mode methods, incorporating mode coupling physics and complex raypaths, to map the structure of the shelfbreak front and the associated frontal variability at a fast sampling rate. In addition to the purely acoustic approach, inverse analysis that combines different types of data and constrained by plausible frontal dynamics will be applied. Because the nature of the tomographic data is quite different (integral as oppose to point), combining the complementary tomographic data with SeaSoar, thermistor-string, ADCP and current-meter data in dynamically-constrained, joint inversions can provide for a powerful means of testing different theories and hypotheses.

WORK COMPLETED

Work completed by the Naval Postgraduate School in FY98 includes:

1. Matched filtered all the summer and winter NW VLA data to produce time-series of omni-directional pulse arrival structure at two transmission frequency bands, centered at 224 Hz and 400 Hz, respectively.

2. Modal beamformed the summer NW VLA omni arrival structure to obtain time-series of the arrivals of individual modes using a high-resolution technique that is constrained by propagation physics (Chiu et al., 1997).

3. Modeled the summer omni and modal arrival structure using the coupled-mode method of Chiu et al. (1996) for six different days (from Yearday 207 to Yearday 212). The modeling results were compared to the observations to check for consistency and to quantify the dominant time scales and sizes of the magnitude and travel-time variations caused by the oceanic frontal processes.

4. Modeled the temporal coherence of the sound field and compared the modeling results to the ping- to-ping coherence observed by the NW VLA.

5. Derived hourly cross-front tomographic maps and compared the daily averages to the SeaSoar hydrographic measurements.

RESULTS

Two of my significant results are discussed here. A computer simulation experiment was performed to study the temporal coherence, particularly the ping-to-ping decorrelation time of the 224 Hz and 400 Hz transmissions from the slope to the NW VLA on the shelf. This was a realistic simulation including the effects of the frontal structure at the shelfbreak and a moving internal solitary wavepacket on the shelf. Pulse transmissions at every 5 s over a period of half an hour were calculated. Figure 1 summaries the results of the simulation analysis for the 400-Hz signal. It shows that the surface-interacting modes (Modes 8 and higher) have rather short and (almost) time-invariant coherence times due to the internal solitary wavepacket. On the contrary, the intermediate modes (Modes 4 to 7) that turn inside the internal-wave zone (i.e., the internal-wave energy-containing region) tend to have much longer but highly non-stationary decorrelation times. The lowest three modes that turn below the internal-wave zone almost never decorrelate. An implication is that the shelfbreak front plays an important role in determining the temporal coherence of an omni-directional receiver on the shelf. This coherence depends strongly on how the shelfbreak front distributes/couples the modal energy before the energy enters the shelf.

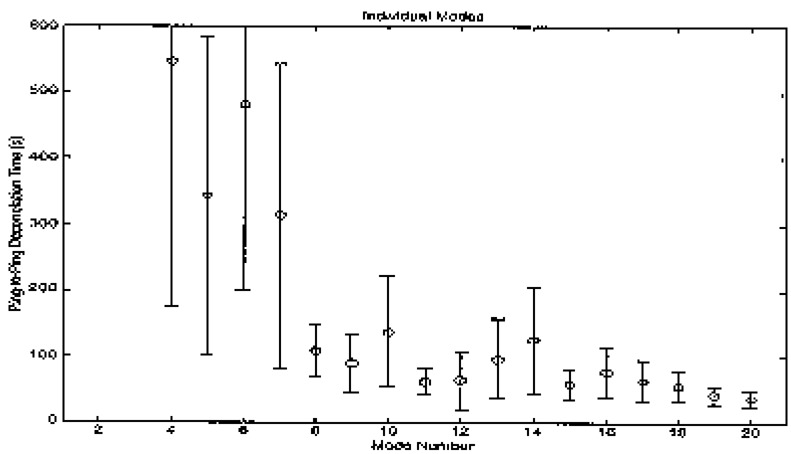

Fig. 1. Mean and standard deviation of modeled ping-to-ping decorrelation time of individual modes at 400-Hz.

Based on the lower bound of the estimated decorrelation times, arrivals were coherently averaged to optimally improve SNR and hence the precision of the travel-time measurements. Based on the resolved travel times of the individual modes at the 224-Hz and 400-Hz bands, preliminary hourly tomographic maps were obtained using an inverse method that assumes mild additional mode coupling in a strongly mode-coupled background field (Chiu et al., 1994). The daily averaged tomographic estimates are displayed in Figure 2. These daily tomographic maps compare extremely well with the daily maps obtained by the SeaSoar.

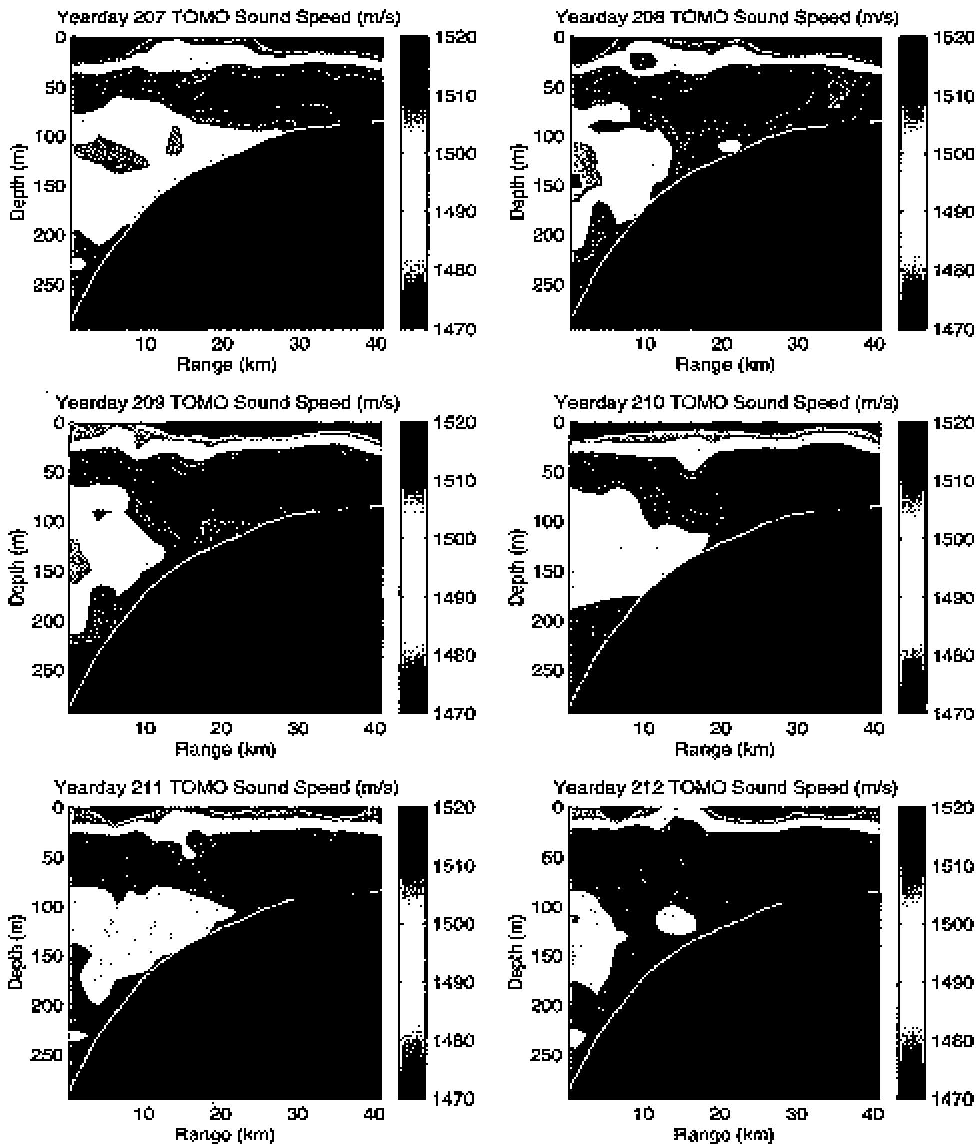

Fig. 2. Daily tomographic maps of sound speed along the western transmission path. Consistent with the SeaSoar measurements, the tomographic maps show the cold shelf water was extending seaward,and the extension was temporarily reversed by an intrusion of warm Gulf Stream water on Yeardays 210and 211.

IMPACT/APPLICATIONS

The oceanographic data gathered in this field study should be valuable in helping to create a general environmental model of shelfbreak regions suitable for assessing present and designing future Navy systems, acoustic as well as non-acoustic. In conjunction with the oceanographic data, the acoustic data will allow for an in-depth understanding of the coherence of the sound field in a shelf-slope environment, as well as for validating whether tomography is a useful tool for coastal monitoring.

TRANSITIONS

This program is combined with 6.2 efforts in ocean data assimilation/nowcasting and acoustic prediction in a ``vertically integrated" fashion, so that the transition to higher levels and systems should be facilitated.

RELATED PROJECTS

This project strongly compliments a number of other current projects including the two other PRIMER experiments (Haro Strait and the CMO high frequency) and the SWARM experiment, which study different aspects of the coastal ocean variability and the relations to coastal acoustic fluctuations.

REFERENCES

Chiu, C.-S., J.H. Miller, and J.F. Lynch, "Inverse Techniques for Coastal Acoustic Tomography," in Environmental Acoustics (D. Lee and M. Schultz editors), World Scientific, 917-931, 1994.

Chiu, C.-S., J.H. Miller and J.F. Lynch, ``Forward coupled-mode propagation modeling for coastal acoustic tomography," J. Acoust. Soc. Am., 99(2), 793-802, 1996.

Chiu, C.-S., C.W. Miller and J.F. Lynch, ``Optimal modal beamforming of bandpass signals using an undersized, sparse vertical hydrophone array: theory and a shallow-water experimentation," IEEE J. Oceanic Engineering, 22(3), 522-533, 1997.

PUBLICATION

Miller, C. W., "Estimating the Acoustic Modal Arrivals using Signals Transmitted from Two Sound Sources to a Vertical Line Hydrophone Array in the 1996 Shelfbreak PRIMER Experiment," Naval Postgraduate School M.S. thesis, June 1998.