Shelfbreak Acoustics: The ASIAEX Volume Interaction Experiment

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Grant Number: N00014-98-1-0413

http://www.oal.whoi.edu/AO/topics/Primer/Primer.html
http://www.oal.whoi.edu/ASIAEX/ASIAEX.html

LONG TERM GOALS

The long term goal of our work in the ASIAEX program is to understand the nature of low frequency (1-600 Hz) acoustic propagation and scattering in shallow water when strong oceanic variability in the form of fronts, eddies, boundary layers, and internal waves is present. We are also greatly interested in the effects of geological variability, which is as important to acoustics as ocean variability in shallow water regions.

OBJECTIVES

In the ASIAEX South China Sea experiment, there were a large number of specific acoustics objectives that were pursued. Over the last year, we have specifically focused on the issues of: 1) horizontal array coherence in shallow water, 2) the travel time and intensity fluctuations of the acoustic field in the 50-600 Hz band, 3) the ambient noise field in the 50-1400 Hz band, and 4) obtaining a good geoacoustic model of the seabed. These efforts both reinforced and extended the goals of the two predecessor experiments to ASIAEX, the 1995 SWARM internal wave experiment and the 1996-97 PRIMER shelfbreak front experiment. We also are pursuing studies of the physical oceanography and geology of the South China Sea (SCS) volume experiment region, in an interdisciplinary approach together with other ASIAEX investigators.

APPROACH

Similar to the SWARM and PRIMER experiments, the ASIAEX SCS effort combined high-resolution physical oceanographic and geologic measurements with precise measurements of the acoustic field (see Figure 1.) Acoustically, the heart of our experiment was a combined vertical/horizontal aperture array, which listened to both moored and towed sources with frequencies from 50 Hz to 600 Hz, as well as a “source of opportunity” with low frequency (1-250 Hz) spectral content. The moored sources enabled us to examine acoustic propagation time series both for a cross slope and an along slope geometry. The towed sources allowed us to study propagation loss versus range, and thus extract bottom information as well as sound scattering details. The “source of opportunity” was local dynamite fishing, which allowed us to probe deeper into the bottom than we could have with the towed and moored sources. The receiver array was also able to support ambient noise studies in the 50-1400 Hz band. The oceanographic support for the acoustics was quite extensive, consisting of twenty-nine separate oceanographic moorings, a Sea Soar hydrography survey, a high frequency acoustic backscatter survey, satellite imagery (SAR and AVHRR), and numerous CTD casts. The geological support was also good, consisting of two high-resolution chirp sonar surveys along the stationary propagation paths, as well as the propagation loss tows.

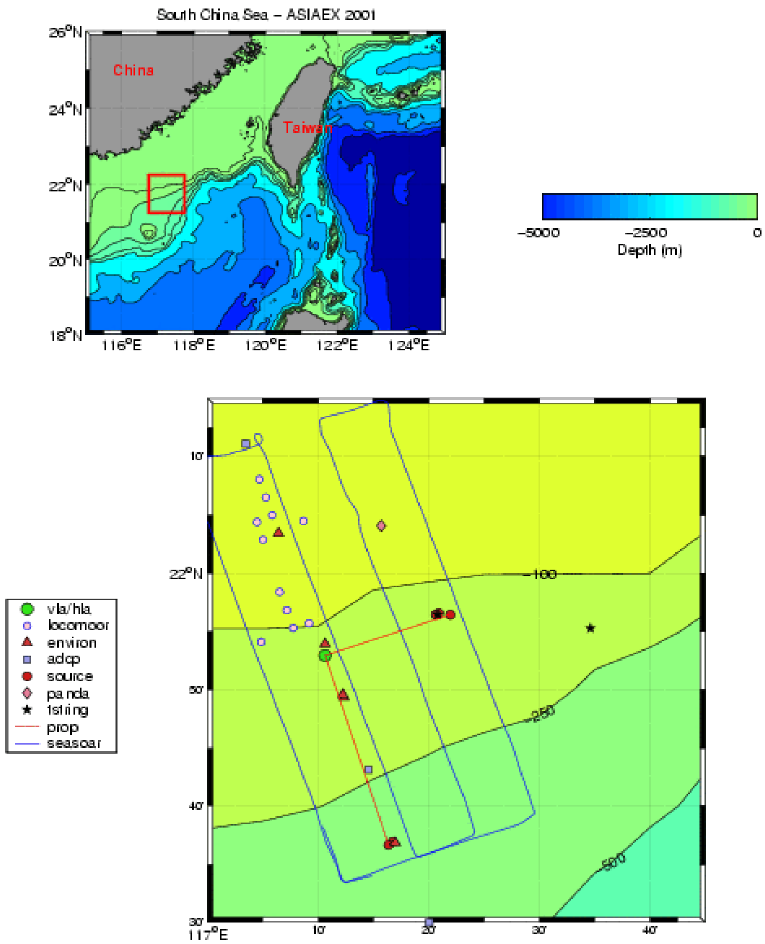

Figure 1. Upper panel shows geographical location of ASIAEX SCS volume interaction experiment. Lower panel shows locations of moorings, as well as fixed acoustic paths and Sea Soar tracks.

(The further chirp sonar and core survey by L. Bartek, in spring, 1993, augments this. We will soon be looking at that new data.) Our experiment extended temporally over a three-week period, so that we were able to examine the effects of a full spring-neap tidal cycle on the acoustics transmissions.

WORK COMPLETED

Our main accomplishment this year was the successful pursuit of the ASIAEX data analysis efforts, concentrating on (as mentioned above) horizontal array coherence, travel time and amplitude fluctuations, bottom property inversions and the ambient noise field. This work was performed in close collaboration with other ASIAEX PI's, specifically: M. Orr and his group from the Naval Research Laboratory (horizontal array coherence, bottom inversions), Lixin Wu of the National Laboratory of Acoustics in Beijing and T. Duda of WHOI (amplitude and travel time fluctuations), R.C. Wei of the National Sun Yat Sen University in Kaohsiung (ambient noise), and Y.T. Lin of National Taiwan University (bottom inversions). Each of these studies has progressed well, and we have submitted journal papers on each topic for the upcoming IEEE Journal of Oceanic Engineering special issue devoted to the Asian Marginal Seas. We have also hosted a Guest Student at WHOI this past year (Mr. Ying-Tsong Lin of National Taiwan University), and he should successfully defend a Ph.D. thesis in January based on the bottom inversion research he did at WHOI.

We also worked on a number of other shallow water acoustics topics this past year, in addition to ASIAEX. These were: 1) ducting of acoustic energy between internal waves in shallow water (three papers in advanced preparation with M. Badiey, W. Siegmann, B. Katsnelson and other investigators), 2) "whispering gallery" trapping of acoustic energy by internal waves and the shelfbreak front (with A. Pierce), 3) array coherence studies (one paper in advanced preparation with W. Carey and others), 4) attachment of a low frequency towed array to the small REMUS AUV (with Boston U. Guest Student J. Holmes), 5) correlation of signal and noise characteristics in shallow water in the PRIMER experiment (with P. Abbot), 6) studies of propagation characteristics in the PRIMER area, both in summer and winter (five papers submitted or in advanced preparation with NRL Stennis personnel, B. Sperry, C. Chiu, and others), and 7) oceanographic studies in the SWARM and PRIMER regions (with G. Gawarkiewicz, K. Sabinin, and others).

RESULTS

We are at an advanced stage in all the analyses, which means that we now have finished work on some topics, but still have a number of other topics left to address. As we have a large number of papers submitted and published on various topics this year, we will just concentrate on one of those topics by way of example. Specifically, I would address the bottom inversion work done by Lin et al (see #14 in our publications list) as a representative study. In the ASIAEX bottom inverse study, we used a broadband "source of opportunity" (a dynamite fishing blast) shown in Figure 2 to provide low frequency energy with which we could invert for the bottom soundspeed profile to a greater depth than we could with just the sources available in the formal experiment. In the course of this work, we developed new linear perturbative inverse methods which work using the Airy phase and mode cutoff frequencies as data, as well as a new method that works for range dependent environments. The bottom models that we created augment the results obtained by Turgut, and are shown in Figure 3. We plan to further extend this work in the coming year by examining what the effects of internal waves are on bottom inverses in a shallow water environment.

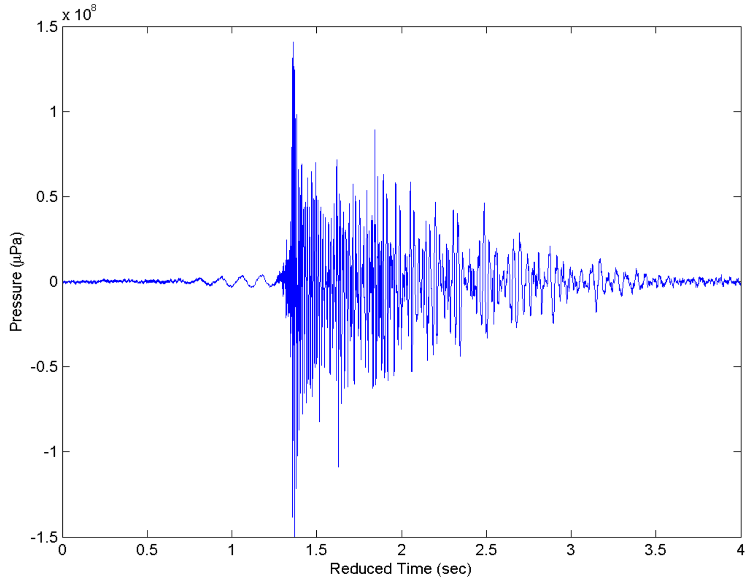

Figure 2. Explosive "source of opportunity" signal registered at the HLA/VLA receiver on May 16, 2001. The ground wave (quasi-sinusoidal leading arrival), water wave (large amplitude middle arrivals), and Airy phase (nearly pure tone latest arrival) components are well defined for this pulse.

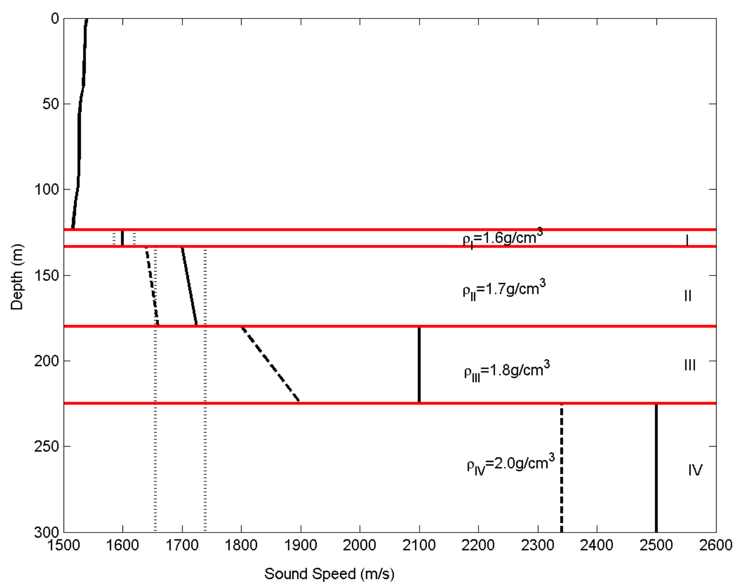

Figure 3. Multi-layered bottom models generated for the ASIAEX SCS receiver position from our "source of opportunity" data. The seabed starts at 124 m. The solid lines are from the range-dependent inverse and the dashed lines represent the range-independent approximation. The lighter grey lines are the upper and lower bounds of A. Turgut's bottom model.

IMPACT/APPLICATIONS

Probably the greatest impact that the ASIAEX volume interaction experiment will have is in seeing just how well we can predict the acoustic field and its variability/fluctuation level for a case where we can check the answers against ground truth. Additionally, our data has provided important quantities such as horizontal and temporal coherence scales, bottom properties and other characteristics of acoustic propagation for the ASIAEX region. Finally, the oceanographic data taken will be of great use in calibrating Navy models, such as MODAS.

TRANSITIONS

One eventual transition of our data will be to ONR's Uncertainty DRI program, where the interest is in "the error bars" in ocean acoustic field and system performance prediction. Also, our ASIAEX data provide a unique database in a region where there are relatively few high-quality data.

RELATED PROJECTS

The SWARM acoustics/internal wave study and the PRIMER acoustics/shelfbreak front study were direct predecessors of ASIAEX, and examined some of the same scientific issues, only with fewer measurement resources. The Uncertainty DRI is also a closely related project to ASIAEX, and it will use some of the data towards its project objectives.

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