ASIAEX Reverberation Studies

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LONG-TERM GOALS

This research is intended to establish an understanding of the scattering mechanisms operating in low frequency reverberation in shallow water typical of continental shelf regions. The intent is to distinguish among the effects of different scattering components, such as sediment interface and layering roughness, fluctuations in sediment properties, and discrete scattering components, and to quantify their relative contributions. This research is being performed with David Knobles (ARL:UT) and Eugene Dorfman (BBN, Cambridge) with these efforts together forming an integrated research activity.

OBJECTIVES

Using a normal mode propagation model and a physics-based bottom scattering coefficient [1 and cited references] in a two stage simulated annealing optimization [2], the specific objectives of the work will be to invert low frequency reverberation and transmission data obtained during the summer 2001 ASIAEX in the East China Sea to recover the bottom scattering strengths associated with volume, surface and sediment layering. The ultimate intent of this research is to infer mechanisms of low frequency bottom scattering in shallow water.

APPROACH

Experimentally, the determination of bottom scattering strength in shallow water is complicated by the multipaths associated with the proximate boundaries: scattering strengths must be extracted from reverberation measurements, which necessitates some integration over the incident and scattering angles involved. As a consequence, comparisons of scattering strength models and measurements must account for experimental constraints and limitations that intrinsically convolve propagation to and from the scattering site with the scattering kernel. The motivation for turning to a high-resolution global inversion method, such as simulated annealing, is that it can be used to efficiently search the large parameter space physically describing transmission to the bottom scatterers and the scattering process to obtain optimal parameter values to extract scattering strength.

Detailed modeling of propagation for the shallow water channels with sand-silt bottoms has indicated that beyond about 5-10 km ranges, propagating energy is confined to bottom grazing angles less than the critical angle. In consequence, beyond the indicated ranges, acoustic bottom penetration is limited to the evanescent field extending about one wavelength into the bottom. Thus, the proposed mechanism for bottom scattering in these environments is scattering of the evanescent field into the

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14. ABSTRACT
This research is intended to establish an understanding of the scattering mechanisms operating in low frequency reverberation in shallow water typical of continental shelf regions. The intent is to distinguish among the effects of different scattering components, such as sediment interface and layering roughness, fluctuations in sediment properties, and discrete scattering components, and to quantify their relative contributions. This research is being performed with David Knobles (ARL:UT) and Eugene Dorfman (BBN, Cambridge) with these efforts together forming an integrated research activity.

15. SUBJECT TERMS

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water by roughness at the sediment-water interface and by volume scatterers just below the interface. Volume scatter candidates include fluctuations in sediment density or compressional wave speed and discrete inhomogeneities within the sediment such as shells or rock fragments. In addition, scattering from roughness at near-surficial sediment layer boundaries, observed in some areas such as the New Jersey Shelf, should be included as a candidate component. The theory describing the sediment fluctuation contributors has been developed in the Born approximation [1]. Extension of the theory to include layering roughness and discrete scattering components is also required and will be used to define the parameters needed to obtain a complete determination of bottom scattering strength.

The activities being performed under this research effort have included: (1) preparations for ASIAEX data collection and coordination with seagoing participants in the tests; (2) preparation of initial models for use in the data inversion process and testing by simulations; (3) performance of two stage data inversion (forward propagation and scattering) on ASIAEX data; (4) refinement of physical models of scattering process based on inversions; (5) performance of refined inversions employing improved physical models to identify and quantify scattering mechanisms. Within the overall effort, Peter Cable and Rob Gibson (BBN, Arlington) are lead for development of the scattering model and comparison with other East China Sea bottom scattering measurements. David Knobles and Tom Yudichak (ARL:UT) are lead for determination of transmission characteristics and extraction of bottom geoacoustics from the ASIAEX data; and Eugene Dorfman (BBN, Cambridge) is lead for extraction of bottom scattering strength and its frequency and grazing angle dependence from the ASIAEX reverberation data.

WORK COMPLETED

During FY02 initial plans were formulated at the Maui ASIAEX International Symposium in early November ’01 for obtaining and using reverberation data obtained during the ASIAEX East China Sea experiment by Institute of Ocean Acoustics (Chinese Academy of Sciences) investigators under the leadership of Profs. Jixun Zhou and Renhe Zhang. A memorandum of understanding for sharing and use of the reverberation data was subsequently finalized at the Seattle ASIAEX East China Sea Post-Experiment Meeting in late January ’02 and the reverberation data were distributed to Knobles, Dorfman and Cable in mid April ’02. A vigorous and interactive collaboration with areas of responsibility as described above has been in place since then, working with the IAO reverberation data and with ASIAEX ECS transmission data obtained by Jim Miller, Gopu Potty (URI) and Peter Dahl (APL/UW), as well as with other East China Sea data sources. Initial forward transmission results and preliminary bottom scattering strengths as a function of frequency and scattering angle have been determined.

Along the modeling aspects of the work, a formulation of scattering from the bottom that includes scattering from layering roughness as well as from volume inhomogeneities for water-sediment incident grazing angles below critical has been formulated.

Also, in March 02, Peter Cable and Jim Miller visited Lou Bartek (UNC) to discuss and review potential ASIAEX geological characterization products, to define a set of products most needed by the ASIAEX acoustic investigators, and to facilitate the distribution of those products. A report on the results of the trip to UNC was distributed to ASIAEX PIs on 29 March 2002.

RESULTS

Analysis of the ASIAEX East China Sea data has progressed to the stage where three papers will be presented at the First Pan-American/Iberian Meeting on Acoustics in Cancun, Mexico, 2-6 December 2002. These papers are: "Analysis of time series data in the East China Sea generated from explosive sources" (Knobles et al), which, by inversion determines bottom geoacoustics and forward propagation; "Mechanisms for the Asian Sea International Acoustics Experiment East China Sea reverberation measurements" (Dorfman et al), which determines the AIAEX ECS bottom scattering strength values and their frequency and grazing angle dependence; and "Comparison of East China Sea low frequency bottom scattering strength determinations" (Cable et al), which compares scattering strength determinations obtained in ASIAEX ECS with those obtained by the HEP and MAASW(DT) program data and indicates theoretical implications of results.

In modeling, during FY02, a Greens function representation of the scattering problem that unifies the specification of scattering from sediment inhomogeneities and layering roughness has been formulated (Cable, in preparation). The formulation parallels the developments of Ivakin [4] and Tang [5] and also explicitly includes the presence of the water sediment interface with incidence grazing angles below or near the critical angle.

IMPACT/APPLICATIONS

Current low frequency shallow water reverberation models for sonar performance prediction use phenomenological bottom scattering strengths arbitrarily extrapolated from high frequency experience. There currently does not exist a model of shallow water reverberation that comprehends the reverberation results obtained in the DARPA Adverse Environments Program and in HEP littoral area surveys or that explains system performance achieved by Distant Thunder (DT) and EER in shallow water operations. Reverberation is the dominant factor in the operation of active sonars in shallow water, and to support mission planning and operational performance prediction for systems such as DT, LFA and EER, especially when HEP-type survey data are unavailable, there is a need for a bottom reverberation predictive capability requiring geoacoustic inputs such as those needed for propagation predictions.

TRANSITIONS

The data and bottom reverberation models, which will be the products of this work, could transition, respectively, to standard Navy acoustic databases and to tactical decision aids (TDA) for low frequency shallow water active systems such as IEER and Distant Thunder (DT). The transition path for these products must be defined as the work progresses.

RELATED PROJECTS

This research is being conducted jointly with David Knobles, ARL:UT and with Eugene Dorfman (BBN, Cambridge). In addition the long range reverberation ASIAEX studies of Renhe Zhang and Jixun Zhou have responsibility for the data that will be used in the present research.

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