# Shallow Water Mid-Frequency Research and FY06 Experiment

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## LONG-TERM GOALS

To Understand mid-frequency (1-10 kHz) acoustics in shallow waters through measurements and modeling, including propagation, reflection, and forward- and backscatter as well as reverberation. The top-level goals of this effort are to understand what are the important environmental processes, which impact mid-frequency sonar performances in shallow water environments; and to develop means to efficiently collect those environmental data.

## OBJECTIVES

Participate in the LEAR acoustics field experiment in 2006 to investigate mid-frequency (1-10 kHz) acoustics interacting with environments.
Acoustics objectives and tasks:

1. Direct-path bottom backscatter – what are the most important physical mechanisms? Equipment: APL 32 element vertical line array.
2. Single interface forward scatter – what are the most important physical mechanisms (with by Peter Dahl). Equipment: APL's MORAY/BASS.
3. Multiple boundary interactions (with by Peter Dahl) – Can we successfully combine our knowledge of single interactions to predict the results of a small number of surface and bottom interactions? Equipment: combination of equipments from 1 and 2.
4. Long-range (10–20 km) propagation – can multiple interactions with rough boundaries actually simplify the field present at long ranges?

Environmental measurements:
Environmental measurements include in situ and remote sensing components. It is important to cover all relevant environments with adequate sampling. The environments are the sea surface (Buoys, Graber and Dahl), the water column (Internal waves by Henyey and Moum), and the sea bottom (APL IMP2 and SAMS and NRL Turgut 's Chirp sonar and Geo-probes).

# Report Documentation Page

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## APPROACH

We successfully completed the comprehensive LEAR (Littoral Environmental Acoustics Research) field measurement off the New Jersey coast in the summer of 2006. Starting with assumptions and hypotheses based on current knowledge of the field, we combined acoustics measurements with modeling efforts using the measured environmental parameters to achieve quantitative model/data comparisons of sound fields interacting with bottom, surface and the water column. We started from a local area on the order of 100 m by 100 m, and studied single interactions of sound with the bottom and the surface over space and time. In each case, we will make detailed model/data comparisons in later analysis. We investigated multiple (2 – 3 bounces) interactions of sound field with the bottom and surface. The point here is to combine the modeling results dealing with individual interaction into an integrated model. Finally, we mede measurements of long- range propagation, multiple forward scattering, and reverberation over a range of 10–20 km. By necessity, the experiment consisted of an acoustics part and an environmental measurement part. We emphasized carrying out environmental measurements at sufficient resolution to properly answer the acoustic questions to be addressed. The acoustics topics included:

1. Single boundary interaction backscattering – what are the most important physical mechanisms?
2. Single boundary interaction forward reflection and forward scattering – what are the most important physical mechanisms?
3. Multiple boundary interactions – Can we successfully combine our knowledge of single interactions to predict the results of a small number of surface and bottom interactions?
4. Long-range (10–20 km) propagation and reverberation – can multiple interactions with rough boundaries actually simplify the field present at long ranges?

Environmental measurement topics included in situ and remote sensing components. They are:

1. In-sediment measurements of sound speed in the bottom over a depth of 1.7 m with spatial resolution of 5-10 cm in depth (Equipment: APL "SAMS").
2. In situ measurements of bottom roughness and volume heterogeneity over several meters with horizontal spatial resolution of 1 cm and vertical resolution of 1 mm (IMP2 from APL).
3. In situ measurements of sea surface roughness spectra and wind speed (Dahl).
4. Measurement of nonlinear littoral internal waves using a CTD chain vs. time and space (Henyey).
5. Analysis of cores to obtain sediment density, attenuation coefficient, and sound speed. (Chapman, Goff and Turgut).
6. Remote sensing using chirp sonar to estimate sediment geo-acoustic properties over large areas. (Turgut).
7. Remote sensing of geo-acoustic parameters using ambient noise (APL vertical array).

In addition, we investigated how to estimate key environmental parameters using only acoustic fields from reflection and backscatter. This will be accomplished by optimizing forward model parameters with acoustic data. For this to be successful, ground truth data (SAMS) in at least one spot is critically necessary.

## WORK COMPLETED

All instruments were successfully deployed and recovered during LEAR and all intended data sets were obtained. Highlights are: (1) the SAMS made its first deployments and collected in situ sediment sound speed data in three locations to as deep as 1.7 m. These data will be valuable to support acoustic modeling for various PI's. (2) Sound scattering from internal solitary waves successfully measured, in collaboration with Henyey, in a two-ship operation, one make acoustics propagation measurements over a range of 1000m, the other towed a CTD chain to make in situ measurements of internal waves. Overall, all intended goals for the LEAR experiment were met. In addition, we also made extensive measurements of ambient noise over a frequency range of 0.2 – 44 kHz.

## RESULTS

We just finished the fieldwork. Result on data analysis will come in the following years. Here some graphic results will be given to show the field efforts.

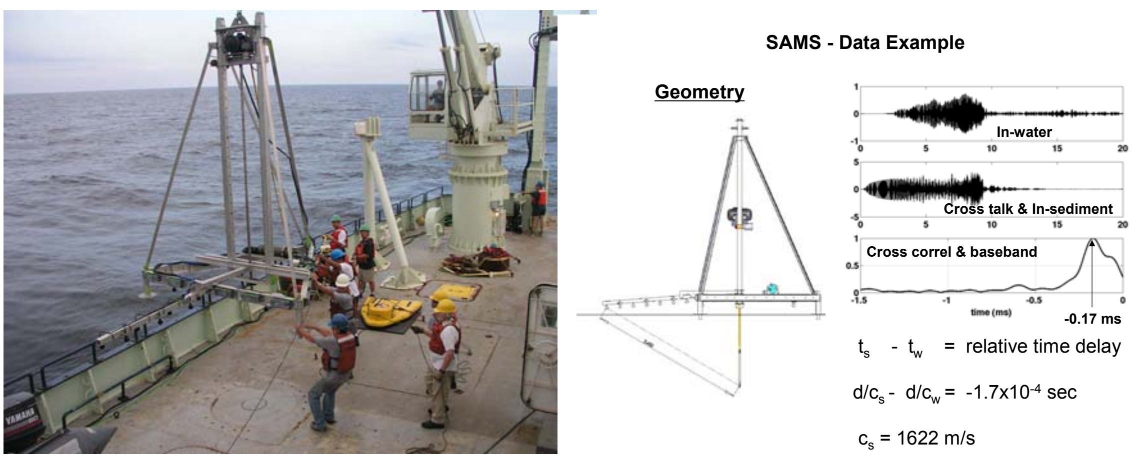


***Figure 1. Deployment of SAMS (Sediment Acoustics Measurement System) During LEAR (left) and initial analysis results (right).***

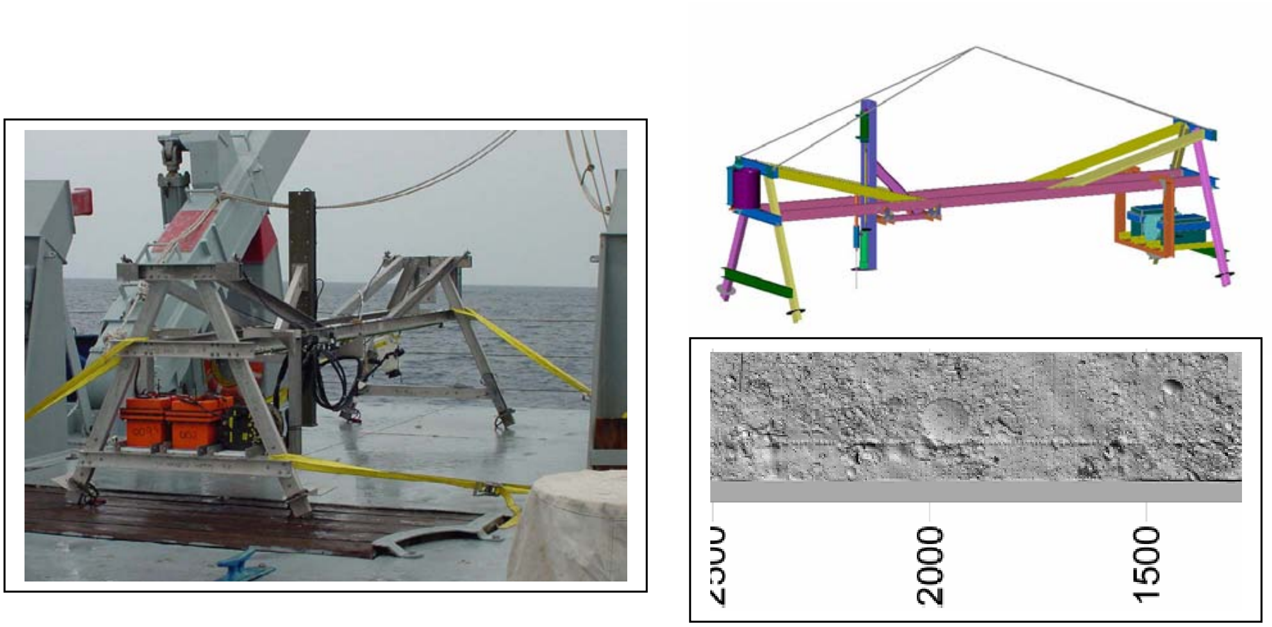


***Figure 2. IMP2 (In situ Measurement of Porosity) with laser scanner, measured bottom roughness (Left and top right). A laser was mounted on the IMP2 to obtain finer resolution. The laser effort is a collaboration with Wang of Taiwan. Laser results are at bottom right in units of mm.***

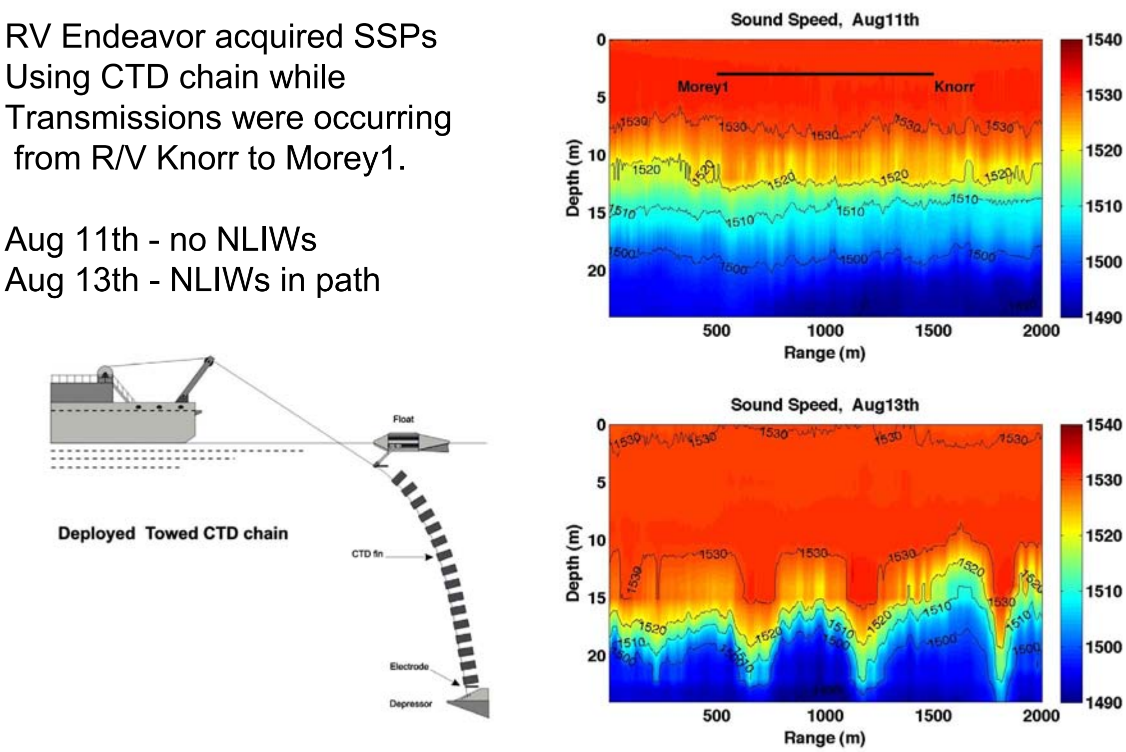


***Figure 3. Collaboration with Henyey on measurements of acoustic propagation through internal solitary waves. The figure shows the CTD chain concept drawing (left), measurements during a day with no internal waves (top right) and a day with internal solitary waves (bottom right).***

## IMPACT/APPLICATIONS

While the LEAR experiment addresses many basic science questions, our goal is to improve mid-frequency sonar performance in shallow waters environments. We anticipate impacts in two areas: First, because we measured all relevant environmental parameters influencing sound waves, we will be able to identify the important environmental process, hence providing the applied community what environmental process to focus on. Second, we can now explore methods such chirp sonar and ambient noise to quantitatively measure bottom parameters. Third, the study on sound interaction with internal waves could provide insight in reverberation clutter.

## RELATED PROJECTS

**NonLinear Internal Wave Initiative (NLIWI).** http://www.nliwi.org

## PUBLICATIONS


D. Rouseff and D. Tang, "Internal wave effect on the ambient noise notch in the East China Sea," J. Acoust. Soc. Am., 120 1284-1294 (2006).

I. leifer and D. Tang, "The acoustic signature of marine seep bubbles", Accepted by J. Acoust. Soc. Am.