

Validation of High-Resolution Inversion Techniques for Measuring Seabed Geoacoustic Properties during the ONR-SW06 Experiment

Altan Turgut

Naval Research Laboratory
Acoustics Division, Code 7120
Washington, DC 20375

phone: (202) 404-8620 fax: (202) 404-7813 email: altan.turgut@nrl.navy.mil

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LONG-TERM GOALS

The long term goals of this work are to develop high-resolution subbottom imaging and inversion techniques that can be complementary to low-frequency geoacoustic inversion methods.

OBJECTIVES

The objectives of this effort are to invert bottom geoacoustic properties along the ONR-SW06 acoustic propagation tracks by using chirp sonar data and to validate the inversion results by using wide-band acoustic probe measurements of sound-speed and attenuation.

APPROACH

Chirp Sonar (2-12 kHz) surveys are conducted at the New Jersey Shelf SW06 experimental site by using NRL Chirp Sonar system. Sound speed, density, and porosity profiles are inverted for the top 10-50 m of sediments by using a high-resolution inversion method that was previously developed at NRL. Four 0.6 m long, wide band (5-150 kHz) acoustic probes are inserted into the sediment at the pre-selected measurement sites and acoustic pulse dispersion and attenuation are measured. Acoustic probes provide accurate measurements of sediment sound-speed and attenuation in a “natural laboratory” setting that will help to determine “whether or not there is velocity dispersion and nonlinear frequency dependency of attenuation in sandy marine sediments” [1,2].

Altan Turgut and Jeff Schindall of Naval Research Laboratory participated two scientific cruises in the SW06 experiment. During the first cruise, in collaboration with John Goff of the University of Texas Institute for Geophysics, NRL collected chirp sonar data to estimate bottom sound speed and attenuation of the entire SW06 experimental site. The estimated bottom properties are expected to be used by other researchers as inputs to their propagation/scattering models and/or validate their acoustic inversion techniques. During the second cruise, NRL deployed the high-resolution chirp sonar for bottom measurement over a 1.5 km by 1 km area along with in-situ measurements of sound-speed and attenuation using wide-band acoustic probes (NRL-Geoprobe). At the same time, Dajun.Tang of the Applied Physical Laboratory of the University of Washington measured the bottom roughness and inhomogeneities at a selected spot in the area, and conducted acoustic scattering measurements from bottom roughness and sediment volume inhomogeneities. This joint effort provides a unique data set with concurrent environmental and acoustics measurements over the same location.

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WORK COMPLETED

High-quality data were collected along the pre-determined survey tracks (~800 mile long) during the wide-area chirp sonar survey. High-resolution (3-D) chirp sonar data were also collected within a ~1.5 km x 1.5 km area. John Goff has completed subbottom profiling analysis of the wide-area chirp sonar data including the corrections for the tow-fish position. Altan Turgut has completed the subbottom image analysis of the high-resolution (3-D) site. Layering information has been provided to the interested scientists (e.g., Peter Gerstoft of SIO and Ross Chapman of Univ. of Victoria) to complement their geoacoustic inversion analysis. Inversion analysis of sound-speed and attenuation along the main propagation tracks is planned to be completed by the end of 2007. Analysis of NRL-Geoprobe data has been completed and the results were presented at the ASA Honolulu meeting [3].

RESULTS

Subbottom imagery in the high-resolution survey area shows well defined “R” reflector at ~22 mbsf (meters below sea floor). Above the “R” reflector, highly heterogeneous sediments overlying a layered structure can be observed (see Fig. 1a).

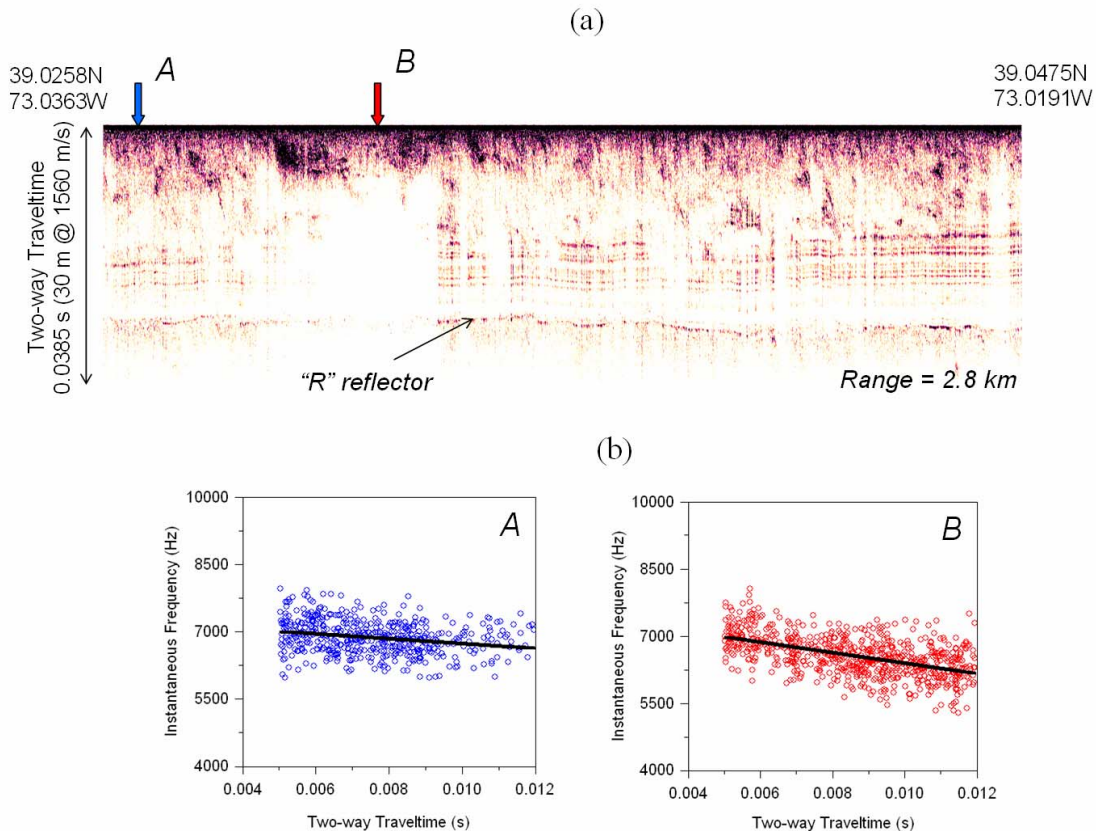


Figure 1. a) A sample chirp sonar subbottom image in the high-resolution survey area showing the “R” reflector at ~22 mbsf, a highly heterogeneous sediment layer near the seafloor, and a layered structure above the “R” reflector, b) attenuation estimation from the instantaneous frequency measurements of top 6 m of sediment showing a center-frequency shift of 34 Hz/m at site-A and 74 Hz/m at site-B separated by only 1 km.

Attenuation estimation from the instantaneous frequency measurements shows high attenuation regions that correlate with the less penetration areas in the subbottom images. In Fig. 1b, the center-frequency shift measured from instantaneous frequency curve is 34 Hz/m at a low attenuation region (site-A) and 74 Hz/m at a high attenuation region (site-B). The attenuation coefficient (dB/m/kHz) is being estimated from the center-frequency shift by using pulse reflection from a bottom with Biot geoacoustic model. Fig. 2 shows the measured sound-speed and attenuation by using NRL-geoprobe system at three sites (1a, 1b, and 1c) separated by 20 m. Measurements were performed at five frequency bands extending from 5 kHz to 150 kHz.

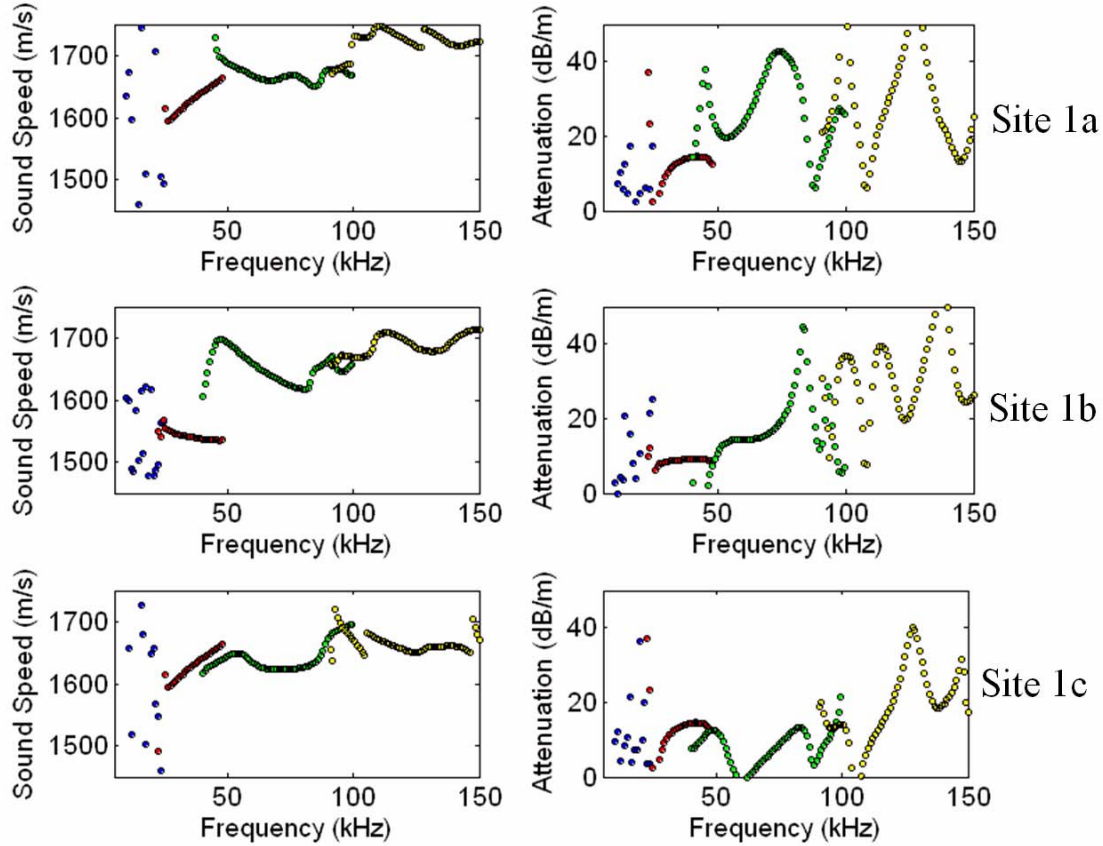


Figure 2. In-situ measurements of sediment sound-speed and attenuation at three sites separated by 20 m. Measurements were performed at five frequency bands extending from 5 kHz to 150 kHz. Sound speed increases from ~1600 m/s at 20 kHz to 1650 m/s at site 1c, 1700 m/s at site 1b, and 1750 m/s at site 1a. Results are not conclusive below 20 kHz due to low SNR. Measured attenuation curves are also depicted. Note the high attenuation values at site-A where the maximum sound-speed dispersion occurs.

Measured sound-speed values and the degree of dispersion are slightly different at three sites separated by only 20 m. Measurements were not reliable below 20 kHz due to low SNR transmission in the highly attenuating sandy sediments. Measured attenuation coefficients are also plotted. Note that high attenuation values measured at site 1a correspond to significant sound speed dispersion. These results will be compared with those of chirp sonar inversions and other geoacoustic inversion methods.

IMPACT/APPLICATIONS

Chirp sonar inversion results will be validated with those of co-located geoprobe measurements. Both deterministic and stochastic features deduced from the chirp sonar surveys will be compared by those of scattering measurements of Dajun Tang and geoacoustic inversions of other researchers (e.g., Bill Hodgkiss and Peter Gerstoft of SIO, Ross Chapman of Univ. of Victoria, Kyle Becker of APL/Penn. State, David Knobles of ARLUTexas). Also, layering information provided by the chirp sonar measurements provide better geoacoustic parameterization of other inversion methods so that the accuracy of their geoacoustic parameter estimation is improved.

RELATED PROJECTS

This project is closely related to the projects that involved in the bottom interacting aspect (both in low frequency and high frequency) of the SW06 experiment. We will continue to interact with D.J Tang of APL/UW, Bill Hodgkiss and Peter Gerstoft of SIO, Ross Chapman of Univ. of Victoria, Kyle Becker of ARL/Penn State, David Knobles of ARL/UT to address bottom interacting propagation and scattering issues as well as geoacoustic inversion.

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