Marine sediment classification using the chirp sonar

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The chirp sonar is a calibrated wideband digital FM sonar that provides quantitative, high-resolution, low-noise subbottom data. In addition, it generates an acoustic pulse with special frequency domain weighting that provides nearly constant resolution with depth. The chirp sonar was developed with the objective of remote acoustic classification of seafloor sediments. In addition to producing high-resolution images, the calibrated digitally recorded data are processed to estimate surficial reflection coefficients as well as a complete sediment acoustic impulse profile. In this paper, surficial sediments in Narragansett Bay, RI are used to provide ground truth for an acoustic model. Quantitative acoustic returns from the chirp sonar are used to estimate surficial acoustic impedance and to predict sediment properties. A robust acoustic sediment classification model that uses core samples to account for the local depositional environment has been developed. The model uses an estimate of acoustic impedance to predict surficial density, porosity, compressibility, and rigidity. The comparisons show a high correlation between the core-determined sediment properties and the estimates obtained from acoustic measurements.

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INTRODUCTION

The remote classification of marine sediments by acoustic means requires a quantitative, high-resolution profiling system as well as a solid theoretical and/or empirically derived basis upon which to convert the acoustic measurements into the desired sediment properties. Recent advances in subbottom profiler design have produced high-quality data suitable for sediment classification work.[1] The collection and acoustic analysis of cores taken in conjunction with these seismic surveys provides a database for developing algorithms for sediment property prediction as well as "ground truthing" of the profiler's ability to remotely identify sediment type.

In this paper we describe an experiment conducted in Narragansett Bay, RI, using the chirp sonar, a calibrated, wideband (2–10 kHz), digital FM sonar that provides quantitative, high-resolution (≈ 10 cm), deep penetration (≈ 100 m) subbottom data.[1,2] The chirp sonar was developed with ONR funding to support the objective of remote acoustic classification of marine sediments. In addition to producing high-resolution images of the subsurface, the calibrated digitally recorded data can be processed to provide surficial reflectivity estimates. Subbottom returns can also be processed for attenuation[1] and when corrected for attenuation, chirp sonar profiles can provide a reflectivity series well suited for acoustic impedance inversion.

Along with chirp sonar profiles, cores were collected in Narragansett Bay. These cores were analyzed for velocity, density, porosity, grain density, and grain size. There is a wealth of literature describing empirical studies of sediment physical and acoustic property relationships.[3-8] These studies have resulted in a number of regression equations that can often be successful in their ability to predict one property from another (typically within a given depositional environment) but have provided only limited insight into the interaction between acoustic waves and marine sediments. Theoretical studies of sediment-acoustic wave interaction, on the other hand, particularly those of Biot[9,10] and Stoll[11] have used sophisticated formulations that take into account the sediment frame properties. In this paper we have initially taken a simplified view of the manner in which a normally incident acoustic wave emitted from an acoustic profiler interacts with a fully saturated marine sediment. In our model, we have assumed that the marine sediment is macroscopically homogeneous and that most of the acoustic-marine sediment interaction can be accounted for by the bulk properties of the sediment, i.e., porosity, specific gravity, elasticity, and

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