High Frequency Bottom Interaction in Range Dependent Biot Media

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LONG TERM GOALS

The long term objective of this project is to understand the dominant physical mechanisms responsible for propagation, attenuation and scattering in low shear velocity, porous sediments such as found on continental margins. Many Navy acoustic systems operate at high frequencies in shallow water over soft, fluid-saturated sedimentary bottoms. In many environments the bottom has range dependent properties such as seafloor roughness or volume heterogeneities within the seafloor. To optimize the performance of these Navy systems it is necessary to fully understand the behavior of acoustic wave propagation and scattering in these complex environments.

OBJECTIVES

The time domain finite difference (TDFD) method has proven to be useful in studying acoustic wave propagation in complex media where other methods become invalid. We have extended our Numerical Scattering Chamber (NSC) [*Stephen and Swift*, 1994b], which is based on the TDFD method, to include poro-elastic effects based on Biot theory. One objective of this study is to validate the new code by comparing results with other methods for simple, canonical models.

With the extended code we will study propagation and scattering effects in real high frequency data from sedimentary environments. What are the dominant physical mechanisms responsible for propagation, attenuation and scattering in low shear velocity, porous sediments such as found on continental margins?

Prior work in non-porous media shows that scattering from wavelength size heterogeneities can be responsible for body waves in the sub-bottom that would not be predicted based on Snell's Law and ray theory using mean medium properties. This phenomenon will cause anomalous sub-bottom penetration and will be relevant for accurately predicting forward and back scatter from realistic environments. We anticipate that similar mechanisms will take place in fluid-saturated porous media and we need to quantify the effect of porosity on the bottom penetration issue. How far below the seafloor do we need to know geophysical parameters in order to accurately predict backscatter in porous environments?

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APPROACH

Over the past twenty years we have developed finite difference methods for bottom interacting ocean acoustics in range dependent elastic and anelastic media. These methods are ideal for studying scattering from soft sediments in shallow water environments [*Greaves and Stephen*, 2000; *Stephen*, 1991]. Because of the shear properties of the bottom and the strong lateral heterogeneity of most shallow water sediments, a fully elastic/anelastic wave code, such as the finite difference method, is necessary to unravel the complex physical mechanisms involved in propagation and scattering [*Stephen*, 1988; *Stephen and Swift*, 1994a; *Swift and Stephen*, 1994]. NSC results can be applied to a broad range of frequencies because the spatial scales of heterogeneities are defined in terms of wavelengths [*Stephen*, 1996, for example].

This work is being carried out by Ralph Stephen, a Senior Scientist at WHOI, who is responsible for deriving and verifying the underlying differential equations, for writing the TDFD code, for defining test models, for assessing the results, and for presenting the results at meetings and in research papers. Stephen is assisted in this work by Tom Bolmer, an Information Systems Associate II, who maintains the network of workstations, writes input and output software, manages the data bases, prepares figures and assists in the preparation of meeting materials and papers.

WORK COMPLETED

In the course of studying porous media , of comparing the results of our TDFD code to results from other codes for seafloor interaction, and of applying the results of our modeling to the analysis of Navy data sets, a number of issues have arisen in basic scattering theory, even for non-porous media. Last year we discovered what we believe to be severe limitations in the standard scattering methodology as defined by Ogilvy [1991]. These limitations were discussed in last year's report. The effort to base our scattering methodology in the context of other approaches continued this year and the results are published in the background section for our paper on monostatic geoacoustic scattering near the mid-Atlantic Ridge [*Greaves and Stephen*, 2003].

RESULTS

There is a continuing perception in the community that the strong scattered field from the mid-Atlantic Ridge acoustic experiment [*Makris and Berkson*, 1994] comes from large-scale escarpments, canyons, cliffs or gullies as either specular reflection from steep topography or as the side-lobes of isolated, truncated antenna-like radiators or facets, but this is not supported in detailed analysis of the reverberation data. The slopes associated with seamounts and ridges that excite the strong backscatter are quite small when measured at the scales of 5 to 200m. At finer scales, even when a patch is insonified at normal incidence, the specular reflection is negligible when the patch has dimensions comparable to an acoustic wavelength (about 6m in this case). To support a normal incidence reflection a patch must be many wavelengths in size and there is no indication from the bathymetry data that such large patches actually exist in the study area. To study numerically the physics of acoustic scattering, it is necessary to describe the medium at a tenth of an acoustic wavelength or less. Bottom backscattering is caused by wavelength scale roughness or lateral heterogeneity. There may be an indirect correlation between scattering strength and larger scale features, if the small-scale roughness or heterogeneity themselves correlate with large-scale features or if the large-scale features change the effective geometry (for example a large-scale slope will change the effective incidence angle).

IMPACT/APPLICATIONS

We expect that our TDFD code will permit a quantitative study of the importance of porous media theory to propagation and scattering models in shallow water environments at high frequencies. Is porous media theory applicable to real problems? What are the best ways to define the necessary parameters for a porous medium? Are there alternative explanations for anomalous features in field data? What are the dominant physical mechanisms for scattering, propagation, and attenuation in heterogeneous porous media? These issues go well beyond seafloor acoustics and will have significant impact on the fields of physical acoustics, aero-acoustics and medical acoustics.

RELATED PROJECTS

None

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PUBLICATIONS

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