High Frequency Bottom Interaction in Range Dependent Biot Media

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LONG TERM GOALS

The long term objective 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 finite difference method has proven to be useful in studying acoustic wave propagation in complex media where other methods become invalid. We propose here to extend our Numerical Scattering Chamber, which is based on the finite difference method, to include poro-elastic effects based on Biot theory. With the extended code we will study propagation and scattering effects in real high frequency data from sedimentary environments.

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 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 Biot 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?

APPROACH

We have a code written for Biot media and we are in the process of validating the results by comparison with other methods (Stephen, 1997). We have perceived a need for reference solutions for Biot media representative of shallow seafloor environments Benchmarks would be constrained by geological and geophysical data that has been acquired by ONR (Stratiform, CBBLE, etc) in shallow water environments of relevance to the Navy. There is a role for simple canonical models but in at least one case we would want to replicate an existing acoustic data set.

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WORK COMPLETED

Over the past year we reviewed published formulations of the wave equations for heterogeneous, porous media. The assumptions used in arriving at various formulations are not always clearly stated and misunderstandings can result. All of the published formulations that we encountered, except for equation 8.24 in Biot (1962), are valid for heterogeneous media with uniform porosity only. The results of this study are discussed in Stephen (1997).

RESULTS

All of the familiar equations from Biot's porous media papers, assume uniform porosity and homogeneous material. In our finite difference approach we rely on gradients of elastic parameters (and porosity) to compute the effects of interfaces. It is important to have the correct equations for heterogeneous, non-uniform porosity material. A finite difference solution for a homogeneous, uniform porosity, medium was treated by Zhu and McMechan (1991). Dai et al (1995) solved Biot's equations for a heterogeneous, uniform porosity medium. None of these approaches is satisfactory for our applications.

Note that contrary to elasticity, in poro-elasticity the infinitesimal cube over which the stresses and strains are defined is <u>not</u> homogeneous. It is necessary to consider the gradients in porosity in the stress-strain relation.

IMPACT ON SCIENCE AND TECHNOLOGY

We expect that this new 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 media? Are there alternative explanations for anomalous features in field data? What are the dominant physical mechanisms for scattering, propagation and attenuation in porous media? These issues go well beyond seafloor acoustics and will have significant impact on the fields of physical acoustics, aeroacoustics and medical acoustics.

TRANSITIONS

RELATED PROJECTS

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