Computation of Seismic Waveforms in Complex Media: Carbon Dioxide Sequestration Imaging

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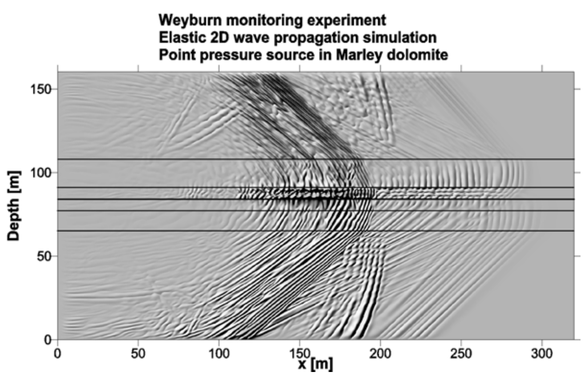
Research Objectives

The underground sequestration of CO_2 presents a subsurface monitoring problem requiring new approaches in seismicwaveform inversion techniques that can take into account the presence and effects of diffracted waves. This CO_2 specific problem is an important example of the need for effective tools applicable to subsurface imaging problems. Seismic tomographic imaging methods are compromised severely when the target region and/or the background medium are complex at the wavelength scale of the probing waves and when diffracted energy becomes a significant part of the wavefield. Travel-time imaging alone is inadequate in such situations - the problem requires use of full-waveform characteristics, where potentially accessible information on image subtlety is contained. Waveform tomography, however, suffers from a lack of fast and accurate numerical simulators necessary for effective and efficient forward computation of the propagating wavefield.

Approach

We develop a seismic mapping technique which will, among other applications, provide monitoring capability for the planned underground CO_2 repositories. For this purpose a new hybrid 3-D finite-difference pseudospectral method is under implementation using overlap-domain decomposition in combination with a new maping algorithms based on liquid saturated layers seismic properties This requires a fundamental understanding of storage properties of potential reservoirs, along with the physics and chemistry involved in multiphase transport of CO_2 in porous and fractured media. A geologically focused disposal strategy will require effective monitoring of the CO_2 injection to define its phase state and distribution, to track migration paths and to map the accumulation in order to control the process and to estimate the potential capacities of CO_2 reservoirs..To study the effects of gas and liquid formations on seismic wave energy we model seismic wave propagation through media containing local low-velocity liquid or gas phase regions. The complex character of CO_2 deposits demands 3D wave-propagation modeling. In order to study capabilities of different inversion techniques, 3D elastic modeling can also be used to compute representative synthetic data sets for testing. CO_2



Numerical modeling of wave propagation in prospective CO2 storage reservoir chosen by Pan Canadian Inc. revealed a dominance of guided waves in transmitted field for cross hole experiment. Direct arrivals of body waves are weak and hidden by head waves coming from adjacent high velocity layers. This suggests use of guided waves for reservoir imaging and monitoring.

The objective of this work is to develop and apply a powerful new inversion technique for imaging and monitoring man-made underground CO_2 repositories, as well as other highly heterogeneous subsurface targets. This will require a development of an effective forward modeling program which will be applied to a set of specific applications covering a wide range of spatial scales, using real data sets we have acquired. One of the applications will be time-lapse imaging of gas/steam and CO_2 injection experiments in existing oil fields, with a goal of better understanding steam floods, CO_2 sequestration, gas storage and geothermal reservoir exploitation.

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