

3-D Prestack Waveform Inversion - A Real Data Example

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Abstract

Development and application of computationally efficient seismic inversion methods for accurate estimation of subsurface properties is a big challenge in seismic exploration. The current state-of-the-art amplitude-variation-with-offset inversions do not account for complex wave propagation effects, which are important for accurate inversion. Some methods like prestack waveform inversion (PWI) solve the full wave equation and have given high quality results. PWI is very computation-intensive and was thus rewritten in a multilevel parallelization scheme successfully applied to 2D seismic data. Since 3D seismic data provide more stratigraphic details than 2D data, this study extends the work to 3D data collected at the Rock Springs Uplift in Wyoming, US for the purpose of CO₂ sequestration. Our PWI uses a genetic algorithm and a forward model named reflectivity method to iteratively compute synthetic data and compare them to observed data until the best match is obtained.

It takes about 20 min of CPU time to invert one common midpoint (CMP) location. For our 3D volume of 30,976 CMPs, it would take about 10,325 hours (~1.2 years), which is not practical. PWI was thus redesigned in a two-level parallelization scheme using the concept of pseudo-master nodes and pseudo-slaves. This assigns N nodes to invert the data at each CMP and M sets each with N nodes so that the inversion is run simultaneously at M different locations. If we have 352 compute nodes and 2 nodes per computation, we can divide the compute nodes into 176 sets each with 2 nodes (M=176, N=2) and run the inversion simultaneously at each set. With each set inverting 176 CMPs, our 3D volume will be inverted in about 59 hours (~2.4 days) instead of 1.2 years. Applying the method to RSU data helped us accurately capture the primary sealing lithologies (Lower Triassic Dinwoody and Permian Amsden formations) that could prevent an upward migration of CO₂ from the main potential storage formations (Weber Sandstone and Madison Limestone). We also identified secondary potential seals (Baxter Shale) and storage reservoirs (Nugget Sandstone) that could increase the CO₂ storage capacity at the RSU. This multilevel parallelization of PWI shows a drastic cut in computation time and high quality subsurface properties. It is applicable not only to CO₂ storage, but also to hydrocarbon exploration, especially in areas with simple geology. Ongoing research investigates how to handle complex structures using PWI.