Towards low-cost, full waveform seismic monitoring of CO_2 injection and storage

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Seismic technologies stand to play a critical role in enabling Carbon Capture and Storage (CCS) and its associated challenges in measurement, monitoring, and verification. The Consortium for Research in Elastic Wave Exploration Seismology (CREWES) is examining a range of variations on standard seismic methods which will provide reliable and low-cost monitoring while providing the user with robust uncertainty estimates. In this presentation we will describe unique multicomponent surface and VSP surveys undertaken by CREWES in collaboration with Carbon Management Canada (CMC) at the CMC Newell County Facility in southern Alberta during CO2 injection into the Basal Belly River Sandstone. Data were acquired using geophones, accelerometers, and single and multi-component Distributed Acoustic Sensing (DAS; Hall et al. 2021). These data enable the assessment of a variety of sensors, and the validation and testing of FWI methods aimed at CCS applications. We show field data examples, 2D and 3D FWI results, FWI error estimation, and our early conclusions on testing and validation of new methods at this well-characterized site.

Our approach is to merge acquisition and processing into a single integrated “technology package” of DAS, VSP, and FWI. This approach drives us towards a desire for low-cost data with the capacity to deliver high-resolution subsurface models, while utilizing the data in a complete manner that is consistent with a well-defined physics model. While this integrated approach has desirable traits, several critical issues are introduced. These include amplitude and phase differences between DAS and accelerometer or geophone data, FWI data sampling subsurface coverage requirements, and FWI computational requirements, which all impact cost.

Uncertainty analysis of models derived from FWI is a critical part of any CCS monitoring scheme. One approach is to use nullspace shuttles where many valid, but equally plausible FWI models are obtained and evaluated (e.g., Fichtner and Zunino, 2019; Liu and Peter, 2020; Keating and Innanen, 2021). The application of the FWI nullspace shuttle concept to CCS plume uncertainty estimation is a focus of current and on-going research (Keating and Innanen, 2024).

References

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