Pressure tomography for delineating the spatial extent of a CO_2 plume and estimating the saturation based on a single-phase proxy

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Successful disposal of CO_2 in deep fomations requires appropriate monitoring techniques. Several 4-D geophysical tomographical approaches (e.g., crosswell seismic tomography and ERT) have been developed for tracking CO_2 plume evolution, but the petrophysical models used for acquiring CO_2 saturation are with uncertainties. This, however, could be improved by pressure-based methods due to their linkage to flow regimes. In this study, we utilize pressure tomography to characterize a CO_2 plume in a deep saline formation. It is based on simulation by a single-phase proxy, considering CO_2 and brine as a phase mixture. The mixed-phase diffusivity varies along with the increased CO_2 saturation, which is reckoned as an indicator of the plume.

Analog to crosswell seismic tomographical experiments, pressure tomography uses pressure sources in one borehole and receivers (pressure transducers) at different depths. A travel-time based inversion technique is used in our work based on the transformation of the groundwater flow in an eikonal solver with high computational efficiency. The reservoir structure and plume geometry at different times are depicted by clustering the diffusivity tomograms prior to and after CO_2 injection. Sequentially, we employ a zonal calibration approach to estimate the hydraulic conductivity and specific storage of the CO_2-free formation. The calibration results are then used as the prior information for calibrating the specific storage change during plume injection. Ultimately, this delivers the average CO_2 saturation of the plume.

We compared the developed pressure tomography to the more common seismic tomography in a 2-D synthetic model with different degrees of heterogeneity. The inversion performance of the two approaches is comparable, but none delivers robust estimates of CO_2 saturation. The reservoir structure can be inferred by pressure tomography, which provides essential information for the zonal calibration. Calibration of the pressures gives better estimation on the saturation. The promising results show a great potential of pressure tomography for complementing seismic tomography, as well as for characterizing CO_2 saturation in a time-lapse strategy.