Quantitative CO2 monitoring workflow

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CO2 storage operators are required to monitor storage safety during injection with a long-term perspective (Ringrose and Meckel, 2019), implying that efficient measurement, monitoring and verification (MMV) plans are of critical importance for the viability of such projects. MMV plans usually include containment, conformance and contingency monitoring. Conformance monitoring is carried out to verify that observations from monitoring data are consistent with predictions from prior reservoir modelling within a given uncertainty range. Quantitative estimates of relevant reservoir parameters (e.g. pore pressure and fluid saturations) are usually derived from geophysical monitoring data (e.g. seismic, electromagnetic and/or gravity data) and potential prior knowledge of the storage reservoir.

In this work, we describe and apply a two-step strategy combining geophysical and rock physics inversions for quantitative CO2 monitoring. Bayesian formulations are used to propagate and account for uncertainties in both steps (Dupuy et al., 2017). We apply our workflow to data from the Sleipner CO2 storage project, located offshore Norway. At Sleipner, the CO2 has been injected at approx. 1000 m deep, in the high porosity, high permeability Utsira aquifer sandstone since 1996 with an approximate rate of 1 million tonnes per year. We combine seismic full waveform inversion and rock physics inversion to show that 2D spatial distribution of CO2 saturation can be obtained. Appropriate and calibrated rock physics models need to take into account the way fluid phases are mixed together (uniform to patchy mixing) and the trade-off effects between pore pressure and fluid saturation. For the Sleipner case, we show that the pore pressure build-up can be neglected and that the derived CO2 saturation distributions mainly depend on P-wave velocities and on the rock physics model. The CO2 saturation is larger at the top of the reservoir and the mixing tends to be more uniform. These mixing properties are, however, one of the main uncertainties in the inversion. We discuss the added value of a joint rock physics inversion approach, where multi-physics (electromagnetic, seismic, gravimetry), and multi-parameter inversion can be used to reduce the under-determination of the inverse problem and to better discriminate pressure, saturation, and fluid mixing effects.

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