Fully coupled hydrogeophysical inversion of CO_2 migration data in a deep saline aquifer

Joseph Doetsch[1], Michael B. Kowalsky[1], Christine Doughty[1], Stefan Finsterle[1], Jonathan B. Ajo-Franklin[1], Xianjin Yang[2], Charles R. Carrigan[2], and Thomas M. Daley[1]

[1]Earth Sciences Division, Lawrence Berkeley National Laboratory, Berkeley, CA, jdoetsch@lbl.gov, mbkowalsky@lbl.gov, cadoughty@lbl.gov, safinsterle@lbl.gov, jbajo-franklin@lbl.gov, tmdaley@lbl.gov
[2]Lawrence Livermore National Laboratory, Livermore, CA, yang25@llnl.gov, carrigan1@llnl.gov

Geologic sequestration of carbon dioxide (CO_2) is a promising approach to offset anthropogenic carbon emissions, and deep saline aquifers have been identified as potential target formations. Several pilot studies are currently underway to demonstrate the feasibility of long-term underground CO_2 storage, to assess risks associated with it, and to improve the overall understanding of CO_2 migration in the subsurface. A key component in these efforts is the integrated analysis of complementary hydrological and geophysical monitoring data. Whereas traditional hydrological measurements are useful for determining the properties immediately surrounding boreholes, geophysical cross-borehole measurements are sensitive to subsurface properties over larger regions, but can have lower spatial or temporal resolution and can be difficult to interpret quantitatively. We combine the advantages of hydrological and geophysical data sets in a fully coupled hydrogeophysical inversion, using the iTOUGH2 software package.

We consider a pilot study conducted near Cranfield, Mississippi. CO_2 injection into a 25-m-thick saline aquifer at ~3.2 km depth started in December 2009. The initial injection rate was ~3 kg/s and was subsequently increased to ~7 kg/s. Two monitoring boreholes were installed approximately 72 m and 98 m from the injector. The gas composition, mainly consisting of CO_2, CH_4, and injected tracers (SF_6 and Kr), was measured frequently in the monitoring boreholes via U-tube sampling with on-site mass spectroscopy. The pressure in the injection borehole was also monitored at a high temporal rate. In addition, the distribution of gas saturation with depth was measured via well logging before and twice during the injection, using a pulsed neutron reservoir saturation tool (RST). The geophysical datasets included electrical resistance measurements (ERT) and a pair of traditional timelapse crosswell seismic surveys. The ERT data were recorded continuously, sweeping through ~3000 ERT configurations, using 21 electrodes mounted on the casing of the two monitoring wells. Time-lapse ERT inversion of the resulting high-temporal-resolution data shows an increase in electrical resistivity of up to 50% due to the CO_2 migrating between the monitoring boreholes. Seismic crosswell datasets were collected before the start of the experiment and after about 9 months of operation. A difference inversion shows a decrease in seismic velocity of about 10% due to the presence of CO_2.

Using the fully coupled hydrogeophysical inversion, we are able to obtain estimates of reservoir parameters that honor all available data. While good results can be achieved using the hydrological data alone, including the geophysical data stabilizes the inversion and yields more reliable estimates.