Rendering Uncertainty in Rocks and Fluids: Stochastic Integration and Inversion in CO_2 Plume and Rock-Volume Prediction and Mapping

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Reservoir simulation, flow-front monitoring, and verification of CO_2 remains important subsurface tasks for geological CO_2 storage. They all involve collection and integration of multiple data sets within the context of some reservoir model. We have developed a computational tool to better render subsurface liquid plumes (e.g., CO_2, steam, water floods) and their reservoirs using new and prior geological, geochemical, and geophysical data. The approach formally and quantitatively integrates all available data and provides a strict measure of probability and uncertainty in the subsurface.

The tool uses statistical theory and geophysical forward models to compute images of the subsurface geology or plumes. It produces images consistent with disparate data types (well-logs, injected CO_2 volume, seismic, cross-borehole electrical resistivity). Through Bayesian inference, we generate a model of the likely plume or rock volume consistent with all data. The method uses a Markov Chain Monte Carlo (MCMC) technique to sample the space of possible models and importance sampling to robustly and rapidly converge on solutions. The outputs are specific models and their probability of occurrence; as such, model uncertainty is explicit and provides insights into what data are needed to reduce uncertainty. This method is computationally expensive, and high performance parallel computation of the geophysical forward problem(s) is required to make MCMC practical. We have applied this approach to several real-world examples of subsurface plume prediction and monitoring. These include a prediction and mapping of a commercial CO_2 flood, contaminant plumes, and tank leakage. They all show results superior to traditional (deterministic) inversion.