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Estimation of porous fluid properties through inversion of geophysical imaging data for reservoir characterization and forecasting

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Monitoring of subsurface fluid motion is important in many fields, such as groundwater management and enhanced oil recovery projects. Typically, the inversion of geophysical data can provide images of changes to geophysical properties within the subsurface over time, but with no direct information about the fluid properties within the subsurface. In enhanced oil recovery management programs reservoir models are built from sparsely sampled fluid properties and used to predict flow. In the history matching process these models are updated and mapped to geophysical parameter models from which data are generated and matched to historical geophysical survey data. This process can be time consuming, lead to inaccuracies in forecasting, and requires the knowledge of the relationship between physical properties and fluid properties.
Here we propose a reformulation of a linear geophysical imaging inverse problem to incorporate a two-dimensional tracer advection flow model without knowledge of the explicit relationship between fluid properties and geophysical properties. This problem assumes that the motion of the tracer in a constant flow field results in changes to geophysical properties within the subsurface, and that away from the injection and recovery wells the divergence of the fluid velocity field is zero. By choosing a particle in cell discretization of the tracer advection model the inverse problem is reformulated to depend only on the fluid velocity field and the initial tracer concentration. A novel regularization term is added to the inverse problem which reflects the geology of the problem by penalizing for sparsity and allowing for discontinuities in the velocity field between rock layers. In this way the inversion of geophysical data now provides an estimate of the fluid velocity field and the initial tracer concentration. Given these results we are able to march the initial tracer distribution along in the velocity field and predict the spatial-temporal evolution of the tracer at later time steps. We demonstrate this method with a synthetic two-dimensional seismic borehole tomography example.