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Fracture network connectivity devolution monitoring using transdimensional data assimilation

Márk Somogyvári[1], Mohammadreza Jalali[2], Irina Engelhardt[1], and Sebastian Reich[3]
[1]TU Berlin, Institute of Applied Geosciences, Department of Hydrogeology, Berlin, Germany (mark.somogyvari@tu-berlin.de)
[2]RWTH Aachen, Department of Engineering Geology and Hydrogeology, Aachen, Germany
[3]University of Potsdam, Institute of Mathematics, Potsdam, Germany

In fractured aquifers, the permeability of open fractures could change over time due to precipitation effects and hydrothermal mineral growth. These processes could lead to the clogging of individual fractures and to the complete rearrangement of flow and transport pathways. Existing fractured rock characterization techniques often neglect this dynamicity and treat the reconstruction as a static inversion problem. The dynamic changes then later added to the model as an independent forward modeling task. In this research we provide a new data assimilation-based methodology to monitor and predict the dynamic changes of fractured aquifers due to mineralization in a quasi-real-time manner.

We formulate the inverse problem as a dynamic 'hidden Markov process' where the underlying model dynamicity is just partly known. Data assimilation methods are specifically designed to model such systems with strong uncertainties. A typical example for such problems is weather forecasting, where the combination of nonlinear processes and the partial observations make the forecasting challenging. To handle the strong random behavior, data assimilation approaches use stochastic algorithms. In this study we combine DFN-based stochastic aquifer reconstruction techniques with data assimilation algorithms to provide a dynamic inverse modelling framework for fractured reservoirs. We use the transdimensional DFN inversion of (Somogyvári et al., 2017) to initialize the data assimilation. This method uses a transdimensional MCMC approach to identify the most probable DFN geometries given the observations. Because the method is transdimensional it can adjust the number of model parameters, the number of fractures within the DFN. We developed this idea further by enhancing a particle filter algorithm with transdimensional model updates, allowing us to infer DFN models with changing fracture numbers.

We demonstrate the applicability of this new approach on outcrop-based synthetic fractured aquifer models. To create a dynamic DFN example, we simulate solute transport in a 2-D fracture network model using an advection-dispersion algorithm. We simulate fracture sealing in a stochastic way: we define a limit concentration above which the fractures could seal with a predefined probability at any timestep. At the initial timestep, a hydraulic tomography experiment is performed to capture the initial aquifer structure, which is then reconstructed by the

transdimensional DFN inversion. At predefined timesteps hydraulic tests are performed at different parts of the aquifer, to obtain information about new state of the synthetic model. These observations are then processed by the data assimilation algorithm, which updates the underlying DFN models to better fit to the observations.