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Reconstruction of two-dimensional fracture network geometry by transdimensional inversion

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Transport processes in a fractured aquifer are mainly controlled by the geometry of the fracture network. Such a network is ideally modelled as discrete fracture network (DFN), which is composed by a skeleton of hydraulically conductive fractures that intersect the impermeable rock matrix. The orientation and connectivity of the fractures are highly case-specific, and mapping especially the hydraulically active parts of a fracture network requires insight from hydraulic or transport related experiments, such as tracer tests. Single tracer tests, however, offer only an integral picture of an aquifer′s transport properties. Here, multiple tracer tests are proposed and evaluated together in a tracer tomography framework to obtain spatially distributed data. The interpretation of the data obtained from these experiments is challenging, since there exists no common recipe for reconstructing the fracture network in a DFN model. A crucial point is that the number of fractures (and thus the number of model parameters) is unknown. We propose the use of a transdimensional inversion method, which can be applied to calibrate fracture properties and number. In this study, the reversible jump Markov Chain Monte Carlo algorithm is selected and conservative tracer tomography experiments are interpreted with two-dimensional DFN models.
In our approach, a randomly generated initial DFN solution is evolved through a Markov sequence. In each iteration the DFN model is updated by a random manipulation of the geometry (fracture addition, fracture deletion or fracture shift). The tracer tomography experiment is simulated with the updated model, and the simulated tracer breakthroughs curves are compared to the original observations. Each updated DFN realization is evaluated using the Metropolis-Hastings-Green acceptance criteria. This evaluation is based on probabilistic properties of the updates and the improvement of the fit of the breakthrough curves. The transdimensional algorithm incorporates the available statistical information of the fractured media, such as fracture intensity, spacing and length distribution. As a result, an ensemble of feasible DFN realizations is obtained. This ensemble can be visualized through a fracture probability map, highlighting probable fracture locations within the investigated domain.