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Inversion of Hydraulic Tomography Data from the Grimsel Test Site with a Discrete Fracture Network Model

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This study aims at the stochastic characterization of fractured rocks with a low-permeability matrix based on transient data from hydraulic tomography experiments. In such rocks, fractures function as main flowpaths. Therefore, adequate insight about distribution and properties of fractures is essential for many applications such as groundwater remediation, constructing nuclear waste repositories or developing enhanced geothermal systems. At the Grimsel test site in Switzerland, multiple hydraulic tests have been conducted to investigate the hydraulic properties and structure of the fracture network between two shear zones. We present results from combined stochastic inversion of these tests to infer the fracture network of the studied crystalline rock formation.

Data from geological mapping at Grimsel and the hydraulic tomography experiments that were undertaken as part of in-situ stimulation and circulation experiments provide the prior knowledge for the model inversion. This information is used for the setting-up of a site-specific conceptual model, to define the boundary and initial conditions of the groundwater flow model, and for the configuration of the inversion problem. The pressure signals we apply for the inversion stem from cross-borehole constant rate injection tests recorded at different depths, whereby the different intervals are isolated by packer systems.

In the forward model, the fractures are represented explicitly as three-dimensional (3D) discrete fracture network (DFN). The geometric and hydraulic properties of the DFN are described by the Bayesian equation. The properties are inferred by sampling iteratively from the posterior density function according to the reversible jump Markov chain Monte Carlo sampling strategy. The goal of this inversion is providing DFN realizations that minimize the error between the simulated and observed pressure signals and that meet the prior information. During the course of the inversion, the number of fractures is iteratively adjusted by adding or deleting a fracture. Furthermore, the parameters of the DFN are adapted by moving a fracture and by changing the fracture length or hydraulic properties. Thereby, the algorithm switches between updates that change the number of parameters and updates that keep the number of parameters but adjust their value. The inversion results reveal the main structural and hydraulic characteristics of the DFN, the preferential flowpaths, and the uncertainty of the estimated model parameters.