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Inverse modeling of flow tomography experiments in fractured media

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Inverse modeling of fracture hydraulic properties and connectivity is a very challenging objective due to the strong heterogeneity of the medium at multiple scales and the scarcity of data. Cross-borehole flowmeter tests, which consist of measuring changes in vertical borehole flows when pumping a neighboring borehole, were shown to be an efficient technique to provide information on the properties of the flow zones that connect borehole pairs (Paillet, 1998, Le Borgne et al., 2007). The interpretation of such experiments may, however, be quite uncertain when multiple connections exist. We propose the flow tomography approach (i.e. sequential cross-borehole flowmeter tests) to characterize the connectivity and transmissivity of preferential permeable flow paths in fractured aquifers (Klepikova et al., 2013). An inverse model approach is developed to estimate log-transformed transmissivity values of hydraulically active fractures between the pumping and observation wells by inverting cross-borehole flow and water level data. Here a simplified discrete fracture network approach that highlights main connectivity structures is used. This conceptual model attempts to reproduce fracture network connectivity without taking fracture geometry (length, orientation, dip) into account. We demonstrate that successively exchanging the roles of pumping and observation boreholes improves the quality of available information and reduces the under-determination of the problem. The inverse method is validated for several synthetic flow scenarios. It is shown to provide a good estimation of connectivity patterns and transmissivities of main flow paths. It also allows the estimation of the transmissivity of fractures that connect the flow paths but do not cross the boreholes, although the associated uncertainty may be high for some geometries. The results of this investigation encourage the application of flow tomography to natural fractured aquifers.