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Ensemble Kalman Filter Assimilation of Temperature Data to Estimate Permeability in Geothermal Reservoirs

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Reliable information on heterogeneous permeability fields of geothermal reservoirs is of particular interest, even after production started. This information permits the prediction of temperature and pressure variation with time, the optimization of the production rate of the geothermal installation in terms of profit or sustainability, and the detection of optimal locations for additional injection or production wells.
Therefore, we study the capability of the data assimilation technique Ensemble Kalman Filter (EnKF) to estimate heterogeneous permeability fields using sparse temperature data from five geothermal wells inside a synthetic reservoir. To simulate the transient temperature variation inside the geothermal system, we use the finite volume software SHEMAT-Suite for solving coupled transient equations for groundwater flow and heat transport in a porous rock matrix.
The EnKF is essentially a sequential assimilation procedure which compares observations to predictions by SHEMAT-Suite and adjusts system variables (in this case: permeability, temperature, and hydraulic head) of the numerical simulator according to the error statistics assuming a Gaussian error distribution. For the EnKF, the error statistics are obtained from the mean and variance of a number of realisations.
This way, estimated permeability converts in the direction of true permeability assimilation step by assimilation step.
We demonstrate that the basic features of the permeability field are reproduced by the EnKF, even when assimilating data from just five wells. In addition, we are able to quantify uncertainty of the permeability estimation. The fit using temperature data is comparable with the fit using tracer concentration data (Vogt et al., 2010). However, different time scales (months respectively years) apply for the two different data types. Optimal fits are obtained when taking into account hydraulic head data in combination with temperature data.
We also present the effect of spatial data density on the fit quality and we investigate the suitability of different spatial permeability distributions for an EnKF inversion.

C. Vogt, C. Kosack, G. Marquart, 2010. Estimation of Geothermal Reservoir Properties Using an Ensemble Kalman Filter Approach, Proceedings of the 16th European Meeting of Environmental and Engineering Geophysics (Near Surface)