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An Integrated Assessment of Geothermal Reservoir Simulation – A Case Study

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The forecast of reservoir temperature and pressure development at depth and their uncertainty is vital for the successful operation of a geothermal reservoir. Our cooperative aims to obtain a calibrated reservoir model, which allows predicting the thermal power, possible expected circulation rates and thermal breakthrough time depending on permeability and operation conditions.
We present a case study on a geothermal reservoir in Northeastern German sedimentary basin using an integrated approach for numerical simulation of reservoir temperature and pressure. To this end, we use (i) interpretation of 3D seismics to identify geological layers in the reservoir and to detect fractures; (ii) laboratory measurements and logging to derive rock properties for the various layers; (iii) forward and inverse modelling to predict temperature and pressure in the given reservoir layout and their variation with time.
In a first step, we infer an initial regional temperature field down to 6 km using a steady-state model. Additionally, we invert for specific heat flow at the lower boundary using corrected bottom-hole temperature (BHT) data from a number of depleted oil and gas drill holes. Uncertainty is quantified using the Monte Carlo technique of Sequential Gaussian Simulation which is based on observed distributions of thermal conductivity and porosity in this case. Additionally, as a major contribution to the temperature field, the error in the inversion of specific heat flow is accounted for. 700 equally likely realizations of the subsurface rock property fields are generated. Simulating heat transport and fluid flow for all members of this stochastic ensemble yields mean and standard deviation of temperature for a possible target sandstone layer at a depth of about 2000 m.
In a second step, we simulate the operation of a synthetic geothermal doublet drilled into the sandstone aquifer. To this end, we use a densly gridded detailed model with dimensions of 1000 m x 2000 m x 200 m. Boundary conditions for the model are obtained from the coarsely gridded temperature model discussed above. The synthetic doublet with 1000 m distance between the boreholes is based on typical operation parameters of a heat use project using circulation rates of 42 L/s and reinjection temperatures of 40 °C. Again, an ensemble of heterogeneous porosity distributions is generated from available logging data in the region using a Monte Carlo approach. Based on the porosity, a corresponding permeability distribution is created for each ensemble realization based on a calibrated relation for Northeastern German sandstones (Pape et al., 1999). Then, the variation of temperature and pressure at the production well is predicted over 30 years, and the uncertainty of the predictions is quantified as a consequence of applying the Monte Carlo approach.

Pape, H., Clauser, C., and Iffland, J., (1999), Permeability Prediction Based on Fractal Pore Space Geometry, Geophysics 64 (6), 1447-1460.