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Quantifying uncertainties in geothermal energy exploration

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An increased use of geothermal energy requires reduction of cost and risk. Information on rock properties in the subsurface is essential for planning of projects for geothermal energy use. Based on a stochastic approach, the uncertainties in the rock properties at a given location and for a target parameter are quantified, such as temperature or flow rate. This way, not only average values and error estimates of the target parameter can be obtained, but also its spatial distribution. Based on this information, the risk within a geothermal project can be estimated better. As a result, cost may be reduced or estimated with less uncertainty.

The approach employed is based on the algorithm of "Sequential Gaussian Simulation" (sgsim): First, the geometry of a geothermal reservoir model is discretized on some grid. Then the algorithm follows a random path through the model, and each grid node is assigned certain values for the required rock properties. These values take into account (a) assumed property distributions; (b) the correlation length; (c) primary data, such as borehole measurements; (d) secondary data, such as seismic data. A first realization is finished when the entire model is initialized. In order to obtain a distribution for the target parameter, more realizations need to be created by following other random paths. Each of these realizations is equally likely with suspect to the real situation which is defined by the measured data.

Sgsim is implemented as a module of the in-house mass and heat flow simulator shemat_suite. This way, the generated realizations are directly used as input for mass and heat flow simulations. Thus, no time and effort is wasted for format conversion.

As a demonstration of this method, an exploration scenario is simulated for a projected geothermal district heat use in The Hague, Netherlands. Multiple realizations are generated using the sgsim algorithm for the distribution of thermal conductivity within the geothermal reservoir at depth. Applying the mass and heat flow simulator shemat_suite, the error with respect to predicted temperature at the target location for a production well is reduced from about 25 % to 4 %.