



## Usage of ensemble geothermal models to consider geological uncertainties

Wolfram Rhaak (1), Sarah Steiner (2), Bastian Welsch (1), and Ingo Sass (2)

(1) Darmstadt Graduate School of Excellence Energy Science and Engineering, Technische Universitt Darmstadt, Germany (ruehaak@geo.tu-darmstadt.de), (2) Technische Universitt Darmstadt, Institute of Applied Geosciences, Chair of Geothermal Science and Technology, Darmstadt, Germany

The usage of geothermal energy for instance by borehole heat exchangers (BHE) is a promising concept for a sustainable supply of heat for buildings.

BHE are closed pipe systems, in which a fluid is circulating. Heat from the surrounding rocks is transferred to the fluid purely by conduction. The fluid carries the heat to the surface, where it can be utilized.

Larger arrays of BHE require typically previous numerical models. Motivations are the design of the system (number and depth of the required BHE) but also regulatory reasons. Especially such regulatory operating permissions often require maximum realistic models. Although such realistic models are possible in many cases with today's codes and computer resources, they are often expensive in terms of time and effort. A particular problem is the knowledge about the accuracy of the achieved results.

An issue, which is often neglected while dealing with highly complex models, is the quantification of parameter uncertainties as a consequence of the natural heterogeneity of the geological subsurface. Experience has shown, that these heterogeneities can lead to wrong forecasts. But also variations in the technical realization and especially of the operational parameters (which are mainly a consequence of the regional climate) can lead to strong variations in the simulation results.

Instead of one very detailed single forecast model, it should be considered, to model numerous more simple models. By varying parameters, the presumed subsurface uncertainties, but also the uncertainties in the presumed operational parameters can be reflected. Finally not only one single result should be reported, but instead the range of possible solutions and their respective probabilities.

In meteorology such an approach is well known as ensemble-modeling.

The concept is demonstrated at a real world data set and discussed.