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Modeling the effects of regional groundwater flow on deep temperatures in Hesse (Germany)

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A successful utilization of deep geothermal resources requires to make accurate predictions about the reservoir temperature distribution as well as an in depth knowledge of the hydraulic processes exerting a direct influence on the subsurface temperature distribution and therefore on the productivity of geothermal reservoirs.

The aim of this study is to investigate and quantify the influence that regional thermo-hydraulic processes exert on the geothermal configuration of potential reservoirs in the German federal state Hesse. Specifically, we address the question of how the regional thermal and hydraulic configuration influences the local reservoir conditions and whether it is possible to improve subsurface predictions iteratively by relying on 3D numerical modeling techniques. Therefore, a 3D structural model of Hesse is used as a basis for coupled 3D thermo hydraulic simulations of the deep fluid and heat transport. To uncover the effects of process coupling, a stepwise workflow is followed. We first simulate the thermal and hydraulic field under steady-state conditions by means of two different uncoupled simulations and then analyze the results of the coupled thermo-hydraulic steady-state simulations. In a last effort, we investigate the influence of fluid viscosity and density varying with temperature and pressure in transient coupled simulations.

As a result of our numerical simulations, Hesse can be differentiated into sub-areas differing in terms of the dominating heat transport processes. In a final attempt to quantify the robustness and reliability of the modeling results, we carry out an analysis of the modelling outcomes by comparing them to available subsurface temperature data. Modelled temperatures show different levels of fit with locally measured well temperatures. These differences in model fit indicate the need for either structurally refined models and/or iterative adaptions within realistic ranges of the hydraulic and thermal properties. Structural refinements can often only be handled with smaller-scale models, which will, in turn, benefit from the boundary conditions and improved process understanding as derived from the regional modelling approach presented here.