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Temperature field and heat flow of the Danish-German border region – borehole measurements and numerical modelling

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We present a regional 3D numerical crustal temperature model and analyze the present-day conductive thermal field of the Danish-German border region located in the North German Basin. A comprehensive analysis of borehole and well-log data on a regional scale is conducted to derive both the model parameterization with a spatial distribution of rock thermal conductivity and new heat-flow values. The latter one are used to setup the numerical lower boundary condition. Measured heat flow and borehole temperature observations (59 values from 24 wells) are used to constrain the modelling results (calibration and validation). The prediction uncertainties between observed and modelled temperatures at deep borehole sites are small (rms = 3.5°C). For eight deep boreholes, new values of terrestrial surface heat flow are derived, ranging between 72 and 84 mW/m^2 (mean of 80 $\pm$ 5 mW/m^2). Those values are up to 20 mW/m^2 higher than low values reported in some previous studies for this region. Heat flow from the mantle is estimated to be between 33 and 40 mW/m^2 (q1–q3; mean of 37 $\pm$ 7 mW/m^2).
Pronounced lateral temperature variations are caused mainly by complex geological structures, including a large amount of salt structures and marked lateral variations in the thickness of basin sediments. The associated variations in rock thermal conductivity generate significant variations in model heat flow and large variations in temperature gradients. Major geothermal sandstone reservoirs (e.g. Rhaetian and Middle Buntsandstein) are mainly found with temperatures within the range of 40–80°C, which is suitable for low enthalpy heating purposes in most of the area. Higher temperatures of up to 120–160°C, of interest for the production of electricity, are observed only in the very south-eastern part of the study area (Glückstadt-Graben area).
In combination with the structural geological model and information on reservoir hydraulic properties, the presented temperature model will constitute a very valuable base for planning and management the subsurface geothermal resources and help preventing conflicts of use in the Danish-German border region.