The temperature field of Denmark: New insights from borehole measurements and 4D numerical modelling

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From the Danish “DSF Geotermi project”, we present the results of a 4D numerical crustal temperature model conducted to analyze the present-day temperature and heat-flow field of onshore Denmark, including large parts of the Danish Basin, the northernmost part of the North German Basin and the Sorgenfrei-Tornquist Zone. An extensive analysis of borehole and well-log data on a basin scale is the basis to derive the model parameterization. We demonstrate the benefit of temperature prognosis when the spatial variability of rock thermal properties and regionally variable heat-flow values are considered. For the temperature model, a new structural geological model with lithological layers is provided by the Geological Survey of Denmark and Greenland (GEUS). Measured heat flow and high-quality borehole temperature observations (two data sets of in sum 102 values from 47 wells) are used to calibrate and validate the modelling results. The prediction uncertainties between modelled and observed temperatures at deep borehole sites are small (rms = 1.3°C). For 22 deep boreholes, new values of terrestrial surface heat flow are derived showing a considerable variation between Danish Basin, North German basin and the Sorgenfrei-Tornquist Zone. Major geothermal sandstone reservoirs show significantly different temperatures according to a large variation in reservoir depth and different thermal properties of overlying lithologies. For example, temperatures of the Gassum Formation (Rhaetian sandstone), covering most of the Danish onshore areas, are within the range of 20–140 °C (top depth). The presented temperature model constitutes a valuable base for planning and management the subsurface geothermal resources in Denmark. It is available online at http://data.geus.dk/geoterm/.