EGU22-9853
https://doi.org/10.5194/egusphere-egu22-9853
EGU General Assembly 2022

Estimating the subsurface thermal conductivity and its uncertainty for shallow geothermal energy use – a methodology based on publicly available data

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Over 50% of the energy consumption in Europe is used for heating and cooling, of which the majority still comes from fossil fuels. For the heating and cooling supply of buildings, heat pumps using borehole heat exchangers (BHE) are an efficient and sustainable alternative. Design and performance of BHE fields strongly depend on the thermal properties of the subsurface. For the dimensioning of BHE fields, the subsurface properties are assessed using geothermal potential maps published by federal states or authorities.

Such maps are created based on available geological and hydrogeological subsurface data. From these data, the stratigraphic sequence a BHE would intersect is inferred and thermal properties are assigned to the rock sequence. The mean thermal conductivity of the intersected sequence has a high uncertainty that is not quantified in most geothermal potential estimates. Moreover, geothermal potential maps are often not comparable because the used calculation methods differ in terms of complexity and calculated quantity. In Germany, for example, almost each of the federal states published its own geothermal potential map showing different quantities.

For these reasons, we propose an approach to estimate the subsurface thermal conductivity together with its uncertainty. To enable applicability to datasets of different regions, e.g., all German federal states, the method takes only publicly available and standardized hydrogeological and geological data as input. Thermal conductivity estimation takes place on

1) a large scale, to obtain a general estimate of thermal conductivity, and

2) on a fine scale, to update the large-scale estimate in smaller target areas.

For both estimations, we consider uncertainty by assigning not only the mean but also the minimum and maximum thermal conductivities of each rock type to the intersected sequence. Data handling and initiation of calculations is done via a geoportal. It connects the calculation method to geodata servers, instead of storing data locally, thus ensuring data up-to-dateness. This way, the approach does not only estimate the thermal conductivity, but also automatizes the cumbersome step of geological data gathering for all types of subsurface investigations.

We demonstrate the approach using data from the federal state of Hamburg and compare our results to a thermal conductivity map published by the city of Hamburg. The partly considerable differences between the two estimates illustrate the uncertainty of the geothermal potential, and thus the need to communicate it.