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Determination of thermal dispersivity using a borehole heat exchanger

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Shallow geothermal energy is a popular option for the heating and air-conditioning of buildings, because it is a regenerative energy and modern heat-pump-based low-enthalpy geothermal systems are often economically advantageous to alternative technologies. Geothermal systems extract heat from the ground, or inject waste heat. This may cause temperature anomalies in the subsurface, and when shallow aquifers exist, these anomalies can be observed in the groundwater. To ensure an efficiently operating, and in the long-run, sustainable, geothermal system, a precise knowledge of the evolving temperature anomaly is desirable. When planning a system, among the subsurface heat transport processes, advection due to flowing groundwater is not often considered. Accordingly, the role of thermal dispersion is rarely inspected. To determine the thermal dispersion influencing the temperature plume around a borehole heat extractor (BHE), a geothermal lab experiment is performed in an artificial aquifer. The size of the aquifer is 9 m $\times$ 6 m $\times$ 4.5 m, it is heterogeneous and composed of five different sand layers. In the lab, a specific hydraulic gradient is imposed. A BHE is installed in this aquifer, and the exact size and temporal evolution of the induced temperature anomaly is measured by a monitoring network of over 100 temperature sensors. Based on the known hydraulic and thermal properties of the different sand layers, a high-resolution finite element model is built, which simulates the transient conditions during the experiment. This model contains a fully discretized BHE, with an integrated heat carrier fluid flow inside the U-pipes, located inside the BHE. Therefore, the model is able to consider the coupled processes between the temperature development of the heat carrier fluid and the heat propagation in the subsurface. Except the longitudinal and transversal dispersivity, all material properties and boundary conditions are known, thus the dispersivities can be determined by parameter estimation. The results confirm previous findings that the effect of longitudinal and transversal dispersion should be considered for the temperature plume calculation caused by BHEs in advection influenced systems.