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Thermal Active Zone space-time evolution: a small-scale monitoring of thermal and electrical conductivity

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The growing demand for renewable energy leads to an increase in the development of alternative energy applications. In this way, shallow geothermics assumes an important role in the global energy transition of building air conditioning. The design of Ground Source Heat Pumps (GSHP) requires a multidisciplinary approach including a good understanding of the underground geological setting, such as hydrogeological aspects and heat flow conditions. Classic monitoring strategies often rely on local and point-based measurements to monitor changes of underground temperature in time, with the limit of not succeeding in a whole delimitation of the Thermal Active Zone (TAZ). In this context, Electrical Resistivity Tomography (ERT) can bring relevant information on the temperature distribution for monitoring the induced thermal plume within BHEs (Borehole Heat Exchangers) systems. Geophysics helps the understanding of the thermal processes, in order to front the difficulties arising from Ground Source Heat Pumps (GSHP) implementation. Thermal conductivity and electrical resistivity depend equally in a complex way on different common subsurface and environmental attributes such as, among the main, mineralogical composition, grain size, density, porosity and saturation. Besides, thermal conductivity increases significantly with temperature in wet ground, by making it clear a relationship between both parameters.

ERT is particularly sensitive to the porous medium temperature and, when applied in time-lapse (TL), could provide spatially distributed information on the changes over time of water content, salinity or temperature. For this reason, in this work we monitored the complex TAZ temporal evolution during a heat injection experiment using a 3D time-lapse ERT survey, arranged in a reduced scale physical model. For a better understanding of measured electrical resistivity values, focused on mapping the extent of a geothermal plume around a borehole, a specific laboratory device was utilized. Grain size distribution, bulk density and saturation of the porous medium are known and established, as well as reliable temperature values acquired through sensors with which calibrate the ERT results. Thus, changes in resistivity can be interpreted to track the evolution of the plume of heated water and used to estimate the temperature change. The propagation of the heat plumes into the ground is also highly sensitive to interstitial water flow rate, thus also this condition was recreated and monitored varying the hydraulic gradient in the experimental device.

The present work aims to demonstrate the ability of ERT to provide complementary insights about

the sub-surface spatio-temporal dynamic for monitoring the extension of TAZ caused by BHEs probes. In addition, the detailed scale adopted and the variable control within a laboratory setup ease the study of the interaction between thermal and electrical properties.