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Development of a direct push based in-situ thermal conductivity measurement system

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Heat pump systems are commonly utilized in Europe, for the exploitation of the shallow geothermal potential. To guarantee a sustainable use of the geothermal heat pump systems by saving resources and minimizing potential negative impacts induced by temperature changes within soil and groundwater, new geothermal exploration methods and tools are required.
The knowledge of the underground thermal properties is a necessity for a correct and optimum design of borehole heat exchangers. The most important parameter that indicates the performance of the systems is thermal conductivity of the ground. Mapping the spatial variability of thermal conductivity, with high resolution in the shallow subsurface for geothermal purposes, requires a high degree of technical effort to procure adequate samples for thermal analysis. A collection of such samples from the soil can disturb sample structure, so great care must be taken during collection to avoid this. Factors such as transportation and sample storage can also influence measurement results. The use of technologies like Thermal Response Test (TRT) require complex mechanical and electrical systems for convective heat transport in the subsurface and longer monitoring times, often three days. Finally, by using thermal response tests, often only one integral value is obtained for the entire coupled subsurface with the borehole heat exchanger.
The common thermal conductivity measurement systems (thermal analyzers) can perform vertical thermal conductivity logs only with the aid of sample procurement, or by integration into a drilling system. However, thermal conductivity measurements using direct push with this type of probes are not possible, due to physical and mechanical limitations. Applying vertical forces using direct push technology, in order to penetrate the shallow subsurface, can damage the probe and the sensors systems.
The aim of this study is to develop a new, robust thermal conductivity measurement probe, for direct push based approaches, called Thermal Conductivity Profiler (TCP), that operates based on the principles of a hollow cylindrical geometry heat source. To determinate thermal conductivity in situ, the transient temperature at the middle of the probe and electrical power dissipation is measured. At the same time, this work presents laboratory results obtained when this novel hollow cylindrical probe system was tested on different materials for calibration. By using the hollow cylindrical probe, the thermal conductivity results have an error of less than 2.5% error for solid samples (Teflon, Agar jelly, and Nylatron).
These findings are useful to achieve a proper thermal energy balance in the shallow subsurface by using direct push technology and TCP. By providing information of layers with high thermal conductivity, suitable for thermal storage capability, can be used determine borehole heat exchanger design and, therefore, determine geothermal heat pump architecture.