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Interactions between the soil environment and a horizontal ground coupled heat pump for a domestic installation in the UK

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Seasonal soil temperature variations are harnessed by Ground Coupled Heat Pumps (GCHPs) to provide heating in the winter and cooling in the summer. The performance of a GCHP system will depend on technical factors (type, length and depth of ground heat exchanger (GHE), as well as spacing of pipes), but it will also be determined to a large extent by interactions between the below-ground parts of the system and the environment (atmospheric conditions, vegetation and soil characteristics). Depending on the balance between extraction and rejection of heat from and to the ground, the soil temperature in the neighbourhood of the GHE may fall or rise. Furthermore, water and vapour transfer will be affected as a result of this temperature gradient. This in turn will have a large influence on the thermal properties of the soil surrounding the GHE, and hence ultimately on the performance of the GCHP.

The GROMIT (GROund coupled heat pumps MITigation potential) project, funded by the Natural Environment Research Council (UK) addresses all these issues. GROMIT is a multi-disciplinary project, which aims to quantify the CO2 mitigation potential of horizontal GCHPs. It considers UK-wide short-term and long-term variations in environmental conditions, and combines model predictions of soil moisture content and soil temperature, and related performance of GCHPs, with measurements obtained for different GCHP installations over the UK (see also Wu, 2010).

In this study we summarize one year of data from an on-going measurement campaign undertaken for a slinky GCHP installation installed in Drayton St Leonard (Oxfordshire, UK). We present the soil physical state variables, together with the soil thermal properties and soil heat fluxes, for two soil profiles (reference soil and soil near slinky) monitored at the field site, as well and the inlet and outlet temperatures of the GCHP system. Overall, soil moisture content in the soil affected by the slinky was always lower, at 0.75 m and 1 m depth. Different patterns were observed near the surface due to the influence of spatially variable vegetation growth (grass). Lower soil moisture contents in the GCHP profile (for those parts of the soil that are being influenced by the GHE) are expected due to the fact that the heat extraction will cause migration of soil moisture away from the GHE. Soil temperatures in the slinky profile were also lower than in the reference profile; the amount by which they are lower can give us an idea of the thermal energy absorbed by the GHE. Almost no temperature differences between the two profiles were observed at a depth of 0.02m, but they became pronounced from approximately 0.25m depth.

Modelling exercises for the GCHP site under investigation showed that the heat exchanger influenced the soil temperatures within a distance of around 0.8 m from the central long axis of the heat exchanger (Wu et al., 2010). We complemented and explained our observations with further sensitivity studies including not only heat, but as well water transfer to understand the dynamic interaction between soil environment and the horizontal GCHP technical properties and their effect on long-term GCHP performance. The interaction between the soil environment and a GCHP was assessed using a detailed land surface model (JULES: Joint UK Land Environment Simulator, Meteorological Office, UK) with additional equations embedded describing the interaction between GCHP heat exchangers and the surrounding soil. This is the first detailed study conducted in the UK that aims to understand the interactions between the soil, horizontal heat exchangers and the environment.

References:

Y. Wu, G. Gan, A. Verhoef, P. L. Vidale, and R. Garcia Gonzalez. Experimental measurement and numerical simulation of horizontal-coupled slinky ground source heat exchangers. Applied Thermal Engineering, pages 1–10, 2010.