Geophysical Research Abstracts
Vol. 21, EGU2019-3127, 2019
EGU General Assembly 2019

Observed controls on the seasonal variability of urban groundwater thermal regimes

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Groundwater temperatures in shallow (<30mbgl) urban aquifers are often elevated above the predicted geothermal gradient due to the subsurface Urban Heat Island effect (sUHI) and may provide an attractive resource for low-enthalpy geothermal energy. However, seasonal variation in temperatures in the near-subsurface, which can exceed 10 °C throughout the year, may make shallow open-loop systems less efficient resulting in the potential benefits of this resource going unrealised. Understanding the controls on the depth to which seasonal variation occurs (termed the Zone of Seasonal Fluctuation - ZSF), and being able to predict its behaviour, would therefore allow open-loop ground source heating systems to be installed at the optimum depth to take advantage of the sUHI whilst avoiding seasonal temperature variations.

In order to better understand and predict the distribution of the ZSF we carried out downhole temperature profiling at 40 groundwater monitoring boreholes across the city of Cardiff, U.K., each month for a period of 13 months. We identified the base of the ZSF at each site by determining the depth of convergence of the monthly temperature profiles. In Cardiff this was found to range from 7.6 to >16.2 mbgl, and the amplitude of annual temperature change in the near-subsurface also varied considerably between the sites, ranging from 2 to 11°C. These spatial variations indicate that factors are present within this urban setting that result in highly variable transfer of heat through the subsurface. In order to explain the variations between sites, we first developed a conceptual model identifying the potential controls on urban subsurface heat transport including lithostratigraphy, material properties, thermal conductivity and diffusivity, groundwater levels, surface infiltration, land use, land cover and the presence of buried infrastructure. We then numerically tested each of these factors for their role in determining the depth to which the ZSF penetrates into the subsurface, and their impacts on the thermal regime of urban aquifers. Finally, these factors are considered in relation to geothermal energy usage with the aim of de-risking the development of shallow ground source heating and cooling systems.