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Backtracking urbanization from borehole temperature

Peter Bayer (1), Jaime A. Rivera (1), Philipp Blum (2), and Ladislaus Rybach (1)

(1) ETH Zurich, Department of Earth Sciences, Zurich, Switzerland (bayer@erdw.ethz.ch), (2) Karlsruhe Institute of Technology (KIT), Institute for Applied Geosciences (AGW), Karlsruhe, Germany

The thermal regime in shallow ground is influenced by various factors such as short and long term climatic variations, atmospheric urban warming, land use change and geothermal energy use. Temperature profiles measured in boreholes represent precious archives of the past thermal conditions at the ground surface. Changes at the ground surface induce time-dependent variations in heat transfer. Consequently, instantaneous and persistent changes such as recent atmospheric climate change or paving of streets cause perturbations in temperature profiles, which now can be found in depths of hundred meters and even more.

In our work, we focus on the influence of urbanization on temperature profiles. We inspect profiles measured in borehole heat exchanger (BHE) tubes before start of energy extraction. These were obtained at four locations in the city and suburbs of Zurich, Switzerland, by lowering a specifically developed temperature logging sensor in the 200-400 m long tubes. Increased temperatures indicate the existence of a subsurface urban heat island (SUHI). At the studied locations groundwater flow can be considered negligible, and thus conduction is the governing heat transport process. These locations are also favorable, as long-term land use changes and atmospheric temperature variations are well documented for more than the last century.

For simulating transient land use changes and their effects on borehole temperature profiles, a novel analytical framework based on the superposition of Green’s functions is presented. This allows flexible and fast computation of the long term three-dimensional evolution of the thermal regime in shallow ground. It also facilitates calibration of unknown spatially distributed parameter values and their correlation. With the given spatial and temporal discretization of land use and background atmospheric temperature variations, we are able to quantify the heat contribution by asphalt and buildings. By Bayesian inversion it is demonstrated that these two factors play a dominant role for the perturbations observed in all profiles. Thus site-specific land use changes reveal to be more relevant for the near surface temperature evolution than long-term climatic changes.