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Urban heat fluxes in the subsurface of Cologne, Germany

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Urbanization during the last hundred years has led to both environmental and thermal impacts on the subsurface. The urban heat island (UHI) effect is mostly described as an atmospheric phenomenon, where the measured above-ground temperatures in cities are elevated in comparison to undisturbed rural regions. However, UHIs can be found below, as well as above ground. A large amount of anthropogenic heat migrates into the urban subsurface, which also raises the ground temperature and permanently changes the thermal conditions in shallow aquifers. The main objective of our work is to study and determine the urban heat fluxes in Cologne, Germany, and to improve our understanding of the dynamics of subsurface energy fluxes in UHIs. Ideally, our findings will contribute to strategic and more sustainable geothermal use in cities. For a quantitative analysis of the energy fluxes within the subsurface and across the atmospheric boundary, two and three-dimensional coupled numerical flow and heat transport models were developed. The simulation results indicate that during the past hundred years, an average vertical urban heat flux that ranges between 80 and 375 mW m-2 can be deduced. Thermal anomalies have migrated into the local urban aquifer system and they reach a depth of about 150 m. In this context, the influence of the regional groundwater flow on the subsurface heat transport and temperature development is comprehensively discussed.