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Comparison of local and regional heat transport processes into the subsurface urban heat island of Karlsruhe, Germany

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Temperatures in shallow urban ground are typically elevated. They manifest as subsurface urban heat islands, which are observed worldwide in different metropolitan areas and which have a site-specific areal extent and intensity. As of right now the governing heat transport processes accumulating heat in the subsurface of cities are insufficiently understood. Based on a spatial assessment of groundwater temperatures, six individual heat flux processes could be identified: (1) heat flux from elevated ground surface temperatures (GST), (2) heat flux from basements of buildings, (3) reinjection of thermal waste water, (4) sewage drains, (5) sewage leakage, and (6) district heating. In this study, the contributions of these processes are quantified on local and regional scales for the city of Karlsruhe in Germany. For the regional scale, the Regionalized Monte Carlo (RMC) method is used. This method applies a single Monte Carlo (MC) simulation for the entire study area. At relatively low data demand, the RMC method provides basic insights into the heat contribution for the entire city. For the local scale, the Local Monte Carlo (LMC) method was developed and applied. This method analyzes all dominant heat fluxes spatially dependent by performing an MC simulation for each arbitrary sized pixel of the study area (here 10 x 10 m). This more intricate approach allows for a spatial representation of all heat flux processes, which is necessary for the local planning of geothermal energy use. In order to evaluate the heat transport processes on a regional scale, we compared the mean annual thermal energies that result from the individual heat flux processes. Both methods identify the heat flux from elevated GST and the heat flux from buildings as the dominant regional processes. However, reinjection of thermal wastewater is by far the most dominant local heat flux processes with an average heat flux of 16 ± 2 W/m^2 in the affected areas. Although being dominant on the regional scale, fluxes from elevated GST and buildings only contribute with minor heat fluxes of 0.1 ± 0.3 W/m^2 and 0.7 ± 0.8 W/m^2, respectively, which clearly shows that such differences in heat fluxes should be carefully considered for the site specific and local planning of geothermal installations.