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Link between Surface and Subsurface Urban Heat Islands

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Urban heat islands exist in all diverse layers of modern cities, such as surface and subsurface. While both layers are typically investigated separately, the coupling of surface and subsurface urban heat islands is insufficiently understood. Hence, this study focuses on the interrelation of both zones and the influence of additional underground heat sources, such as heated basements, on this interaction. Using satellite derived land surface temperatures and interpolated groundwater temperature measurements the spatial properties of both heat islands are compared. Significant correlations of 0.5 up to more than 0.8 are found between surface and subsurface urban heat islands. If groundwater flow is considered this correlation increases by approximately 10%. Next we analyzed the dissimilarities between both heat islands in order to understand the interaction between the urban surface and subsurface. We find that local groundwater hotspots under the city center and industrial areas are not revealed in satellite derived land surface temperatures. Overall groundwater temperatures are higher than land surface temperatures in 95% of the analyzed area due to the influence of below ground anthropogenic heat sources such as sewage systems, district heating systems, and especially elevated basement temperatures. Thus, an estimation method is proposed that relates groundwater temperatures to mean annual land surface temperatures, building density, and elevated basement temperatures. Using this method regional groundwater temperatures can be accurately estimated with a mean absolute error of 0.9 K.
Since land surface temperatures and building densities are available from remote sensing, this method has the potential for a large scale estimations of urban groundwater temperatures. Thus, it is feasible to detect subsurface urban heat islands on a global level and to investigate sustainable geothermal potentials using satellite derived data.