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Investigating the subsurface urban heat island of Paris

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The thermal conditions beneath cities are special. Multiple anthropogenic heat sources interact with the shallow ground and generate large-scale subsurface urban heat islands with regionally increased temperatures. Major heat sources are paved ground, buildings, tunnels, sewage and district heating systems, which continuously feed the subsurface with heat that accumulates in soil and groundwater. Accordingly, the heat input tends to be highest where the degree of urbanization is highest and heat is emitted over a long time period, such as in old city centers. We analyze the subsurface of Paris, France, applying a new approach to estimate groundwater temperatures from recent satellite data. The estimations are validated by available in-situ measurements of groundwater temperatures. The approach combines existing remote-sensing based techniques for the prediction of groundwater temperaures in rural and urban areas by taking into account the land surface temperature, evapotransipration, snow cover, building density and basement temperature. This enables to account for diverse land use types in the broader region of Paris such as forests, green spaces, and built-up areas. In the subsurface urban heat island of Paris, which has a maximum positive thermal anomaly (or intensity) of around 7 K in the city center, using this approach we were able to estimate GWTs with a RMSE below 1 K (0.96 K). Overall, GWTs are only slightly underestimated with a mean error of -0.23 K. This approach improves existing estimation procedures and can be adopted to other cities or climates, which will help to obtain higher reliability and deeper knowledge of the spatial distribution of subsurface temperatures in urban and semi-urban environments.