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Impact of Subsurface Thermal Anomalies on Air Temperatures in Idealized Scenarios Using PALM-4U

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The impact of underground heat (or cold) sources such as man-made infrastructures or geothermal systems have been extensively studied in geosciences. Soil temperatures near underground parking garages may be up to 10 K warmer than their surroundings. However, the coupling between these temperature anomalies in the soil and the atmosphere as a bottom-up scheme has been neglected so far. We investigated how this scenario can be modeled in the turbulence and building resolving large eddy simulation urban climate model PALM-4U and assessed the impact of modified soil temperatures on air temperatures in an idealized domain. Hereby, the soil temperatures at 2-meter depth were increased and decreased by 5 K, respectively. Multiple scenarios were considered, differentiating between cyclic and Dirichlet/radiation boundary conditions along the x-axis. Further, we ran the simulations under summer and winter conditions, day and night, and three land cover types which are bare soil, short grass, and tall grass. After three days of simulation time, cyclic boundary conditions induced air temperature anomalies due to changes in the subsurface temperature. However, Dirichlet/radiation boundary conditions did not show alterations. Analyzing the cyclic scenarios, although the absolute air temperature was significantly influenced by the landcover, the magnitude of the air temperature anomaly shows little variation. Daytime and seasonality exerted a greater influence on the magnitude. The greatest positive near-surface air temperature anomaly when increasing the soil temperature was 0.38 K for all land cover types and develops during winter between 09:00 and 10:00 CET. Smallest influence was found during summer at 09:00 CET, where increased soil temperatures resulted in a 0.02 K rise over short- and tall grass, and 0.18 K over bare soil. Conversely, decreasing soil temperatures showed predominantly inverse patterns.

The findings contribute to the general comprehension of the coupling of soil- and atmospheric temperatures, inferring also insights of simulating idealized but reality-oriented scenarios in PALM-4U.