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Investigating the causes of the Urban Heat Island effect in Rotterdam using WRF

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The meteorology of the Dutch coastal town Rotterdam has been simulated for three consecutive days during a heat wave in August 2009. In this period, the Urban Heat Island (UHI) effect for Rotterdam was relatively strong, amounting to a temperature difference between the urban and rural areas of about 6 o C. The meteorology of Rotterdam is very complex is governed by a multiple processes such as the interaction between the sea and the land, the availability of open water close to the city centre and the influence of nearby large towns such as Dordrecht and The Hague. Therefore, detailed simulations of the urban meteorology of Rotterdam have been performed with the Weather Research & Forecasting (WRF) model, which incorporates a detailed description of the exchange processes between the urban surface and the overlying atmosphere, the so-called SLUCM model. Simulated temperatures are compared to measurements taken by hobby meteorologists within the urban area of Rotterdam and synoptic measurements taken at a SYNOP weather station in the rural areas outside Rotterdam. It appears that the meso-scale model WRF is able to simulate the temperatures within the urban area of Rotterdam and the rural station outside Rotterdam, especially during the late afternoon and during nighttime conditions. The model results reveal that the main cause of the UHI in Rotterdam is the evident daily cycle of the energy flux between the surface and the underlying material. It appears that during daytime the urban surface of the city of Rotterdam takes up about 200 W/m2, a value that is considerably higher than the value of the ground heat flux at the rural site where during daytime only 50 W/m2 is taken up by the vegetation and underlying soil. At night, part of the heat that is absorbed by the surface during daytime is released again to the atmosphere explaining the observed higher temperature in the urban areas during nighttime as compared to the rural areas. Another energy source for the urban atmosphere during nighttime, is the energy release from anthropogenic sources such as industrial plants, traffic and houses. We find that prescribing the city-averaged anthropogenic heat flux to 38 W/m2, the impact of anthropogenic sources is relatively minor: about 0.5 oC. However, locally the anthropogenic heat release can however be much higher than the mean for the municipality. Therefore, additional calculations are performed using both the 3D and the 1D version of the WRF meso-scale model. As such, we investigate how the spatial variability of the temperature at screen level depends on the spatial variability of the anthropogenic heat release. We conclude that, although on average the effect of anthropogenic sources is relatively small, it can be expected to have important local effects in locations where these anthropogenic sources produce larger amounts of energy.