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Investigation of urban-induced mesoclimatic anomalies in the lower atmosphere over Moscow megacity based on simulations with COSMO-CLM model for multiple summers

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Urbanization leads to distinct meteorological anomalies such as well-known urban heat island (UHI) effect. For megacities, these anomalies become mesoscale phenomena (scale $\geq$ 10km) that extends to atmospheric boundary layer (ABL), are amplified by the tropospheric feedbacks and have substantial implications on human well-being. However, the number of studies devoted to urban-caused climate phenomena that takes the lower troposphere into consideration is much smaller than those focusing only on the near-surface climate anomalies. And the most part of the such studies is based only on episodic observations (case-studies), which have the insufficient timespan for making conclusions on urban-climate statistics.
Recent developments in field of numerical weather modelling have opened new opportunities to study these urban-induced mesoscale features in a systematic way towards the climatological timescale. In this study, for the first time, a three-dimensional statistical description the megacity-induced meteorological anomalies extending towards the lower troposphere is acquired based on long-term (for multiple summers) and high-resolution (1 km) simulations for Moscow megacity with the COSMO-CLM model with and without its urban canopy model TERRA_URB (Wouters et al., 2016). The details of simulations are described in (Varentsov et al., 2017).
Our results confirm the features from previous observational and modelling studies, including the "boundary layer" UHI itself, the cold anomaly above established at night by the so-called cross-over effect, the urban dry/moist islands (UDI/UMI) and the urban breeze mesoscale circulation. Particularly, the UHI shows a strong diurnal variation in terms of intensity/vertical extent between daytime ($\approx$0.5K/$\approx$1.5 km), evening ($\approx$1.5K/$\approx$1.5 km) and nighttime (>3K/$\approx$150 m). Such results agree with existing estimates for Moscow, including the newest observations by the network of MTP-5 microwave temperature profilers.
Moreover, we have discovered a systematic veering of the UHI spatial pattern established by the wind and Coriolis effect, and an enhanced stable stratification of the rural surroundings established by the urban heat plumes further downwind. Finally, a substantial increase of summer precipitation (up to +25%) and daytime cloud cover is found over the city center and its leeward side. Our results highlight that these urban-caused mesoclimatic anomalies need to be taken into account in various weather and climate services, including weather and air quality forecasts, biometeorological applications and the design of future megacities.
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