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Impact of the boundary-layer low-level jet on the three-dimensional structure of the urban heat island in Beijing, China

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The boundary-layer low-level jet (LLJ) is a widespread wind phenomenon that can strongly affect urban heat islands (UHIs). However, the influence of LLJ on the three-dimensional structure of UHI remains poorly understood. Thus, in this study, we focused on the impacts of boundary-layer LLJs on the horizontal distribution, vertical development, and three-dimensional structure of UHIs. Observational data for the surface values of meteorological parameters were collected from 376 automatic weather stations (AWSs) in Beijing and its surrounding areas. Vertical profiles of the atmospheric boundary layer were also obtained from a field sounding campaign conducted in Beijing from August 28 to September 2, 2016. In addition, we also performed three-dimensional model simulations using the Weather Research and Forecasting (WRF) model to capture the change of meteorological parameters. The conclusions achieved in the present study are as follows:

(1) When a LLJ occurs in Beijing, the Richardson number *Ri* was found to be smaller than 0.25 at all these urban and suburban stations. As *Ri* represents the stability of the whole atmosphere, it can indicate the influence of upper winds on the horizontal distribution of the canopy UHI. When *Ri* <0.25 and LLJ occurs, the momentum is transmitted downwards, leading to the increase of the wind speed near the ground. This enlarged wind speed would carry the heat from urban areas downwards to the suburban regions, resulting in a downwind drift of the canopy UHI position and a expansion of the UHI area by approximately 1,000 km^2. (2) It was also found that when a LLJ occurs, the vertical mixing above the urban area is enhanced, with a TKE up to 0.52 m^2/s^2 near the ground. This enhanced vertical mixing causes a decrease in the lapse rate of the temperature in the urban area. The lapse rate when LLJ presents (0.3°C/100m) is less than half of that when LLJ is absent (0.7°C/100m). Under this condition, the height of the heat island also elevates up to approximately 200m. (3) We found that the LLJ is capable of increasing the temperature of the downwind urban area by a maximum of 8.5°C/h through the warm advection. The temperature advection in the upper air caused by LLJ also tilted the three-dimensional structure of UHI. As a result, the heat island behaves as a plume under the influence of LLJ.