Introduction

Anthropogenic heat (AH) is an important component of the urban energy budgets that can affect land surface and atmospheric boundary layer processes. Representation of anthropogenic heat in numerical climate modeling systems is, therefore, important when simulating urban meteorology and climate, and has the potential to improve weather forecasts, climate process studies, and energy demand analysis.

Our objective is to study the sensitivity of simulated precipitation to AH, to evaluate the impact that AH has on model performance relative to available observations, and to investigate mechanisms through which AH influences the convective environment.

WRF-UCM-BEM Experiment

We incorporate spatiotemporally dynamic anthropogenic heat data estimated by the Building Effects Parameterization and Building Energy Model (BEP-BEM) into the Weather Research and Forecasting system (WRF) to investigate its impact on simulation of summertime rainfall in Beijing, China.

Four summertime local rainfall events are selected and simulations are conducted with and without anthropogenic heat.

Results and Discussion

1. AH Spatiotemporal pattern

- The area of higher building density has higher AH values.
- The peak of AH appears in the late afternoon, reflecting the timing of maximum air-conditioning loads.

2. Urban Energy Balance

- AH influence on the atmosphere is primarily via sensible heat.
- The peak area of sensible heat increase is located in the commercial area, which is consistent with the spatial pattern of AH.

3. Atmospheric boundary layer

- Urban averaged PBL heights in the pre-storm period in Ahw are systematically greater than Ahon.
- Greater atmospheric dry-down and a higher post-storm LCL are found in Ahw. AH impacts on pre-storm MSE density within PBL are negligible, as the contribution of AH to thermal energy (c_\text{B}) is approximately counterbalanced by the evaporation of the PBL and associated entrainment of lower energy air from the free troposphere.

- Stronger upward motion before the onset of precipitation.
- Enhanced convergence due to AH are more likely to generate over the interface of three urban land covers and urban-rural borders possibly due to the flux gradients.

4. Atmospheric stability

AH increases rainfall in the urban area and surroundings. However, it influences rainfall through multiple mechanisms. In event 1 and 3, AH causes the PBL to deepen to the LCL faster in Ahw than Ahon, there can be an earlier onset of rainfall, while in event 2 and 4, entrainment at the top of the PBL can delay the onset of rainfall, but destabilization of the lower atmosphere due to AH eventually leads to more total rainfall.

5. Cumulative Rainfall

Fig.9 Urban averaged and domain 3 (D3) averaged cumulative rainfall in Ahw and Ahon for each event.

Conclusion

Anthropogenic heat emission increases sensible heat flux, enhances mixing and turbulent energy transport, lifts PBL height, increases dry static energy and destabilizes the atmosphere in urban areas through thermal perturbation and strong upwelling motion during the pre-storm period, resulting in enhanced convergence during the major rainfall period. Intensified rainfall leads to greater atmospheric dry-down during the storm and a higher post-storm LCL.

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References