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Understanding the influence of urban form on the spatial pattern of precipitation

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Urban areas are known to modify the spatial pattern of precipitation climatology. Existing observational evidence suggests that precipitation can be enhanced downwind of a city, albeit other locations of precipitation enhancement have also been reported. Among the proposed mechanisms that modify the precipitation, the thermodynamic and aerodynamic processes in the urban lower atmosphere interact with the synoptic conditions and could play a key role in determining the resulting spatial variability of precipitation. In addition, these processes are intricately shaped by urban form characteristics, such as the spatial extent of the impervious land. This study aims to unravel how different urban forms impact the spatial organizations of precipitation climatology under different synoptic conditions. We use the Multi-Radar Multi-Sensor (MRMS) quantitative precipitation estimation data products and analyze the hourly precipitation maps for a selected set of cities across the continental United States from the years 2015 to 2021. Results suggest that a statistically significant downwind enhancement of precipitation does exist in about four-fifths of these cities, while the magnitude is comparable to previous findings. Additionally, we find that the precipitation distribution tends to be more clustered for higher wind speed; the location for precipitation maxima is located closer to the city center under low synoptic winds but shifts towards the urban-rural interface under high wind conditions. The magnitude of downwind precipitation enhancement is highly dependent on wind directions and is positively correlated with the city size for the south, southwest, and west directions. This study provides observational proof through a cross-city analysis that the spatial pattern of urban precipitation can be attributed to the modified atmospheric processes by distinct urban forms.