

# Urbanization Impact on Regional Climate and Extreme Weather: Current Understanding, Uncertainties, and Future Research Directions

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## ABSTRACT

Urban environments lie at the confluence of social, cultural, and economic activities and have unique biophysical characteristics due to continued infrastructure development that generally replaces natural landscapes with built-up structures. The vast majority of studies on urban perturbation of local weather and climate have been centered on the urban heat island (UHI) effect, referring to the higher temperature in cities compared to their natural surroundings. Besides the UHI effect and heat waves, urbanization also impacts atmospheric moisture, wind, boundary layer structure, cloud formation, dispersion of air pollutants, precipitation, and storms. In this review article, we first introduce the datasets and methods used in studying urban areas and their impacts through both observation and modeling and then summarize the scientific insights on the impact of urbanization on various aspects of regional climate and extreme weather based on more than 500 studies. We also highlight the major research gaps and challenges in our understanding of the impacts of urbanization and provide our perspective and recommendations for future research priorities and directions.

**Key words:** urbanization, regional climate, extreme weather, urban heat island, urban flooding

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## Article Highlights:

- As urban areas expand and populations grow, we urgently need to better understand cities and their interactions with weather and climate.
- Urbanization can impact heat waves, atmospheric moisture, clouds, wind patterns, air pollution, boundary-layer, precipitation, and storms.
- Research gaps due to complexity of urban areas and deficiencies in current methods are identified and future priorities are highlighted.

## 1. Introduction

Cities are the nexus of modern social, cultural, and economic activities, and they have unique biophysical, morphological, and thermodynamic properties due to the physical process of urbanization, where natural landscapes are replaced

by buildings, roads, parking lots, etc. (built-up structures). Urban areas are also centers of resource utilization, with high energy and water consumption (Chen and Chen, 2016), which lead to anthropogenic heat fluxes (Zhang et al., 2013) and greenhouse gas and aerosols emissions (Fig. 1). These characteristics and activities give rise to unique urban climates from micro to regional scales (Oke, 1981; Arnfield, 2003; Kalnay and Cai, 2003; Rizwan et al., 2008; Feng et al., 2012; Yan et al., 2016; Chapman et al., 2017a; Oke et

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