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Urbanization signature in the observed heavy rainfall climatology over India

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ABSTRACT: We assess the urbanization impacts on the heavy rainfall climatology during the Indian summer monsoon. While a number of studies have identified the impact of urbanization on local precipitation, a large-scale assessment has been lacking. This relation between urbanization and Indian monsoon rainfall changes is investigated by analyzing *in situ* and satellite-based precipitation and population datasets. Using a long-term daily rainfall dataset and high-resolution gridded analysis of human population, this study showed a significantly increasing trend in the frequency of heavy rainfall climatology over urban regions of India during the monsoon season. Urban regions experience less occurrences of light rainfall and significantly higher occurrences of intense precipitation compared to nonurban regions. Very heavy and extreme rainfall events showed increased trends over both urban and rural areas, but the trends over urban areas were larger and statistically more significant. Our analysis suggests that there is adequate statistical basis to conclude that the observed increasing trend in the frequency of heavy rainfall events over Indian monsoon region is more likely to be over regions where the pace of urbanization is faster. Moreover, rainfall measurements from satellites also indicate that urban areas are more (less) likely to experience heavier (lighter) precipitation rates compared to those in nonurban areas. While the mechanisms causing this enhancement in rainfall remain to be studied, the results provide the evidence that the increase in the heavy rainfall climatology over the Indian monsoon region is a signature of urban-induced rainfall anomaly. Copyright © 2009 Royal Meteorological Society

KEY WORDS land use land cover change; Indian monsoon; population growth; precipitation; urbanization; climate change

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1. Introduction

The Indian summer monsoon is a giant feedback system involving interactions between land, ocean, and the atmosphere. The Indian summer monsoon rainfall (ISMR), defined here as the cumulative rainfall over continental India during June–July–August–September (JJAS), also has important implications on the socioeconomic system of the subcontinent. For example, the domestic crop yield in India has traditionally been linked to the ISMR (Parthasarathy, 1984); the agricultural sector accounts for about a quarter of India's gross domestic product and 60% of the labor force. The initiation of the cross-equatorial flow off the Somalia coast of Africa during May in response to heating over the South Asian continent marks the beginning of the summer monsoon evolution process over the Arabian Sea.

The analysis of 100 years of surface rainfall observations over the Indian monsoon region suggests that the mean monsoon seasonal rainfall has not changed significantly (Goswami *et al*., 2006), but several locations across India show an increasing trend in heavy rainfall occurrence (>70 mm/day) during the summer monsoon season (Sinha Ray and Srivastava, 2000). The increase in extreme rainfall (>120 mm/day) events during the Indian monsoon has been particularly strong in the last 50 years (Goswami *et al*., 2006).

Parallel to these climatic changes, the Indian landscape has also been rapidly urbanizing. In the present study, we seek to assess if there is a relation between urbanization and the occurrence of heavy rainfall events during the Indian summer monsoon. This relation between urbanization and Indian monsoon rainfall changes is examined by analyzing satellite observations, surface-based precipitation data, and population datasets.

2. Background

With half the global population now living in cities and the urban infrastructure of the world expected to double over the next 35 years, urban environments are playing

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