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Effect of explicit urban land surface representation on the simulation of the 26 July 2005 heavy rain event over Mumbai, India

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Abstract. We investigate whether explicit representation of the urban land surface improves the simulation of the record-breaking 24-h heavy rain event that occurred over Mumbai, India on 26 July 2005 as the event has been poorly simulated by operational weather forecasting models. We conducted experiments using the Regional Atmosphere modeling system (RAMS 4.3), coupled with and without explicit urban energy balance model-town energy budget (TEB) to study the role of urban land – atmosphere interactions in modulating the heavy rain event over the Indian monsoon region. The impact of including an explicit urban energy balance on surface thermodynamic, boundary layer, and circulation changes are analyzed. The results indicate that even for this synoptically active rainfall event, the vertical wind and precipitation are significantly influenced by heterogeneity in surface temperatures due to urbanization, and the effect is more significant during the storm initiation. Interestingly, precipitation in the upwind region of Mumbai city is increased in the simulation, possibly as a feedback from the sea breeze – urban landscape convergence. We find that even with the active monsoon, the representation of urbanization contributes to local heavy precipitation and mesoscale precipitation distribution over the Indian monsoon region. Additional experiments within a statistical dynamical framework show that an urban model by itself is not the dominant factor for the enhanced rainfall for a Mumbai heavy rain event; the combination of updated SST fields using Tropical Rainfall Measurement Mission (TRMM) data with the detailed representation of urban effects simulated by the TEB model created realistic gradients that successfully maintained the convergence zone over Mumbai. Further research will require more detailed morphology data for simulating weather events in such urban regions. The results suggest that urbanization can significantly contribute to extremes in monsoonal rain events that have been reported to be on the rise.

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1 Introduction

On 26 July 2005, an unexpected heavy precipitation event occurred over the Mumbai urban region and adjacent areas. A steady downpour initiated around 11:00 a.m. local time (06:00 UTC), and several regions within a 100 km area showed an unprecedented amount of rainfall over the following 24-h period. For instance, the Santacruz India Meteorological Department (IMD) official rainfall data recorded a record-breaking 944 mm 24-h rainfall total. Storm reports recorded locations in north Mumbai that received around 1000 mm of rainfall. The event also showed remarkable variability between locations, with stations in southern Mumbai receiving from a trace to ∼74 mm of rain at another IMD rainfall gauge at Colaba (25 km south of Santacruz). The event caused nearly 500 deaths and is classified as a billion US Dollars natural disaster (NCDC, 2007).

Most forecasting models did not successfully predict this heavy rain event. This event is being studied by a number of forecasting groups and teams to improve model performance and subsequently, forecast accuracy. Chang et al. (2008) used a MM5 and WRF model to simulate this event and found that the MM5 could reproduce about 40–60% of the Mumbai rainfall, while the WRF simulated about 60–80% of the observed precipitation. Bohra et al. (2006) documented the India National Center for Medium Range Weather Forecasting