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Analysis of the 26 July 2005 heavy rain event over Mumbai, India using the Weather Research and Forecasting (WRF) model

Anil Kumar,[a,b] J. Dudhia,[a] R. Rotunno,[a] Dev Niyogi[b]* and U. C. Mohanty[c]
[a]*National Center for Atmospheric Research, Boulder, Colorado, USA*
[b]*Purdue University, Department of Earth and Atmospheric Science, West Lafayette, Indiana, USA*
[c]*Indian Institute of Technology, Centre for Atmospheric Sciences, Delhi, India*

ABSTRACT: A case-study of the 26 July 2005 Mumbai heavy-rain event that recorded 944 mm rainfall in 24 h with significant spatial variability was carried out using the Weather Research and Forecasting (WRF) model. The event was poorly forecasted by operational models and resulted in large human and economic losses. The present results indicate that the WRF system was able to reproduce the heavy rainfall event and the associated dynamical and thermo- dynamical features. A number of experiments were conducted with the WRF model that suggest the highly localized, heavy rain was the result of an interaction of synoptic-scale weather systems with the mesoscale, coastal land-surface features. These experiments indicate that the large-scale rising motion over the Mumbai region was synoptically forced. Analysis of the model-simulated intense, but short-lived, convective rain cells forming in the large-scale rising motion over Mumbai traces their moisture source to the north and northwesterly flow from the Arabian Sea. Synthetic sensitivity simulations without topography and without a land surface (land replaced with water) show that the large-scale synoptic flow positioned the low-pressure system over the Arabian Sea, while the mesoscale land-surface (including topography and latent heating) feedback modulated the location and intensity of the rain by changes in the winds and regional moisture convergences. Another important feature captured in the high-resolution model analysis is the formation of a mesoscale vortex over Mumbai that appears to have enhanced the conditions for localized, heavy rainfall over Mumbai.

KEY WORDS Western Ghats; mesoscale model; land surface processes; Indian summer monsoon

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1. Introduction

On 26 July 2005, an official India Meteorological Department (IMD) rain-gauge at Santacruz International Airport (19.11 °N, 72.85 °E) on the north side of the metropolis Mumbai (18 °56′N, 72 °51′E), located on the west coast of India, recorded a 944 mm 24 h accumulated rainfall (0300 UTC 26 July to 0300 UTC 27 July 2005). Mumbai, influenced by the Western Ghats mountains that run parallel to the Indian coast, normally receives heavy rainfall during the summer monsoon; however, several features make the 26 July 2005 event unique. First, the rainfall amount of 944 mm is thus far a record amount for a single-day rain event for a megacity (population over 10 million) such as Mumbai†. Second, it exceeds some of the heaviest single-day rainfall amounts over the Western Ghats region and Mumbai (Santacruz) such as 375 mm on 5 July 1975, 318 mm on 23 September 1981, 399 mm on 10 June 1991 and 346 mm on 23 August 1997 (Jenamani et al., 2006). Third, the rainfall was highly localized with the majority of the rain occurring over northern Mumbai with no comparable amounts occurring in the surrounding region. An IMD observatory in northern Mumbai (Santacruz) showed 944 mm of rain, while the other official observatory about 27 km away in southern Mumbai (Colaba) received only 73 mm of rain for the same event. Another feature which makes this event interesting is the availability of observations from *in situ* and satellite sources, such as the Tropical Rainfall Measuring Mission (TRMM). Further, the operational models were unable to simulate the magnitude, location and extent of such heavy rains, making the study of the processes associated with this event additionally important (Bohra et al., 2006; Sikka and Rao, 2008).

Several factors have been identified that can potentially affect the timing, location, and intensity of heavy rains during an Indian monsoon. The strong winds of the southwest monsoon (Somali Jet), carrying the moisture-laden monsoon air from the Arabian Sea, are orographically lifted when they encounter the Western Ghats (Sarker, 1967; Saha, 1974). Grossman and Durran (1984) concluded that the Western Ghats are capable of

*Correspondence to: Dev Niyogi, Purdue University, 915 W. State Street, West Lafayette, IN 47906, USA
E-mail: climate@purdue.edu
†Mumbai is the most populated city and the commercial capital of India; this rain event caused 409 deaths and an unprecedented loss of $1 billion to the socio-economic sector (Jenamani et al., 2006).