

# Simulation of heavy rainfall events over Indian monsoon region using WRF-3DVAR data assimilation system

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**Abstract** We present the results of the impact of the 3D variational data assimilation (3DVAR) system within the Weather Research and Forecasting (WRF) model to simulate three heavy rainfall events (25–28 June 2005, 29–31 July 2004, and 7–9 August 2002) over the Indian monsoon region. For each event, two numerical experiments were performed. In the first experiment, namely the control simulation (CNTL), the low-resolution global analyses are used as the initial and boundary conditions of the model. In the second experiment (3DV-ANA), the model integration was carried out by inserting additional observations in the model's initial conditions using the 3DVAR scheme. The 3DVAR used surface weather stations, buoy, ship, radio-sonde/rawinsonde, and satellite (oceanic surface wind, cloud motion wind, and cloud top temperature) observations obtained from the India Meteorological Department (IMD). After the successful inclusion of additional observational data using the 3DVAR data assimilation technique, the resulting reanalysis was able to successfully reproduce the structure of convective organization as well as prominent synoptic features associated with the mid-tropospheric cyclones (MTC). The location and intensity of the MTC were better simulated in the 3DV-ANA as

compared to the CNTL. The results demonstrate that the improved initial conditions of the mesoscale model using 3DVAR enhanced the location and amount of rainfall over the Indian monsoon region. Model verification and statistical skill were assessed with the help of available upper-air sounding data. The objective verification further highlighted the efficiency of the data assimilation system. The improvements in the 3DVAR run are uniformly better as compared to the CNTL run for all the three cases. The mesoscale 3DVAR data assimilation system is not operational in the weather forecasting centers in India and a significant finding in this study is that the assimilation of Indian conventional and non-conventional observation datasets into numerical weather forecast models can help improve the simulation accuracy of meso-convective activities over the Indian monsoon region. Results from the control experiments also highlight that weather and regional climate model simulations with coarse analysis have high uncertainty in simulating heavy rain events over the Indian monsoon region and assimilation approaches, such as the 3DVAR can help reduce this uncertainty.

## 1 Introduction

The west coast of India routinely receives very heavy rainfall (defined as more than 125 mm per day) during the southwest monsoon. The heavy rainfall events are often a result of quasi-stationary mid-tropospheric cyclones (MTC; wavelength  $\sim 1,000$  km) that are common over the north-eastern part of the Arabian Sea and the west coast of India (Sikka and Gadgil 1980). The dynamics and development of MTC over the Indian monsoon region has been extensively studied (Ramage 1966; Miller and Keshavamurthy 1967; Sadler et al. 1968; Krishnamurti and Hawkins 1970;

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