Simulation of a Heavy Rainfall Episode Over the West Coast of India Using Analysis Nudging in MM5

Someshwar Das[1], Jimy Dudhia[2], D. M. Barker[2] and M. Moncrieff[2]

[1]National Center for Medium Range Weather Forecasting, New Delhi – 110003
[2]National Center for Atmospheric Research, Boulder, CO - 80307

1. Introduction

Several heavy rainfall episodes occurred over the west coast of India during monsoon-2002. Rainfall values as much as 54 cm/day were recorded at some of the places during the period. The T80 global forecast model of the National Centre for Medium Range Weather Forecasting (NCMRWF), hereafter referred to as MRF model, was unable to forecast the intensity of the rainfall as observed. In order to forecast the intensity and structure of heavy rainfall events, a high resolution mesoscale model (MM5) is used at NCMRWF. The MM5 model is run operationally using the input boundary conditions from the MRF model. Presently, the data assimilation is carried out only with the MRF model using a Spectral Statistical Interpolation (SSI) method. The mesoscale model does forecast a better distribution of rainfall than the MRF model, however, sometimes the location of maximum rainfall is misplaced as compared to observations. In order to rectify this problem, experiments have been conducted to investigate the impact of analysis nudging using conventional and non-conventional observations at high resolution in the mesoscale model.

Section 2 describes the basic features of the MM5 model used at NCMRWF. The synoptic conditions leading to the heavy rainfall event is described in the third section. Finally, the results and conclusions are presented in the section 4 and 5.

2. MM5 Model Configuration

The MM5 model is a 5th generation PSU/NCAR Mesoscale Model (limited area), non-hydrostatic, terrain-following sigma coordinate, designed to simulate or predict mesoscale & regional scale atmospheric circulation (Dudhia et al, 2002). The model has been adapted for real time mesoscale weather forecasting at NCMRWF (Das, 2002). It is run on triple-nested domains at 90, 30 and 10 km resolutions. The model is run using the Grell scheme (Grell et al., 1994) for cumulus parameterization and, a non local closure scheme for the boundary layer parameterization. Explicit treatment of cloud water, rain water, snow and ice has been performed using the simple ice scheme of Dudhia (1996). Cloud radiation interaction is allowed between explicit cloud and clear air (IFRAD=2). The initial and lateral boundary conditions are obtained from the operational global T80 model of NCMRWF.

A multiquadric interpolation scheme is used for mesoscale analysis during the four dimensional data assimilation/ nudging (hereafter referred to as FDDA). The multiquadric scheme uses a hyperboloid radial basis functions to perform the objective analysis (Nuss and Titley, 1994).

3. Synoptic Conditions & Experiments

Heavy to very heavy rainfall was recorded on 26, 27 and 28 June 2002 over the west coast of India and inland stations of Maharastra and Gujarat. Rainfall ranging from 2-54 cm/ day were recorded at many places over the region. Fig. 1 depicts the cloud imagery and observed rainfall on 28th June 2002.

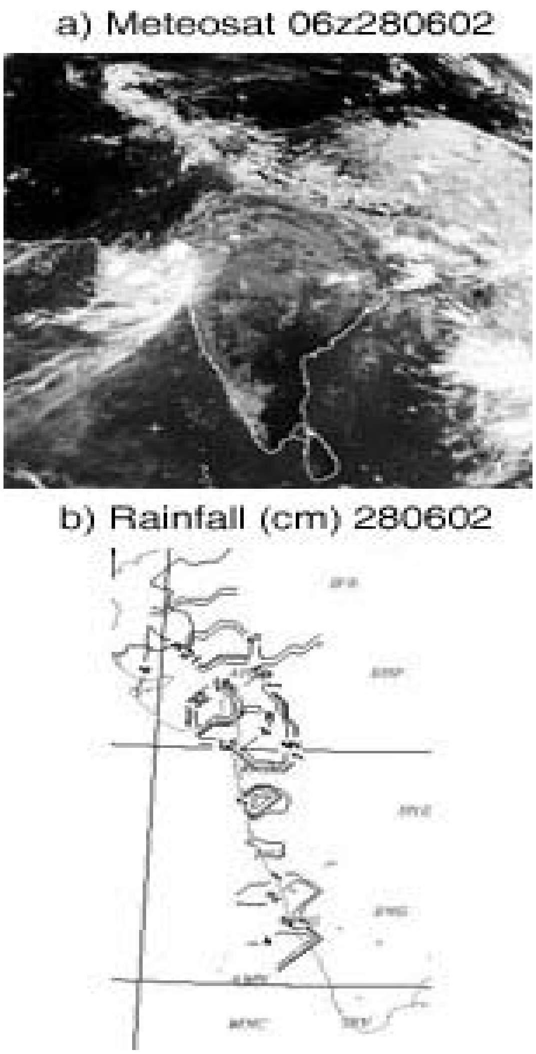

Fig. 1: (a) IR cloud imagery at 06 UTC, 28th June 2002 from METEOSAT and (b) observed rainfall in cm from rain gauge.

An off-shore trough at sea level extending from Maharastra coast to Kerala coast was observed on all days (26-28 June). The heavy precipitation occurred as a result of a low pressure system moving from the head Bay of Bengal to Maharastra and Gujarat and the off shore trough in which a vortex formed off Gujarat coast in the Arabian sea.

Observations from a wide variety of sources such as radiosonde, pilot wind, synoptic stations, drifting buoys, aircraft reports, high resolution cloud motion vectors from METEOSAT and INSAT, temperature and moisture profiles from TOVS, wind speed and total precipitable water from SSMI carried aboard the DMSP satellites are assimilated in the T80 global data assimilation system of the NCMRWF. The assimilated data is used by the T80 model for medium-range weather forecasting. In the present study, three sets of 72 hours forecasts are made from the MM5 model using the initial conditions of 25 June 2002. The experiments are summarized in the table-1.

Table 1: Summary of Experiments

Experiments	Description
1. CTRL	Control
2. FDDA-UA	3D Analysis Nudging
3. FDD-UASF	3D Analysis Nudging with surface data

The first run known as control (CTRL) is carried out using the input boundary conditions from the forecast

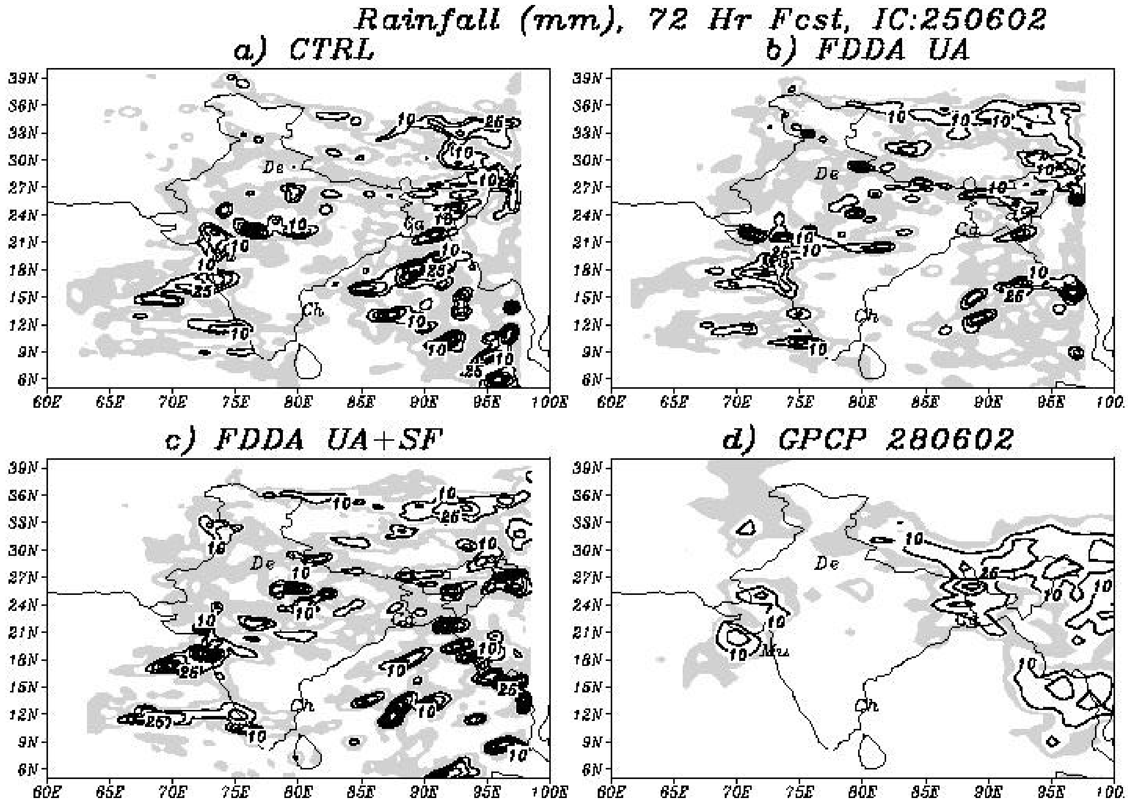

Fig. 2: Rainfall forecasts for 72 hours valid on 00 UTC, 28 June 2002, (a) CTRL (b) FDDA-UA (c) FDDA UA+SF, and (d) observed values from GPCP.

files of the global model. The second run called FDDA-UA is carried out by reanalyzing the observations at 90 and 30 km resolutions of the MM5 model and grid nudging of upper air data at 12 hours interval for the initial 24 hours. The third experiment FDDA-UASF is similar to the second experiment, but including the surface data also in the nudging process. All the observations mentioned earlier are utilized in the high resolution analysis.

In the grid nudging, Newtonian relaxation terms are added to the prognostic equations for wind, temperature and moisture fields. The model linearly interpolates the analyses in time to determine the value towards which the model relaxes its solution. The model values are relaxed towards the analysis using the nudging terms. The nudging is performed for 24 hours before the forecast is made from the model.

4. Results & Discussion

Fig. 2 (a, b & c) illustrates the 72 hours rainfall forecast obtained from the three experiments based on the initial condition of 00 UTC, 25 June 2002. Values less than 10 mm day^{-1} are shaded in the diagrams. Contours are drawn at intervals of 10, 25, 50, 75, 100, 150, 200, 250 and 300 mm day^{-1}. The diagram (Fig. 2d) also shows rainfall derived from the Global Precipitation Climatology Project (GPCP).

It is noted that the GPCP values are highly underestimated as compared to the observed rainfall (Fig. 1b). The magnitude of GPCP rainfall over land depends on the number of rain gauge reports available during the analysis. Moreover, the GPCP values are very coarse analysis at 2.5 x 2.5 degree resolution, whereas the model forecasts are at 30 km resolution. The analysis based on rain gauge data (Fig. 1b) also may not represent the true picture as it is based on the available reports from the GTS. None of the diagrams show the rainfall value of 54 cm as recorded at some of the stations over Gujarat region. Nevertheless, all the diagrams show an area of heavy rainfall over the west coast Gujarat region. The MM5 forecasts show the mesoscale structure of the variation of rainfall. The amounts have increased in the FDDA experiments. The FDDA-UA produced significant improvement in the rainfall forecast as seen in the diagram. It also removed excess rainfall produced over the Bay of Bengal in the CTRL. The improved rainfall in FDDA is due to improved initial conditions in the high resolution analysis. Evidently, the third experiment FDDA-UASF does not produce significant improvement over the second experiment except over the Arakan coast of the Bay of Bengal. The magnitude of rainfall is slightly enhanced by including the surface observations in the nudging process. We plan to carry out 3 hourly nudging as well as use 3DVAR assimilation in future.

Conclusion

A mesoscale model (MM5) was used to study heavy rainfall events over the west coast of India during monsoon-2002. The model was run on triple-nested domains at 90, 30 and 10 km resolutions. Three experiments have been conducted to examine the impact of high resolution analysis nudging using conventional (Radiosonde, Pilot and surface data) and non-conventional (satellite data) in the rainfall forecasts. Results indicate that the forecasts are improved when 4-dimensional data assimilation using analysis nudging is performed. The improvement in the rainfall forecasts are due to improved initial conditions produced by the analysis nudging.

References

Das, S., 2002: "Real time mesoscale weather forecasting over Indian region using MM5 modeling system", NCMRWF report no. NMRF/RR/3/2002.

Dudhia, J., D. Gill, K. Manning, W. Wang and C. Bruyere, 2002: PSU/NCAR Mesoscale Modeling System (MM5 version 3) tutorial class notes and user's guide. *Available from the National Center for Atmospheric Research, Boulder, Colorado, USA, June 2002*.

Dudhia, J., 1996: A multi-layer soil temperature model for MM5". *Preprints, The sixth PSU/ NCAR Mesoscale Model User's Workshop, 22-24 July 1996, Boulder, Colorado, 49-50.*

Grell, G.A., J. Dudhia and D.R. Stauffer, 1994: A description of the 5th generation Penn State/ NCAR Mesoscale model (MM5)". *NCAR technical note, NCAR/TN-398+STR, 117 pp, 122.*

Nuss, W. A. and W. D. Titley, 1994: Use of multiquadric interpolation for meteorological objective analysis". *Mon. Wea. Rev., 122, 1611-1631.*