Impact of Doppler Weather Radar Data on Simulation of Indian Monsoon Depressions

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Abstract

The present study highlighting, the impact of assimilation of Doppler Weather Radar (DWR) radial velocity and reflectivity on the prediction of two distinct monsoon depressions (MDs) over Bay of Bengal (BOB) using WRF-Var. DWR data from Kolkata radar are used in WRF-Var assimilation system. For this study, two numerical experiments are carried out. The results show that assimilation of DWR data has a positive impact on prediction of location, propagation and rain bands associated with the MDs. The track errors are significantly reduced in assimilation experiment compared with control simulation.

1. Introduction:

Monsoon depression is one of the most important synoptic scale disturbances on the quasi-stationary planetary scale monsoon trough over the Indian region during the summer monsoon season. MDs are responsible for majority of the heavy rain events and related natural hazards that occur over the Indian monsoon region.

The non-hydrostatic mesoscale models have shown great potential in predicting short-range prediction of extreme weather events associated with meso-convective systems (MCS). Most importantly, the forecast performance of the mesoscale models critically depends on the quality of initial and boundary conditions. The variational data assimilation approach is one of most promising techniques available to directly assimilate heterogeneous observations in order to improve the estimate of the model's initial state. Routray et al. (2005) and Das Gupta et al. (2005) made the attempt to investigate the application of the MM5-three dimensional variational (3DVAR) data assimilation system over Indian region and evaluated the impact of various conventional and non-conventional observations for the prediction of high impact weather events over India.

Doppler weather radar (DWR) observation is an important data source for mesoscale and microscale weather analysis and forecasting. Xiao et al. (2005 and 2006) carried out a study on the assimilation of Doppler velocities (RV) and reflectivity (RF) into MM5 model using the 3DVAR system for heavy rainfall events over South Korea region and performance of the model forecast is enhanced with the improved model initial condition. In Weather Research and Forecasting (WRF)-3DVAR system (hereafter WRF-Var) is capable of assimilating the DWR RV and RF data. The detail descriptions of the WRF and WRF-Var system can be found in Dudhia (2004) and Barker et al. (2004) respectively. The main objective of this study is to asses the impact of DWR RV and RF data on simulation of precipitation, wind fields etc. associated with the MDs using WRF-Var analysis system.

2. Numerical Experiments:

A Software (preprocessor) is developed for processing the voluminous raw Indian DWR data to retrieve RV and RF along with other required information. The detail description of the preprocessor software can be found in the scientific report submitted at NCAR/MMM division (Routray 2007). For this study, two MDs that occurred in 02-04 August 2006 (case-1) and 04-07 July 2007 (case-2) over BOB are considered. The preprocessor software is preprocessed the voluminous Kolkata DWR raw data and make suitable input to WRF-

Var system. For this study, two numerical experiments (CNTL and 3DV) are carried out with each MD case. In CNTL experiment, the model is integrated without any data assimilation. In the 3DV experiment, the 6 hour assimilation cycle is performed using the DWR data. In this 6-hour 3DVAR update cycle, the 6hr forecast from previous cycle serve as the background for the next cycle. The total four cycles are performed to initialized the model prior to the actual model integration start. Table 1 shows the statistical RMSE of the DWR data assimilation before (O-B) and after (O-A) 3DVAR analysis at model initial time for both the cases. The RMSE of RV and RF are reduced after minimization, relative to the background first guess. The WRF model with 30 km horizontal resolution is integrated upto 54 hours in both experiments from the initial time 00 UTC of 02 August 2006 and 05 July 2007 for case-1 and case-2 respectively. The FiNaL analyses (FNL; 1^o X 1^o) are provided as first guess and boundary conditions for CNTL and starting time of the 3DV experiment.

Table 1

Time	**RV (m/s)**		**RF (dBz)**	
(yyyymmdd_hh)	**O-B**	**O-A**	**O-B**	**O-A**
20060802_00UTC (case-1)	2.8301	1.4798	2.8307	2.2801
20070705_00UTC (case-2)	2.5506	1.7405	2.4416	2.1712

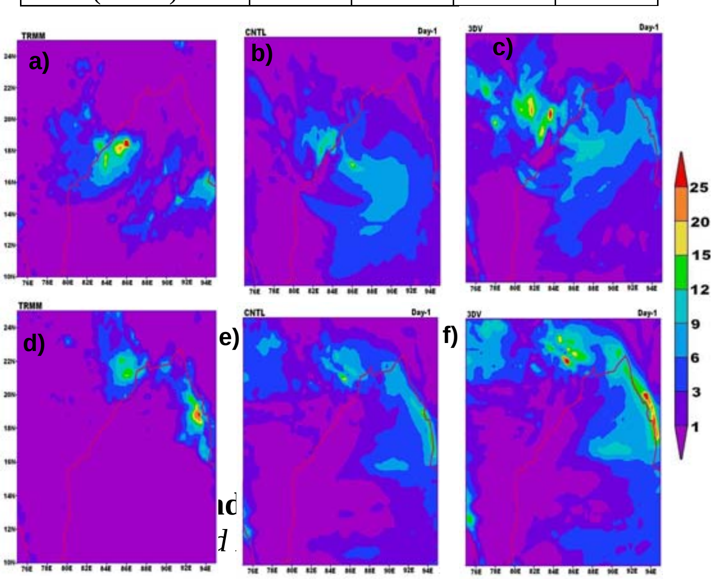

Fig-1: 24 hrs accumulated precipitation (cm) from CNTL and 3DV experiments a) TRMM, b) CNTL and c) 3DV valid at 00 UTC of 03 August 2006 (case-1). Similarly, (a-c) are same as (d-f) but for case-2 valid at 00 UTC of 06 July 2007.

The 24hrs accumulated precipitation measurements of day-1 as obtained from CNTL and 3DV simulations and the observed rainfall from TRMM satellite are shown in Fig-1(a-f) for case-1 and case-2. For case-1, the 3DV simulation (Fig-1c) shows maximum rainfall (15-25 cm) over the land masses and wide spread rainfall over oceanic region as compared with the CNTL (Fig-1b). But the TRMM (Fig-1a) observation shows maximum rainfall over oceanic regions. The rainfall observed by TRMM may be underestimated as it depends on the pass of the satellite and rain gauge observations included in its analysis. However, the Kalpana-1 satellite cloud image (figs not provided) shows intense and wide spread convective clouds over the landmasses as well as oceanic regions. The spatial distribution of rainfall forecast by the 3DV is closed to the cloud representation in the satellite image. For case-2 {Fig-1(d-f)}, the spatial and temporal distribution of simulated rainfall from 3DV experiment (Fig-1f) indicates that assimilation of DWR data has produced reasonably well rainfall during day-1 as seen from TRMM observations (Fig-1d) and satellite imaginary. The CNTL experiment under estimates the rainfall. An important result from 3DV experiment is the simulation of intense convective rain bearing clouds and their northwesterly movement along with MD. The radar reflectivity information ingested into the 3DVAR analysis and the positive impacts on the rainfall forecast skill is observed.

3.2 *Track prediction of Depressions*

The 54 hrs forecasts of the tracks (6 hour intervals) along with the observed track provided by IMD and track errors for case-1 and case-2 are illustrated in Fig-2a-d. For case-1, the initial position of the depression in 3DV simulation is relatively closed to the observed one as compared to the CNTL simulation. The formation and movement of

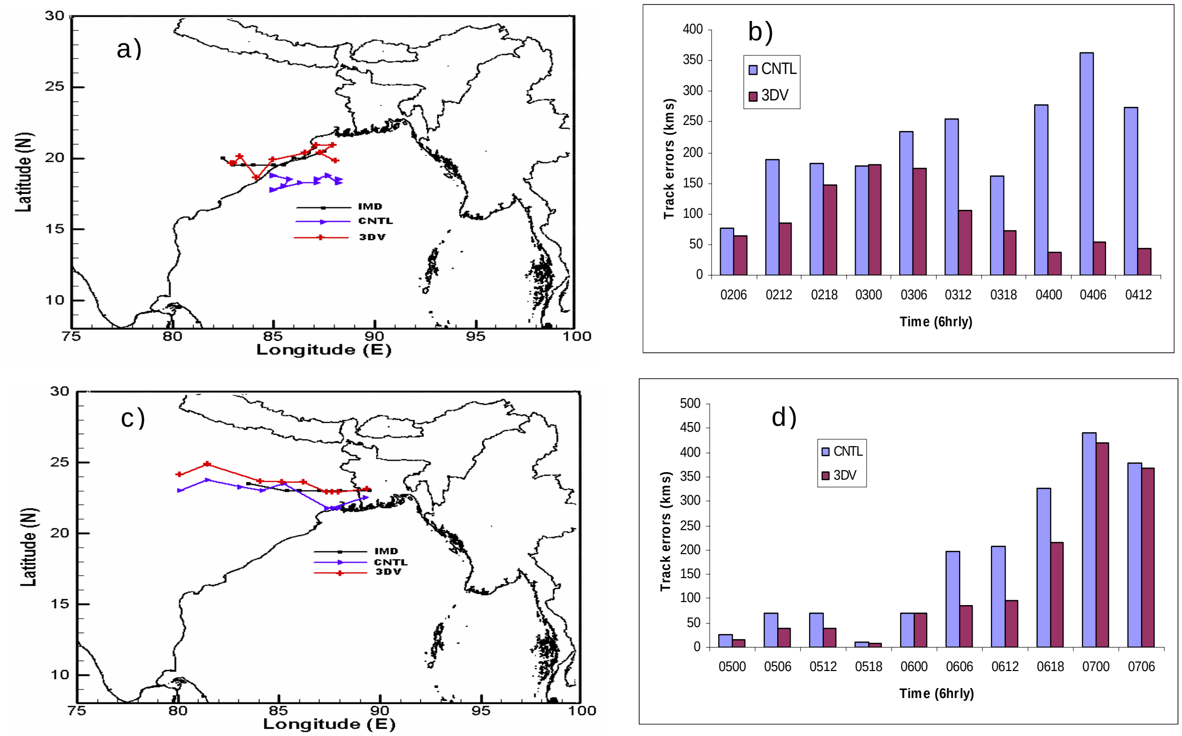

Fig-2: 6hourly track (observed and simulated) and track errors from CNTL and 3DV experiment for a) track and b) track error for case-1 (Initial time: 06 UTC 02 August 2006). (c) and (d) are same as (a) and (b) respectively but for case-2 (Initial time: 00 UTC 05 July 2007).

the depression is restricted over the oceanic region in the CNTL simulation. While the 3DV simulated track of the depression follows the accurate trend of the IMD best track during the forecast period. The track errors are relatively less due to 3DV simulation during whole forecast period as compared with the track errors obtained from CNTL simulation. For case-2, the model simulated speed of the depression is slightly high than the observed. However, the 3DV simulated track is exactly match with observed track up to 0600 UTC of 06 July 2007. Forward with the model integration period, the simulated track of the depression moved fast but followed the trend that observed. The increasing trends of the track errors are found in the two experiments with increase of the forecast period. However, the track errors in 3DV simulation are comparatively less than that in the CNTL simulation. An assimilation of DWR data through WRF-Var system, the model forecast skill of track prediction of MDs is improved as analyzed in this section.

Overall results show that the track errors are reduced significantly in assimilation experiments as compared with other experiment (CNTL).

4. Conclusions:

This study mainly focuses on the impact of assimilation of DWR RV and RF collectively into WRF-Var data assimilation system in simulating the characteristics associated with the MDs. In all cases, the 3DV experiment could simulate the large-scale fields reasonably well compared with the CNTL simulation. The movement and location of the depression are well represented in the assimilation experiments and match with the IMD observation. The precipitation field predicted by the model for all cases has been compared with the observed rainfall from TRMM. The simulated 3DV experiment rainfall is closer to the observed precipitation both intensity and location in each case. Observed maximum precipitation over the south-west quadrant of the depression has also been simulated well by the 3DV experiment for each case. Prediction of monsoon depression tracks are well simulated by 3DV experiment with the forward of model integration time and fairly follow the observed IMD tracks. The track errors are significantly improved in 3DV simulation as compared with the CNTL simulation.

This work is a first attempt in utilizing IMD DWR radial velocity and reflectivity in mesoscale model. The simulated results from this study shows the positive impact of assimilation of DWR data on simulation of intense convective systems which influence the large scale monsoonal flow. These results are preliminary and also quite encouraging. Further extensive investigation is being carried out to assimilate the multi radar radial velocity and reflectivity in the assimilation system along with other available observations.

5. Acknowledgement:

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