Evaluation and Verification of MM5 Forecasts Over The Indian Region

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ABSTRACT

The Indian region experiences a wide variety of weather systems such as the monsoons, tropical cyclones, western disturbances and heavy rainfall episodes involving severe thunderstorms. In order to study these systems, the MM5 model is run at a nested 90, 30 and 10 km resolutions on real-time basis over the Indian region on a CRAY-SV1 machine. The forecasts from MM5 are compared with those obtained from the observations and T80 operational global model.

1. INTRODUCTION

Owing to its geographical structure such as the Himalayan range in the north and oceans on the other three sides, accurate prediction of the weather phenomena over the Indian region is a challenging task on real-time basis. Despite progress made in numerical weather prediction (NWP) techniques, development of advance computing system and observation networks, the accuracy of forecasts on a regional scale is not very satisfactory. The National Center for Medium Range Weather Forecasting (NCMRWF) was established at New Delhi in 1989 for making medium range forecasts up to 10 days using global T80 model. Experiences in the past 12 years have shown that though the global model is able to provide a signature of the large scale weather systems fairly well particularly in the winter season, it is unable to produce accurate weather forecasts on a regional scale. The forecasts become much less accurate particularly over the mountain regions. In order to make accurate forecasts of the mesoscale systems such as the western disturbances, severe thunderstorms, tropical cyclones and heavy rainfall episodes during the active monsoon season, high resolution mesoscale models such as MM5 and ETA are run at NCMRWF on real-time basis.

The MM5 model is run on triple nested domains at 90, 30 and 10 km resolutions as shown in the Fig. 1. The model is run using the Grell (1993) scheme for cumulus parameterization and, the non local closure scheme of Hong and Pan (1996) 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 has been allowed between explicit cloud and clear air (FRAD=2). The initial and lateral boundary conditions are obtained from the operational global T80 model of NCMRWF.

In the following sections, we describe the results of some of the cases of typical weather systems simulated over the Indian region and compare them with observations and outputs from other models.

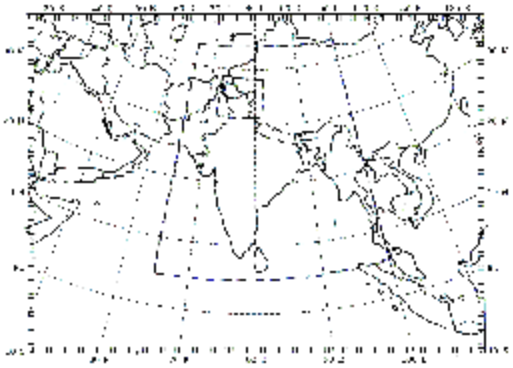

Fig. 1: Triple nested domains used for integration.

2. WESTERN DISTURBANCE

Western disturbances are troughs in the westerlies that originate from the frontal systems over the Mediterranean and Caspian sea area and move eastwards producing severe weather over the Indian region during winter season. We present here one of the cases that affected the northwest India during September 2001.

Well marked westerly trough at 500 mb associated with a western disturbance passed over the Jammu and Kashmir (J&K) region during 14 – 16 September 2001. Fig. 2 shows the 500 mb wind forecast valid for 15th September at 00 UTC using MM5. More than 7 cm of rainfall occurred over the J&K and adjoining Pakistan region during the subsequent days.

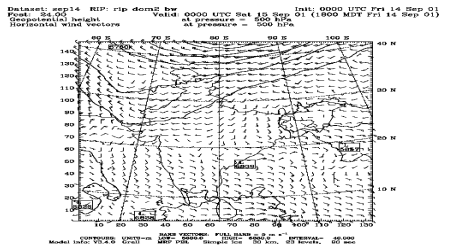

Fig.2: 24 hours forecast of 500 mb wind based on 00UTC, 14th Sep., 2001.

Fig. 3 shows the observed rainfall based upon the estimates of satellite and rain gauge (Mitra et al., 1997). It may be noted here that the observed rainfall are averaged over 150 km resolution and hence, it may not be able to represent the mesoscale features. Moreover, data from all the rain gauge stations might not have been received at the time of rainfall analysis. The satellite derived rainfall values are based on the Quantitative Precipitation Estimates (QPE), which are based on Outgoing Longwave radiation (OLR) from the deep convective clouds whose tops are colder than 235°K. Therefore, the QPE may themselves be underestimated with respect to reality.

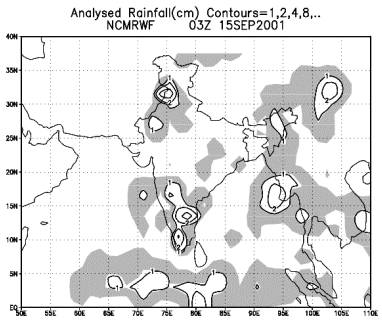

Fig.3: Observed rainfall at 03UTC, 150901.

Fig. 4 shows the 24 hours forecast of rainfall over the J&K region obtained from third nest of the model at 10 km resolution. The maximum predicted rainfall over the J&K and adjoining region were about 7 cm on 15th September. The predicted rainfall are much larger than the observations shown in Fig.3 due to the reasons explained earlier.

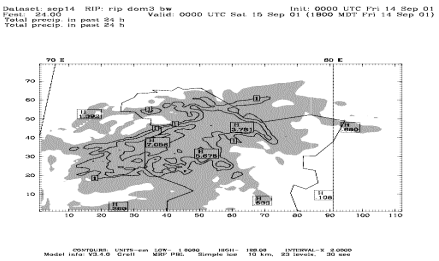

Fig. 4: Rainfall forecast for 24 hours valid on 15th Sept. 2001, 00UTC

The results of 48 hours forecasts are not shown for brevity. Fig. 5 shows the 72 hours forecast of rainfall valid for 17th September. The westerly trough had weakened and moved eastward by this day. The predicted rainfall values were about 4 cm on that day.

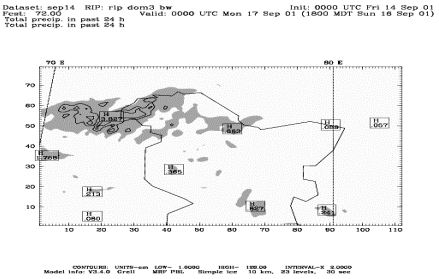

Fig. 5: 72 hours forecast of rainfall valid at 00 UTC, 17th September, 2001.

3. ACTIVE MONSOON

Heavy rainfall occurred over most parts of north India during 13-15 August, 2001 associated with an active monsoon trough over the Indo-Gangetic plain and well marked low pressure circulation. Axis of the monsoon trough passed through Amritsar, Delhi, Kanpur and Sagar Islands during the period. Rainfall amounts ranging from 1 to 19 cm were recorded in 24 hours over Delhi and neighborhoods (Fig. 6). The global T80 model of NCMRWF was unable to predict the intensity of rainfall observed over the region. Das (2002) has conducted detailed study of this case. Three experiments have been conducted to investigate the rainfall episode by configuring the model at different resolutions and by using different physics options. Table-2 shows the summary of experiments.

Table-1

Experiments	Scale	Description
EXPT1	Mesoscale (90 and 30 km)	Double nesting with Physics options: Grell-convection, MRF PBL, Simple ice and Radiation (Dudhia) and 5-layer soil model.
EXPT2	Mesoscale + Cloud scale (27, 9, 3, 1 km)	Four nests with Physics options as in EXPT1
EXPT3	Mesoscale + Cloud scale (27, 9, 3, 1 km)	Four nests with Physics options as in EXPT1, but with explicit clouds of NASA and cloud radiation interaction in third and fourth nests

The cloud process is based on simple ice scheme of Dudhia (1993) in EXPT1 and EXPT2, while the explicit cloud scheme of NASA (Tao and Simpson, 1993) has been used in the EXPT3.

Fig. 6: The Observed rainfall over India on 03z140899 (a) and over Delhi in cm.

The 24 hours forecast based on the global T80 model severely underestimated this rainfall and predicted less than 1 cm around Delhi. The MM5 model (EXPT1) predicted much better rainfall (Fig. 7) compared to T80, but the amounts over Delhi region were much less compared to observations. It may be noted that the T80 model uses Kuo-Anthes scheme and MRF PBL.

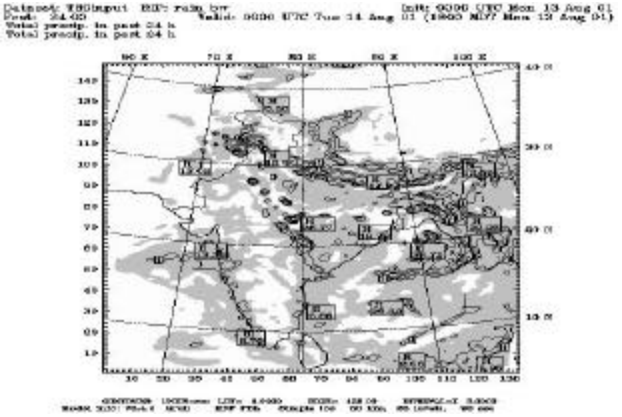

Fig 7: Rainfall forecast (24 hrs) valid on 00z140899 using MM5 at 30 km grid

Experiments showed that the rainfall forecast improved significantly when the resolution was increased to 1 km (EXPT2) in the MM5. However, the maximum value of rainfall obtained from this experiment around Delhi region was only about 10 cm (Fig. 8a), which is still less than the observed 19 cm over the region. The rainfall forecast was improved further in the EXPT3 when the explicit cloud scheme of NASA was used in the inner domains at 1 km resolution (Fig. 8b). This experiment produced rainfall values about 18-19 cm over the region, which matched very well with observations.

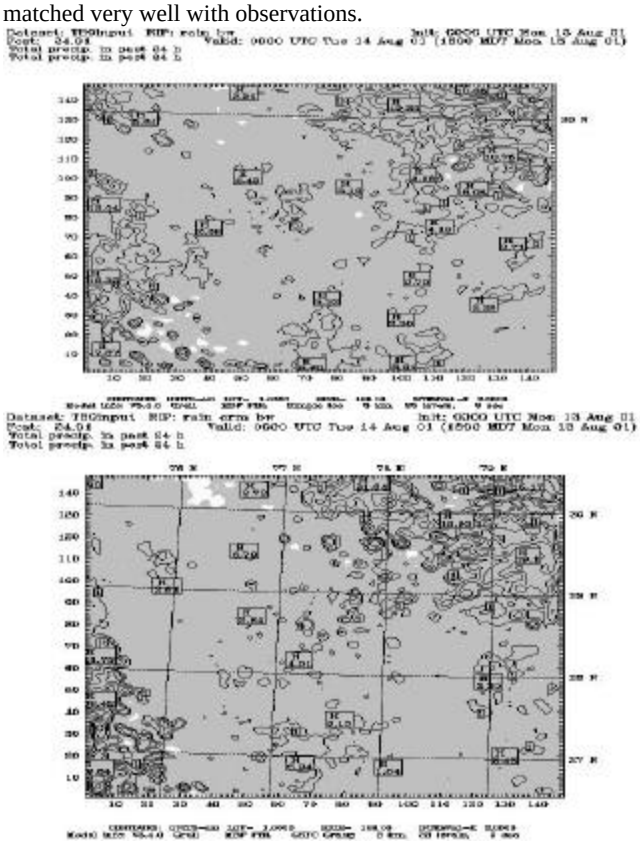

Fig 8: Rainfall forecasts around Delhi at 1 km resolution (a) CTRL (b) GSFC

4. TROPICAL CYCLONE

A super cyclonic storm formed over the Bay of Bengal during 25-31 October 1999 and hit the coast of Orissa on 29th. The intensity of the storm was assessed to T7.0 having central pressure at 912 hPa and maximum wind of 95 kts. It was the most intense tropical cyclone in the history of Orissa for the last 114 years. It affected 12.922 million population killing 9887 people. Fig. 9 shows the image of the super cyclone taken by INSAT.

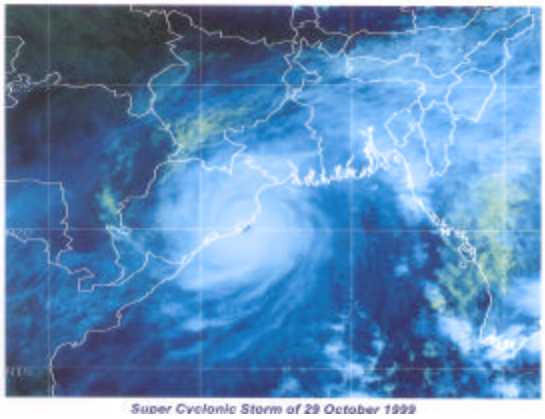

Fig. 9 Super Cyclonic storm of 29 October 1999.

The cyclone produced storm surge of about 9 m and rainfall as much as 43 cm in one day at Bhubaneshwar. Fig. 10 presents the track of the cyclone as seen from the analysis and forecasts from the T80 and the MM5 models.

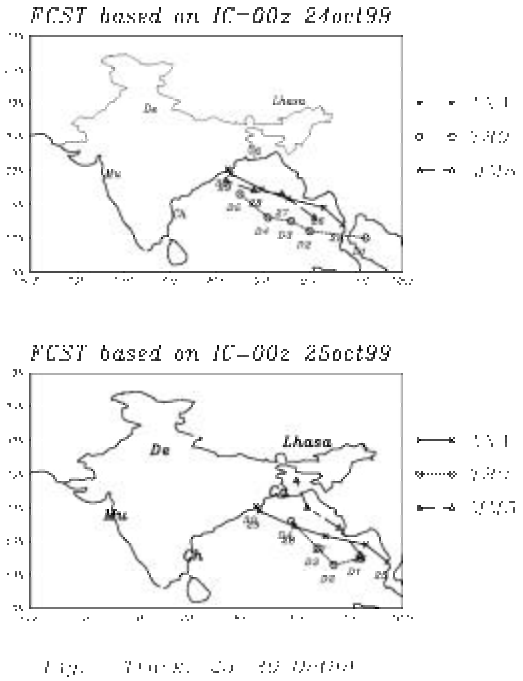

Fig. 10: Tracks of the super cyclone predicted by the T80 and MM5 models based on the initial conditions of 24 and 25 October 1999.

The diagram shows that the track of the cyclone predicted based upon the initial condition of 24th October was close to observations and was better than the T80 forecast. However, MM5 predicted a slight re-curvature of the storm based on the initial condition of 25 October. It may be recalled that the input data for MM5 is based on the analysis of T80 model. Study showed that there were not enough data from satellite over the Bay of Bengal during the period of the cyclone. Hence, the position of the cyclone was not well defined in the initial condition.

5. CONCLUSIONS

The MM5 model with triple nested domains at 90, 30 and 10 km resolutions over the Indian region has been used to predict the rainfall and wind fields associated with western disturbances, active monsoon and tropical cyclone over the Indian region. The outputs have been compared with observations and those from the T80 model. Results indicate that the MM5 model has been able to make fairly good forecasts of the wind and rainfall associated with the systems over the region. Detailed study however, is required to assess the bias and other forecast skill

scores of the wind, temperature and rainfall fields compared to ETA and T80 models.

ACKNOWLEDGEMENTS

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