High resolution model simulation of a Nor'wester over Kolkata, India

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1. Introduction

Eastern and north-eastern states of India experience thunderstorms with high frequency during pre-monsoon (March-May) season. The thunderstorms are locally known as "Nor'wester" as it travels from northwest to southeast direction. These storms are generally associated with strong wind followed by heavy rain and sometimes with hail. Due to smaller spatial and temporal dimension, Nor'westers are generally not resolved by conventional synoptic observational network. It remains a challenge of numerical weather prediction to simulate such system using a model. As such an attempt is made to simulate the nor'wester of 22 May 2003. This happened to be the last nor'wester of premonsoon season of 2003 and it caused havoc to the city of Kolkata and its surrounding areas.

2. Model and Methodology

RAMS version 4.30 is used to carry out the simulation experiments. RAMS is used with two way interactive nested grids of resolutions 16 km and 4 km as shown in Fig. 1. The grids are centered at 22.6^o N, 88.4^o E and the number of grid points for 16 km resolution is 68 x 68 in east-west and north-south direction and that for 4 km grid are 58 x 58. The numbers of terrain following levels in both the domains are 36. A Modified Kuo convection scheme (Tremback, 1990) is used for the large scale precipitation and Bulk microphysics of Walko et al. (1995) is used for prognosing cloud constituents and grid scale precipitation. A two-stream radiation scheme developed by Harrington (1997) is used. Two simulation experiments are carried out to study the impact of assimilating regional data on the simulation. In one of the experiments (expt-A) RAMS is initialized with 0000 UTC NCEP/NCAR reanalyses data (2.5 deg x 2.5 deg) of 22 May 2003 and run in four dimensional data assimilation (FDDA) nudging mode for initial six hours and then followed by 12 hour integration in forecast mode till 1800 UTC of 22 May. In the other experiment (expt-B), the radiosonde data at 0000 UTC of 22 May from the stations namely Kolkata, Ranchi and Patna (located in the Gangetic plains at a distance of ~250-300 km) are assimilated in the gridded analyses and the model is run in similar manner as that of expt-A.

3. Discussion of results

Simulation experiments suggest that the incorporation of the upper air and surface data have significantly improved the initial condition in terms of better representation of the thermodynamic instability prevailing over the region. Different thermodynamic instability indices derived from the enhanced input is found to be closely matching with the values derived from the radiosonde data of the stations (Kolkata, Ranchi and Patna). Mainly due to this improvement the 12 hour forecast by expt-B has significantly improved in comparison to that of expt-A. The streamline analyses at 850 hPa of 0000 UTC of 22 May with NCEP (Fig. 2a) and enhanced NCEP data (Fig. 2b) show significant change. The streamline in Fig. 2b suggests a cyclonic circulation over Bihar region which is weakly seen at the north-west corner of the coarse domain in Fig. 2a. The corresponding analyses for the relative humidity (Fig. not shown) at 850 hPa show particularly over Bihar region isolines of 60-90% in the enhanced analyses. The assimilation of regional upper air data appears to have improved the instability over the said region. The forecast wind barbs in expt-A are able to show a circulation (Fig. not shown) at 6 hour forecast (1200 UTC) and wind speed of the order of 15 Kt is predicted over Kolkata which matches well with the Doppler observation. At 7, 8 and 9 h (1300, 1400 and 1500 UTC) forecasts, the wind over Kolkata is found to be of north-westerly and of the order of 20-25 knot

which is better comparable with the Doppler radar derived wind of the corresponding hour than that of expt-B. The hourly forecast of cloud condensate at 850 hPa is also significantly improved in terms of location and strength in expt-B (Fig. 3) as supported by the LWC of Doppler radar shown in Fig. 4 as compared to that of expt-B. The 12 hour accumulated precipitation by expt-A and B are shown in Fig. 5a and 5b and compared with the CPC 24 hour accumulated and Doppler radar 12 hour accumulated precipitation (Fig. 5c and Fig. 5d). Expt-A has shown significant improvement in improving the precipitation (Fig. 5b) which is found to be in and around Kolkata and well supported by the Doppler estimate (Fig. 5c). However the amount of forecast precipitation (2 cm) by expt-A is found to have underestimated the observed value of 7-8 cm.
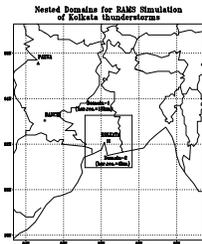

FIG. 1. Domain of the two grids along with the locations of three upper air stations. Grid-1 stands for 16 km and Grid-2 stands for 4 km domain.
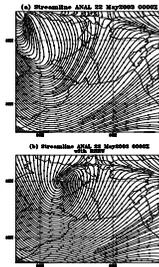

FIG. 2. Streamline analysis at 850 hPa of 22 May 2003 (a) NCEP interpolated to RAMS 16-km grid; (b) enhanced analysis at 0000 UTC.
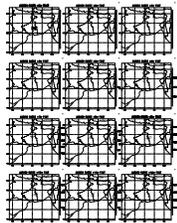

FIG. 3. Hourly forecast of total cloud condensate (g kg^{-1}) at 850 hPa by coarse domain as obtained from EXP-3 for 22 May 2003 Nor'wester.
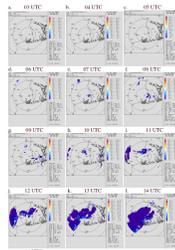

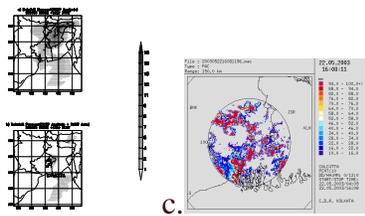FIG. 4. Doppler radar estimated hourly cloud liquid water content of 12 March 2003 Nor'wester.

c.   Fig. 5 Precipitation forecast (a) 12-h accumulated in expt-A; (b) 12-h accumulated in expt-B; and (c) Doppler radar 12-h accumulated estimate.

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