6R.3 IMPACTS OF MM5 MODEL DATA ON THE PERFORMANCE OF THE NCAR AUTO-NOWCAST SYSTEM

Huaqing Cai *, Rita Roberts, Cindy Mueller, Tom Saxen, Mei Xu, Stanley Trier, and Dan Megenhardt

National Center for Atmospheric Research, P.O. Box 3000, Boulder CO 80307

1. INTRODUCTION

The Auto-Nowcast System (ANC), a software system that produces time- and space-specific, routine short term nowcasts of storm location and intensity, has been developed by National Center for Atmospheric Research (NCAR) and deployed successfully in a number of field projects around the world (Mueller et al. 2003). One feature of the ANC is its ability of forecasting storm initiation. The 60 min storm initiation forecast is based on observations (radar, satellite, sounding and mesonet), a numerical boundary layer model and it's adjoint [Variational Doppler Radar Analysis System (VDRAS)], forecaster input, automatic feature detection algorithms, as well as the operational RUC20 model (Rapid Update Cycle model at 20 km resolution). The input dataset to ANC spans multiple scales ranging from storm to synoptic scales. The large scale environmental instability variables derived from RUC20 model play an important role in the initiation forecasts, therefore, any improvements in the accurate estimates of these fields will be helpful to the ANC performance.

Since RUC20 model is the only model which has ever been used in the ANC to derive large scale environmental variables and it has a relatively coarse spatial resolution of 20 km, it would be interesting to find out how the performance of ANC will be affected if the RUC20 model were replaced by a high-resolution model with different model physics, such as 3.3 km resolution MM5 (fifth-generation Pennsylvania State University-NCAR Mesoscale Model). Another advantage of MM5 model is its ability of assimilating radar reflectivity data through a nudging technique (Liu et al. 2002). The instability parameters derived from model output are discussed in section 2. High-resolution MM5 model configurations are described in section 3. The ANC performance using both RUC20 and high-resolution MM5 model are compared in section 4.

* *Corresponding author address:* Huaqing Cai, National Center for Atmospheric Research, Boulder, CO 80307; e-mail: caihq@ucar.edu

2. INSTIBILITY PARAMETERS USED IN ANC

The ANC employed a set of predictor fields which are based on storm scale features obtained from radar, satellite and VDRAS and large scale environmental instability parameters derived from RUC20 model. Each predictor field is associated with a membership function which converts the predictor field into an interest field. All the interest fields are fused together to produce a likelihood field using a fuzzy logic algorithm according to their respective weights. A final forecast of convective storms is generated by filtering and smoothing the likelihood field.

A total of five instability parameters derived from RUC20 model data is being used in the current ANC. These five fields have a combined weight of ~0.68, which accounts for ~36% of the total weight of all membership functions for storm initiation. Apparently the accurate estimates of these instability parameters are essential to ANC. Each of the five instability parameters is discussed as follows.

(a) CAPE (Convective Available Potential Energy)

The atmosphere is divided into 25 mb layers in the vertical and all instability calculations are performed on those layers. The maximum CAPE value between 900 mb and 700 mb is chosen as the predictor field for CAPE.

(b) CIN (Convective Inhibition)

The average CIN value between 975 mb and 700 mb is used.

(c) Averaged Relative Humidity

The mean relative humidity between 875 mb and 725 mb is used as an indicator for the overall moisture content in the convective boundary layer.

(d) Frontal Likelihood Field

This is an interest field which is designed to pinpoint the location of surface frontal zone. Surface convergence, vorticity and equivalent potential temperature gradient are used as input to produce the front likelihood field. The reader is referred to Mueller and Megenhardt (2003) for details of this technique.

(e) Number of Unstable Layers in the Vertical

This field is a count of how many unstable layers in the vertical according to the RUC20 model data. Detailed of this technique can be found at Trier et al. (2002).

The large scale environmental conditions from the RUC20 model affect the ANC storm initiation forecasts through the five instability parameters described above. The impact of replacing the RUC20 model with the high-resolution MM5 in ANC is unknown until some necessary tests are performed.

3. MM5 MODEL CONFIGRATIONS

The reasons to use high-resolution MM5 model in ANC are: 1) high spatial resolution (i.e., 3.3 km versus 20 km in the horizontal), 2) radar reflectivity nudging in MM5 which has yet been done in RUC20 model, and 3) a in-house model which is easy to modify versus an operational model which can not be changed by its users.

The MM5 model used in this study assimilates observations from various sources continuously and provides real-time local analyses and short-term forecasts in a cycling fashion. A three-grid configuration, with grid resolution of 3.3, 10 and 30 km is used (see Fig. 1). The model is cold started once a week, at 12 Z on Sundays. At each 3-hr cycle, a final analysis and a 9-hr forecast is produced.

The high-resolution MM5 runs on a Linux cluster of 20 parallel nodes. It takes approximately 30 min to obtain decode all the observations, and another 30 min to finish the 3-hr analysis, and an hour to do the 9-hr forecast. The 2-, 3- and 4-hr forecasts are being used in the calculations of all the stability parameters described in section 2.

A grid nudging scheme is used to assimilate the mosaic radar reflectivity data generated for CONUS (Xu et al. 2004). The radar reflectivity is first converted to 3D precipitation field and interpolated to the model grid. Then the precipitation field, together with the corresponding latent heat, is nudged onto

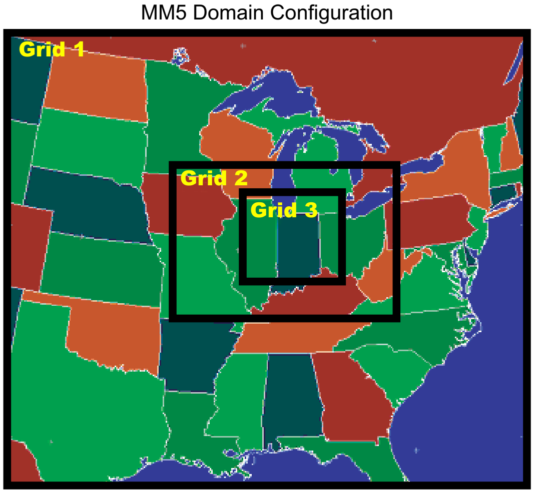

Fig. 1. Domain configuration for the MM5 model. Three nested domains are used in this study, which are represented by grid 1 (30 km resolution), grid 2 (10 km resolution) and grid 3 (3.3km resolution), respectively.

the two inner domains (grid 3 and grid 2 in Fig. 1). The data insertion is performed at an interval of 30 min on grid 2 (10 km resolution) and 15 min on grid 3 (3.3 km resolution). Humidity field is also adjusted according to the radar reflectivity data.

The nudging parameters can be tuned to optimize data effects on the model forecasts. For details of the MM5 model used in this study, the reader is referred to Liu et al. (2002).

4. PRELIMINARY RESULTS

A total of six cases from the Federal Aviation Administration (FAA) summer demonstration project conducted over Illinois/Indiana in 2005 have been selected to investigate the impacts of MM5 model data on ANC performance. Examples of the side-by-side comparisons between the instability fields derived from RUC20 and MM5 model are shown in Fig. 2 and 3, respectively. A cold front, which is represented by the yellow line in the figures, can be easily identified as a convergence line in the low-level VDRAS wind fields. MM5 model clearly suggests larger CAPE along and in the warm sector of the cold front for this particular case. The front likelihood interest field, which indicates the position of the surface frontal zone, is also better defined using MM5 model data. Notice the high front likelihood in-

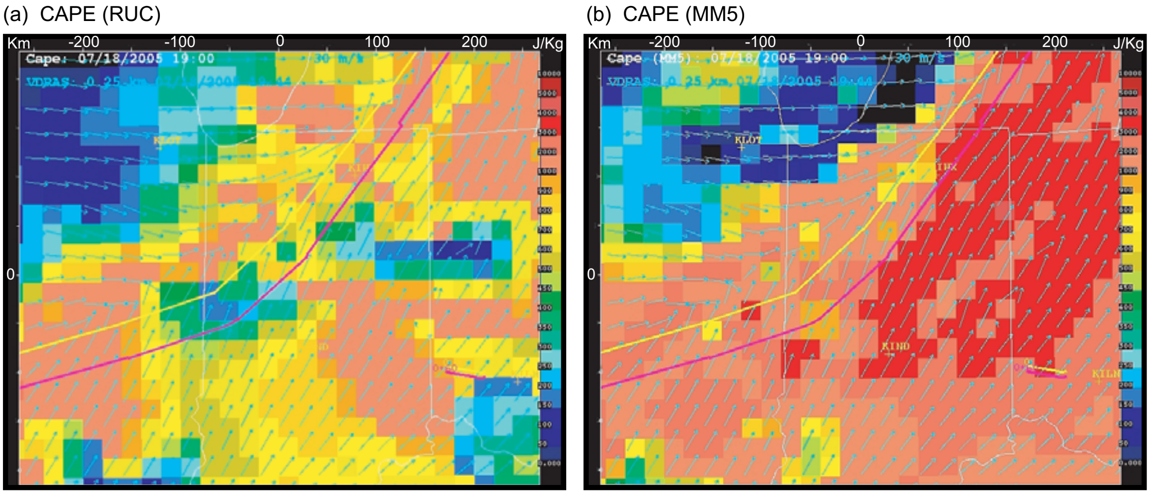

Fig. 2. Comparison of CAPE fields at 1900 UTC on 18 July 2005 derived from a) RUC20 model, and b) MM5 model. VDRAS surface winds are shown as arrows. The current boundary (a cold front) position is represented the yellow line. The magenta line denotes the 60 min extrapolated boundary position.

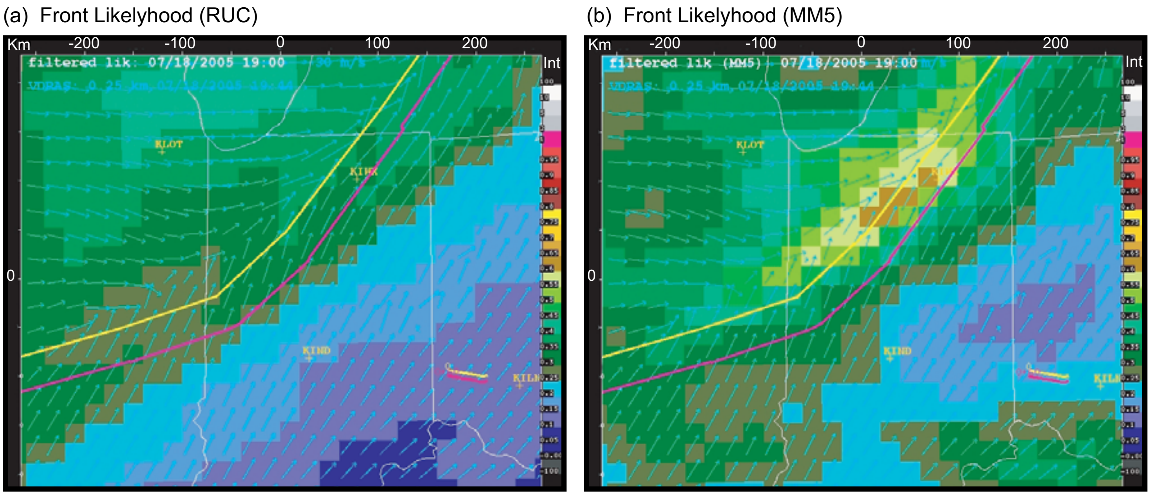

Fig. 3. Same as Fig. 2 except for the front likelihood interest fields.

terest values are co-located nicely with the frontal zone derived from VDRAS winds and the current front position entered by a forecaster (the yellow line) in Fig. 3b.

The 60 min ANC forecasts (Initiation plus extrapolation) using both RUC20 and MM5 model data for the six cases occurred during summer 2005 are carefully analyzed. Generally speaking, both models give pretty similar results most of the time. Occasionally, MM5 model performed slightly better than RUC20. Figure 4 and 5 are two examples of comparisons between ANC 60 min forecasts created using RUC20 and MM5 model data. Figure 4 is the same case as shown in Fig. 2 and 3. As a result of stronger CAPE and better-defined front likelihood interest fields derived from MM5 model, ANC using MM5 data greatly increased the storm initiation forecasts along the cold front. Notice the initiation zone near the southern end of boundary shown in Fig. 4b. This initiation forecast, which did not exist in Fig. 4a when RUC20 was used, probably is an indication that ANC was trying to forecast the cluster of smaller cells which occurred 60 min later near the southern end of the cold front.

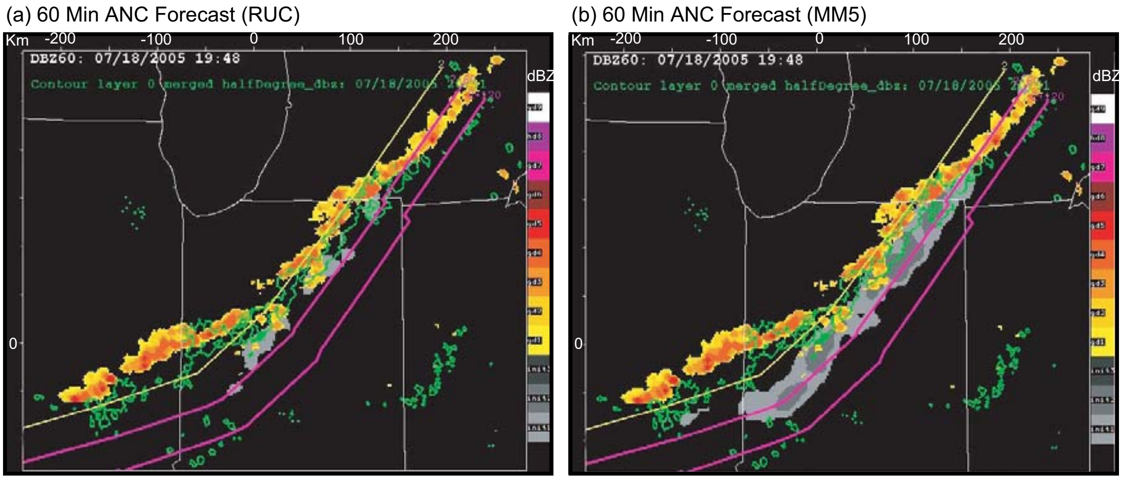

Fig. 4. Comparison of the 60 min ANC forecasts issued at 1948 UTC on 18 July 2005 using a) RUC20 model, and b) MM5 model. The green contour is the 35 dBZ radar reflectivity line at verification time (2051 UTC). The filled color contour represents the 60 min extrapolated radar reflectivity; the gray shading represents the 60 min initiation forecasts. The current boundary position is denoted by the yellow line; the 60 min and 120 min extrapolated boundary positions are shown as magenta lines.

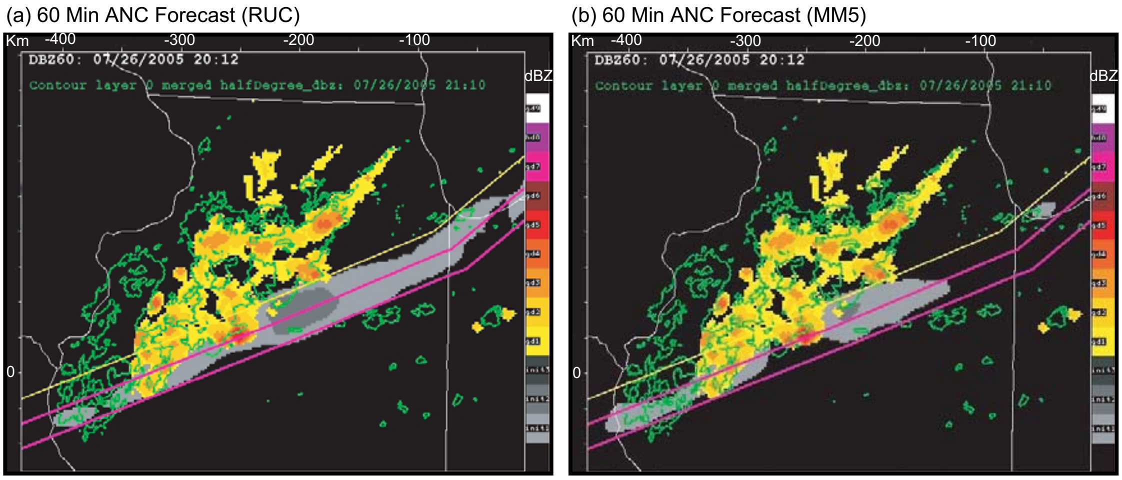

Fig. 5. Same as Fig. 4 except for 2012 UTC on 26 July 2005.

Figure 4 shows one example in which ANC produced more initiation forecasts as a result of using MM5 model data. On the other hand, using MM5 model data could also reduce the initiation forecast by ANC. One such example is shown in Fig. 5. It is another cold front passing through ANC domain. ANC with MM5 data correctly reduced the false alarm along part of the cold front, and amazingly kept the correct initiation forecasts near both south and north end of the boundary.

It should be pointed out that the evaluation of the impact of the MM5 model data on ANC performance conducted in this study is purely subjective. Objective and statistically meaningful investigations of this problem should be pursued before MM5 data is finally put into use in operational ANC.

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