P1.24 The Impact of Different Microphysical Schemes on Mesoscale Circulations and Convective System Morphology in 4-10 km Grid Spacing WRF Simulations

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1. INTRODUCTION

The Weather Research and Forecasting (WRF) model was used to determine the effects of different microphysical schemes on the mesoscale circulations and morphology of a bow echo that was thoroughly examined during the Bow Echo and Mesoscale Convective Vortex Experiment 2003 (BAMEX). All of the simulations were run with horizontal grid spacing of 4 and 10 km and predicted rainfall explicitly using the Ferrier et al., Lin et al., NCEP 5-class, WSM 5-class and WSM 6-class microphysics schemes. All simulations were integrated over a 24 hour period beginning at 12 UTC 09 June 2003 and used NCEP 40 km Eta GRIB output for initial and lateral boundary conditions. The first section of this study gives a brief synoptic overview of the case used in this study followed by a comparison of the 4 km WRF rainfall simulations with observed rainfall amounts from 4 km gridded Stage IV multi-sensor data (Baldwin and Mitchell 1997). It will be shown that the 4 km simulation using the Ferrier et al. microphysics best simulated the development and movement of the convection in Nebraska. High resolution sounding data (BAMEX, 2003), provided detailed thermodynamic and kinematic profiles of the environment ahead of and behind the bow echo that moved through southeastern Nebraska. The winds in the Ferrier et al. run were then compared to those observed from the high resolution sounding data.

2. CASE STUDY: 10 JUNE 2003

During the evening hours of 10 June 2003, a shortwave trough and associated cold front located over the northern High Plains moved into central Nebraska. The cold front extended southward from a low pressure system in North Dakota around 00 UTC with its attendant warm front situated along the Iowa/Nebraska border. The cold front then swept across Nebraska overnight and was located near southwestern Iowa by 12 UTC 10 June 2003. Convection developed in central Nebraska shortly after 00 UTC and developed into a bow echo ahead of the cold front. The bow echo then moved into southeastern Nebraska, southwestern Iowa and northwestern Missouri between 05 and 06 UTC. Interestingly, a NOAA-P3 aircraft measured a very strong rear inflow jet in the apex region of the bow echo (BAMEX,2003) and in one instance measured an 80 knot (~ 41 m s^{-1}) wind from the northwest.

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2.1 *Initiation Problem*

Between 00 and 01 UTC 10 June 2003, tornadic storms developed in central Nebraska and propagated east southeastward (Fig. 1a). The 4 km WRF simulation with the Ferrier et al. microphysics did the best job predicting the system in Nebraska (Fig. 1b). Notice how the simulations using the Lin et al., NCEP 5-class, WSM 5-class and WSM 6-class microphysics (Fig. 1c-f) barely produced rainfall in central Nebraska, and did a poor job in predicting the bow echo that moved through southeastern Nebraska between 06 and 12 UTC (Fig. 2a-f).

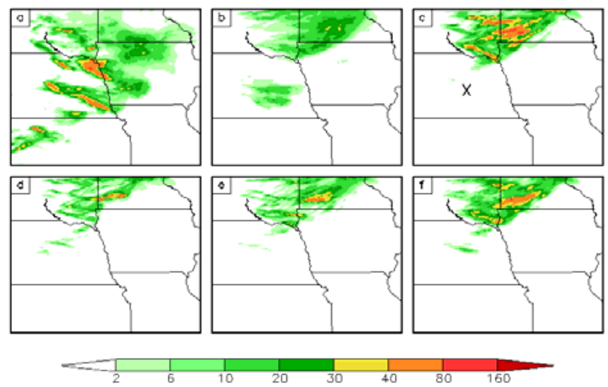

Figure 1. Rainfall from (a) 4 km gridded Stage IV multi-sensor data and simulated by 4 km WRF using (b) Ferrier et al., (c) Lin et al., (d) NCEP 5-class, (e) WSM 5-class and (f) WSM 6-class microphysics for 00-06 UTC 10 June 2003. All units are in millimeters.

Thermodynamic and kinematic profiles from the WRF simulations with the different microphysics were analyzed in central Nebraska at 00 UTC 10 June 2003 (several hours before rain was predicted [not shown]) and at 03 UTC (up to one hour before rain was predicted [Fig. 3]). Note that the location of this sounding is marked by the letter X in Fig. 1c. The vertical profiles at 00 UTC are not shown because they were the same in all of the model simulations. However, at 03 UTC (Fig. 3), the simulation with the Ferrier et al. microphysics was the most saturated especially from 2 to 6 km and also above 10 km indicating that the microphysical scheme was likely active. Note that the largest differences in the moisture profiles among the different microphysical schemes occurred between 3 and 7 km above ground. Future work will determine why the thermodynamic profiles in the Ferrier et al. run differed from those in the other runs and essentially why most of the runs did a poor job with the system in Nebraska.

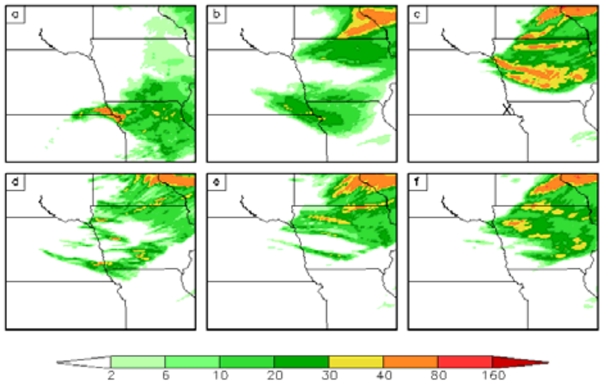

Figure 2. Rainfall from (a) 4 km gridded Stage IV multi-sensor data and simulated by 4 km WRF using (b) Ferrier et al., (c) Lin et al., (d) NCEP 5-class, (e) WSM 5-class and (f) WSM 6-class microphysics for 06-12 UTC 10 June 2003. All units are in millimeters.

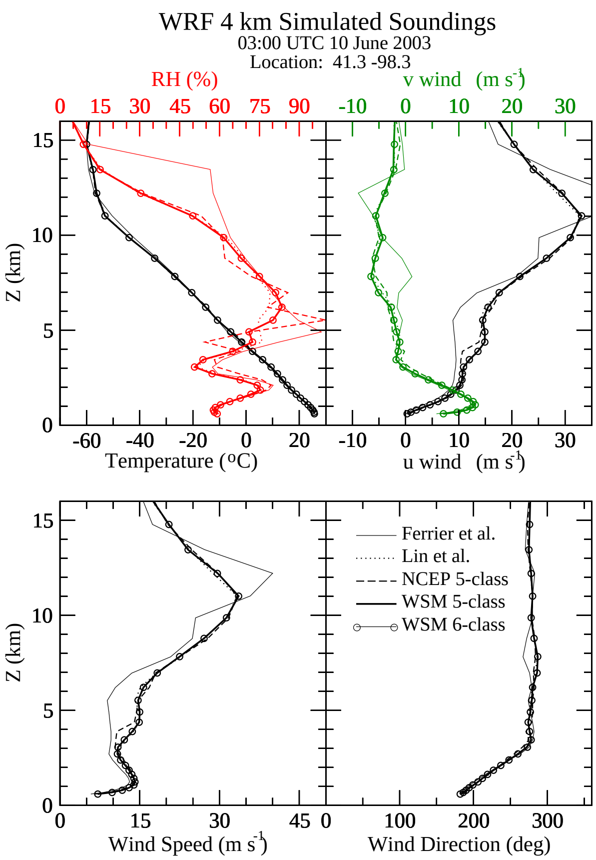

Figure 3. WRF 4 km Soundings at 03 UTC 10 June 2003 for runs using the Ferrier et al., Lin et al., NCEP 5-class, WSM 5-class and WSM 6-class microphysics. The location of this sounding is marked by the letter X in Fig. 1c

2.2 *Interaction between Convection and Large-scale Dynamics*

Prior to convective initiation (around 00 UTC 10 June 2003), a weak 500 mb shortwave trough was located in all of the WRF simulations and in the 20 km RUC analyses. See Fig. 4a-c for a comparison of the Ferrier et al. and WSM 6-class simulation of 500 mb heights and absolute vorticity with the analysis of these fields from the 20 km RUC model. Since the 500 mb patterns in the Lin et al., NCEP 5-class and WSM 5-class runs were very similar to those in the WSM 6-class run, comparisons between the WSM 6-class and the Ferrier et al. runs are only shown. Five hours later (05 UTC), the trough in the Ferrier et al. run was deeper and more intense than the trough in the WSM 6-class run. Compared to the 20 km RUC analysis (Fig. 4f), the Ferrier et al. run best simulated the upper-level dynamics at that time (Fig. 4d-f). Both the analysis and the Ferrier et al. run agree on a fairly significant trough with the trough axis near the Iowa and Nebraska border, while no such feature was simulated in the WSM 6-class run. It is possible that the deeper, more intense trough in the Ferrier et al. run played a role in the longevity of the convection that developed in central Nebraska. This convection eventually developed into a bow echo that moved through southeastern Nebraska.

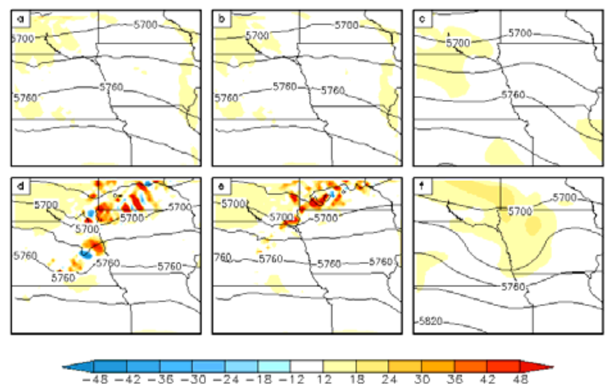

Figure 4. Absolute vorticity (shaded [x10^5 s^{-1}]) and heights (meters) at 500 mb at 00 UTC 10 June 2003 in (a) the WRF 4 km run with the Ferrier et al. microphysics, (b) the WRF 4 km run with the WSM 6-class microphysics and (c) the 20 km RUC analysis. Figures 4d-f are the same plots as those in a,b and c except at 05 UTC 10 June 2003. Contour intervals are every 30 meters.

2.3 *Mesoscale Circulations in 4-10 km Runs*

As shown in Fig. 2, the 4 km WRF run with the Ferrier et al. microphysics did the best job simulating the bow echo that moved into southwestern Iowa, southeastern Nebraska and northwestern Missouri between 05 and 06 UTC 10 June 2003. Thermodynamic and kinematic profiles in the Ferrier et al. run were compared with observations in the vicinity of the bow echo. Four soundings were launched in southeastern Nebraska prior to and just after the passage of the bow echo (the letter X in Fig. 2c indicates the location of the soundings). Fig. 5

illustrates the observed soundings launched at 02:43, 04:03, 05:19 and 05:56 UTC 10 June 2003. The last sounding occurred after the bow echo passage indicated by the wind shift near the surface. There was a gradual cooling and moistening with time near the surface and a very sharp moistening at 1.5 km with the relative humidity increasing from about 60% to nearly 100% from the first sounding to the last. The wind at 1 km above ground level increased to 30 m s^{-1} from the south-southwest during the 4:03 launch and then decreased with time. The strong winds near 1.5 km could have been associated with a low-level jet (LLJ). In the last sounding, there was a dry layer around 1.5 km at which height there was a small temperature inversion.

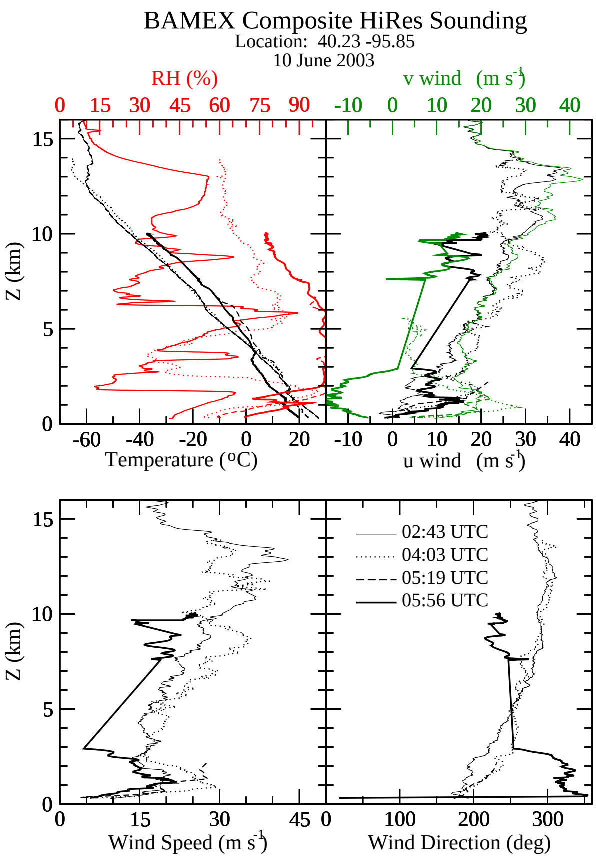

Figure 5. BAMEX Composite HiRes Sounding located at 40.23N, 95.85W (southeastern Nebraska) as indicated by the letter X in Fig. 2c. The soundings were launched at 02:43, 04:03, 05:19 and 05:56 UTC 10 June 2003.

The WRF 4 km run with the Ferrier et al. microphysics (Fig. 6) had a temperature inversion and a dry layer around 2.5 km above ground after the bow echo passage, slightly higher than where those features were observed. The LLJ feature could also be seen in the WRF simulation at 1.5 km with maximum winds of 20 m s^{-1} at 05 UTC 10 June 2003, two to three hours before the bow echo passage in this run. Notice how the wind shift did not occur until after 07 UTC in the WRF simulation, while observations indicated the wind shift occurred between 05 and 06 UTC. Also, the strongest winds in the WRF model were 35 m s^{-1} at 08 UTC at 1.5 km, but these winds were simulated after the wind shift, which would be more representative of a rear inflow jet rather than a LLJ.

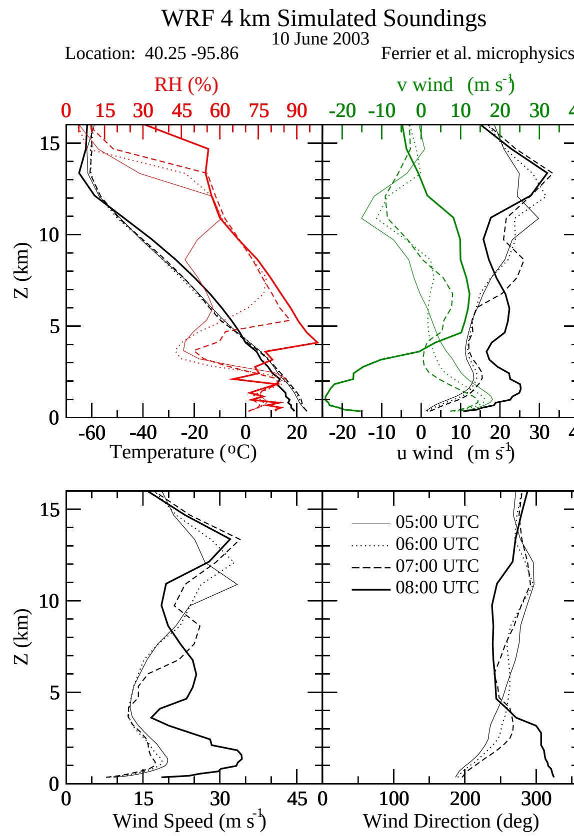

Figure 6. WRF 4 km soundings at the same location as the observed soundings valid at 05,06,07 and 08 UTC 10 June 2003. This run used the Ferrier et al. microphysics.

When the WRF model was run with 10 km horizontal grid spacing, once again, the Ferrier et al. microphysics did the best job predicting rainfall in central Nebraska and the bow echo that moved through southeastern Nebraska during the early morning hours of 10 June 2003 (not shown). Fig. 7 illustrates the 10 km WRF rainfall amounts from 06-12 UTC 10 June 2003 using the Ferrier et al. microphysics. It is interesting to note that the forecasted rainfall maximum of 40 mm, associated with the bow echo in the 10 km WRF run, was closer to the observed amoount as seen in Figure 2a. The peak rainfall area in the 10 km run was located north of the observed peak rainfall area, and was shifted north of the peak rainfall area in the 4 km WRF run with the same microphysics (Fig. 2a,b). Since the simulation period ended at 12 UTC 10 June 2003, it is not clear if the bow echo in the 10 km run would have progressed farther south, closer to where the peak rainfall was observed. Similar to what was done earlier, thermodynamic and kinematic profiles were constructed for the 10 km WRF run with the Ferrier et al. microphysics in approximately the same location as the BAMEX and 4 km WRF soundings in southeastern Nebraska (Fig. 8).

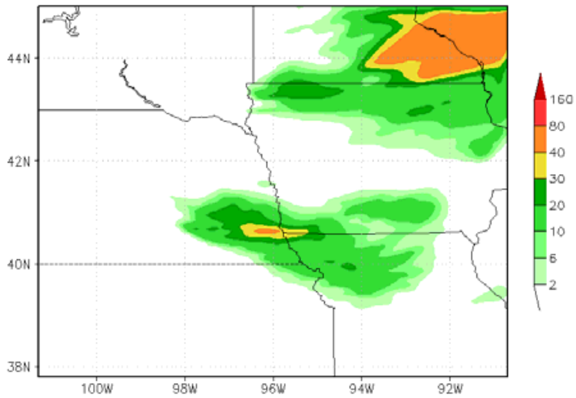

Figure 7. WRF 10 km (explicit) rainfall forecast from 06-12 UTC 10 June 2003 using the Ferrier et al. microphysics. Units are in millimeters.

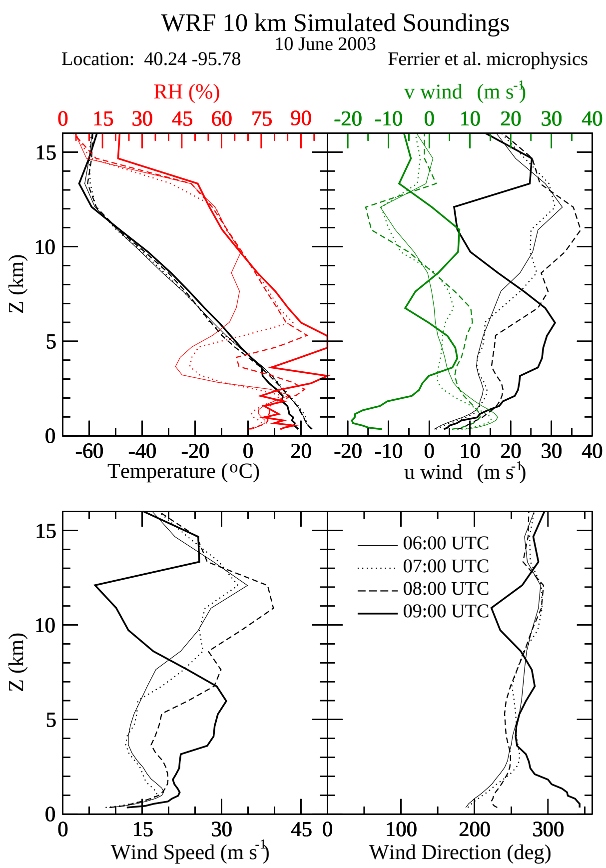

Figure 8. WRF 10 km soundings at the same location as the BAMEX and 4 km WRF soundings valid at 06,07,08 and 09 UTC 10 June 2003. This run used the Ferrier et al. microphysics.

The most notable differences between the 4 and 10 km runs are in the moisture and wind profiles. The atmosphere above 12 km was less saturated in the 10 km run compared to the 4 km run (Fig. 8 versus Fig. 6), while it was more saturated than the 4 km run below 5 km. Also, the LLJ and possible rear inflow jet were both simulated in the 10 km run, but the winds did not exceed 22 m s^{-1} in any of the times indicated in the plot.

3. SUMMARY AND FUTURE WORK

From the case presented in this study, the 4 km WRF run with the Ferrier et al. microphysics did the best job with the convection in Nebraska, and had the most saturated environment just before convective initiation as compared to the runs with the Lin et al., NCEP 5-class, WSM 5-class and WSM 6-class microphysics. Convection in the Ferrier et al. run could have strengthened a short wave trough, which could have played a role in the longevity of the convection that eventually developed into a bow echo. The WRF 4 km run with Ferrier et al. microphysics appeared to capture the LLJ and possibly a rear inflow jet of 35 m s^{-1}. The WRF 10 km run with Ferrier et al. microphysics had a weaker rear inflow jet compared to the 4 km run and had different moisture profiles at low-levels and upper-levels.

In the future, additional analysis will be undertaken for this case and several others. One of the goals will be to explore each microphysical scheme in detail to understand why the Ferrier et al. microphysics did the best job with the system in Nebraska. Vertical cross sections of winds will be constructed for a better comparison of the WRF 4 and 10 km runs. The temporal evolution of wind fields will be examined with a resolution greater than 1 hour to determine the peak winds in the vicinity of the bow echo simulated in both the 4 km and 10 km WRF runs. In addition, it was found that the location and size of the domain affected the results of this case. Future work will take advantage of the two-way nested grid capabilities of the WRF model in hopes of reducing the influence of the lateral boundary conditions. See Warner et al. (1997) for a discussion of the limitations of lateral boundary conditions.

4. ACKNOWLEDGEMENT

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5. REFERENCES

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