A Comparison of WRF-Simulated Radar Information to Observations for a Well-Forecasted Derecho Event

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1. Introduction

In recent years, the increased availability of computer resources has allowed for the rapid growth in use of convection-allowing grid spacings in numerical models run pseudo-operationally. Several studies have suggested that such grid spacings are needed to improve forecasts of convective systems (e.g. Clark et al. 2010). Whereas simulations using convective parameterizations have serious problems accurately depicting the diurnal cycle of convection in the central U.S., these convection-allowing runs appear to do a much better job with this fundamental aspect of convective systems. In addition, such simulations have been shown to occasionally forecast even the fine-scale structure of some convective events surprisingly well (e.g., Weisman et al. 2010).

The present study examines a convective system that led to a damaging derecho (Bentley and Mote 1998) event across portions of central Iowa during the night of July 17-18, 2010. Both 2 and 4 km Weather Research and Forecasting (WRF) model simulations forecasted the event very well. Therefore, the present study examines more closely how well simulated radar parameters matched those observed during this bowing convective system event.

2. Data and Methodology

The WRF model version 3.2 with both 2 and 4-km horizontal grid spacing over a small domain (roughly 1000 x 1000 km) centered over Iowa was used to simulate the derecho event. The model used the Thompson microphysical scheme (Thompson et al. 2008) with a bug fix later implemented in version 3.3 of WRF, with the YSU PBL scheme (Hong et al. 2006), RRTM longwave and Dudhia shortwave radiation, and no convective parameterization. Initial and lateral boundary conditions were supplied by the 12 UTC 17 July 2010 NAM run. Simulations were integrated for 24 hours. Model output was compared to KDMX radar information displayed via Gibson Ridge Analyst software.

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3. Overview of Event

Operational forecast models run by NCEP at 12 UTC 17 July gave mixed messages about the likelihood of significant convection in central Iowa that night (12-24 hour forecasts). The NAM run (Fig. 1a) showed heavy precipitation along a NNW-SSE axis, implying a significant event, while the GFS run (Fig. 1b) had the heavier convection both north and south of Iowa. As the event approached, the 00 UTC runs from both models (not shown) showed the heavier rains staying north of Iowa.

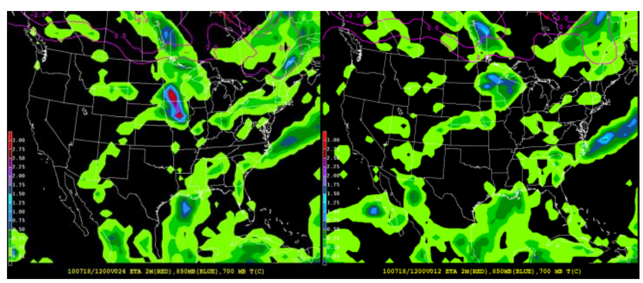

Figure 1: NAM (left) and GFS (right) 12 hour rainfall predictions from 12 UTC 17 July initializations, valid for the period 00-12 UTC 18 July 2010.

Convection first developed along the SD/ND border around 19 UTC and moved eastward for the first few hours. By 21 UTC, the southern part of the system began to veer noticeably to the southeast as it approached the western MN border. Around 00 UTC, a broken line of storms expanded from north of Minneapolis southwest into central Nebraska, giving the implication the entire system was growing rapidly upscale. However, within 2 hours, much of the convection dissipated, leaving only a small but intense cell along the MN/IA border in far southwestern MN at 03 UTC. It was this small remnant of convection that quickly intensified and grew upscale into a damaging bow echo that moved SSE across most of central Iowa between 05 and 10 UTC 18 July (Fig. 2). Severe

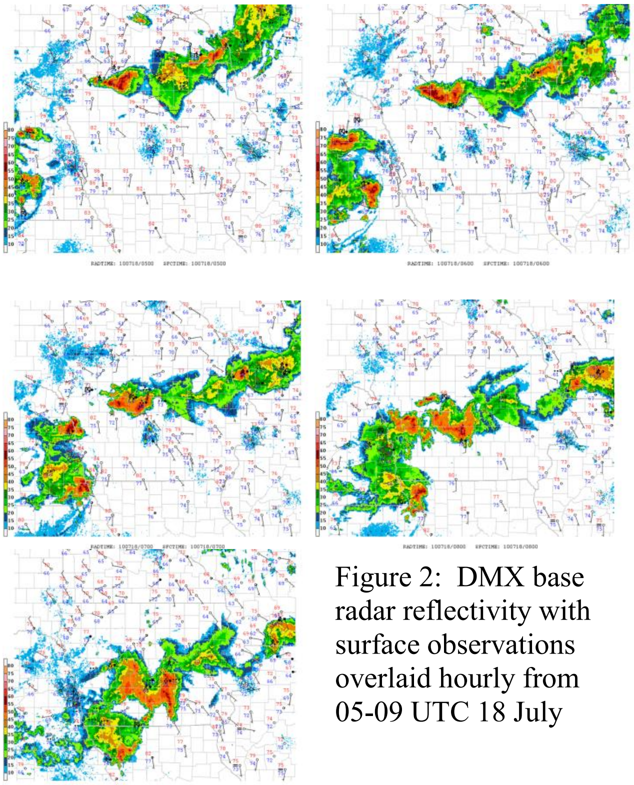

Figure 2: DMX base radar reflectivity with surface observations overlaid hourly from 05-09 UTC 18 July

weather was common along a narrow path associated with the system (Fig. 3), with many reports of substantial tree damage, and a few reports of winds reaching 70-80 knots. Thousands of trees were

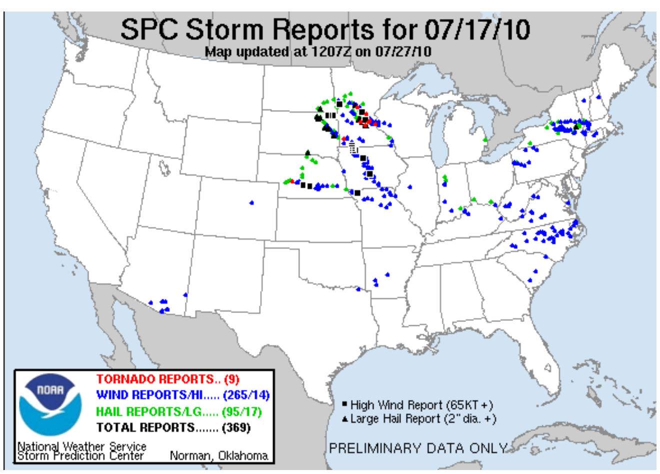

Figure 3: Storm Reports for 24 hours ending 12 UTC 18 July 2010. Note the NNW-SSE path across Iowa.

damaged along with many roofs in the Ames, IA area, where the strong winds lasted for approximately 15 minutes, and nearly 2 inches of rain fell in less than one hour. Base velocity images from the KDMX radar support the long period of damaging winds, showing a rather wide zone with high winds of 65-80 knots (Fig. 4). Peak speeds exceeded 80 knots in the radar data, and because these values were relatively close to the radar, the elevations at these times were generally only 1000-2000 feet above ground. Shortly after these times, the system weakened a bit, but 60 knot flow was detected at heights of less than 500 feet above ground.

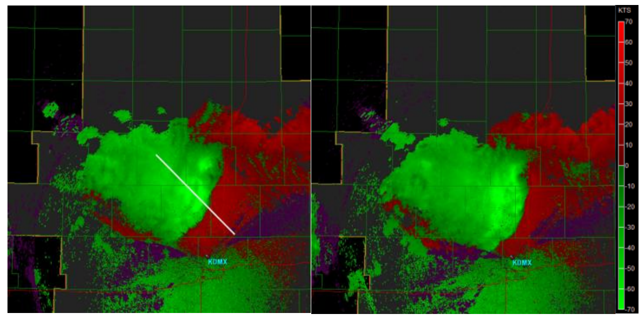

Figure 4: Base velocity data from KDMX at 0721 (left) and 0731 UTC (right). Bright greens indicate flow toward the radar generally greater than 65 knots (color bar on right). White line in left image shows rough location of vertical cross-sections shown later.

4. Comparison of Simulations to Radar Data

As stated earlier, both 2 km and 4 km grid spacing versions of the WRF model did a very good job of simulating the bowing convective system, and showing damaging wind potential in central Iowa. In general, spatial errors with this derecho event were 100 km or less, and timing errors were around 1 hour with the model being too quick to move the system through central Iowa. Considering the event was happening roughly 18 hours into the simulation, this accuracy is surprisingly good and may be related to the use of the 12 UTC NAM for initial and lateral boundary conditions, since this was the one operational model that had implied very heavy QPF in Iowa.

Simulated reflectivity from both the 2 km and 4 km versions of the model is shown over a one hour period corresponding to 06 – 07 UTC in Figure 5. Although there is not exact agreement with the fine-scale details in the convective system (compare to Fig. 2), the general shape and evolution of the most intense

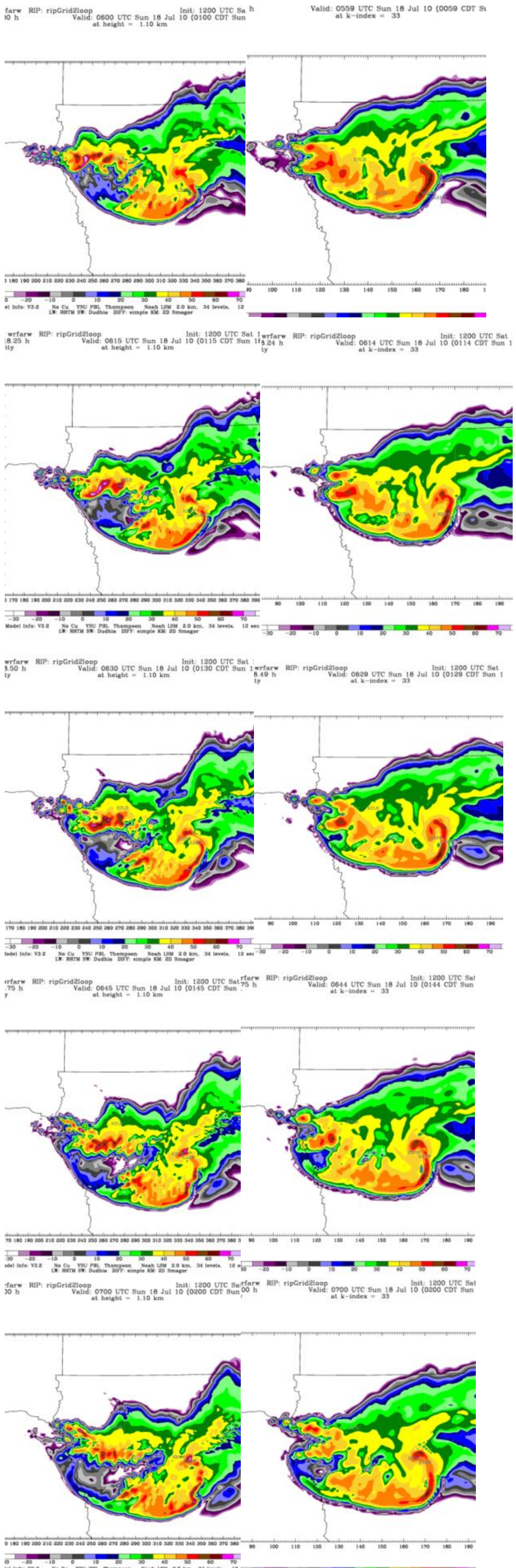

Figure 5: Simulated near-surface reflectivities (see color bar) at 15 minute intervals from 06 (top) through 07 (bottom) UTC (18-19 hour forecasts) from the 2 km WRF simulation (left) and 4 km run (right).

part of the system is well-forecasted in central Iowa. However, the model had too broad a region covered by reflectivity and was too strong with an extension of intense echo back into northwestern Iowa. Interestingly, the model failed to depict convection in eastern Nebraska that was moving more eastward and not south-southeast as was the bowing system.

Although finer scale structure can be seen in the 2 km run than in the 4 km run, as would be expected, the meso-beta structures do not differ much, a result matching that of Kain et al. (2008). However, the convection in the leading line was more intense in the 4 km run, and appeared to have more organization with a more evident comma head at the northern end of the bowing line. This result may suggest that convection is simulated too intensely in 4 km runs that arguably only marginally resolve it. As would be expected, the fine-scale details in the 2 km run better match typical displays like those shown in Fig. 6. At this time, as well as earlier times (not shown), the observed system did not contain as pronounced a comma head as seen in the simulations.

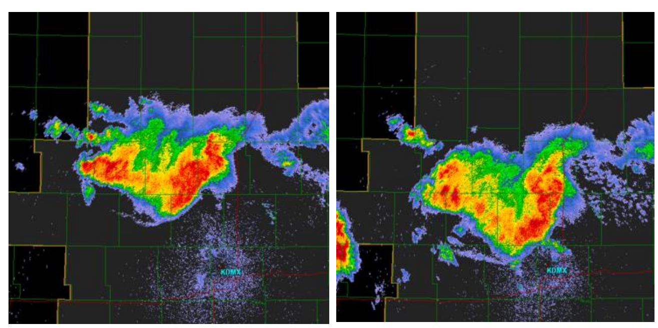

Figure 6: KDMX base reflectivity from Gibson Ridge Analyst software zoomed in on most active convection in central Iowa at 0703 UTC (left) and 0731 UTC (right).

To get a better idea of how simulated reflectivities in the 2 km run compared to those observed throughout the troposphere, vertical cross-sections are compared in Figure 7. It should be noted that the cross-sections do not correspond exactly to the same locations and times, but are sinply meant to represent general conditions through the bowing parts of both the observed and simulated systems when they were in the same general area. It can be seen that peak reflectivities within the convective line do exceed 65 dBZ in both the observed and simulated fields. In fact, at the time shown, observed values exceed 70 dBZ, and at other times, simulated values also were this high. In the simulation, the highest reflectivities are restricted to around the melting level, and drop off to 50-55 dBZ at the ground. Observed reflectivities at the ground reached to 60 dBZ in isolated locations at a few times when the system was tracking through central Iowa.

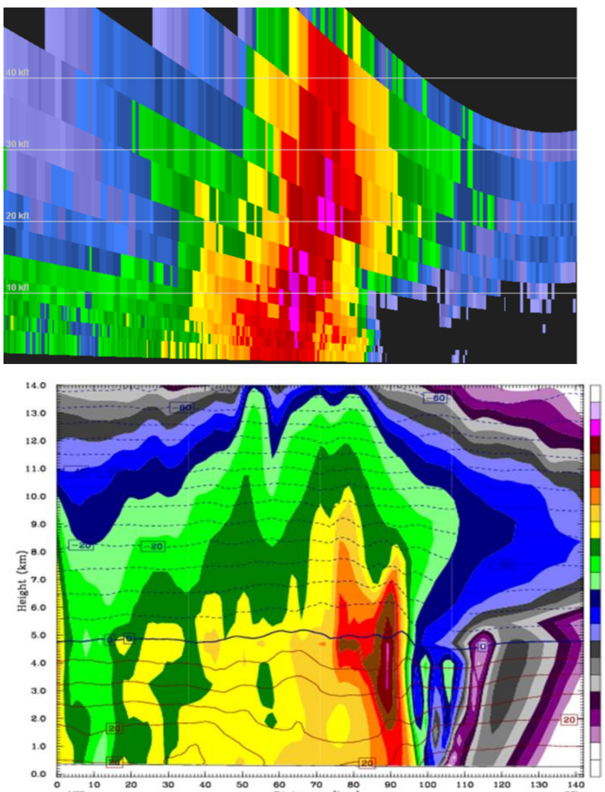

Figure 7: Observed reflectivity (top) in a vertical cross-section across the convective line in central Iowa at 0721 UTC and simulated reflectivity (bottom) across a similar cross-section at roughly 0627 UTC.

Plots of 10 m wind speed from the 2 and 4 km simulations are shown in Fig. 8. Doppler velocities shown earlier (Fig. 4) depicted a rather wide region of strong winds. In the simulation, strong winds can be seen in a narrow band along the gust front with speeds peaking in the 15-20 m/s range, with an even stronger area of winds, reaching 30-35 m/s, over a somewhat broader region near or just southwest of the comma head signature found in reflectivity data (e.g. Fig. 5).There may be some evidence in the Doppler velocity data (Fig. 4) of enhanced speeds as well toward the north end of the line of more intense echo seen in Fig. 6. As in the reflectivity fields, the winds are stronger in the 4 km run than in the 2 km run. The depiction of strongest winds in the WRF runs well behind the gust front is similar to the very successfully simulated "Super Derecho" case of May 8, 2009 discussed in Weisman et al. (2010).

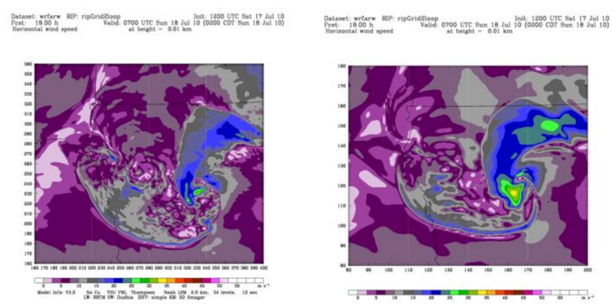

Figure 8: Simulated 10 m wind speeds in the 2 km (left) and 4 km (right) WRF simulations.

Vertical cross-sections from the DMX Doppler radar are shown for two times in Fig. 9. These can be qualitatively compared to cross-sections of wind speed from the 2 km WRF runs in Fig. 10. The radar data show strongest flow toward the radar in the lowest 8000 ft (~ 2500 m) or so of the troposphere with hints of multiple areas where the strongest flow moves closer to the surface. Because the wind speed output from the model has not been converted to the toward/away component relative to the radar, only general comparisons to the radar observations can be made, although it should be pointed out that the strong winds behind the gust front in much of central Iowa were observed to come from a generally northerly direction, or almost directly toward the radar, so that the Doppler velocities shown in the figures in this paper likely do depict most of the full magnitude of the observed winds.

Rather large changes in the simulated wind pattern occur over this 30 minute period with a very strong zone of winds peaking at nearly 50 m/s roughly 2000 m above the ground about 35 km behind the leading edge of the convection at 0600 UTC. By 0630 UTC, the strongest winds shift much closer to the ground, about 500 m above ground, and weaken to around 40 m/s. Aloft, about 3 km above ground, a secondary zone of strong winds can be seen.

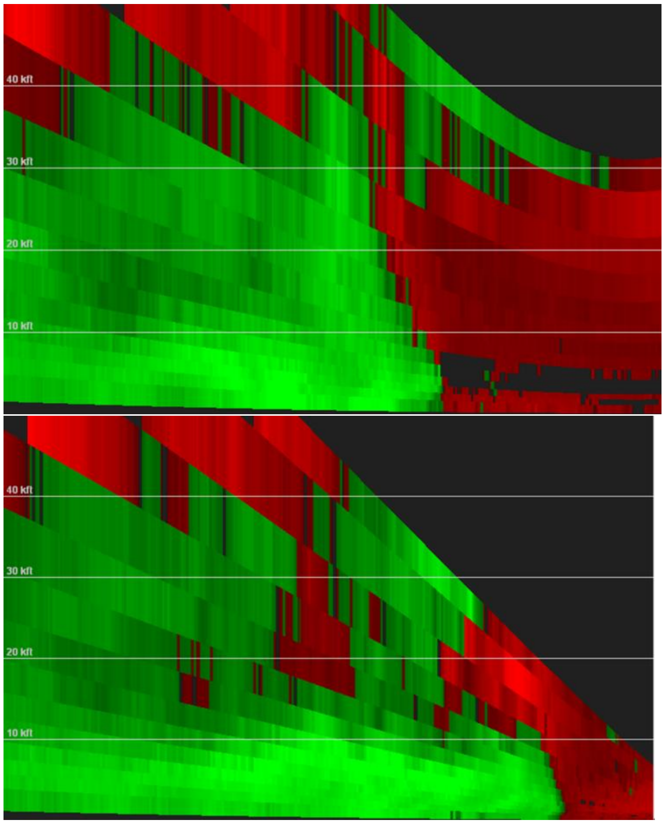

Figure 9: KDMX velocity data at 0721 UTC (top) and 0731 UTC (bottom) along cross-section shown in Fig. 4. Color scale same as in Fig. 4.

5. Summary and Conclusions

An intense derecho that affected central Iowa 17-18 July 2010 has been successfully simulated with 2 and 4 km horizontal grid spacing in the WRF model. Although the event occurred roughly 18 hours after the 12 UTC initialization of the model, the simulation captured well the general location and timing of a bowing line of convection accompanied by surface winds exceeding 60 knots in many places. Timing and location errors for the convection in central Iowa were generally on the order of 1 hour (model too fast) and 100 km or less, respectively.

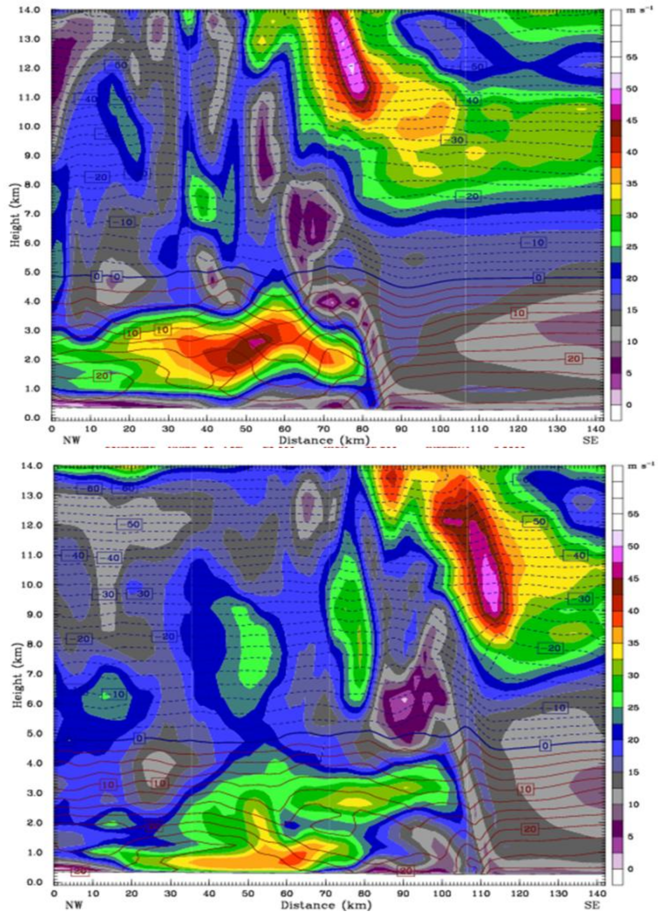

Figure 10: Vertical cross-section of wind speed (see color bar on right side) from 2 km WRF run valid at 0600 (top) and 0630 (bottom) UTC.

Differences between the 2 km and 4 km simulations were found to be relatively small, although the coarser simulation did produce higher reflectivities near the surface in the leading line of intense convection, a more pronounced rotating comma head at the north end of the system, and stronger surface winds. Both simulations, despite showing peak wind speeds very close to the values observed, tended to concentrate the winds too much in the region just behind or southwest of the comma head, and did not have the correct shape of the region that was observed to have strong winds.

This study was an exploratory one focused on general radar characteristics in the 2 and 4 km WRF simulations and their comparison to KDMX radar observations. Future work should look in more detail at why the simulations produced too strong of a comma head feature, and also compute simulated Doppler velocities from the model output to better determine similarities and differences in the low-level wind fields.

6. Acknowledgments

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