11.2 A Cyclone at the Cyclone Game on Nov. 12, 2005 – A Near-Miss Worst-Case Scenario

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1. Introduction

Increasingly, meteorologists and emergency managers alike have commented that perhaps the greatest loss of life due to a tornado in this country will occur if a tornado hits a crowded sporting venue. The near misses that occurred at the Ak-Sar-Ben horse racing track in Omaha in 1975 and the dog racing track near Memphis in 1987 are well-known (e.g., Edwards and Lemon 2002).

On November 12, 2005, another near-miss occurred when an F2 tornado passed 3 miles away from over 50,000 fans gathering for a college football game at Iowa State University in Ames. Because the severe weather threat was well-forecasted, emergency managers implemented a series of actions to reduce potential casualties; however, a lack of shelter options around the stadium, a situation common at many large universities, could have proved catastrophic. A detailed description of the evolution of events on November 12 along with subtle mesoscale features that enhanced the tornado risk will follow.

2. Synopsis of Event

For several days prior to Nov. 12, forecast models indicated a strong short-wave trough moving northeastward across an abnormally warm and humid airmass in the Upper Midwest, suggesting a possibility for unusually late in the season severe thunderstorms around the time of the 1800 LST kickoff of the Iowa State Cyclone - Colorado Buffalo football game in Ames, IA. Because of the consistently-forecasted threat for severe weather, an emergency meeting was held at 0900 LST with university, city of Ames, and hospital officials present. An existing critical incident plan was reviewed and adjusted at that time. Extra medical supplies were moved to various portions of the stadium, while several large buildings within a roughly 5-10 minute brisk walk from the stadium were selected to be unlocked so that they might be used as shelters. In addition, over 6,000 flyers discussing the enhanced severe weather risk and safety procedures were printed to be distributed to arriving fans and read from police bullhorns to the gathering afternoon crowds. The flyers described what to do in two different scenarios – (i) for lightning and hail, fans were told to seek shelter in cars, (ii) for tornadoes, fans were instructed to move to nearby buildings or seek shelter in ditches.

By 1200 LST, satellite imagery showed a narrow wedge of clearing advancing into southwestern Iowa, just ahead of a surface dry line. This clearing allowed for destabilization in this region by 1400 LST (Fig. 1), and a tornado watch was issued for much of Iowa around that time. Already by early afternoon, detailed surface observations available from the Iowa Environmental Mesonetwork (IEM), a partnership between Iowa State University, the National Weather

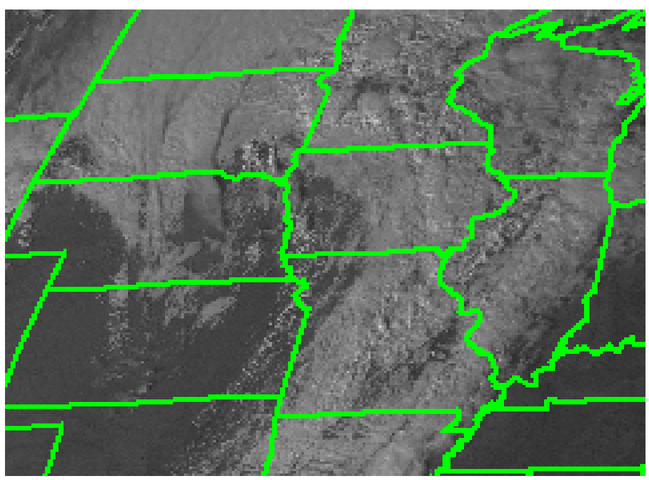

Figure 1: Visible satellite image from 1400 LST (20 UTC)

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Service in Des Moines, KCCI-TV of Des Moines, and the Iowa Dept. of Transportation, revealed some enhanced backing of surface winds in portions of central Iowa. As will be shown in the modeling work to follow, this backing was apparently the result of differential heating taking place over Iowa as persistent cloudcover and frequent light showers occurred into the afternoon in areas near and east of Ames, with substantial clearing to the immediate west on both sides of a dry line advancing into western Iowa. Severe thunderstorms had developed by 1439 LST and NEXRAD radar indicated rapid development of low-level rotation. Tornado warnings were issued for several of the storms as early as 1519 LST. The storms were racing north-northeastward with speeds exceeding 50 miles per hour, a factor that would work to reduce warning times later in the afternoon. Although several tornado warnings had been issued prior to 1600 LST, no tornadoes were reported by that time. Figure 2 depicts an IEM surface plot valid at 1600 LST, at which time the backed surface winds were very prominent in central Iowa.

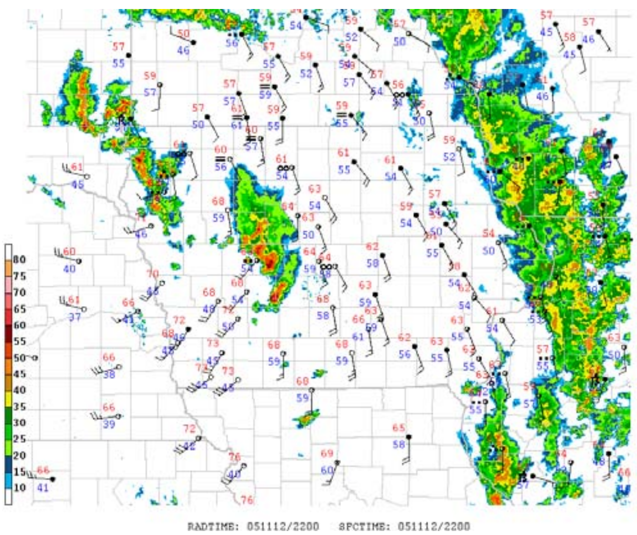

Figure 2: Surface observations at 1600 LST (22 UTC) with radar reflectivity overlaid.

By this time, a crowd estimated at over 50,000 had gathered around the stadium, enjoying the unusually warm mid-November weather. Athletic department officials at the stadium were maintaining frequent phone contact with the National Weather Service office near Des Moines, and were also utilizing a feed of data from a private meteorological firm. Based on the presence of a strong storm almost directly upstream (SSW) from Ames (the farthest south storm in Fig. 2), officials decided to open the gates to the stadium 10 minutes early, at 1620 LST, believing that people would be safer inside the stadium than stuck outside if a storm should hit. Officials had already decided that because of the rapid movement of the storms, they would not wait for a weather warning to be issued before acting. Instead, they planned to make announcements to the crowd the moment any storm crossed the county line. It is interesting to note, though, that the stadium is only 3 miles from the western end of Story County, and although the general idea of needing to act quickly was admirable, with storm movements exceeding 50 mph, it is clear that decisions would have had to be made far before any storm reached the county line.

Around 1630 LST, two different supercells began producing tornadoes. One of the tornadoes was causing F2 damage in the town of Woodward, roughly 15 miles southwest of the stadium. One component of the IEM that proved very valuable on this day was 20 web cameras remotely controlled from Iowa State University. During the period 1635-1639 LST, one camera located in Madrid, IA, captured the damaging tornado (see Fig. 3). This footage was shown live on KCCI-TV and was viewed by many tailgaters who had portable televisions. This tornado lifted by 1641 LST.

Figure 3: IEM web camera photograph from Madrid IA looking WSW toward Woodward IA.

Based partly on these observations of the tornadic storm, evidence from a storm-tracking algorithm supplied by a private vendor that suggested the supercell was turning slightly rightward and would pass closer to the stadium than originally believed, and observations of flags at the stadium shifting in direction due to backing winds, at 1645 LST evacuations of the stadium for a scenario 1 event (hail & lightning) were begun. People were told to report to their automobiles to avoid the lightning and hail threat. Immediately after this evacuation was ordered, another tornado was reported on the ground near the town of Luther, only 8 miles SW of the stadium. Based on this report, at 1650 LST, the evacuation was changed to scenario 2, and the crowds were now told to seek shelter in nearby buildings and ditches due to a tornado threat. The relatively small number of people already in the stadium were told to seek shelter in lower concourses and nearby restrooms. Those outside had to choose to walk 5-10 minutes to several large buildings, or seek shelter in ditches. The tornado warning for Story county was issued at 1656 LST. An F2 tornado touched down around 3 minutes later, roughly 3 miles west of the stadium, and could be seen from the IEM web camera at the nearby ISU campus at 1701 LST (Fig. 4). This particular storm had a very pronounced rear-flank downdraft clear slot. All of the rain and hail stayed to the northwest of the tornado track, such that this danger was minimized for the fans at the game. As further evidence of the intensity of this rear-flank downdraft, a brief anticyclonic tornado was documented roughly 1 mile south of the main tornado at the southwest corner of the city of Ames, again roughly 3 miles from the stadium, roughly 2 minutes prior to the time shown in Fig. 4.

Figure 4: IEM web camera view looking NW from the ISU campus in Ames.

The tornado that passed across the northwest edge of Ames remained on the ground for over 5 miles. The storm continued to produce several more tornadoes over the next hour as it raced north-northeastward. In total, over 10 tornadoes hit central Iowa during a roughly 2 hour period. One person was killed.

3. Modeling results

In addition to the challenges of having a large group of people gathered outside and particularly vulnerable to severe weather on this day, another difficult challenge was determining the actual risk of tornadoes. Early statements from the Storm Prediction Center emphasized a damaging wind threat from linear storms. For over an hour after the first tornado warnings were issued based on radar rotational signatures, no tornadoes were reported. It was not until around 1630 LST when suddenly two separate supercells began producing significant tornadoes.

As discussed earlier, winds in a small region of central Iowa during the afternoon exhibited enhanced backing. Many prior studies have shown that enhanced backing may increase the probability of tornadogenesis (e.g., Maddox et al. 1980; Markowski et al. 1998; Atkins et al. 1999). The synoptic-scale low pressure system itself was deepening throughout the day as it passed across southeast SD and into MN, and the isallobaric component may have played some role in the enhanced backing. However, if the backing was primarily the result of the deepening surface low, it is unusual that the most pronounced backing was confined to a small region of central Iowa. It seems more likely that this enhanced backing took place because central Iowa marked a region where persistent cloud cover and frequent light showers lasted into the mid-afternoon hours just to the east while rapid clearing had occurred just to the west. It is possible that differential heating resulted in the enhanced backing, and that this backing was the necessary ingredient for these rotating supercells to produce significant, long-tracked tornadoes.

To investigate this question, a series of near-cloud resolving 4 km WRF-ARW simulations were performed using 18 UTC RUC output for initial and boundary condition data. Simulations were integrated for 12 hours.

In the control run, using the RUC initial data, the first substantial convection developed in NW IA around 22 UTC (see Fig. 5). With 4 km grid spacing, the storms would be only marginally resolved. They may be assumed to be supercellular by their isolated appearance. No storms formed south of 42.8 N in this region, and thus the simulation had the southern extent of convection too far north by over 100 km and was too slow in initiation by roughly 2 hours. Of perhaps more importance, the surface winds were generally southerly at most points near the more southern convection, and the directional wind shear (at best from 150 degrees at the surface to 210 aloft) was somewhat restricted compared to observations.

A series of tests were performed by making small adjustments in the WRF initial conditions. Because the differential heating gradient was believed to be influenced both by persistent overcast conditions and showers just northeast of Ames and the sharp clearing in western Iowa, these initial condition adjustments included (i) adding a region of high relative humidity to central Iowa to enhance cloud and precipitation there, (ii) reducing relative humidity behind the dry line to ensure clear skies, while expanding slightly the area of moistening in central IA down into north-central MO and (iii) adding a 50 km band of enhanced moistening just ahead of the dry line while maintaining the other conditions of (ii).

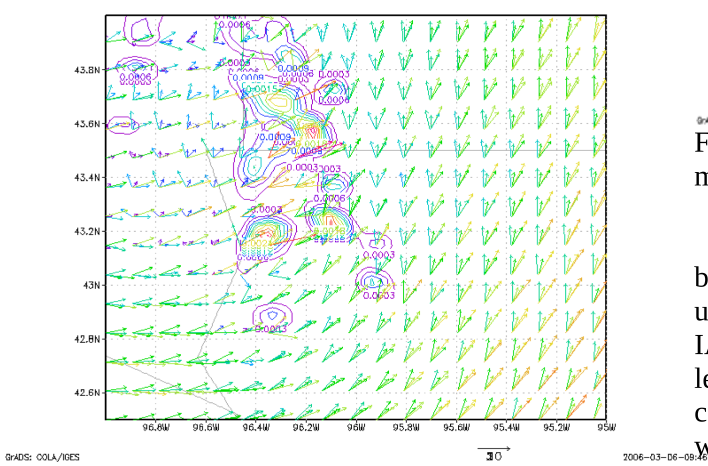

Figure 5: Control WRF run showing 800 mb rain mixing ratio (contoured) with surface, 850, 700 and 500 mb vectors overlaid.

In the first test, when relative humidity was enhanced (set to a minimum of 98% in the 300-850 mb layer) in a region of central IA near and northeast of Ames, heavy precipitation formed immediately on the west side of this rectangular region and was quickly advected northeast and out of the domain. Again in this test, no convection formed in central Iowa, but the first strong convection to develop later no longer formed in NW IA but instead in NC IA (Fig. 6). The changes in locations of precipitation were accompanied by a change in surface winds. Increased easterly flow developed over a larger area in this part of the state than was present in the control run, so that more of these storms would have had access to enhanced storm relative helicity values. The winds in this region generally didn't exhibit more veering than in the control run, but a larger region had the roughly 60 degrees of directional shear. Even greater shear was present in a region behind the easternmost supercells in southern MN where winds veered about 90 degrees, from around 130 at the surface to 220 at 700 mb, with most of that shear below 800 mb.

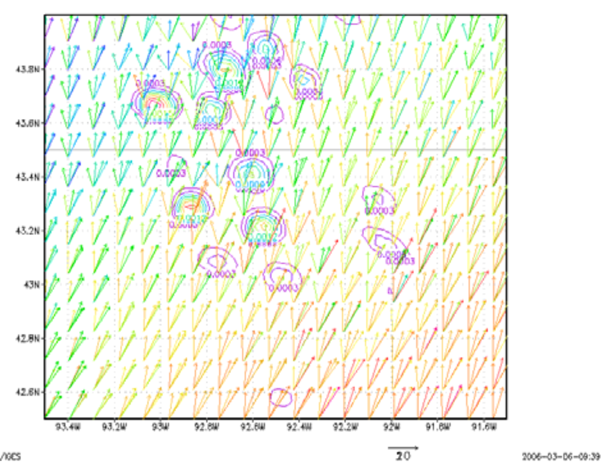

Figure 6: As in Fig. 5 but for test run with enhanced moistening in central Iowa.

In the second test, where drying was enhanced behind the dry line (a value of 50% was used as an upper limit in an effort to ensure full insolation in W IA where it was observed) much greater backing at low levels was present by 23 UTC over a bigger portion of central Iowa, with enhanced backing extending to the west into western Iowa (Fig. 7). The larger area of moistened conditions in the central parts of Iowa and northern MO resulted in a large line of precipitation quickly forming at the west edge of the moisture and moving rapidly east into WI and IL during the afternoon. Although in a few small regions, enhanced easterly winds appeared to be related to outflow, these small regions were confined to the back edge of the precipitation region, which quickly exited Iowa by

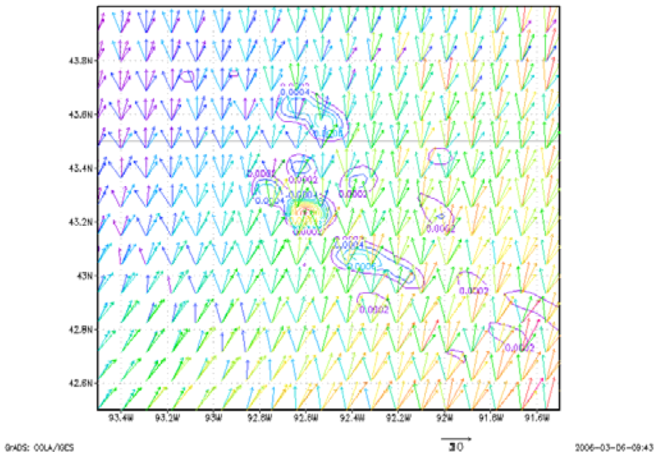

Figure 7: As in Fig. 5 but for run with enhanced drying behind dry line and enhanced moistening in C IA and NC MO.

around 20-21 UTC. The enhanced backing in the model appeared to develop as the afternoon progressed, suggesting it was due to the enhanced E-W temperature gradient that developed in parts of C and W IA compared to the control run.

Despite a more realistic surface wind field that better matched observations, the first storms in this test were again confined to the same part of north-central or northeastern Iowa as in the previous test.

In the final test, an even larger area had at least 90 degrees of directional shear in the lowest 2-3 km and the strongest cells that developed were better co-located with the enhanced shear (Fig. 8). In this run, an intense band of convection quickly developed all along the dry line and raced eastward. This feature was not observed, although weaker banded precipitation was found in many areas well ahead of the dry line. Of note, the first isolated cells that developed near the dry line in the late afternoon occurred in regions much more similar to the control run than in the previous two tests, although the cells were shifted eastward about 50 km, and thus occurred closer to Ames (~150 km NW) than in any of the other tests.

Many additional tests were performed, where the areas of high relative humidity were shifted and re-defined, or the values adjusted slightly. The impacts on the forecast were surprisingly large. When the band of enhanced humidity just ahead of the dry line was narrowed to about half the width used in test 3, the

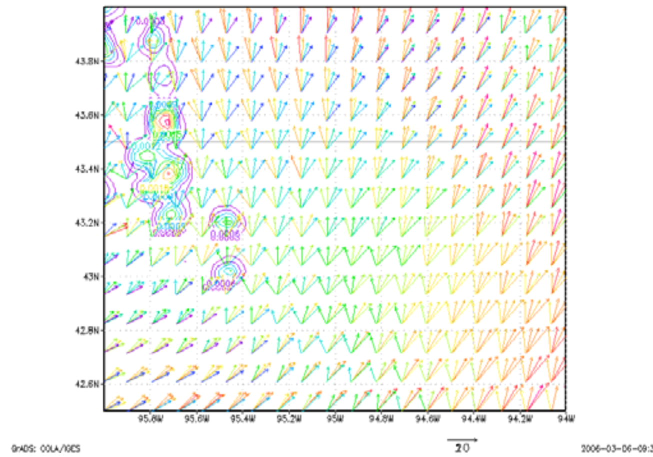

Figure 8: As in Fig. 5 except for test with drying behind dry line, moistening in C IA and NC MO, and moistening just ahead of dry line.

backing of winds was greatly reduced and no convection formed in NW Iowa. Likewise when the relative humidity in the band was reduced from 98% to 88%, the backing was shifted northward, along with the development of any precipitation. Even a 1% change in relative humidity in this band was found to affect how far south convection initiated in the model, although the backing region matched well with that in test 3.

In the WRF runs that were performed, convection never developed as far south as was observed, and the techniques used to change the simulations resulted in anomalous regions of organized convection early in the afternoon. It is interesting that in the third test where moisture was enhanced along the dryline, storms exploded all along the dryline and raced eastward much faster than any of the observed storms. Observations did suggest enhanced towering cumulus formed along the dryline shortly after 18 UTC, but only a few cells formed here and they moved more slowly, bringing the tornadoes to central Iowa during the 2230-2330 UTC period. The WRF runs suggested that the enhanced cloudcover and precipitation in central Iowa helped to keep winds more backed in that general area, and a sharper moisture gradient near the dryline did the same. Both of these findings support the idea that differential heating led to a region of enhanced backing on November 12 that contributed to tornadogenesis.

4. Summary and Conclusions

The November 12 2005 tornado outbreak in central IA posed several serious challenges. Persistent cloudcover and light precipitation in one area of the state, along with dramatic clearing in another resulted in a region with a tight gradient in diabatic heating that may have enhanced surface backing of the winds. The increased storm relative helicities in this area seemed to be associated with the production of significant tornadoes in a 2 hour period as storms raced across this small region at over 50 mph. These subtle features might have been difficult to observe were it not for the presence of the Iowa Environmental Mesonet.

Accurate prediction of the tornadic threat was particularly important on this day because of the presence of over 50,000 fans who had gathered at ISU's football stadium to watch an 1800 LST game. The well-advertised severe threat resulted in admirable actions by safety officials in advance, with special meetings and the printing of over 6,000 flyers to convey important information to the crowds. However, had the tornado path been shifted by 3 miles, an enormous amount of casualties would have resulted. The ISU stadium, like many others at large universities, is somewhat removed from the rest of campus, and is not convenient to other buildings. In this case, it would have taken at least 10 minutes for most people to walk to the nearest large buildings, and this does not take into account congestion delays. In addition, the buildings designated for shelters could not have held more than half of the crowd. An especially troubling aspect of the actions on this day was the belief that by making decisions when the storm crossed the county line, enough extra time would result to allow people to find shelter. Although this action did provide 6 minutes of extra time compared to what would have happened by waiting until the tornado warning was issued for the county, it still would have allowed only 10-11 minutes for 50,000 people to try to reach the shelters. This event demonstrates that for fast-moving storms, decisions may need to be made when a storm is 2 or 3 counties downstream.

5. Acknowledgments

The author thanks Daryl Herzmann for his assistance in creating some figures. Phone conversations with ISU Athletic Department personnel and the Ames police department were appreciated. This research was funded in part by National Science Foundation grant ATM-0537043.

6. References

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