P2.10 Composite Environmental Conditions Associated with Nocturnal Severe Weather across the Northern

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1. INTRODUCTION

The occurrence of damaging wind can lead to significant property damage and even the loss of life. Walker et al. (2007) described how the threat to life can increases for nocturnal events associated with tornadoes. This is in part because the majority of the population is sleeping and may be unaware a threat is approaching. The threat for nocturnal tornadoes, especially significant, is less across the central and northern Plains due to the normal decoupling of the Plains boundary layer. Although the decoupling of the boundary over the central and northern Plains may also affect the development of significant damaging wind during nocturnal hours, Storm Data (NCDC 2010) indicates that these reports happen at a higher frequency than significant nocturnal tornadoes.

One type of significant nocturnal wind event has been shown to occur in association with derechos (Johns and Hirt 1987), but also can occur from discrete supercells. The environment in which supercells occur at night has not received a significant amount of attention in the literature. Kuchera and Parker (2006) did examine environments associated with damaging wind events, but this was not limited to nocturnal events, or associated with any one mode of convection. Due to the potential for substantial property damage, as well as enhanced threat to life, it is very important for forecasters with warning responsibility to recognize situations where significant nocturnal damaging wind is possible. Supercells offer a way to determine the role of the environment in inhibiting the development of damaging winds at the surface. The evolution of supercells which are surface-based is such that the many downdrafts are associated with damaging winds (Johns and Doswell 1992). Therefore if a supercell is producing large hail but not damaging winds, the environment may be playing a critical role in preventing damaging winds from reaching the surface. This study compares the environment that produces supercells with significant damage winds and hail to those that produce significant hail but fail to produce damaging wind.

2. DATA AND METHODOLOGY

Storm reports are compiled from Storm Data for the period 1996 through 2008 for parts of the central and northern Plains outlined in figure 1. Reports were included that occur between the hours of 2100 through 0800 CST. A series of reports was classified as an event if any of the following occurred: there were at least 3 reports per hour for two consecutive hours, there were 6 reports during one hour, or there were any significant reports (significant report is defined as hail to 5 cm in diameter or wind gusts to 31 m s^{-1}). Finally, the reports were grouped into events that contained only significant hail and those that contained both significant hail and significant wind.

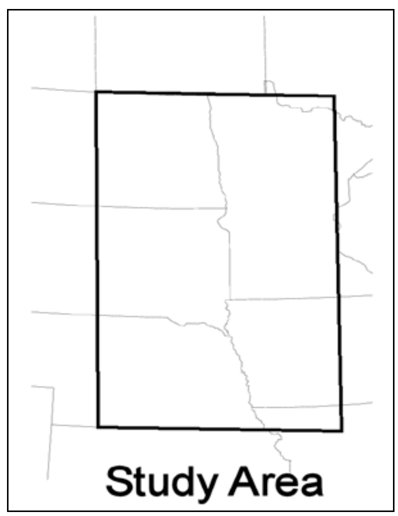

Figure 1. Outline of the study area.

Radar data was obtained from the National Climatic Data Center (NCDC) for the events in the database. The radar data was subjectively analyzed to determine if the events occurred from a supercell. A supercell for this study is defined as any storm that has 10 m s^{-1} of pure rotation on two adjacent elevations scans for 20 consecutive minutes and did not interact with any other convection during that time.

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Once the final database was obtained, North American Regional Reanalysis (NARR) was obtained from the NCDC NOMADS website for each event. The NARR data is available in 3-hr resolution, and the analysis closest to, but prior to, the occurrence of the first significant storm report was used. A supercell relative composite was then developed for each group using the NARR data. The composites were analyzed using the General Meteorological Package (GEMPAK ; DesJardins et al. 1991).

3. RESULTS

A. Climatological Results

Analysis of the database was conducted to investigate if there was any discernable climatological signal (Fig. 2). It appears that nocturnal events of significant hail only typically peak in July, with no events observed past this time of year. Events containing both significant wind and hail also peak in July, but events were observed into the month of August. The distribution of wind to hail showed a significant evolution through the spring into the summer months, with the greater part of the events starting as predominantly hail before transitioning to predominantly wind by August.

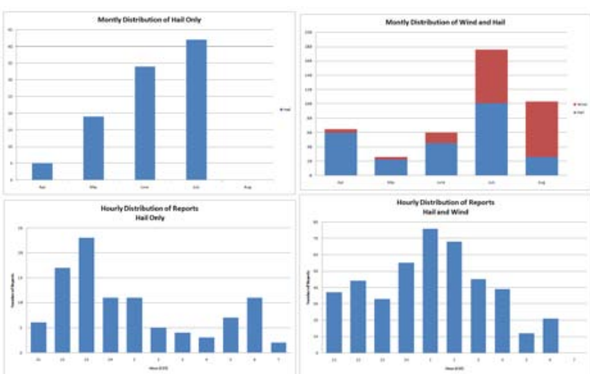

Figure 2. A 4-panel of climatological information.

There were also differences noted in the time of day the reports occurred. For significant hail only events, two peaks were noted. The first peak occurred just prior to local midnight time and was responsible for the majority of the events. The next peak occurs near 0600 CST and likely is a result of veering of the nocturnal Plains low-level jet. Similar results were also noted in a northern Plains nocturnal thunderstorm climatology noted by Schumacher et al. (2006). The significant wind and hail events peaked just after midnight local time and generally did not show a second peak toward dawn as with the significant hail only events.

B. Composite Results

The synoptic scale pattern was generally similar for both types of events (Fig. 3). The composite indicates a ridge upstream, with the report located on the anticyclonic side of the upper level jet. The main differences in the synoptic pattern are that the jet is generally stronger in the hail and wind cases and the position of the upstream ridge axis in the hail only cases is farther west. The difference in placement of the upstream ridge is also apparent in the 850 hPa composite. In the significant hail and wind cases the equivalent potential temperature (θ_e) ridge is more expansive to the south and east of the report. In the significant hail only composite, the report occurs near the gradient of the θ_e with decreasing values downstream.

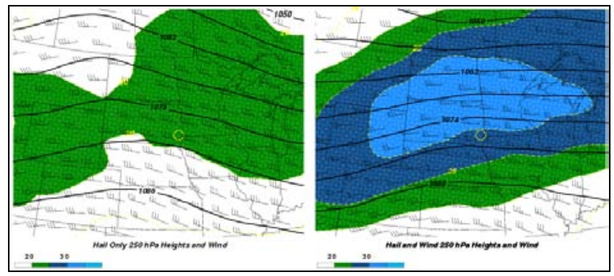

Figure 3. The 250 hPa composite. Thick black lines are heights contoured ever 60 meters. Shading is wind starting at 20 m s^{-1}. Barbs are wind in knots with a half barb equal to 2.5 m s^{-1} and a full barb equal to 5 m s^{-1}.

Although the synoptic conditions appear similar in both composites, there were some potentially significant differences noted. The first of these is the increase in differences in wind speed with height. The wind speeds above 4 km in the significant wind and hail events were stronger than in the hail only cases. This results in strong differences in deep-layer bulk shear (Fig. 4). This was most noticeable in the 1 to 8 and 3 to 8 km layers. There were few if any differences in low-level shear (not shown).

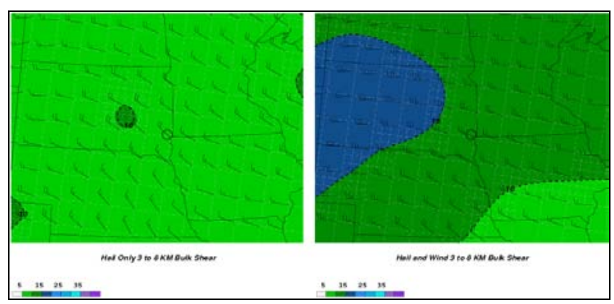

Figure 4. The 3 to 8 km bulk wind shear. Shading is bulk shear starting at 10 m s^{-1}. Barbs are in knots. A half barb is equal to 2.5 m s^{-1} and a full barb is equal to 5 m s^{-1}.

In addition, there were strong differences noted in both low and mid-level relative humidity. In the significant wind and hail events, there is lower sub-cloud layer relative humidity than in the hail-only cases. In contrast, in the mid-levels there is higher relative humidity in the significant hail and wind cases than in the hail-only cases (Fig. 5.). Finally, there were also differences noted in the low-level thermodynamic environment in the composites. In the significant hail only cases the 100 mb mean mixed-layer convective inhibition (MLCIN) was lower than that seen in the significant wind and hail composite.

4. CONCLUSIONS

The nocturnal environmental conditions associated with discrete supercells producing both significant hail and wind to those that produce only significant hail for parts of the central and northern Plains was examined. Initial conclusions indicate two primary environmental factors which allow for significant damaging winds from these discrete supercells to reach the surface. First, the composites indicated that in the supercells which produced significant wind and hail, there was a drier sub-cloud layer, possibly allowing for stronger evaporative cooling and downward momentum transfer to the surface. Also of interest, the reverse appears to be true in the mid-levels where the composites indicated a higher relative humidity in the significant wind and hail composites than in the hail only. The second factor appears to be stronger mid- and upper-level winds, which create high values of deep-layer shear in the significant wind and hail composites. This was especially noticeable in the 1 to 8 and 3 to 8 km layers. There was very little difference noted in the low-level winds or shear in either composite.

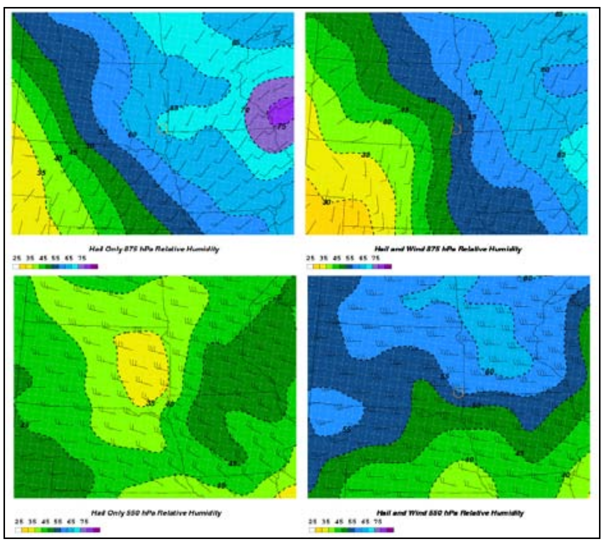

Figure 5. A 4-panel of relative humidity. Relative humidity at 875 hPa is the top 2 images, and the 550 hPa relative humidity are the bottom 2 images.

Although the sub-cloud relative humidity and deep-layer shear appear to be the most significant in the preliminary findings, it was also interesting to note the difference in low-level MLCIN in the two composites. It was found that the MLCIN was actually higher in the significant wind and hail composite than in the hail only. This may indicate that the strength of a low-level inversion may not be a reliable predictor of whether damaging surface winds will occur from supercells in a nocturnal environment. Instead, it may be a combination of evaporative cooling and the internal dynamics of the storm that determine the ability of damaging winds to reach the surface.

On the synoptic scale, the two composites appear very similar. There is short-wave ridge well upstream of the report location for the hail only composite, while the significant hail and wind cases tend to occur near or just downstream of this ridge axis. At 850 hPa, it appears that the hail-only cases tend to occur in a strong warm air advection pattern where there is a well defined warm front near the report location, as indicated in the θ_e gradient. In the significant hail and wind cases, a more expansive θ_e ridge was indicated in the composite, suggesting less of a strong association to an advection pattern.

Future work will add more cases to the event climatology. This will allow statistical-significant test to be conducted on the composites to determine which differences are most important and where they are located with respect to the occurrence of the hail and wind. A high-resolution modeling experiment using representative environments associated with cases in the database to allow a more detailed analysis of the evolution of the near-storm environment. The aspect of the supercell longevity contributing to the occurrence of significant damaging surface winds will be analyzed.

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