The 13 April 2006 Severe Thunderstorm and Large Hail Event in Iowa & Wisconsin:A Case Study

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ABSTRACT

One of the most spectacular severe weather events witnessed is large-hail events. These ice stones can cause millions of dollars in damage in a very short time and turn an otherwise green pasture into a looking like a January-esque snow event. The oddity of white precipitation falling during the warm spring and summer months coupled with the loud, ominous sounds of hail hitting roofs can leave lasting impressions on many people. Such was case in the late evening hours in southwest Wisconsin. After a devastating tornado outbreak in eastern Iowa, a supercell thunderstorm had migrated from Iowa and as it moved across the central counties of Wisconsin, dozens of reports of hail and high-wind events were filed. Hail in excess of softball-size were reported in Iowa and Jefferson (Wisconsin) counties with the largest being a 4.25" ice rock near Lake Mills, Wisconsin. Radar analysis of hail has grown tremendously with the addition of WSR-88D radar and certain signatures become apparent on reflectivities when hail is present in severe thunderstorms. Three-body scatter spikes (TBSS) and flare echoes are two of the ways meteorologists can detect large hail before it reaches the ground. In this is case study, careful examination will attempt to explain the mesoscale dynamics of the initiation of these supercell thunderstorms in Iowa, their advancement eastward, and hail production/observations as they moved through southern Wisconsin. Focus shall remain on the largest severe thunderstorm in southern Wisconsin (~0140Z – 400Z) with only slight reference to the tornadic event in Iowa.

I. Introduction.

During the late evening, early night hours of 13 April 2006, several supercell storms were pushing through eastern Iowa and into southwest Wisconsin. Earlier, the severe storms began around 2300Z 13 April 2006 in Central Iowa with numerous hail reports.

As the storms strengthened as they roared eastward, several tornado reports occurred. Such was the case in Iowa City (Figure 1) where 21 people were injured and the University of Iowa suffered

Figure 1. Iowa City, 14 April 2006. A high-end F2 tornado ravaged part of the downtown with numerous roofs tore off, overturned cars, and scattered debris. Photographer: unknown.

significant damage to dormitories and other university buildings.

This mesoscale convective complex began to reform and the multicellular pattern began to take shape. Before the main complex moved southeast into northern Illinois, one cell broke left and took aim on southern Wisconsin. The very nature of supercells being attracted to certain, localized regions (hence, their otherwise erratic movements) could have many possible reasons.

These include but are not limited to moisture convergences, the ability to follow any mean winds, strong deep-layer vertical wind shear with weaker mid-level storm-relative winds, and a stronger cold pool.

The complexities arise by the very nature of supercells. The internal dynamics of the storms themselves create mesoscale circulations that can drive these storms to move in unpredictable ways. However, initiation of such storms under the right atmospheric conditions are well known.

It is the hypothesis of the researcher that the supercells developed from these classically understood dynamics and the extraordinary hail event was the result of shear from the surface to mid-levels to the upper-air, the remnants of the already intense updraft, and crossing the warm frontal boundary.

II. Data.

The National Weather Service (NWS), the National Severe Storms Laboratory (NSSL), and the Storm Prediction Center (SPC) contributed to the comprehensive damage and storm reports. In addition, the National Climate Data Center served to provide radar data. The Cooperative Institute for Meteorological Satellite Studies (CIMSS) and Space Science and Engineering Center (SSEC) supplied an extensive array of products.

Data analysis was synthesized by graphical-user interface software programs such as Integrated Data Viewer (IDV), General Meteorological Package (GEMPAK), GEMPAK Analysis and Rendering Program (GARP), Java NEXRAD Viewer, GrLevel2, and GrLevel2Analysis.

Satellite retrievals were taken from GOES-8 archives using the infrared spectrums as evidence in this investigation.

Radar data was provided by the NCDC with scans at multiple elevation angles using both WSR-88D's base and composite reflectives.

Convective Outlooks, and Forecast and Mesoscale Discussions were provided by the SPC's archives as well as previous case study synopsizes provided by the NWS and CIMSS.

Model results and forecasts were taken from the Rapid Update Cycle (RUC) and North American Model (NAM, or ETA) model set. The date and times were as of 14 April 2006 from approximately 0000Z to 0400Z 14 April 2006. Upper air and surface plots were provided by Unisys Weather Image and Map Archive.

Regional analysis for the mesoscale investigation includes the Midwest; namely, eastern Iowa, southwest Wisconsin, and northern Illinois. The synoptic overview spans the entire contiguous United States focusing on the states in the upper Mississippi Valley.

III. Synoptic Overview.

A surface plot of CONUS is shown in Figure 2 0000Z 14 April 2006. The storms

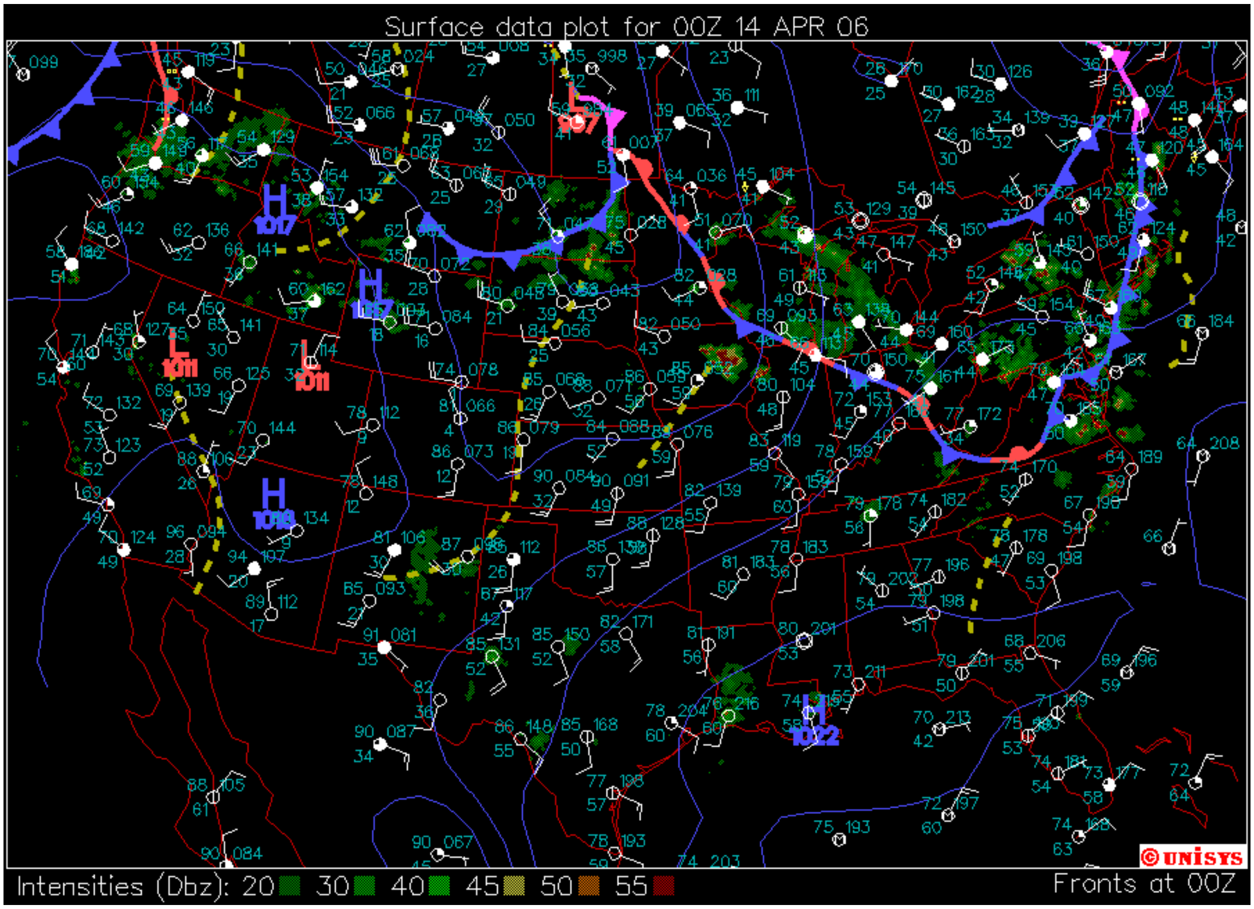


Figure 2: Surface Data Plot 0000Z 14 April 2006. Courtesy: Unisys Data.

in eastern Iowa had already formed into a mesoscale convective complex just below a warm frontal boundary stretching from southern Manitoba southeastward into northwestern Indiana.

Connected to this warm front was a surface anticyclone situated north of North Dakota and an associated cold front draped across the Dakotas and into Montana. The warm moist air (Figure 3) over the Mid-Mississippi Valley is being advected north to northwestward by the lower level wind field. Dewpoints across Iowa ranged from the upper 50s C to mid 60s throughout the better part of the day.

Coupled with converging surface winds and strong daytime heating this created an area of high instability. As the atmosphere began to destabilize in the early evening hours, the lifted indices peaked (with a bull's eye centered on south central Iowa, Figure 4) of negative values.

A surface trough in western Iowa created another area of lower-level convergence separating drier westerly winds with the winds feeding moisture into Iowa.

IV. Mesoscale Analysis.

In Figure 3, we see a moist tongue (green) with dewpoints greater than or equal to 60 C. Accompanying the moist tongue is a thermal ridge (red dots). Ushering in this warm, Gulf moisture northward is the 850mb low-level jet (green arrow).

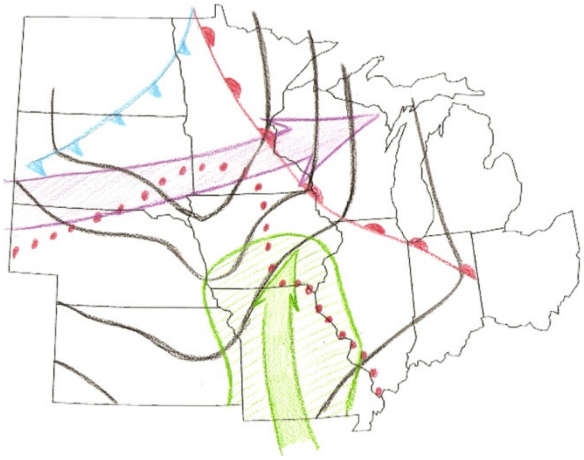


Figure 3: Miller Diagram. 2100Z 13 April 2006. Features Depicted: Cold Front, Warm Front, 300mb Jet Streak (Purple Arrow), 850mb Thermal Ridge (Red Dots), Surface Isobars (Black Lines), Moist Tongue (Green), Lower-Level Jet (Green Arrow).

As these lower-level southerly winds slide under the zonally oriented jet streak (purple arrow), a strong vertical wind shear component is created.

Not only are they winds veering with height (turning clockwise), but the speed of these winds are also increasing. Although the jet streak was not oriented to produce any upper-level divergence (and thus surface convergence) over southern Minnesota/Iowa/southwestern Wisconsin to initiate the convection, the streak did have wind speeds greater than 100 knots.

The initiation was most likely the result of the small short wave moving eastward converging with the warm, moist wind field

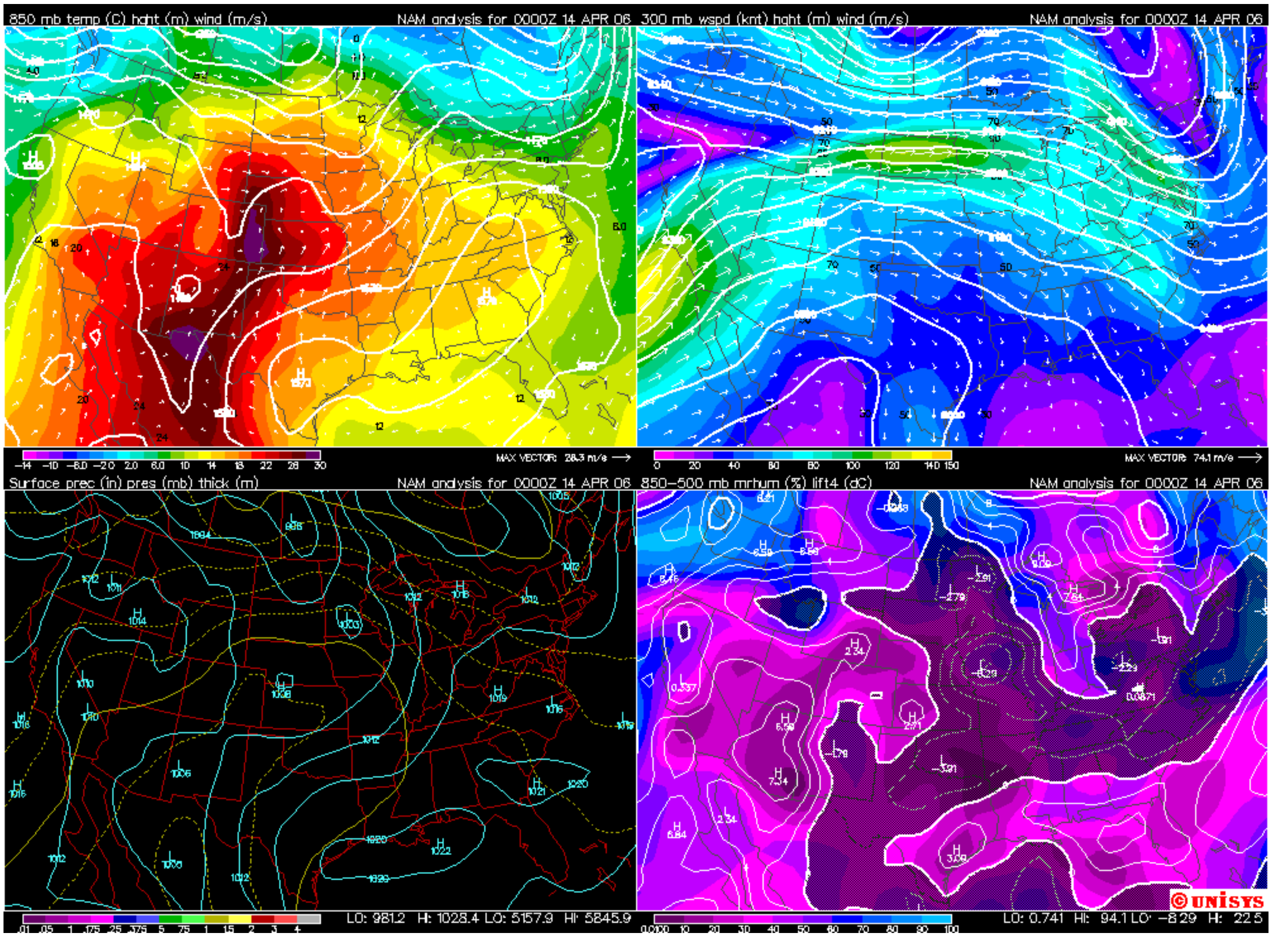


Figure 4: 850mb Thermal Field, 300mb, Surface Plot, and Humidity/Lifted Index. Courtesy: Unisys.

(as discussed in the Synoptic Overview).

Interactions between the warm front are also likely. The relatively strong southerly winds at the surface continually warmed while the upper-levels stayed near the same temperature. This caused an increase in instability (see Figure 5).

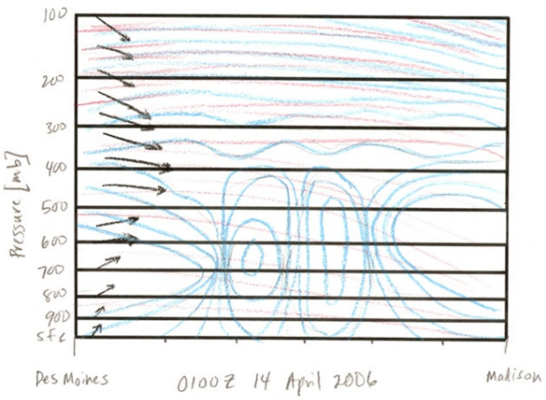


Figure 5: Cross Section. 0100Z 14 April 2006. Des Moines, Iowa to Madison, Wisconsin. Mean Wind Vectors (Black), Equivalent Potential Temperature (Blue), Potential Temperature (Red).

Supercells are conducive when there is strong veering in the low levels (warm air advection) with wind speeds greater than 20 knots and greater than 100 knots up to 300mb (NWS-LSX).

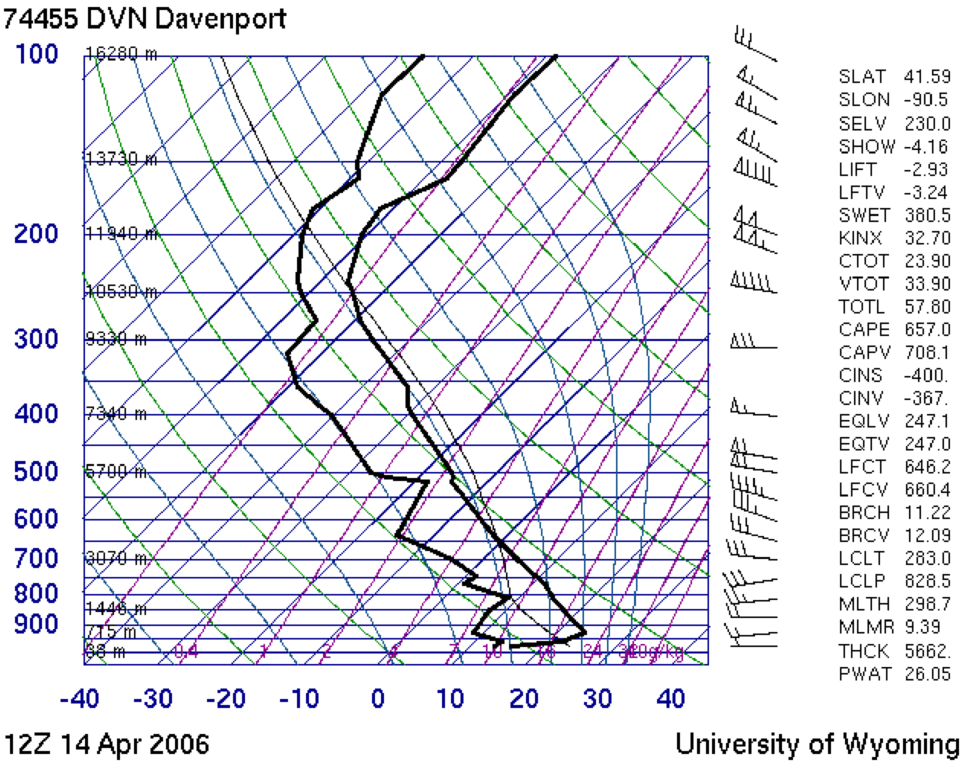
The veering with height creates positive helicity values which have been known to be a highly contributing factor in the generation and lifetime of supercell thunderstorms.

An analysis of the nearest sounding (Figure 6), Davenport, Iowa, at 0000Z 14 April 2006 shows how unstable the atmosphere was just prior to the convection moving through eastern Iowa.

Unfortunately, with the balloon experiencing technical difficulties at 400mb, a true sounding was not able to be taken. Thus the indices generated are prone to error.

The convective available potential energy (CAPE) is just over 700 J/kg and the veering winds can also be shown (the sustained southwesterly winds below 700mb are between 15-35 knots which confirm the necessary horizontal wind shear that supercells need to develop).

Figure 6: Sounding for Davenport (DVN), Iowa. 1200Z 14 April 2006. Courtesy: University of Wyoming

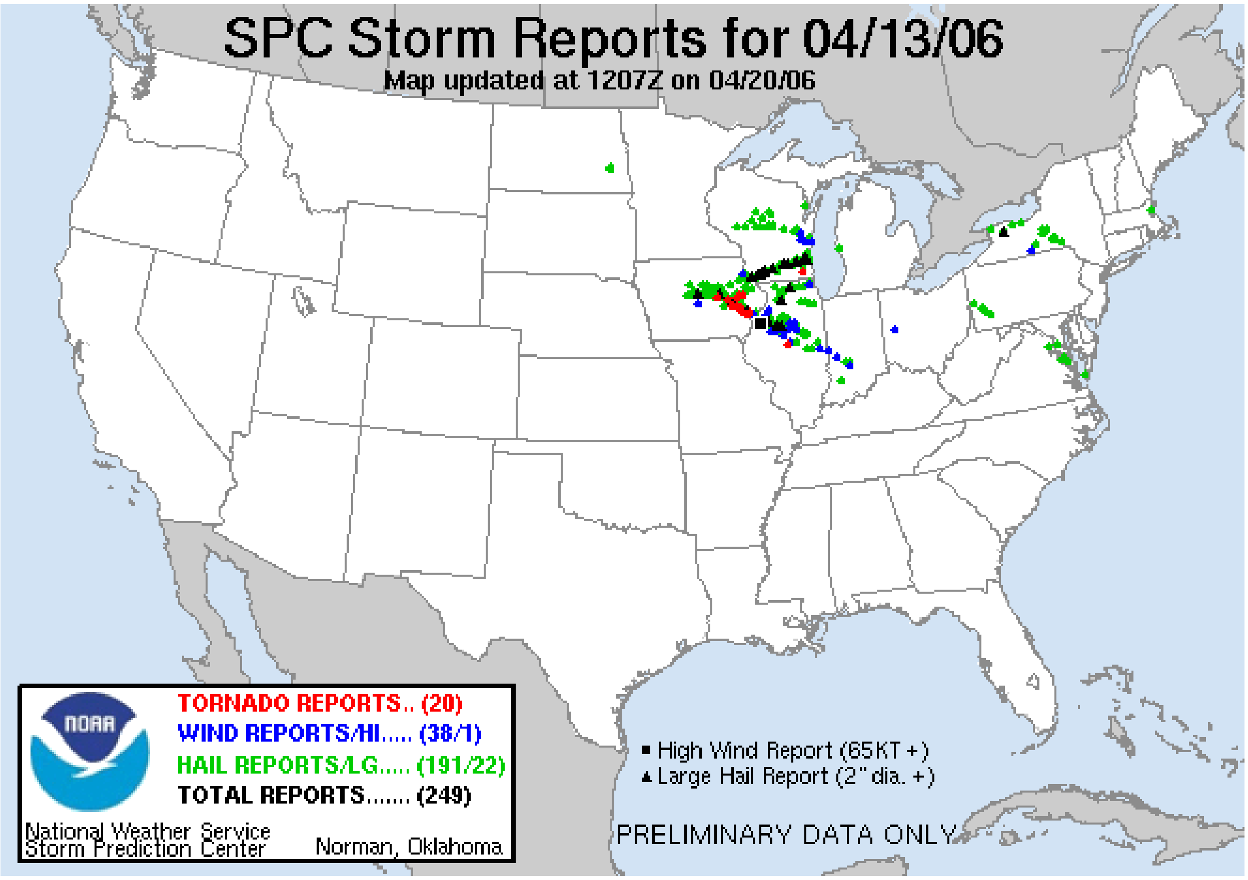


As the system moved southeasterly, new cells formed on the northeast side and began moving to the north-northeast. These are the cells that would eventually impact southern Wisconsin. The thunderstorms here are not trying to use the moist boundary layer as a mechanism of propagation, but instead are caught in the mean mid-level wind pattern. These storms did not necessarily split from the main complex, but instead grew as a result of the complex and propagated on their own accord (as the mean wind would allow).

The air in southern Wisconsin, while unstable, is however, less moist and closer to the warm front. This introduces a unique set of conditions. Since these storms are moving into an area with less horizontal wind shear, rotation within the storm itself will be noticeably weaker. Furthermore, the upper atmosphere will become much colder on the other side of the warm front. This is why it is not unusual that the large hail reports began at about 0104Z just as the thunderstorms neared the warm frontal boundary across northwest Iowa/southwest Wisconsin (Figure 7).

This allowed for the large-hail event to take place. The thunderstorms already contained a strong updraft, but with little mesocyclonic rotations, tornadoes would not be expected. Hailstones grow in the mid-levels in and around an updraft where there is an abundance of super-cooled water (Lemon, 1997). The updrafts associated with large hail are most often intense, large, and rarely mix with environmental air aloft.

Figure 7: SPC's Storm Reports for 13 April 2006. Take note of the large hail reports (black triangles) in southern Wisconsin and the tornado reports angled to the right.



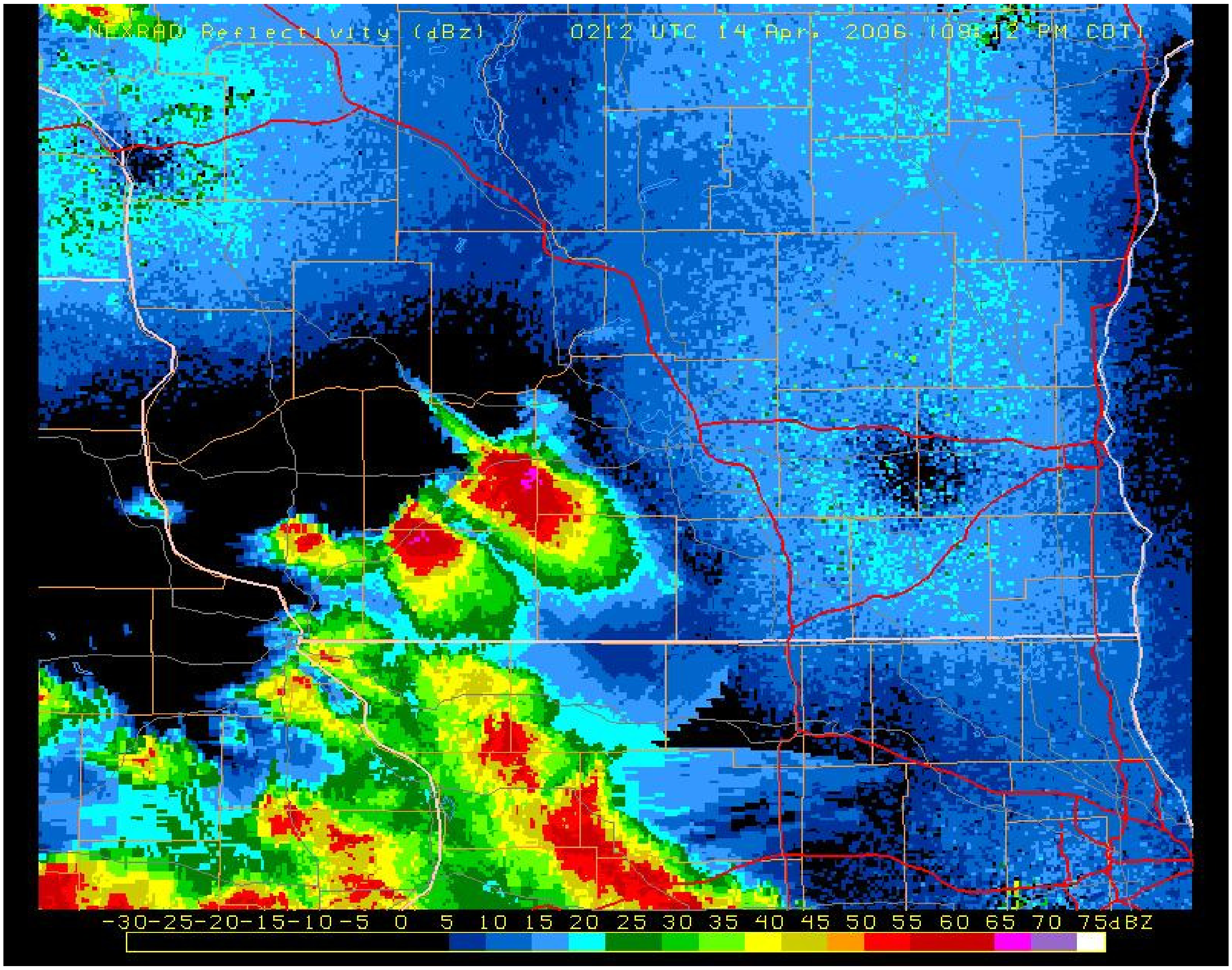


Figure 8: UW-AOS generated NEXRAD radar image of southern Wisconsin. 0212Z 14 April 2006. Special importance to the TBSS.

Studying a radar image at 0212Z 14 April 2006 (Figure 8), we see the intense storm on the southern border of Dane and Iowa counties (Wisconsin). The obvious feature that clearly stands out is the strange spike protruding from the main supercell thunderstorm: the three body scatter signature (spike).

The three-body scatter signature or flare echo is produced on radar by non-Rayleigh radar microwave scattering most likely due from 'dry' or wet hail on scales greater than 1/16 the diameter to wavelength ratio (Lemon, 1997). The triple reflection is the result of

1) scattering by the hail onto the ground
2) backscattering by the ground to the same hail region aloft and finally
3) backscattering by the hail to the radar

A visualization of this is shown in the conceptual figure Figure 9 (top right, with acknowledgments to Lemon, 2007). The signature of the three-body scattering is the 2D representation of the flare. Remember, that this flare does not actually exist, it is a false reflectivity with no precipitation associated with it. To see an actual 3D image of this storm, refer back to Figure 9.

Typically, the TBSS is caused by reflectivities greater than 63 dBz and contains false echoes of 20 dBz or less.

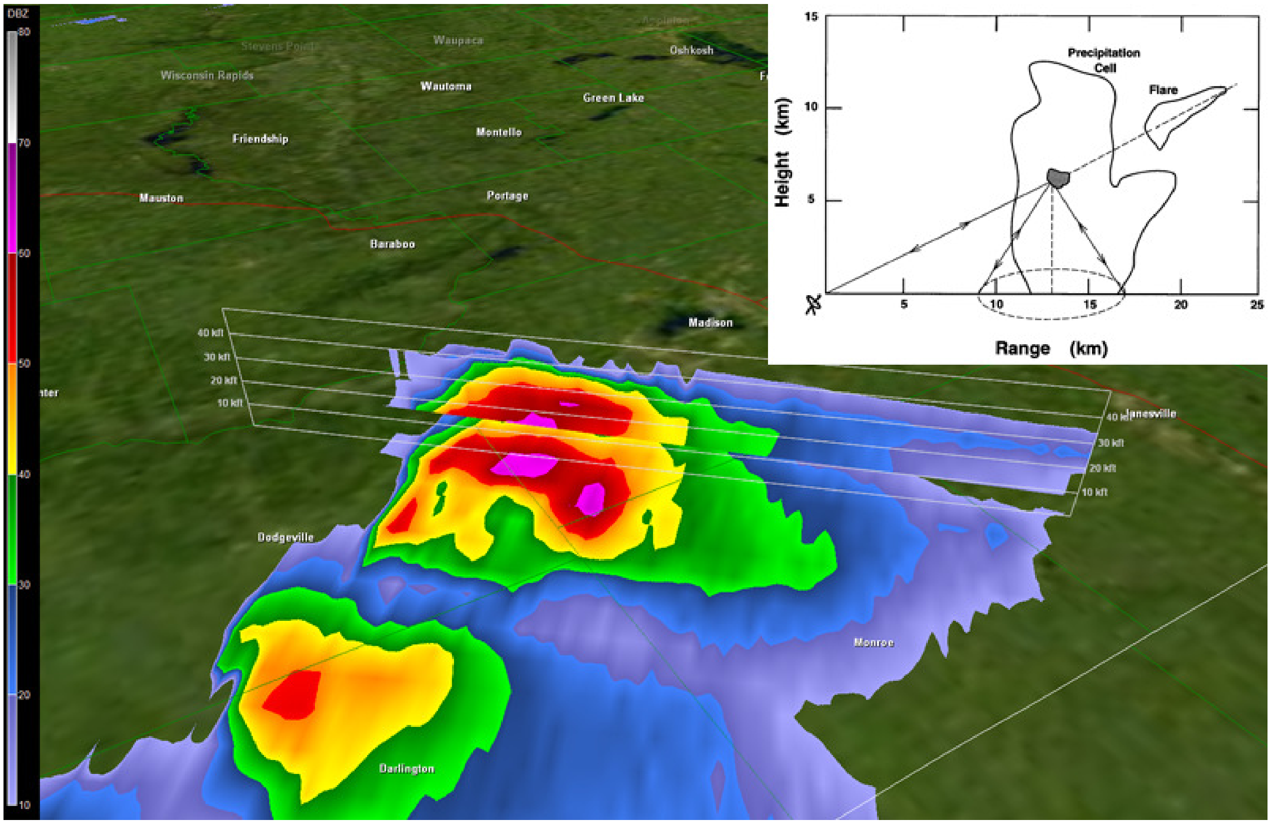


Figure 9: 3D Cross Section of the radar reflectivity (NWS-LOT) of the large hail producing thunderstorm over southwest Dane County, Wisconsin. (0211Z 14 April 2006). Top Right: Conceptual Schematic of the TBSS as viewed from the side. Take note of the 'flare' in each image.

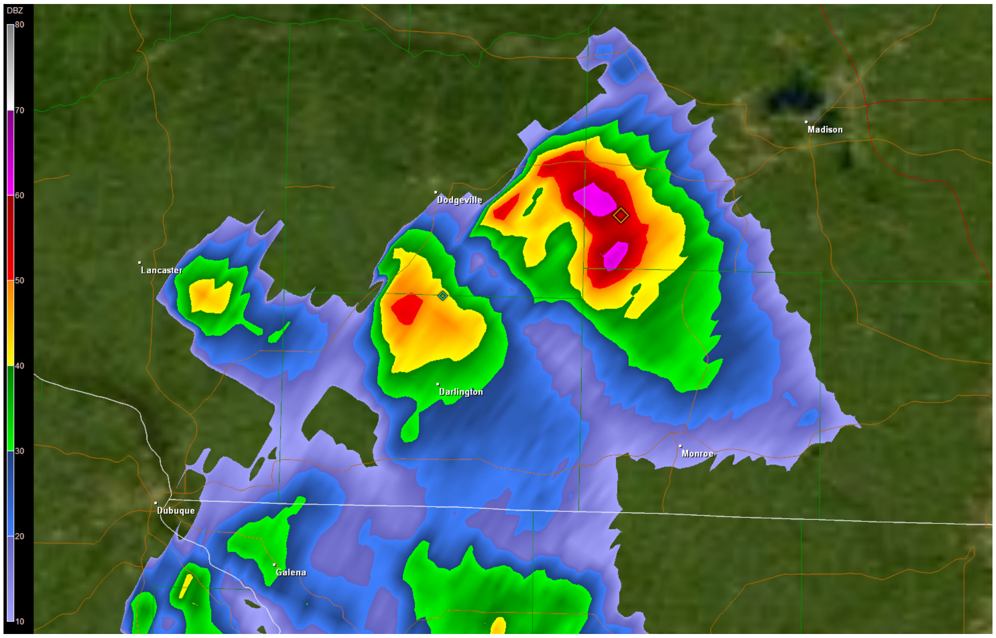


Figure 10: Radar Reflectivity from the NWS-LOT (Chicago, IL) 0211Z 14 April 2006.

Figure 11: Actual hailstones from the severe thunderstorm that struck Madison, Wisconsin. Photography: David M. DeMeuse

The length scale of such spikes are usually on the order on 15 km (Lemon, 1997). In Figure 9 or Figure 10, the greatest reflectivities are upwards of 65dBz, false echoes of ~25 dBz, and length scales of 30 km. While these numbers are rough and rudimentary, they can vary. And, as in this case, very large hail was confirmed (Figure 11); the scatter spike is a real phenomenon.

V. Conclusion.

Although the SPC did issue a severe thunderstorm watch for the evening with special regard to "large, damaging hail", the sometimes sporadic behavior of supercell thunderstorms makes forecasting hail for a localized area extremely difficult. The tornadic mesoscale convective complex corresponding to this event was especially powerful leaving millions of dollars of damage and one person dead.

The storms originally formed as a result of a converging wind field carrying a warm, moist air mass against a warm front. The overhead jet streak allowed for the flow of the storms to prosper and move, although not contributing to the initiation.

Because of their long lifetime, inertial oscillations began to take the storms southeastward (to the right of the mean wind). It was during this time that two cells developed and began their march through southern Wisconsin. These storms followed the mean wind (separated from the complex) and were the major hail producers. Because of their strong updrafts and interactions between the warm frontal boundary, hail was able to grow to enormous sizes.

Future research into this event might include a more detailed synopsis of the structure of the tornadic supercells themselves and the apparent disorganization of the multicellular system and their movements.

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