

# The Supercells of April 13<sup>th</sup>, 2006 in Iowa and Wisconsin

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Photo taken by Ryan Pfannkuch and Ben McMillan.



Photo taken by Dr. Pao Wang.

## ABSTRACT

The night of April 13<sup>th</sup>, 2006 was a very interesting night for many citizens of a certain section of the Midwest. The states of Iowa, Wisconsin, and Illinois were all affected by a severe weather event. This event started as convection in west-central Iowa and developed into supercells over eastern Iowa. The supercells then went separate directions into Wisconsin and Iowa. This was a result of mesoscale interaction between the cells and the overall synoptic circulation. The mesoscale interaction is very confusing and will be a subject of debate for a long time into the future. Overall, the storms produced many tornadoes in Iowa and many reports of large hail in Wisconsin. Two pictures which represent this event are the placed before the abstract. The first picture is of the tornado to hit Iowa City, IA area and the second picture is of the hail to hit the Madison, WI area. Using different tools both the synoptic and mesoscale conditions will be discussed to understand the origins and movement of the supercells.

### 1. Introduction

The movement of supercell thunderstorms are never that easy to predict. Supercells have their own distinct circulation patterns that lead to their hard to predict movement. Sometimes they follow the synoptic flow pattern and sometimes they do not. Supercell thunderstorms are most prevalent during the spring and early summer when the temperatures warm and the synoptic flow is still relatively strong. There are also many other atmospheric characteristics that are conducive to supercells. Some of the characteristics are shear, instability, moisture, and low level convergence. All four of these characteristics are present on April 13<sup>th</sup>, 2006 in the evening hours.

The intent of this case study is to concentrate on the movement of the supercells from their inception through the time they produce their impressive severe weather. It is hypothesized that this movement was a product of individual circulations and large scale circulations. The severe weather they produced will be discussed in relation to each cells movement. In each supercell lies an interesting correlation between

the movement and the severe weather produced. With the help of hand analyses, surface data, storm reports, and model products the storms that hit Iowa, Wisconsin, and Illinois on the night of April 13<sup>th</sup>, 2006 will be diagnosed in order to gain better insights into their peculiar movements.

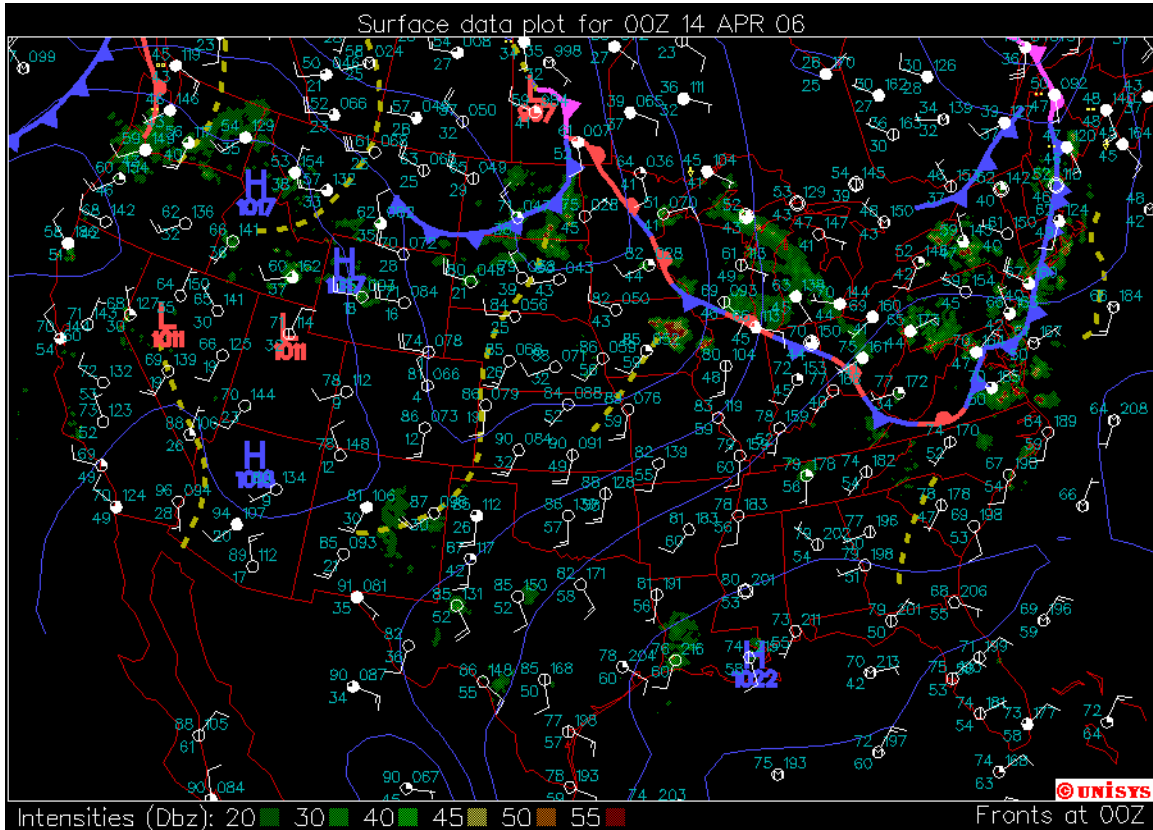
### 2. Data

For this case study hand analyses are used to aid in the discussion. Some of these hand drawn diagrams were developed with the aid of computer plotting programs. The computer software packages used in this case study are General Meteorological Package (GEMPAK) and General Meteorological Package Analysis and Rendering Program (GARP). In addition to actual observational data, model data from the North American Model (NAM, formerly known as the ETA) model on the 211 and 212 grids was also available for use. Model data from the Rapid Update Cycle (RUC) model was also used since in it is run more frequently. Also, surface and upper air plots from [www.weather.unisys.com](http://www.weather.unisys.com) are used to view the overall situation. Radar and

Satellite images are taken from the National Weather Service along with storm information. The radar images come from WSR-88D Doppler radar network, which is run by the National Weather Service. Lastly, the satellite images come from the GOES-8 satellite run by NASA.

### 3. Synoptic Overview

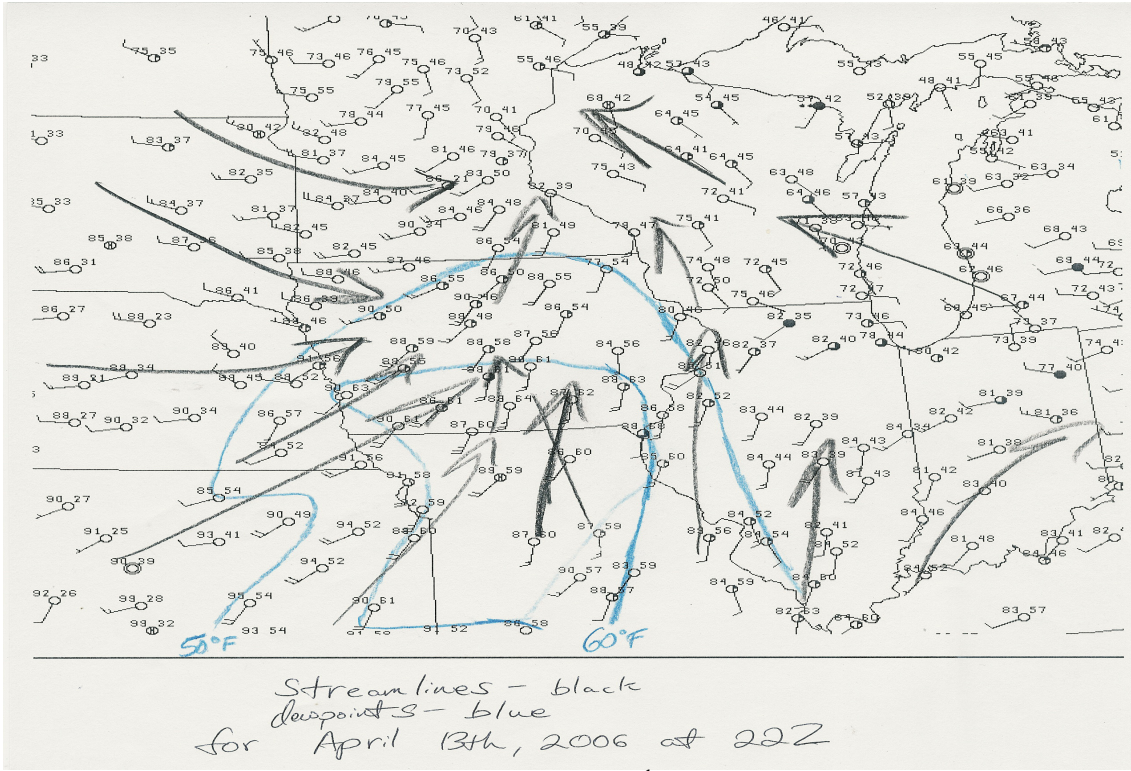
The first way to see the synoptic set up is by looking at a Unisys surface map from April 14<sup>th</sup>, 2006 at 0Z shown in figure 1.



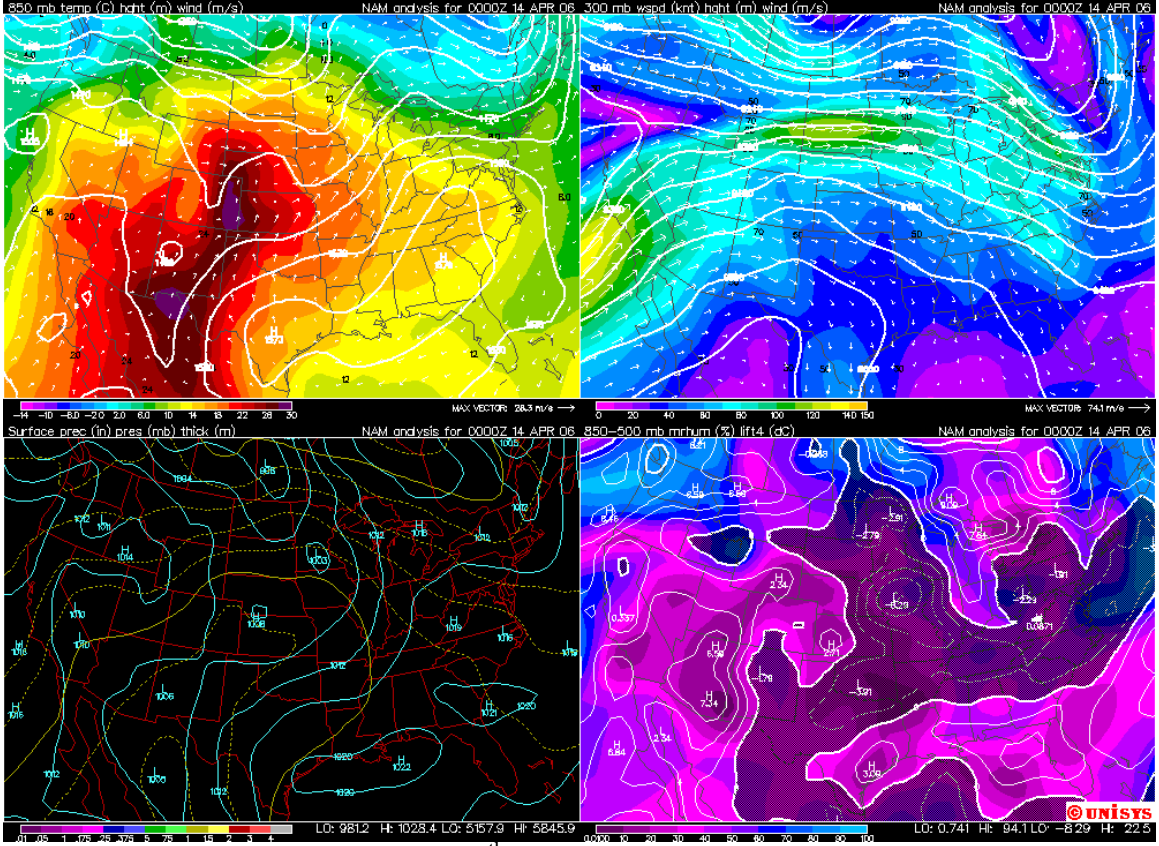
**Figure 1.** Surface map for 00Z on April 14<sup>th</sup>, 2006.

This is a few hours after the beginning of the convection but gives a good view of the synoptic situation. The surface map shows a front stretching from Minnesota southeastward through southern Wisconsin and into northeastern Illinois. The surface map from Unisys shows this

as a stationary front, but it more probably was just a warm front. This diagnosis is made based on both surface observations in figure 2 and upper air observations in figure 3 in addition to figure 1.



**Figure 2.** Streamlines and dewpoints for April 13<sup>th</sup>, 2006 at 22Z.



**Figure 3.** 4 panel plot for April, 14<sup>th</sup>, 2006 at 0Z using ETA analysis of in clockwise order from top left the (a) 850mb, (b)300mb, (c)850-500mb, (d)surface levels.

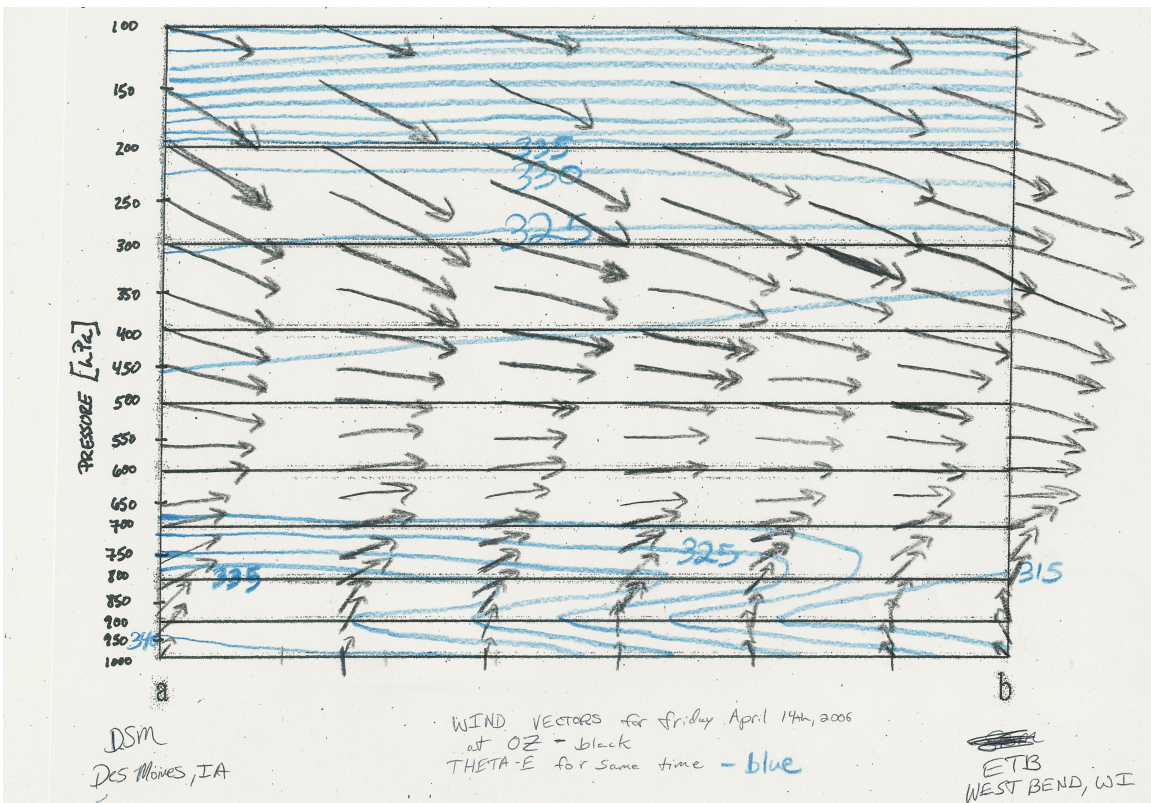
Figure 1 shows a low pressure system in southern Manitoba and associated cold front. A developed low usually has a cold and warm frontal feature. In addition the Unisys upper air plot in figure 3 shows warm air advection south of the supposed stationary front along with a temperature gradient, which is emblematic of a baroclinic zone. Also, the surface observations in figure 2 show a distinct wind shift along this front from south and southwest to east and southeast. There is distinct warm pool of air to the southwest of the front and cooler air northeast of it.

Now that the warm front has been diagnosed its importance can be discussed. The position of the warm front leads to intense warm air advection and heating in western and central Iowa during the day of April 13<sup>th</sup>. Temperatures reached 90 degrees in some places while the normal average high temperature is in the lower 60's. Omaha, Nebraska set their record high for April 13<sup>th</sup> with a recorded temperature of 89 and Des Moines, Iowa tied their record high with the same temperature. April 13<sup>th</sup> was the hottest day in April for most of this region. This advection coupled with solar radiation from the lack of cloudiness resulted in an overall destabilization of the air over Iowa. The process, known as differential advection, was not an instantaneous event, but a process that developed from persistent heating and transfer from the Great Plains. This instability can be seen in figure 3 with the high lifted indices. This combined with the moisture laden flow from the Gulf of Mexico as seen in figure 2. When this air collided with the

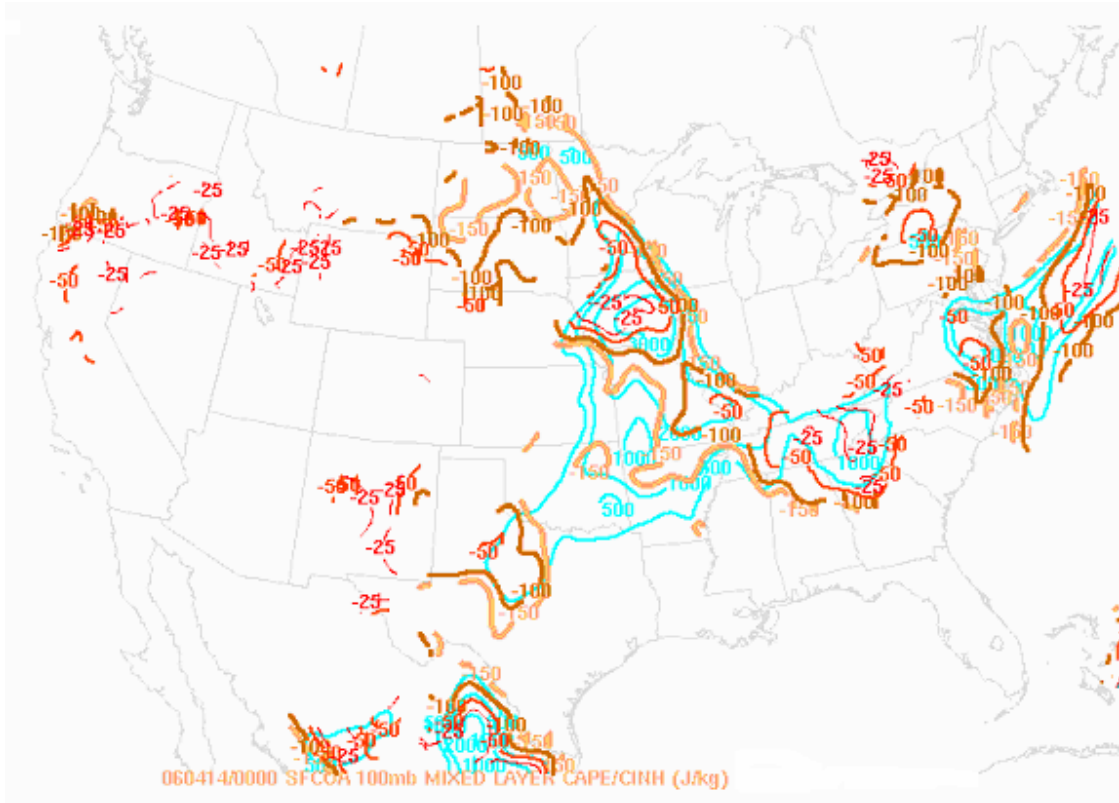
more westerly and slightly northwesterly flow around the southern edge of the low pressure and along the trough axis, as denoted by the yellow dotted line over Iowa in figure 1, a convergence zone was formed in western Iowa. In order to satisfy the mass continuity equation, this convergence must result in upper air transport—an important stimuli for convective triggering. A final feature that was important in the set up was the location of the Jet. A jet streak was located over the South Dakota eastward into Wisconsin. This jet was not important in the initiation of the storm, but was important later in the development. The jet location to the north and northeast of the storms means the inertial stability was low due to the anticyclonic shear. This allowed the outflow to more easily flow to the north and northeast, which created a negative back pressure thus sucking up the updraft. This enhanced the instability and allowed for the storms to continue to develop and stay vigorous as they moved eastward.

#### **4. Mesoscale Analysis**

In order to have severe storms certain mesoscale features must be present in addition to the right synoptic set up. Two of these features are large amounts of small scale instability and wind shear. These features are not necessary for the initiation of convection, but must be present for the enhancement of convection. The small scale instability can be seen by figures 4 and 5.



**Figure 4.** A cross section taken from W-E along a line from Des Moines, IA to West Bend, WI on April 14<sup>th</sup>, 2006 at 0Z. Wind vectors are in black and lines of equivalent potential temperature are in blue.



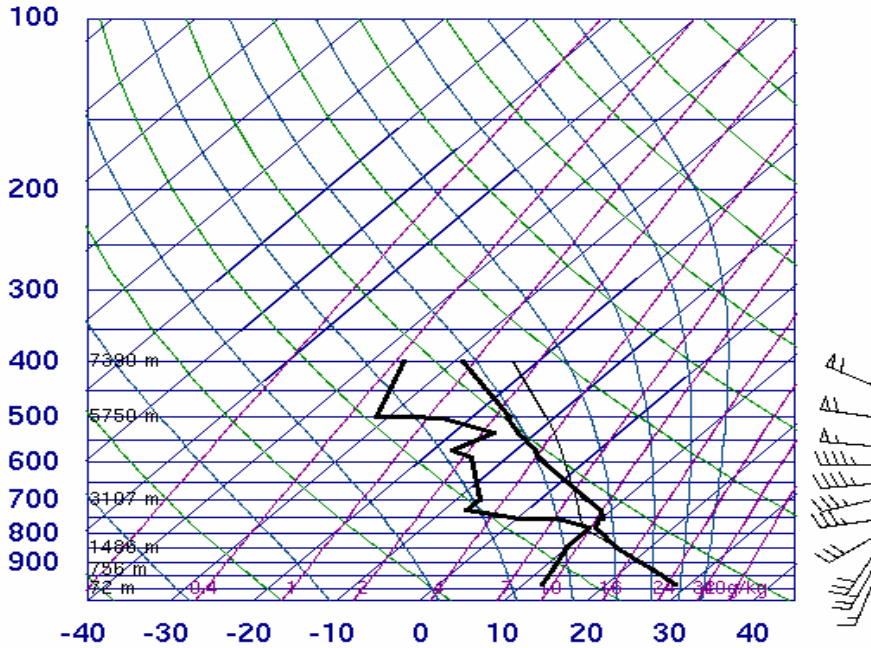
**Figure 5.** SPC analysis of CAPE (blues) and CINH (orange, red), 4.13.06, 00Z

Figure 4 shows a moisture tongue extending eastward from Des Moines. Combine this with figure 5, which shows high Convective Available Potential Energy (CAPE) values over Iowa and the result is high small scale instability. Wind shear with height is shown by figure 4. Across the whole cross section the winds increase greatly with height up until the jet stream at 250mb. Also, the winds veer with height. This means that the winds turn counterclockwise. This is symbolic of warm air advection and positive helicities. Helicity is a product of the vorticity vector dotted with the velocity of the wind vector. Higher helicities increase the likelihood that supercells will form. Usually, helicities are the highest right in the vicinity of the warm front. Even in the eastern part of the cross section in figure 4 at West

Bend the clockwise turning is emblematic of positive helicity is present. The positive helicities everywhere suggest left moving supercells are unlikely. Another feature that is conducive to supercells is the lack of much upper level wind shear. If the upper levels winds change too much the anvil can be torn apart and the updraft destroyed. Figure 4 shows that there is not much upper level wind shear on April 13<sup>th</sup> allowing for the supercells to form and maintain there updrafts.

Another way to see mesoscale features is by looking at soundings. Two soundings that are somewhat helpful in this case are the 0Z sounding for Davenport, IA and the 12Z sounding for Lincoln, IL on April 14<sup>th</sup>, 2006. These soundings are shown in figures 6 and 7.

74455 DVN Davenport



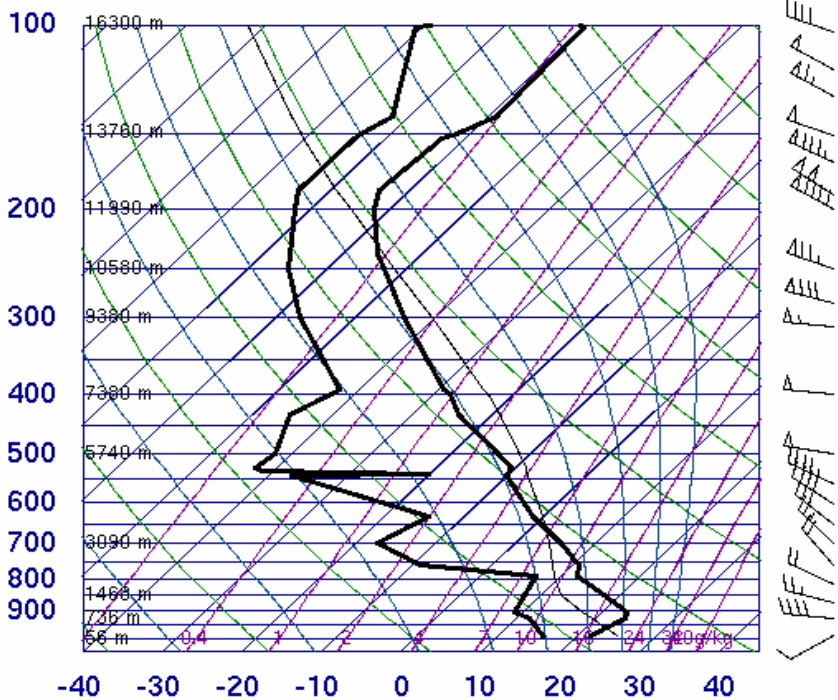
SLAT	41.61
SLON	-90.5
SELV	229.0
SHOW	-4.83
LIFT	-4.72
LFTV	-5.12
SWET	555.6
KINX	29.10
CTOT	25.90
VTOT	31.90
TOTL	57.80
CAPE	708.7
CAPV	772.2
CINS	-102.
CINV	-78.6
EQLV	338.8
EQTV	335.7
LFCT	664.7
LFCV	682.3
BRCH	7.01
BRCV	7.64
LCLT	281.8
LCLP	775.7
MLTH	303.0
MLMR	9.20
THCK	5678.
PWAT	29.36

00Z 14 Apr 2006

University of Wyoming

Figure 6. Sounding taken at 0Z on April 14<sup>th</sup>, 2006 at Davenport, Iowa

74560 ILX Lincoln



SLAT	40.15
SLON	-89.3
SELV	178.0
SHOW	-2.43
LIFT	-2.81
LFTV	-3.30
SWET	298.0
KINX	17.10
CTOT	22.10
VTOT	32.10
TOTL	54.20
CAPE	946.6
CAPV	1032.
CINS	-331.
CINV	-271.
EQLV	228.8
EQTV	228.4
LFCT	660.6
LFCV	683.2
BRCH	21.73
BRCV	23.71
LCLT	285.0
LCLP	843.2
MLTH	299.2
MLMR	10.48
THCK	5684.
PWAT	23.01

12Z 14 Apr 2006

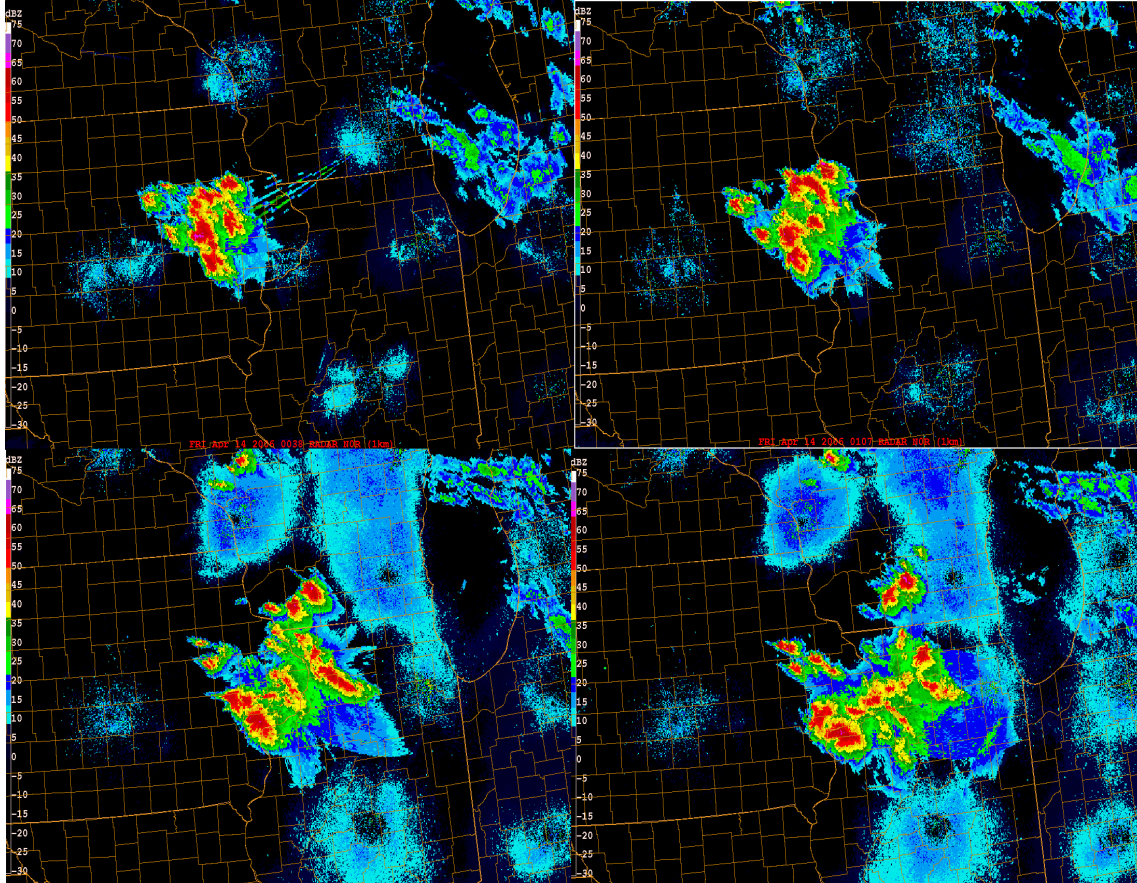
University of Wyoming

Figure 7. Sounding taken at 12Z on April 14<sup>th</sup>, 2006 at Lincoln, Illinois.

The Davenport sounding is taken about an hour before the supercells move through the area. The air balloon quit sending data at 400mb, which is why the sounding cuts off at that point. This was more than likely due to the severe weather entering the area. The convective available potential energy (CAPE) is just over 700 Joules/kilogram. There are two possible explanations for this relatively modest assessment of energy. The first is simply error. As shown, the sounding stopped at 400mb, which could affect this value. The second, and non-mutually exclusive case, could be convective activity already began 'overturning' the air mass. Either way, this sounding shows the destabilization by differentially advected air. Only a slight inversion exists, which will be eroded even further as the colder and moister air moves in. This in turn will lower the lifted condensation level and level of free convection bringing the convection lower to the surface. This is likely what was happening just to the west of Davenport at this time. The lowering of the cloud base makes it more likely a tornado could occur, which is what was happening in Iowa City just

to the west of Davenport. A subsidence inversion is possibly due to a rear inflow jet from the west where there are lower dewpoints. Above this a small elevated mixed layer is present around 600mb. When the convection approaches it will break through this mixed layer and use its plentiful moisture. The sounding from Lincoln is taken after the storms moved through. But it is still useful in understanding the supercells. The feature that is interesting is the strong westerly wind at approximately 900mb, which is larger than both the winds below it and above it. This strong wind is what is left the low level jet. The low level jet started out from the south approximately 12 hours beforehand and turned westward with time due to the inertial oscillation. This helped to steer the supercellular development into Illinois with time as the axis of warm advection was shifted eastward.

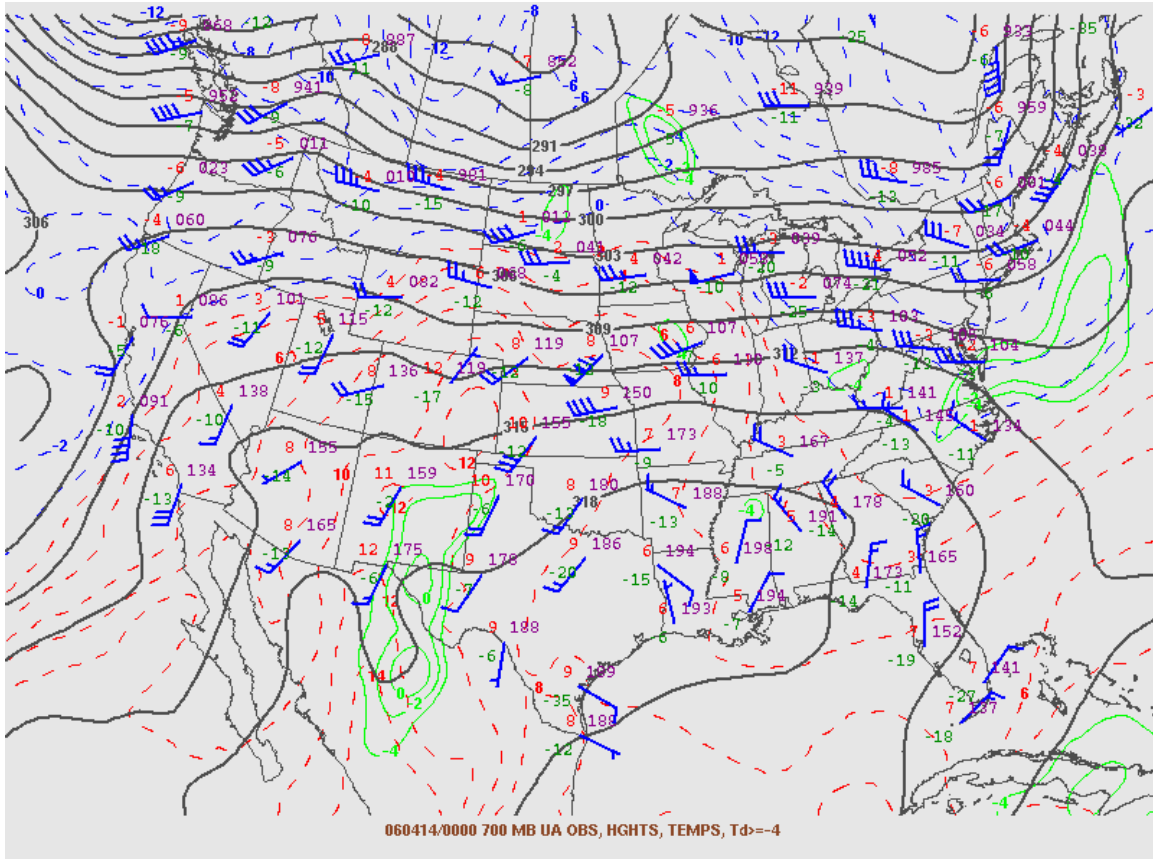
The best way to see the movement of the supercells is using one of the most powerful mesoscale tools, which is radar. Figure 8 is radar images taken at different times which show the propagation of the supercells.



**Figure 8.** NEXRAD Radar images taken from 0Z thru 3Z on April 16<sup>th</sup>, 2006. The order of the images is top left, top right, bottom left, bottom right.

There are several interesting features of note from these figures. Initially one major supercell seems to dominate in central Iowa, but as the cell moves east more cells develop to the north and west of it. These seem to be separate cells and not the original cell splitting. As time goes on the northern cells continue make a slight move to the northeast and then continue eastward into Wisconsin. The southern cells meanwhile move southeastward through western Iowa and into Illinois. The northern cells eventually move over Lake Michigan

and weaken slightly, while the southern cells continue to have more cells develop on both the forward and rear flanks. This split of the cells in Iowa is very interesting especially when considering the factors involved. Normally a split would be associated with two different cell circulations forming; right and left moving storms. This implies storms moving to left and right of the mean flow. But this case is different, which can be seen through the 700mb map presented in figure 9.



**Figure 9.** 700mb map from SPC at 0Z on April 14<sup>th</sup>, 2006.

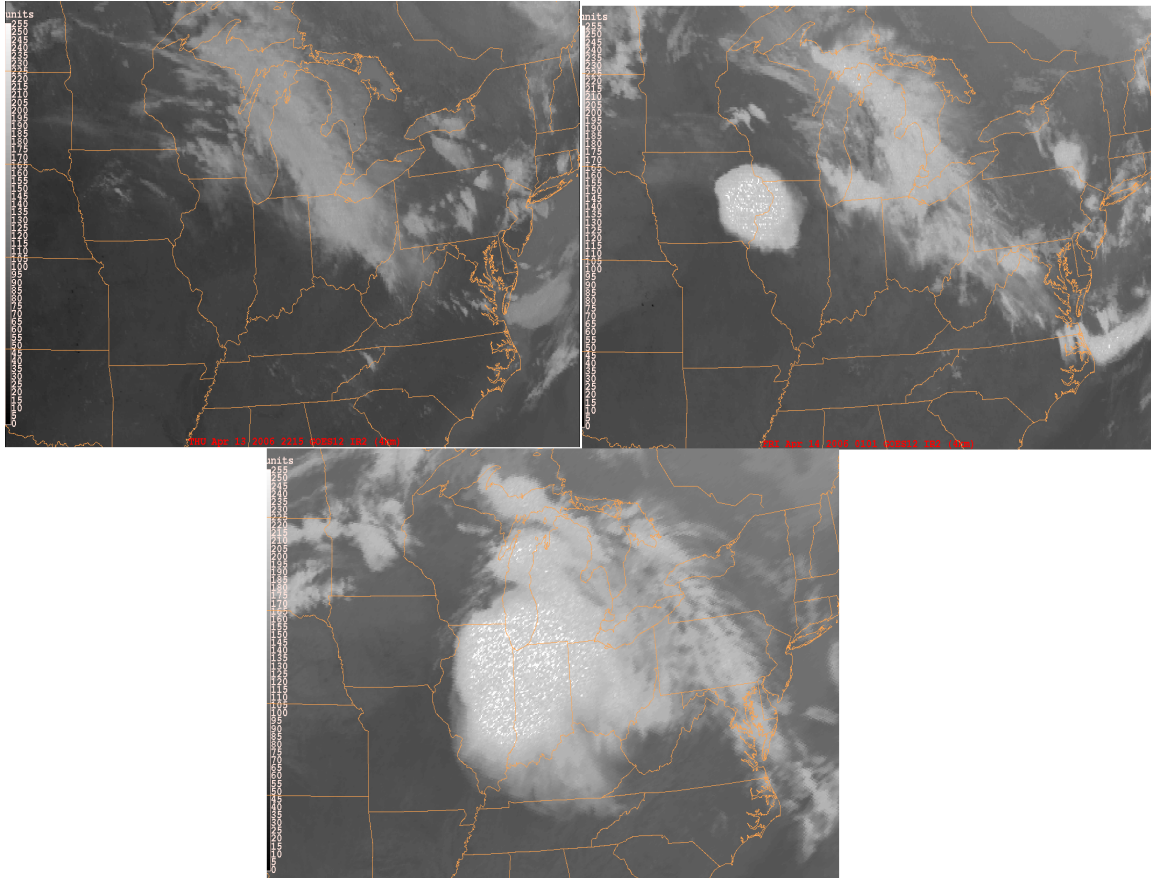
This map shows slight divergence in the flow over Iowa and western Illinois. It also shows the direction of the mean flow from the southwest over Iowa meaning the direction of mean propagation would be to the northeast. This then implies then the northern supercells move with the mean flow and are not left movers. It also implies the storms that the southern storms move against the mean flow and are right movers. These right movers are due to the intense circulation in these cells. A possible reason for this is they are more mature cells and thus the northern cells have small or no mesocyclones present at the time. These mesocyclones act like large scale baroclinic systems and as the air rises up into them new mesocyclones form to the right every time leading to the abnormal storm

motion. By the time the northern cells have really developed any mesocyclones they are to the north of the warm frontal boundary in Wisconsin. This is more conducive to hail formation rather than tornadoes. This is because north of the warm front the temperatures are colder and thus hail will be less likely to melt. Also, tornadoes are less likely to form because of the lack of moisture in the lower part of the troposphere. Thus the cells in Iowa produced tornadoes and then wind damage in Illinois, while the cells in Wisconsin were mostly hail producers. Finally, even though not fully discussed a probable reason the Wisconsin storms produced record hail was the small amount of upper level wind shear and thus strong updrafts in the supercells. This most likely helped in allowing for the hail to be circulated

many times in the cloud before finally becoming too heavy and falling to the ground.

Up until now the overall organization of these cells has not been answered. Because of the different circulations it might seem as if these

supercells are different entities especially from the radar images when they split. But another helpful mesoscale tool that helps show this is not the case is satellite. Figure 10 shows infrared satellite images taken at different times.



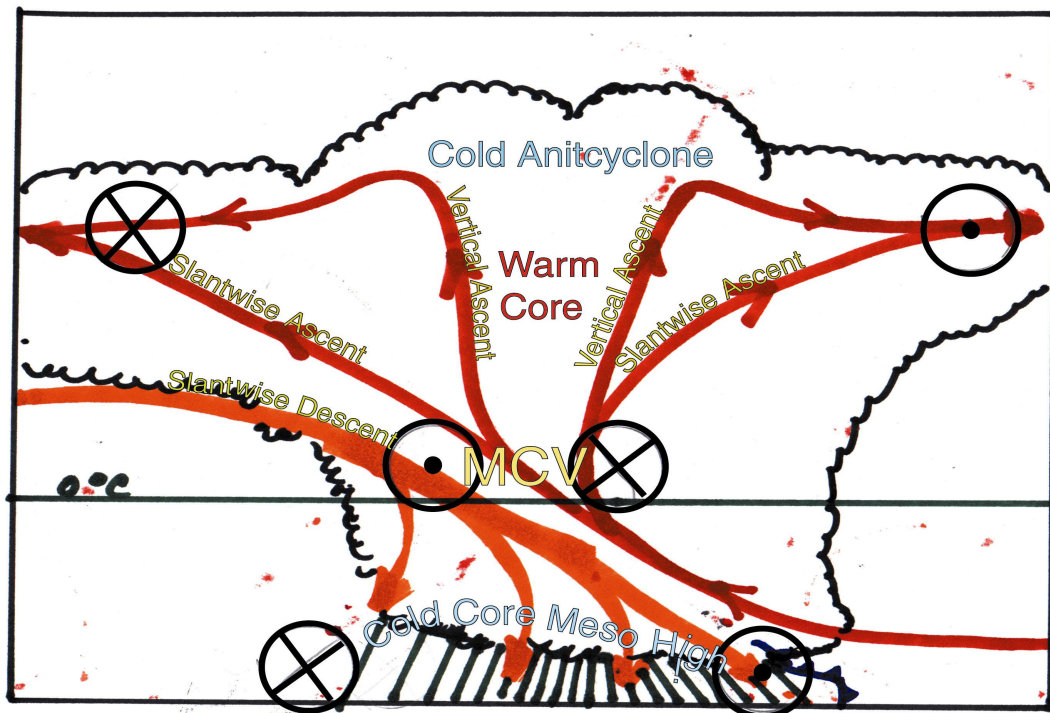
**Figure 10.** Infrared Satellite images using the GOES-8 satellite taken from April 13<sup>th</sup> at 22Z thru April 14<sup>th</sup> at 0530Z. The images are sequenced clockwise from top left.

Infrared was used because it can still be viewed during the night and cloud top temperatures can be deciphered from it. Initially there are no clouds present over Iowa near 22Z on the 13<sup>th</sup> of April. The clouds increase in coverage as the convection begins with the anvils spreading out. Just before the storms split in Iowa the satellite imagery gives the impression they are connected at outflow level even though they seem to

have distinct circulations at the surface. This would seem to imply that the cells are organized in a supercell squall line at the time, which is a subset of a mesoscale convective system (MCS). Mesoscale convective systems are groupings of thunderstorms and as they get bigger they produce system scale motions in addition to the motion of the individual cells. MCS implies that there are one or dynamics driving the system.

In this case the organization is likely based on the synoptic circulations with possible mesoscale self organization occurring through the interaction of the individual cells. Eventually the MCS continues to grow during the evening of April 13<sup>th</sup> and by the time April 14<sup>th</sup> rolls around the cloud mass occupies the states of Illinois, Indiana, Ohio, and Michigan. The cloud mass is circular in orientation and the outflow extends outward very far to the north and east. The tremendous outflow is representative of the fact that there is low inertial stability to the north and east; a result of the jet location and anticyclonic shear below the jet. When the outflow has less back pressure on it an increased updraft results to replace the loss of mass at the top. By the early hours of April 14<sup>th</sup> the MCS has most likely evolved from a supercell squall line into mesoscale convective complex

(MCC). An MCC is just another type of MCS which is circular in appearance and very large. The MCC has many characteristics that make it slightly different than other MCS's. MCC's must be large with a warm core vortex at middle levels and a cold core meso-anticyclone at the surface associated with a density current. An anticyclone is also present aloft feeding into the jet streak. This outflow aloft creates a dynamic flywheel that stores energy and persists the system for a long period of time even after the energy supplying the convection stops. Some of the features that can not be seen from the satellite are presented in figure 11, which is a conceptual model of an MCC (credit Dr. Greg Tripoli). Model data also confirmed this theory when looked at through the vertical cross section tool in GARP.



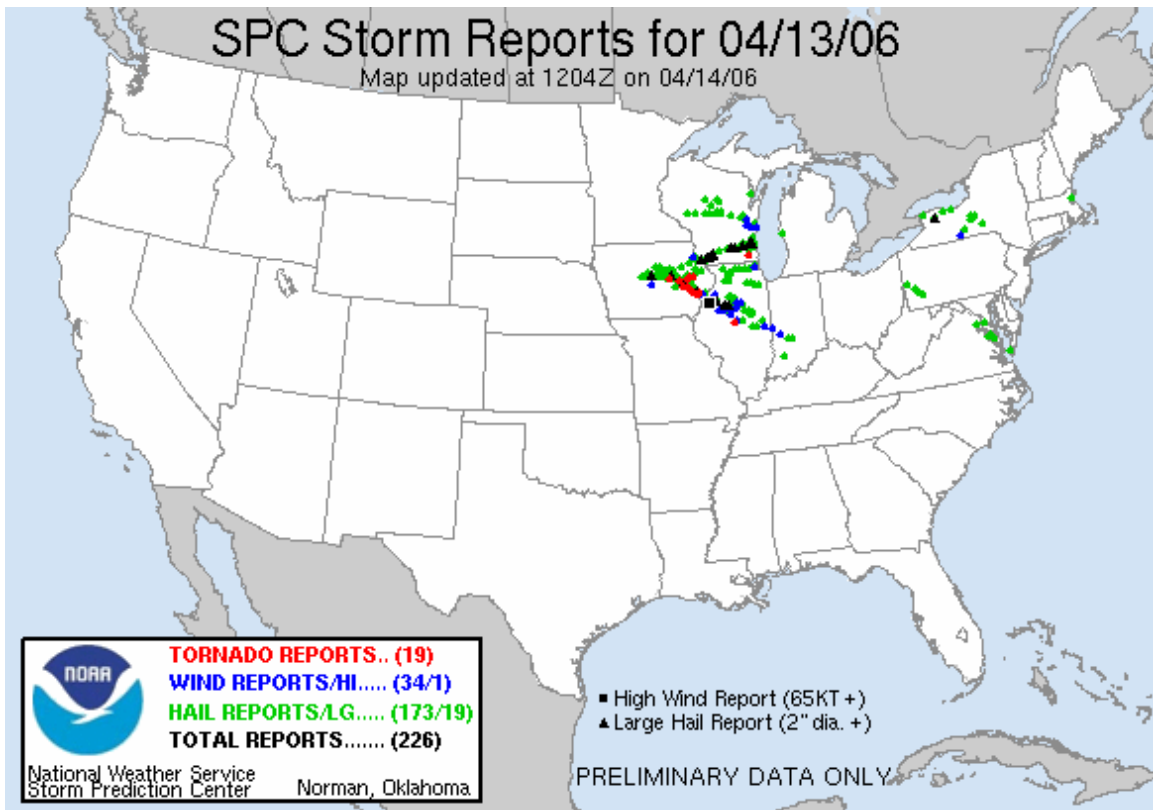
**Figure 11.** Conceptual model of a MCC, credit Dr. Greg Tripoli

This model shows all the typical characteristics mentioned before. The previous information shows the evolution of this storms organization is a key component in the movement of the supercells.

## 5. Conclusion

It is still no that well known why supercell thunderstorms move erratically sometimes. Why the cells move atypically can be different in each case.

In the case of the supercells that developed over Iowa on April 13<sup>th</sup> many factors were shown to be involved. The location of the right synoptic and mesoscale features conducive to supercells was the first thing discussed. Another important part was the individually cellular circulation. Finally the overall system scale circulation was the last key part. When these factors combined it led to the interesting movement of the cells and the different severe weather events produced. The types of severe weather can be seen in the SPC storm reports in figure 12.



**Figure 12.** SPC storm reports for April 13<sup>th</sup>, 2006

One person died, many were injured, and a large amount of damage was caused from these supercells. The hail produced was of record proportions in Wisconsin. Because of the unusual evolution of these storms many people were affected

and the night of April 13<sup>th</sup>, 2006 be discussed for a long time.

## **6. References**

Holly Hassenzahl- TA University of Wisconsin- Madison (provided background information and answered questions)

Dr. Greg Tripoli- Professor University of Wisconsin- Madison (provided lecture material)

National Weather Service and National Climate Data Center (used their figures and storm information)

[www.weather.unisys.com](http://www.weather.unisys.com) (for use of their figures)