

A Mesoscale Analysis of the April 13, 2006 Eastern Iowa Severe Weather Outbreak

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Abstract

On the evening of April 13th, 2006, a line of super-cell thunderstorms passed through eastern Iowa spawning large hail and multiple tornadoes. The system moved into Southern Wisconsin and Illinois and produced extreme hail in those regions as well. The convection that started the whole process was very rapid and somewhat unexpected. The day experienced warm temperatures from an incoming warm front and daytime solar heating. Due to this heating, evapo-transpiration occurred over the corn fields of Iowa and created an unstable planetary boundary layer. After a subsidence inversion cap was broken by a passing low-level jet, deep convection was started throughout western Iowa and worked its way eastward. Strong wind shear throughout the troposphere allowed for the production of super-cell thunderstorms in eastern Iowa.

Introduction

On April 13, 2006, strong convection began to occur across western Iowa during the afternoon hours. The convection spawned a line of severe thunderstorms which would later turn into a line of super-cellular storms as the system passed over eastern Iowa. As the system strengthened, the Quad Cities region in eastern Iowa and Illinois were hardest hit. A total of 15 tornadoes were reported in the area, along with hail up to two inches in diameter (SPC). Once the storm moved beyond Iowa, large hail and strong winds were reported in southern Wisconsin and Illinois. The highest intensity tornado reported was an F2 that passed through Iowa City, Iowa (SPC). This particular tornado was responsible for an estimated \$12 million in damage as it destroyed 1,016 residential and 35 commercial buildings throughout the city (SPC). It also passed through the University of Iowa campus where the tornado did significant damage to a sorority house and other student housing areas near campus (SPC). Tornadoes elsewhere in the area generally ranged

from low to high intensity F1, however still leaving their mark with significant damage and injury reports.

The outbreak of these super-cells was not extremely well forecasted relative to the intensity they became. The synoptic situation was not very conducive to a severe weather outbreak, but it will be shown that several key synoptic features were necessary for the storm to occur. A warm front moving into Iowa coupled with a strong jet passing overhead helped to set up a decent "loaded gun" sounding. Once the synoptic situation was put together, mesoscale forcing became the significant factor in the genesis of the storms. Several factors contributed to the continual destabilization of the atmosphere prior to the genesis of the storm system. One was the influx of strong moisture convergence in the afternoon, possibly due to strong evapo-transpiration over the corn crop soil from warm air advection and daytime heating. A second was very strong vertical wind shear through Iowa that continued as the storm propagated eastward. By the time the atmosphere had become very unstable above and below the inversion cap, a low-level southwesterly jet passed

by and had strong enough ageostrophic circulation to break the cap and initiate deep convection throughout the atmosphere.

Data

The initial convection began at approximately 22:00 UTC on 13 April, 2006. The super-cells that produced tornadoes and strong hail formed around 00:00 UTC on 14 April, 2006. Both the ETA forecast model and the RUC model were used to analyze data from the storm. The ETA model was used more for providing the data used in the synoptic analysis section since the model runs tend to be more accurate. Model output data from the RUC was used in order to get more accurate data for the storm itself since model re-analysis from the RUC was done every hour. In order to make the plots of the model output data, the program GEMPACK was used. Hand drawn analysis of several variables was also done. In order to track the evolution of the storm satellite data taken from the GOES-East satellite was used. Images of the 10.7 micron wavelength channel were made using the program IDV. Radar data was also analyzed by looking at a NEXRAD composite image of the entire United States. Radar stations in Des Moines, Iowa and Davenport, Iowa were looked at more in depth in order to track the storm using base reflectivity and radial velocity. An atmospheric sounding was taken from Davenport, Iowa courtesy of the University of Wyoming webpage.

Synoptic Overview

The synoptic situation did not play an extremely large role in the genesis of

this storm system, but there were several influences that it had on the environment in Iowa at the time. The first time period in which the atmospheric flow becomes a factor for Iowa is at 12 UTC on 13 April. Figure 1a is a plot of 850 mb temperature and heights with wind for the given time period. Temperatures at this time are very high for normal April averages over the plains states. There is also a warm bubble of air that had formed in the lee of the Rockies over western Kansas. Height and wind vectors were oriented in such a manner to advect this warm air bubble into Iowa. The warm air advection into Iowa during the day would help to strongly destabilize the atmosphere at lower levels. The day of the 13th was also relatively cloud free, so significant daytime heating was able to occur. Along with the warm air advection at the lower-mid levels, a jet streak at 300 mb was moving eastward (Figure 1b). The right exit region of the jet at this time was located over southeastern South Dakota. The right exit region of the jet is associated with subsidence and thermally indirect flow due to ageostrophic divergence. Subsidence in the jet exit region therefore creates a dry upper level mixed layer. This creates an inversion cap in a similar way to the elevated mixed-layer that generally causes the inversion cap in severe weather situations. The inversion caused by subsidence in the jet does not create as strong of a cap as an elevated mixed-layer, but it allows for the setup of a "loaded gun" sounding nonetheless. Finally, it is necessary to note the mean sea level pressure in order to point out that there is not strong moisture flow into the Midwest (Figure 1c). It will be shown later that a major source of moisture throughout Iowa was due to strong evapo-transpiration from corn crop soil due to the warm weather during the day.

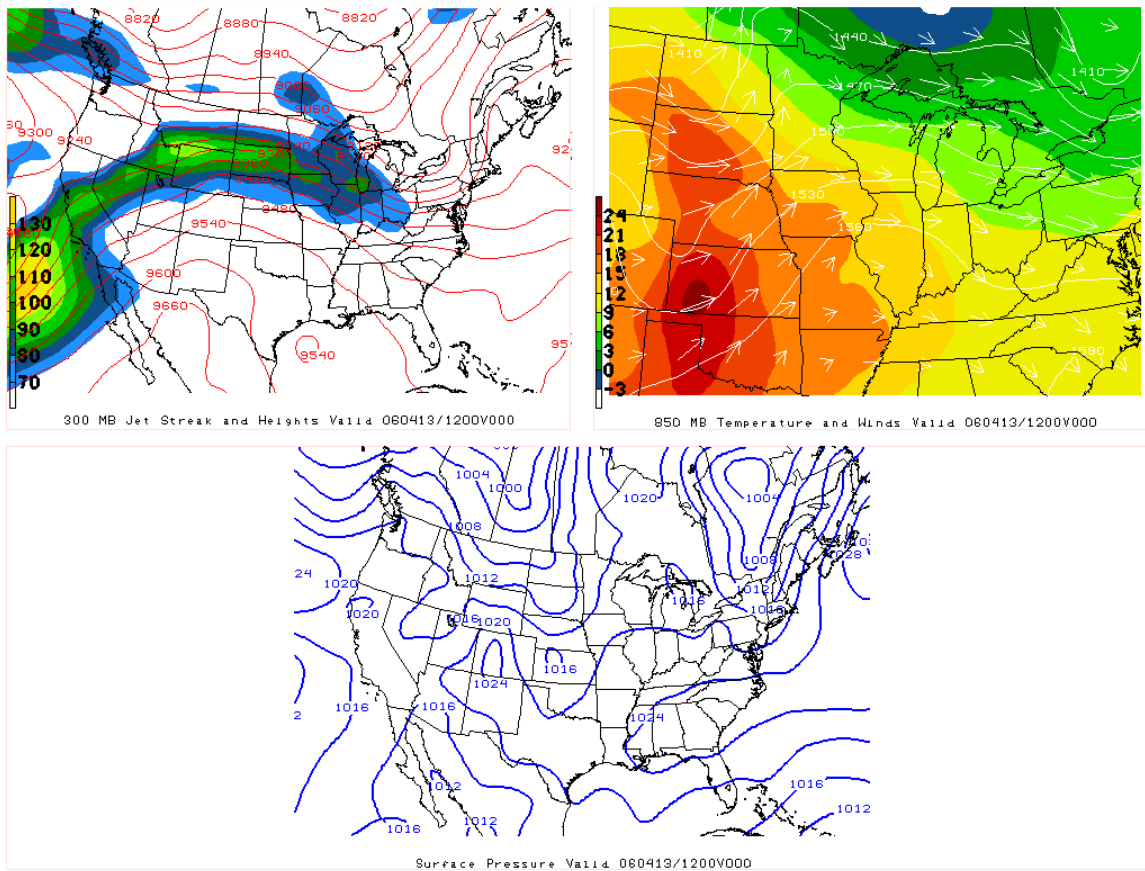


Figure 1: Synoptic overview at 12 UTC on 13 April. a) Upper left panel-300 mb jet streak and heights over CONUS, b) Upper right panel-850 mb temperature, wind and height fields centered over Davenport, IA, c) Lower middle panel-mean sea level pressure at surface over CONUS

At 00 UTC on 14 April, the deep convection had already begun and was producing strong thunderstorms. The synoptic setup at this time, however, is fairly accurate as to what was going on at the conception of the convection. Figure 2a shows the 850 mb temperatures and heights with wind vectors. The temperature at this level has increased by about three to four degrees Celsius since the previous 12-hour time period. The temperature difference at the surface was actually much larger than that at upper levels, with surface observations in western Iowa being over 30 degrees warmer by 00 UTC on the 14th than at 12 UTC on the 13th. The most likely cause for this was strong daytime heating due to the lack of clouds in the hours prior to the deep

convection. The heating helped to destabilize the boundary layer beneath the subsidence inversion caused by the approaching jet streak. Figure 2b shows the jet streak at 300 mb at the 00 UTC on 14 April. The jet maximum had increased slightly and the right exit region had moved more directly over western Iowa. This would cause the ageostrophic divergence of the jet to now force subsidence directly over western Iowa. A sounding taken from Davenport, IA at 00 UTC on 14 April shows the presence of this subsidence layer from the jet at upper levels (Figure 3). The sounding is slightly out ahead of the super-cells being formed at this time, but it is likely the balloon was cut short by the large eastward extending anvil into Davenport. This sounding

highlights the low-level inversion cap at 775 mb, with a dry mixed layer above to about 550 mb, with another extending until the sounding is cutoff. The sounding also highlights the extreme instability of the air both in the boundary layer and in the well mixed layer. The temperature profile is basically dry adiabatic at this point and is just waiting for a forcing to break the

inversion. One last thing to note again is the mean sea level pressure contour in figure 2c. The contours do not promote moisture advection from any large source; yet significant moisture convergence was present at the inception of the storm. This setup just contributes to the idea of evapo-transpiration from the corn fields.

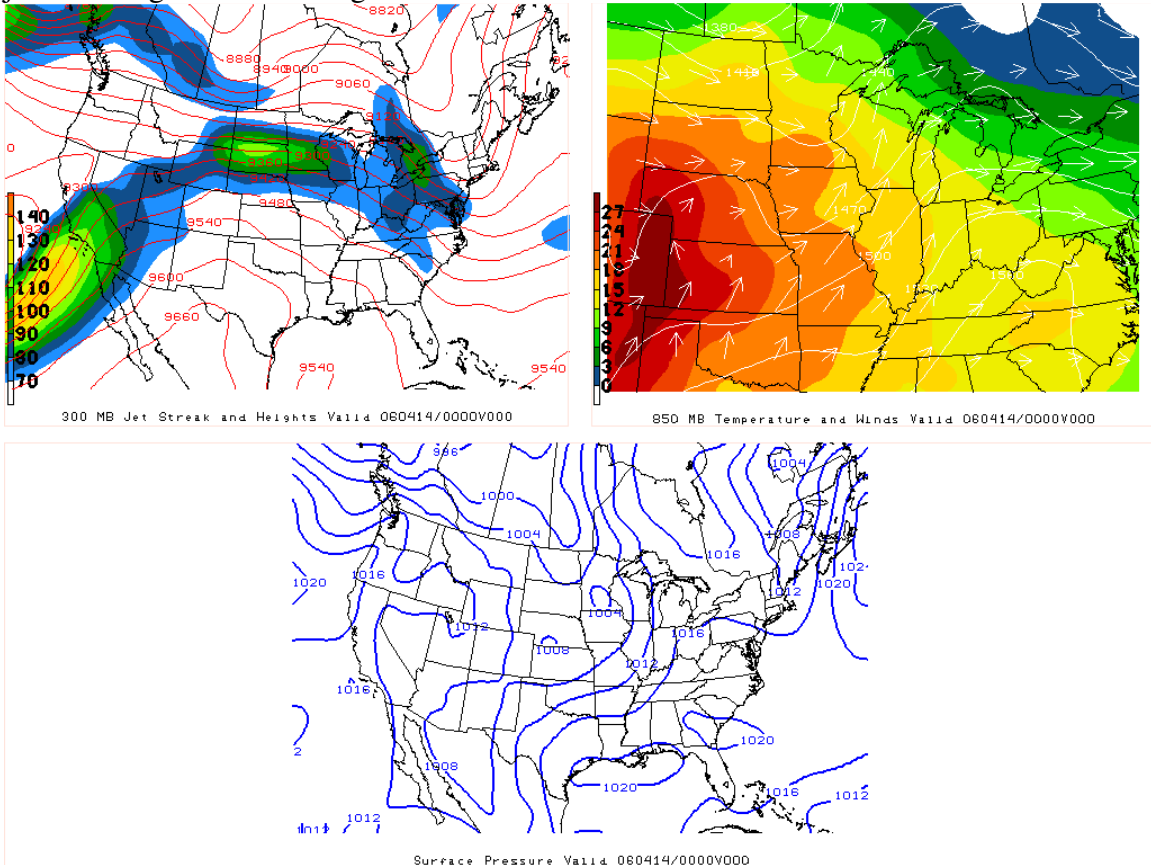
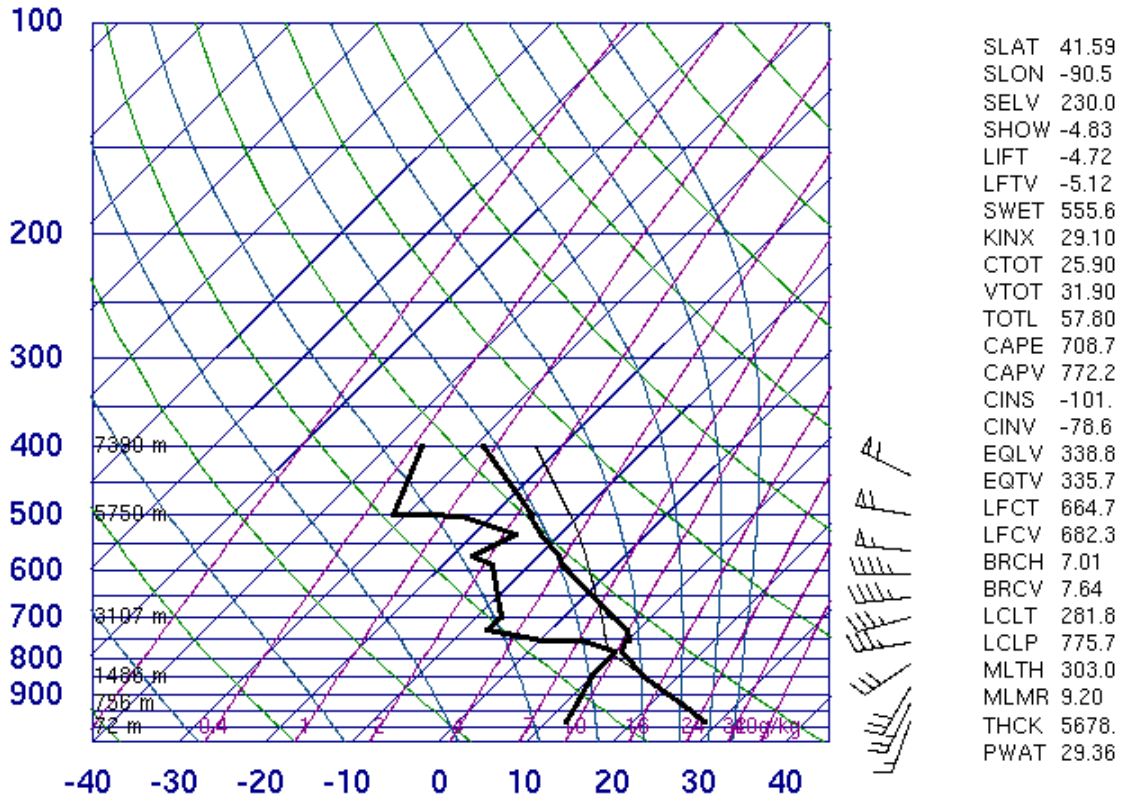


Figure 2: Synoptic overview at 00 UTC on 14 April. a) Upper left panel-300 mb jet streak and heights over CONUS, b) Upper right panel-850 mb temperature, wind and height fields centered over Davenport, IA, c) Lower middle panel-mean sea level pressure at surface over CONUS

74455 DVN Davenport



00Z 14 Apr 2006

University of Wyoming

Figure 3: Skew-T diagram of atmospheric sounding taken at 00 UTC on 14 April over Davenport, IA. Note instability, inversion cap at 775 mb, and wind shear profile. (Univ. Wyoming)

Mesoscale Analysis

1) Low-Level Jet

The synoptic setup throughout the day on 13 April, 2006 left the planetary boundary layer in a state of strong destabilization with a relatively weak inversion cap above. When the atmosphere is set up with the “loaded gun” sounding it will remain in that state until nocturnal cooling begins to stabilize the atmosphere, or until a forcing mechanism strong enough to break the inversion cap comes along. In this particular case, an influx of a low-level southwesterly jet was enough to break the inversion cap and promote strong moisture convergence at the surface. The low-level jet in this case was at approximately 850 mb. Low-level

jets tend to form at the top of the nocturnal boundary layer as a maximum in wind speed. The jet is generally southerly or southwesterly because they form to the east of the Rocky Mountains. The low-level jet often tends to be a source of moisture at low levels; however the jet in this case was oriented southwesterly and originated over dryer air from the southwest. The height fields at 850 mb had a high located over the southeast, with a lee-side trough forming off the Rockies causing this flow move from the southwest towards Iowa.

The low-level southwesterly jet on the 13th can be traced from the southwestern United States, where it started, to where it initiated convection over Iowa. At 12 UTC on the 13th, the jet maximum is located over the panhandle of Texas (Figure 4a). The maximum wind

speed at this time is approximately 35 knots and is moving southwesterly. By 18 UTC on the 13th, the jet had not strengthened much, but its maximum had moved into eastern Kansas (Figure 4b). These two time periods were not as significant for the low-level jet causing convection because the atmosphere was

not as unstable in the lower plains region on the 13th. The main importance in showing these first two time period is to highlight that moisture was not being advected from the Gulf of Mexico at low levels, which often is the case during severe weather outbreaks.

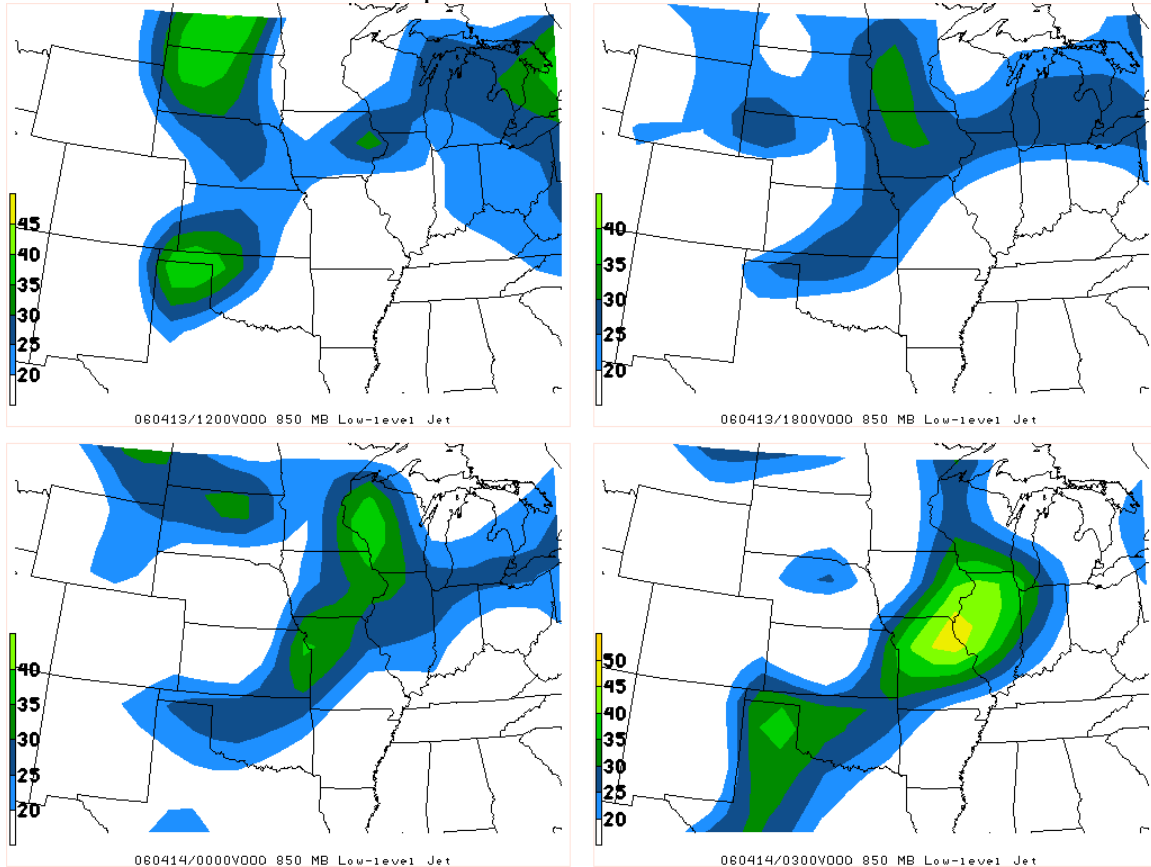


Figure 4: 850 mb low-level southwesterly jet streak, a) Upper left panel is 12 UTC on 13 April, b) Upper right panel is 18 UTC on 13 April, c) Lower left panel is 00 UTC on 14 April, d) Lower right panel is 03 UTC on 14 April

The most important time period for the low-level jet initiating convection is seen at 00 UTC on 14 April (Figure 4c). This time period is two hours after the convection was first initiated, but the jet maximum was still in about the same area, which was right over northern Missouri. The location of the jet at this time is crucial in breaking the weak inversion cap over western Iowa. As in the case with the upper jet, ageostrophic divergence occurs around the entrance and exit regions of a

jet streak. In the left exit region there is divergence at the low-level jet, which signifies convergence at the surface. The convergence at the surface forces upward vertical motion and was able to break the inversion cap over Iowa, which looks similar to that in Figure 3 in Davenport, Iowa. Once the inversion cap is broken, the unstable air in both the boundary layer and the mixed layer above are able to start deep convection. The low-level jet can help account for the continued propagation

and strength of the storm system that was created. At 03 UTC on 14 April, the jet maximum had strengthened and moved over western Illinois (Figure 4d). The actual storm system seemed to propagate in the same direction as the convergence region in the low-level jet. The system also stayed fairly strong and produced large hail past the time it hit the Quad Cities of Iowa. This would suggest that the low-level jet not only had a part in initiating the convection in western Iowa, but also had a role in the evolution and movement as well. It is not always the case that this happens, but it would tend to agree considering the propagation of the storm and jet was fairly similar. Another possibility is that the storm interacted with the low-level jet after it formed, and caused the winds at 850 mb to shift and follow the overall storm flow that may have been propagating eastward due to the upper-level westerly jet. Either way the divergence of the left jet exit region helped continue the mass convergence at the surface and therefore cause upward vertical motion.

2) *Moisture Interactions*

An unstable atmosphere and vertical forcing are both very necessary in order to initiate the deep convection seen on 13 April, but nothing can happen unless

sufficient moisture exists in the atmosphere. The moisture would be needed to for convection to begin in the first place, but especially to produce the amount and size of the hail it did later on in its life. It was shown earlier in this case study that there was not strong low level moisture advection into the area from either the surface or even up to 850 mb. Neither the surface flow nor the low-level jet was oriented in a way to advect moisture from the Gulf of Mexico, which is often the source for such severe weather outbreaks. Instead, the air was being taken from the relatively dry regions of the southwest United States. Although moisture had not been sufficiently brought into the Midwest region, mixing ratio values at 12 UTC on 13 April were already high enough to allow for severe thunderstorms to occur (Figure 5a). An appropriate mixing ratio value to support severe weather is about 9 g/kg (Schaefer 1986). At the 12 UTC time period there was already a mixing ratio of 10 g/kg in some of the western portions of Iowa. By 00 UTC on the 13th, just after the deep convection occurred and before the supercells formed, the mixing ratio was at 12 g/kg (Figure 5b). The water content in the air would have been enough to support the development of severe thunderstorms early on in the day and into the evening, when they actually occurred.

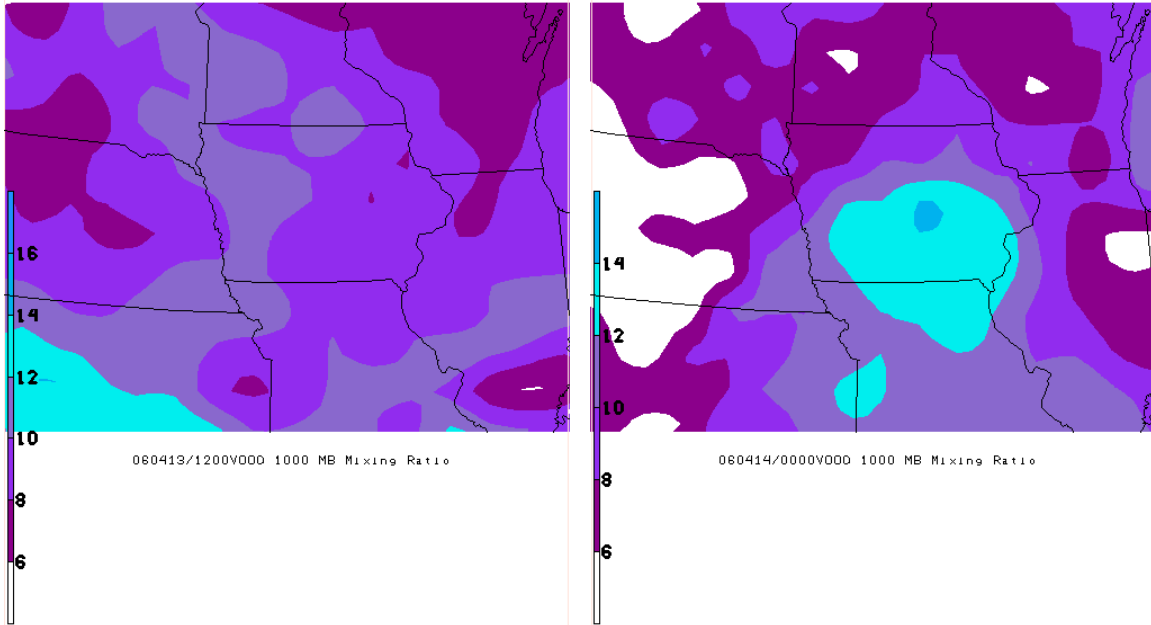


Figure 5: Mixing ratio plotted at the surface centered over Des Moines, IA, a) Left panel at 12 UTC on 13 April, b) Right panel at 00 UTC on 14 April

Since moisture was not advected into the Midwest region, there must have been some other source large enough to support such high mixing ratios. The most likely cause of this moisture was the abundance of corn crops that are located in Iowa. Over such large regions of corn crops, a process called evapo-transpiration occurs during the growing season. The evaporation part is the amount of water lost from the soil surface, and the transpiration comes from the loss of water due to the plants usage (Lauer). This process is very common during the growing seasons because of the amount of moisture in the soil. During April, the time of this storm, the crops are generally just being planted and bare, nutrient rich soil exists with corn seedlings in it (Lauer). At this stage most of the water lost is due to evaporation from the soil itself (Lauer). Several atmospheric conditions make the crop more prone to heavy evapo-transpiration during the early season. Days that are windy, hot, and sunny with low relative humidity cause the most strain on crops due to the large amount of moisture that is evaporated

(Shaw). As previously pointed out, the 13th of April was a very warm and sunny day due to the warm air advection from the southwest and cloud-free skies. Temperatures during the day reached into the upper 80's, which are abnormally high for that time of year. Surface wind speed also reached up to 15-20 knots at some points in the day. Relative humidity values were also low throughout the whole day, generally only around 20-30%. The appearance of high moisture values near the surface and general atmospheric conditions strongly point to evapo-transpiration as the main source of water.

The presence of moisture from evapo-transpiration allowed for deep convection to begin after the low-level jet had broken the inversion cap above the boundary layer. As mentioned earlier, when the jet propagated towards Iowa, ageostrophic divergence in the left exit region of the jet caused convergence at the surface. By 21 UTC on the 13th, the moisture content in the atmosphere had increased due to the strong heating during day and the low-level jet was in position

over western Iowa where the deep convection was about to begin. Figure 6a shows a plot of moisture convergence at the surface at 21 UTC on the 13th. The moisture convergence has a strong bulls-eye located over western Iowa where the convection first occurred. The plot does a good job of combining both the vertical forcing caused by the low-level jet and the moisture content in the air. At 00 UTC on

the 13th, the storm had progressed to central Iowa and would head towards southeastern Iowa. Figure 6b shows the moisture convergence at the surface for this time period, and the strong bulls-eye has progressed along with the storm path. These plots help reinforce the idea that the low-level jet propagation played a large roll in the strength and direction that the storm had.

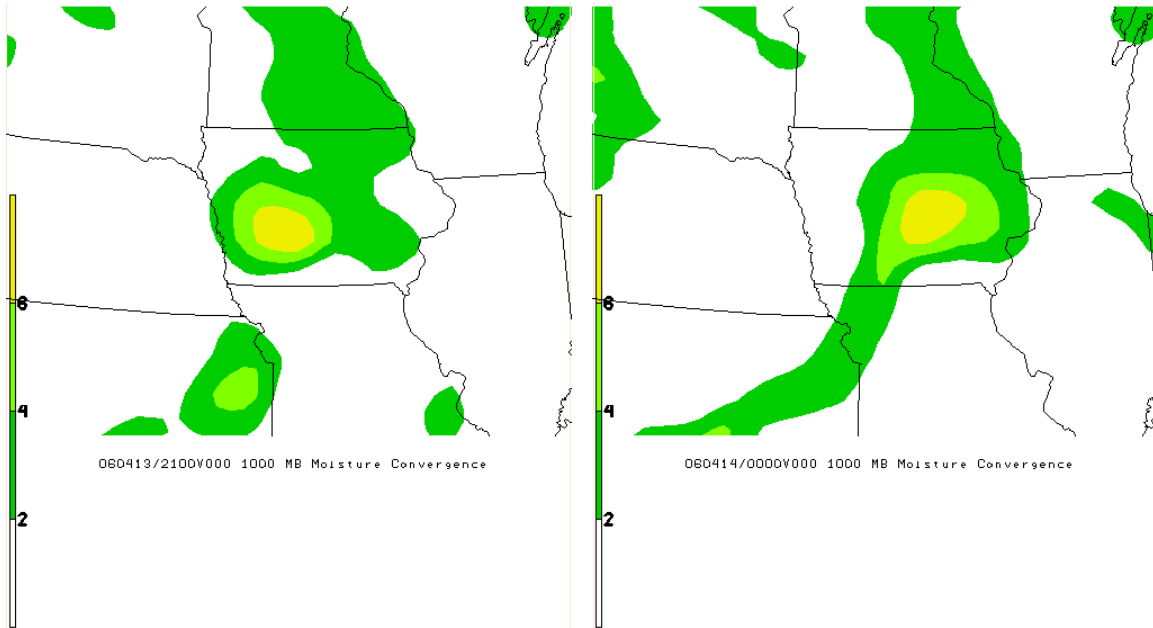


Figure 6: Moisture convergence plotted at the surface centered over Des Moines, IA, a) Left panel at 21 UTC on 13 April, b) Right panel at 00 UTC on 14 April

One other variable that helps diagnose the moisture in Iowa during the storm is theta-E. The theta-E variable is the potential temperature of the atmosphere at a given point if the atmosphere were saturated. High values of theta-E near the surface represent a very warm, moist atmosphere. Theta-E can generally tell the motion of the wind at a given point, which is why thunderstorms have vertical lines of constant theta-E as apposed to horizontal. A cross-section of theta-E was taken from Sioux Falls, South Dakota to Lincoln, Illinois at 00 UTC on 14 April (Figure 7). The line of severe thunderstorms was just to the west of the cross section between these two stations at this time. There is a large warm bubble of theta-E contours in

the center of the two stations, which is located in central Iowa before the storms passed. The location of this high theta-E value at the surface is located in the same region as the bulls-eye of moisture convergence at the same time period. This makes sense because this is the region that has been subjected to both strong heating and upward vertical motion due to the low-level jet. The warm theta-E bubble is the main indicator of a very moist atmosphere beneath an inversion cap. Once the storm system passed through this moist bubble the inversion would break and the high theta-E values at the surface would create a plume all the way to the top of the troposphere. This pre-storm setup was

once of the main reasons for the deep convection seen in Iowa that day.

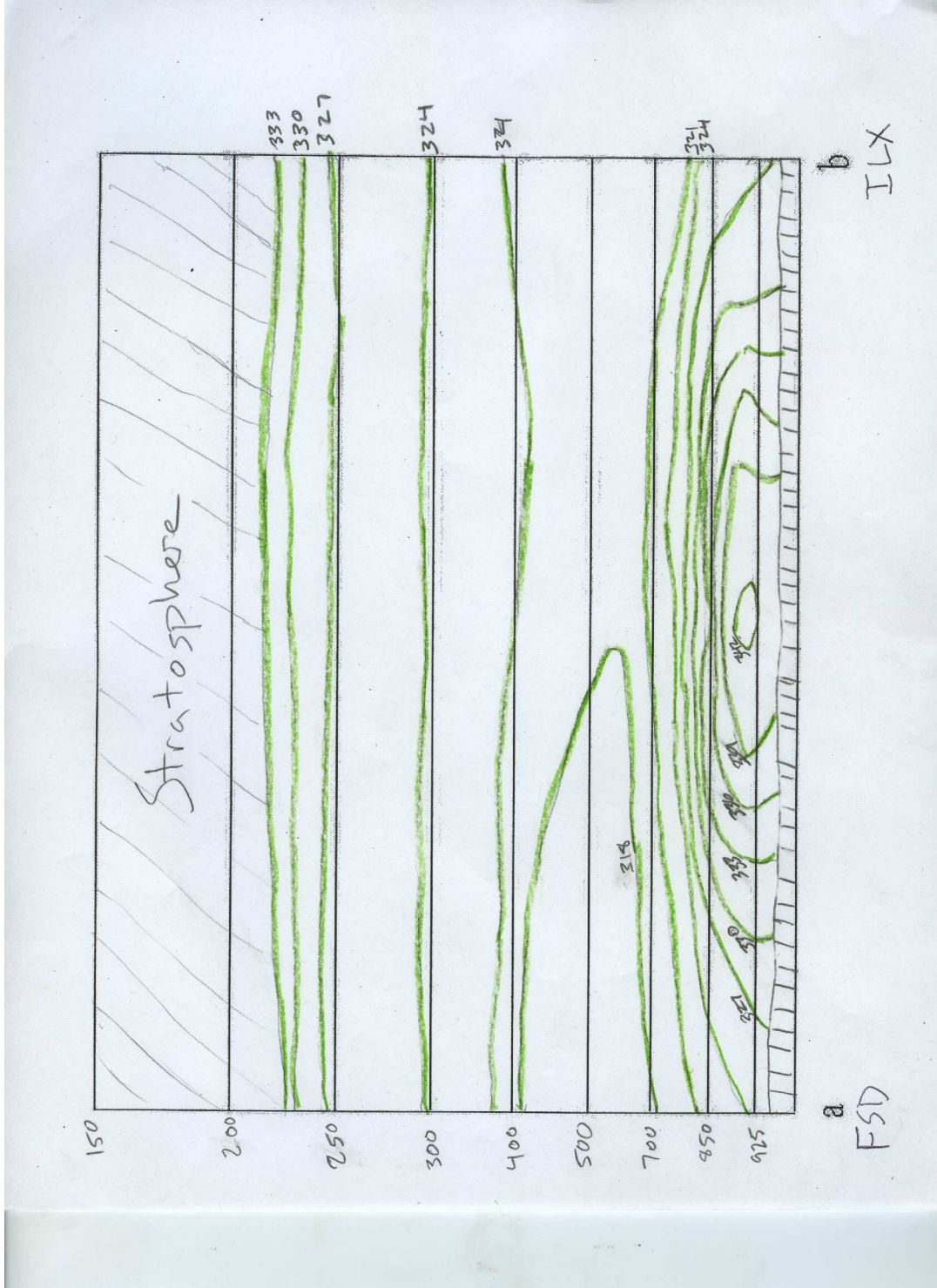


Figure 7: Cross section between Sioux Falls, SD and Lincoln, IL. Contours of Theta-E plotted every 3 degrees Kelvin. Note warm bubble at surface between two locations

3) Wind Shear

The last important factor that led to both the initial convective system and the ultimate formation of the super-cells was

the wind shear throughout the atmosphere. A key component to the development of any strong thunderstorm or mesocyclone is having wind shear throughout the troposphere. Wind shear can be represented by either an increasing wind speed with height, a veering of the winds with height, or by both at the same time. The wind shear is represented by a hodograph, which is a two-dimensional plot of the wind with height by measuring the U and V components of the wind. This graph can be used in order to determine the likelihood of creating a mesocyclone capable of producing tornadoes. In general, the hodograph should be curving down and to the right in order to create a storm cell that will move to the right and hence have a better chance at re-spawning itself with time. The tornadic super-cell that formed in Iowa has the characteristics of a right mover and will be analyzed in the last section.

The wind shear throughout the troposphere during the storm system over Iowa was oriented in a manner that was very conducive to the production of the tornadic super-cells. A wind shear analysis at 00 UTC on 14 April is shown in figure 8. The plot shows surface streamlines, low-level jet flow, and upper-level jet flow. The surface streamlines over Iowa have a southerly tendency into the region where the storm system was located. The 850 mb low-level jet is oriented southwesterly, and the 300 mb jet streak is westerly. Refer back to the sounding at Davenport, Iowa in figure 3 and note the wind vectors on the side of the sounding. The analysis has the same structure of wind veering with height throughout the whole troposphere. The sounding also indicates the steady increase in wind speed throughout the whole troposphere. The combination of wind veering and speed increase with height highlights a setup very conducive to the creation of super-cells within the large convective region.

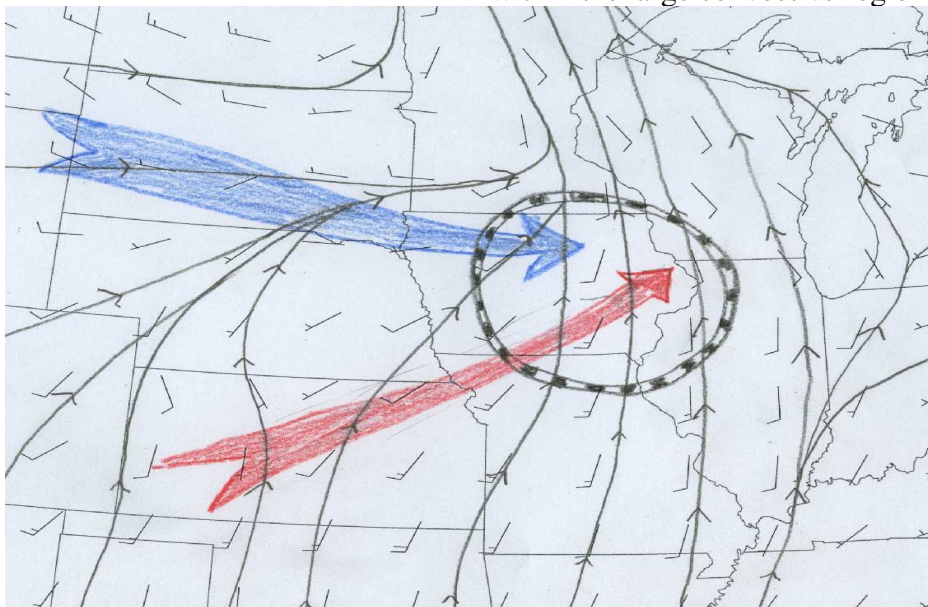


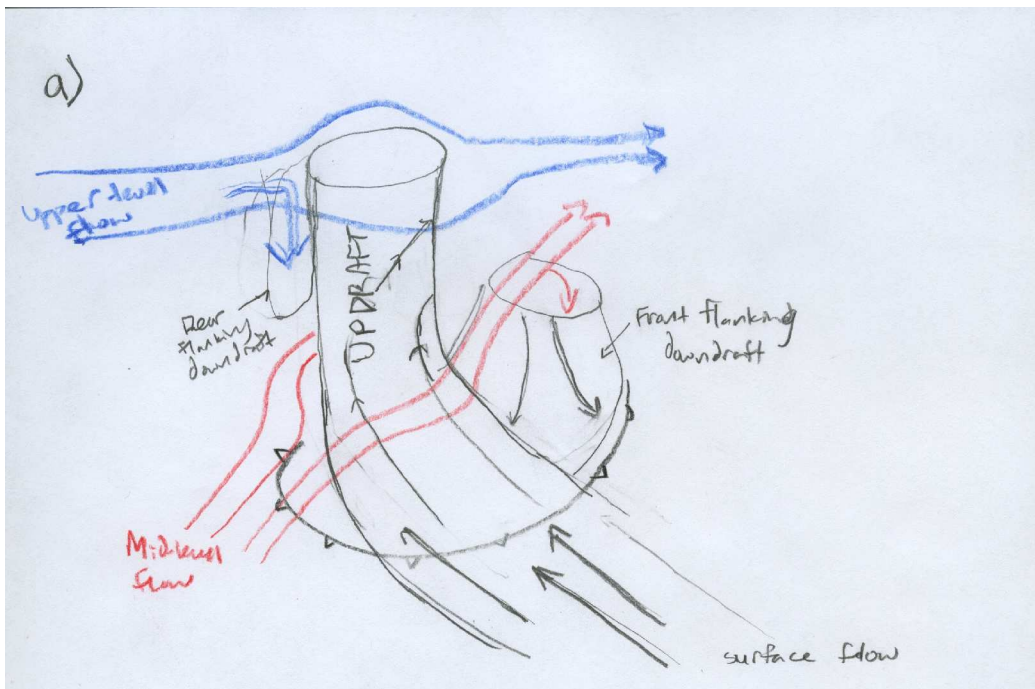
Figure 8: Wind shear analysis at 00 UTC on 14 April centered over Iowa regions. Streamlines represent surface flow, red arrow represents 850 mb flow, blue arrow represents 300 mb jet flow. Hatched region is area of storm system at same time period.

The wind shear with height oriented the way it is in this case is very similar to an idealized mesocyclone in a

super-cell storm. Figure 9a is a conceptual model of this idealized super-cell in its early and late stages of development. The

original model concept was presented by Lemon and Doswell in 1979. The first stage highlights the wind shear veering with height to the top of the super-cell. Note the wind shear in the model is oriented in an extremely similar way as that of the atmospheric wind profile through Iowa. The surface flow is forced upward over an approaching gust front created by the storm system. The updraft veers with height and creates a barrier to incoming flow at the upper levels. Once the upper level flow hits the updraft, flow is forced down and a rear flanking downdraft is created. Mid-level flow also feeds into the front flanking downdraft once it moves around the updraft, which helps to strengthen the gust front and therefore the updraft. Figure 9b shows the final mature stage of the super-cell. A cyclonic vortex is created between the updraft and the rear flanking downdraft, and a new rear gust front has been created

at the surface. The inclusion of the two gust fronts at the surface acts to strengthen the updraft. Near the surface of the rear flanking downdraft is where a tornado is generally spawned from in these super-cells. The wind shear at each level is still helping to feed all the vertical motions occurring in the super-cell. The surface flow contributes to the updraft; the mid-level flow contributes to the front flanking downdraft; and the upper-level flow contributes to the rear flanking downdraft. This process continues until the vortex cuts off the updraft, in which the downdrafts become much weaker. However, after the original updraft is cutoff from the super-cell, the surface flow creates a new updraft and helps in the genesis of a new super-cell if the wind shear and helicity stays strong enough. Based on the region of Iowa where tornadoes were reported, it is likely that the wind shear played a large part in creating super-cellular structures.



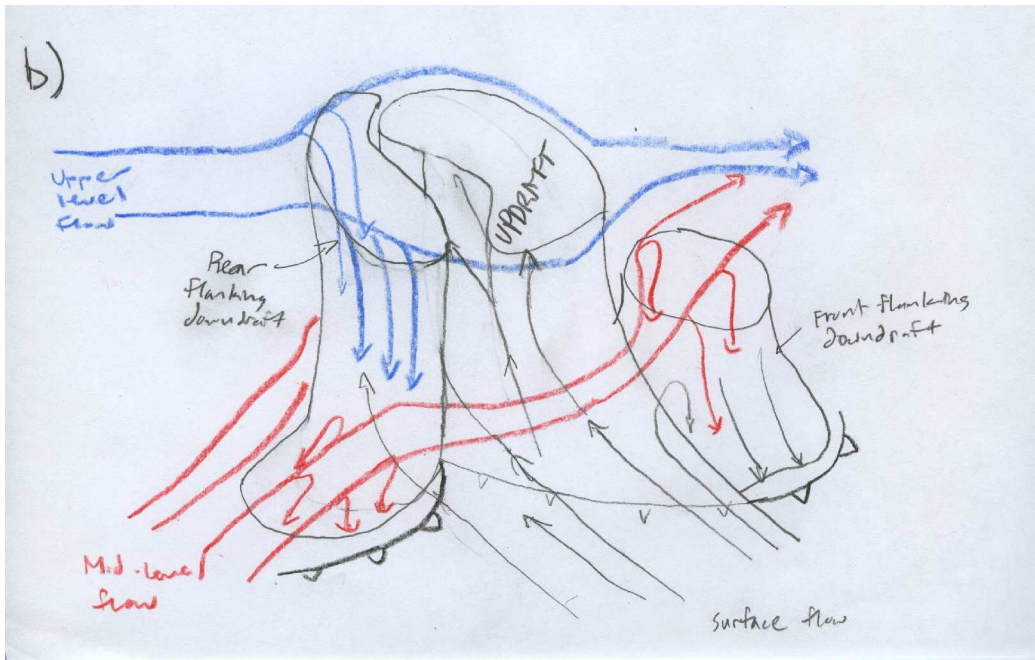


Figure 9: Conceptual model of a super-cell thunderstorm based on a diagram by Lemon and Doswell in 1979. Light streamlines represent surface flow, red lines represent mid-level flow, blue lines represent upper-level flow, a) Beginning stage of development for a super-cell, b) Mature stage of development for a super-cell.

4) *Analysis of Quad Cities Outbreak, 22:00 UTC 13 April – 2:00 UTC 14 April*

The state of the atmosphere over Iowa on the 13th of April became subject to deep convection and the formation of deadly storms. A satellite and radar analysis of these storms through the Quad Cities of Iowa can give insight into the evolution of the hail and tornadoes that were spawned. Imagery taken from the GOES-East satellite in the 10.7 micron infrared wavelength was used to analyze the cloud structure of the storm. At 22:01 UTC on the 13th, the skies were mostly clear over western Iowa (Figure 10a). Steady winds and low relative humidity throughout the day was enough to keep the day clear with strong solar heating. As conditions became unstable, the low-level southwesterly jet passed through southeastern Iowa and was able to break the inversion cap over the planetary boundary layer. Only two hours later at 00:15 UTC on the 14th, an area of

convection covered a large portion of eastern Iowa (Figure 10b). There were severe thunderstorms located along the western edge of the cloud region. This is the area in which the super-cells would form and drop 15 tornadoes through the Quad Cities in southeastern Iowa. At 01:37 UTC on the 14th, the strongest tornado reported in the region dropped on Iowa City, Iowa. The satellite imagery at this time shows the whole convective storm region, which now looks similar to a mesoscale convective system (Figure 10c). It is a very large region of clouds with cloud top temperatures well below -32 degrees Celsius throughout. The low cloud top temperatures represent clouds that extend nearly to the troposphere due to the deep convection throughout the whole region. Several areas on the western edge of the system have slightly warmer cloud top temperatures, which are indicators of super-cell storms because air from the surface is being sucked all the way to the tropopause. These regions are indicated by

an enhanced-V signature. The enhanced-V signature can be seen over the Quad Cities in southeastern Iowa. The temperatures in that area are much higher than surrounding

regions. The satellite data shows how quickly the storm developed in the late afternoon and the strength it had by the time it reached the Quad Cities.

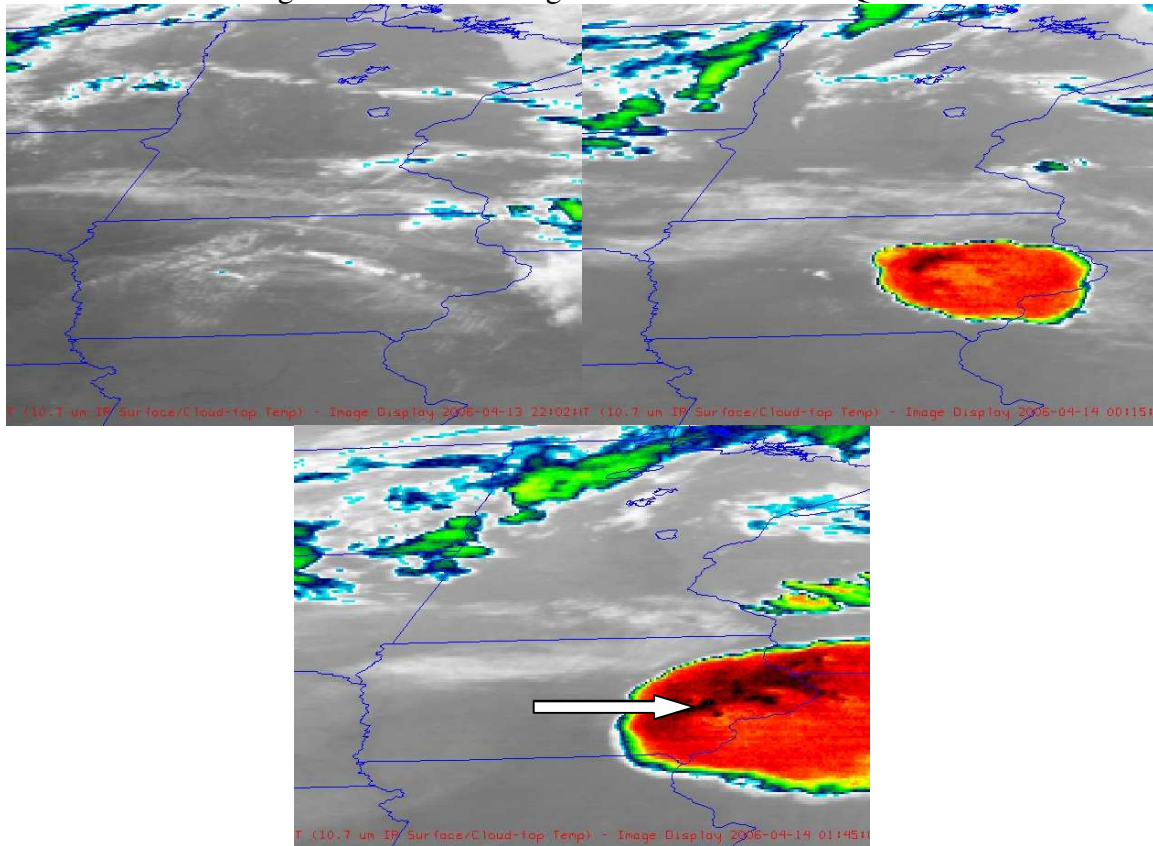


Figure 10: GOES-East satellite image in the 10.7 micron wavelength centered over Iowa, a) Upper left panel image at 22:01 UTC on 13 April, b) Upper right panel image at 00:15 UTC on 14 April, c) Lower panel image at 01:37 UTC on 14 April.

In order to view the specific areas of where the hail and tornadoes formed, a radar analysis of the data must be done. The closest radar to the storms during this time period was located in Davenport, Iowa. Base reflectivity and radial velocity scans are the best indicators of severe weather when looking at radar data. The radar imagery will first be used to show the progression of the super-cell structures themselves. Throughout the two hour period of 00:04 UTC – 02:01 UTC on 14 April, the storm cells show qualities of very good helicity values and rotation. At 00:04 UTC a large super-cell is located over Tama County (Figure 11a). The super-cell has high dBz values, which

likely represents hail. There is some separation in the northern part of the cell. By 00:42 UTC on the 14th, there are now three super-cells oriented in a vertical manner (Figure 11b). The original super-cell has now moved a county over into Benton, and it has split off both left and right movers from its original cell. The left moving cell had become very strong at this time as well. When a super-cell is able to produce such strong left moving cells, the helicity and wind shear of the storm is very sufficient. At 01:22 UTC on the 14th, the two lower cells had begun to merge together, and the right mover created from the first cell was strengthening (Figure 11c). This is the cell that would hit Iowa

City and cause extensive damage to the downtown area. When helicity is strong like it was in this case, the tendency for super-cells to break up and reform to the southeast is common. The left moving tornado had also died down a little, but strong cyclonic rotation could still be seen in it based on the structure of the precipitation. At 02:01 UTC on the 14th the super-cells were beginning to make their way out of Iowa (Figure 11d). The southeastern-most super-cell began to strengthen further, which is common with

the right moving super-cell. The original left mover can still be seen in southeastern Wisconsin, where it began to strengthen and produce other super-cells that would drop extremely large hail. The progression of the super-cells through this two hour time period does a wonderful job of showing characteristics of a storm with great wind shear and helicity. The movement of the right movers also is representative of strong cyclonic rotation of the storms.

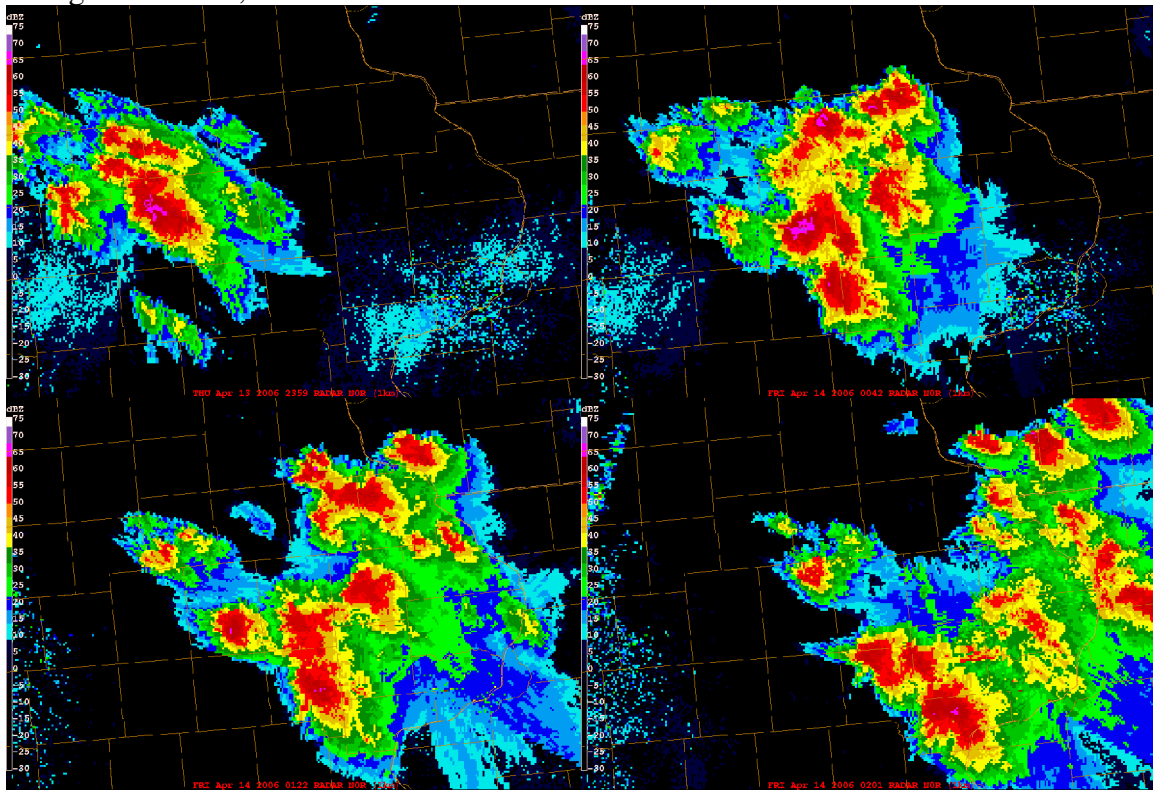


Figure 11: NEXRAD base reflectivity from Davenport, IA, a) Upper left panel image at 00:04 UTC on 14 April, b) Upper right panel image at 00:42 UTC on 14 April, c) Lower left panel image at 01:22 UTC on 14 April, d) Lower right panel image at 02:01UTC on 14 April.

The radar is also useful in zeroing in on where the strong F2 tornado hit Iowa City, Iowa. Storm reports indicate that the tornado touched down in Iowa City at 01:37 UTC on 14 April. Radar at 01:37 UTC shows the southeastern-most super-cell that was mentioned previously located over Iowa City (Figure 12a). The tornado signature can be seen by the hook echo

located in the southern portion of the county. A hook echo is a strong indication of a tornado because it represents the area of the rear flanking downdraft and location of the wall cloud. It is an extension of the rotation of the mesocyclone itself, and is where a super-cell most often drops a tornado. This is clearly the case over Iowa City, as the hook echo is very well defined.

Another way to confirm the location of where the tornado would be is by looking at the radial velocity. A radial velocity scan at 01:37 UTC on the 14th indicates a tornado in the northern part of where the hook echo was located (Figure 12b). The couplet of positive and negative radial velocities in this region highlights where

strong rotation is occurring. Based on the size of the couplet, it is likely very close to where the tornado would be, but is also incorporating rotation of the mesocyclone it is associated with. The analysis of these two radar attributes confirms the reports of the tornado over Iowa City at the time.

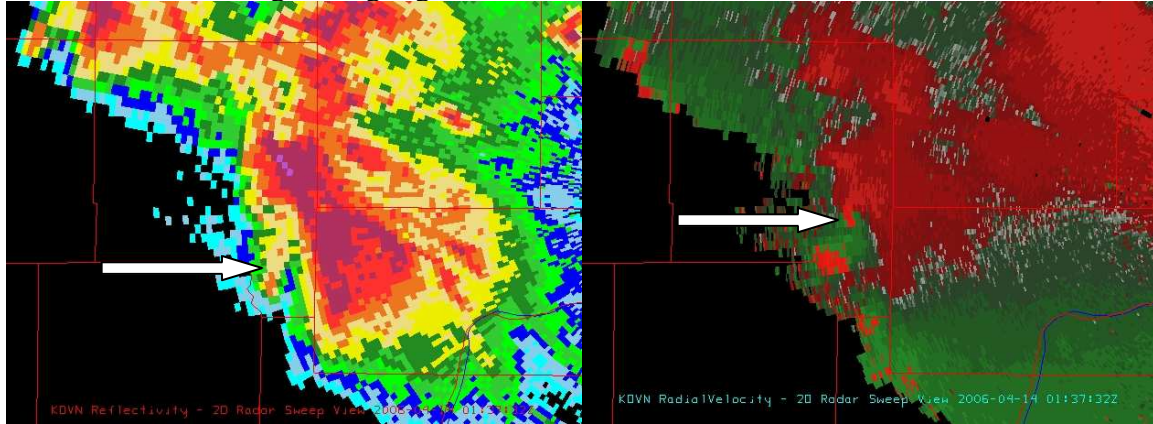


Figure 12: NEXRAD radar imagery from Davenport, IA centered of Iowa City, IA, a) Base reflectivity scan taken at 01:37 UTC on 14 April, b) Radial velocity scan taken at 01:37 UTC on 14 April.

Conclusion

The severe weather outbreak in eastern Iowa on 13 April, 2006 was an unexpected and unwelcome event. Despite the destruction that it caused, it provided an interesting aspect of convection over the plains region of the United States. The typical severe weather parameters such as daytime heating, low-level jet streaks and “loaded gun” soundings were all present. An interesting aspect of the case, however, was the heavy influence of evapo-transpiration over the corn fields of the Midwest. A severe weather outbreak was created in a situation that forecasters would have struggled with predicting.

The idea of evapo-transpiration is not a new one to farmers, as they have learned from experience what situations present hazards for their crops. In meteorology, however, the idea of evapo-transpiration as a sufficient moisture source is still a topic up for debate. Sufficient tools could still be developed in order to better predict the occurrence of when soil moisture has an effect on weather systems. Improving the accuracy and assessment of moisture released from crops could yield as much information in the field of meteorology as it has for farmers determining their crop yield.

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