Synoptic and Mesoscale Analysis of the 07 – 09 June 2008 Heavy Precipitation Severe Weather Event over Central and Southern Wisconsin

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Abstract

Between 07 June and 09 June 2008, central and southern Wisconsin received round after round of heavy rainfall associated with severe thunderstorms. After a record-setting snowfall the previous winter, this region was already moisture laden, and any significant rainfall would be catastrophic. There were numerous factors that went into this historic event, both at the synoptic and the mesoscale levels. The 300mb jet was virtually stationary from a trough axis over western Nevada and extended through the Midwest and into southern Canada. This left the case study region in a consistent area of upper-level divergence, giving needed lift to force the severe weather. Mid-level patterns were historically favorable for flooding and a strong 850mb ridge kept the Upper Midwest ensconced in warm air. At the surface, a stationary front reaching into western Wisconsin provided another way for the air to rise in the region. On a smaller scale, the air over central and southern Wisconsin was rife with the energy necessary for strong thunderstorms. The atmospheric wind profile was also favorable for the continuation and longevity of intense thunderstorms. A strong low-level jet kept the area under a severe threat during the overnight hours, constantly pouring moisture-rich air into Wisconsin. The 850mb moisture transport variable, a key ingredient in heavy rainfall events, was in position to cause extreme rainfall in central and southern Wisconsin.

Introduction

From 07 June through 09 June 2008, a series of severe weather events occurred over central and southern Wisconsin that caused dramatic rainfall over much of the area. Round after round of heavy rains battered the area, with portions of Vernon and Sauk Counties picking up more than a foot of rainfall over those two days, according to radar estimates. Milwaukee also picked up its highest 48 hour rainfall total of 7.18 inches. The associated severe thunderstorms produced widespread damage via two different mechanisms. On 07 June, 15 tornadoes were reported throughout central and southern Wisconsin. The following day, wind damage reports were scattered across the region. It cannot be overstated that the most far-reaching impact these storms had resided in the heavy rainfall.

The year of 2008 was a banner year for the state of Wisconsin with regards to weather phenomena. The winter of 2007-2008 broke many seasonal and monthly snowfall totals across the central and southern regions. Of note, the cities of Madison and Milwaukee went over 100 inches total, obliterating their seasonal averages of 49.9 inches and 52.4 inches, respectively. The added precipitation in the winter undoubtedly added to the record flooding that followed in the spring and summer. It was the rainfall from 07 to 09 June that pushed waterways to their brink, as mudslides, dam failures, road closures, and evacuations resulted almost immediately. This unfortunate set of precipitation circumstances caused catastrophic damage to portions of Wisconsin.

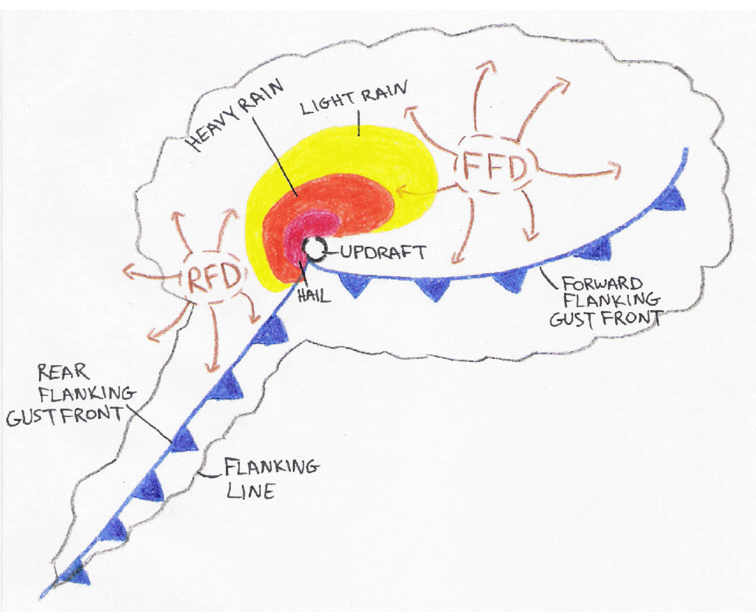

Figure 1: Conceptual model of a supercell thunderstorm based on Lemon and Doswell (1979). Note the regions of air flow in the storm, including the rear flanking downdraft (RFD) and forward flanking downdraft (FFD). Also note the large area of heavy rain a supercell can produce.

What was unique to the 07 - 09 June period was the frequency of severe weather events that produced heavy rain. The cause behind the heavy rainfall lies in the nature of the supercell thunderstorm, and the associated mesoscale convective systems. What makes a thunderstorm a supercell is its rotating and sustainable nature. They have the ability to stay together for hours at a time given the right set of atmospheric conditions. The Lemon and Doswell (1979) supercell thunderstorm conceptual model (Figure 1) illustrates how these beasts can have pockets of torrential rainfall that can vary depending on the size of the thunderstorm. If one area experiences heightened supercellular activity over a short amount of time, it would not be surprising if that area experiences a flooding event.

The goal of this paper is to illustrate how central and southern Wisconsin was a breading ground for supercell thunderstorms from 07 June to 09 June 2008. It will begin by analyzing the synoptic forcings, including the 300mb jet, mid-level flow patterns, and the surface features that were essential in this region seeing heightened rainfall. The synoptic pattern will be reinforced with a Miller Diagram to demonstrate the likelihood for severe weather. It will then transition into the mesoscale analysis, including the energy that was available in the atmosphere, the atmospheric wind profile, the persistent low-level jet, and the 850mb moisture transport variable. The synoptic and mesoscale weather conditions were favorable for severe weather development for much of the 48 hour period in the study. It were these conditions and subsequent severe events that caused the flooding in central and southern Wisconsin on the days following 09 June.

Data

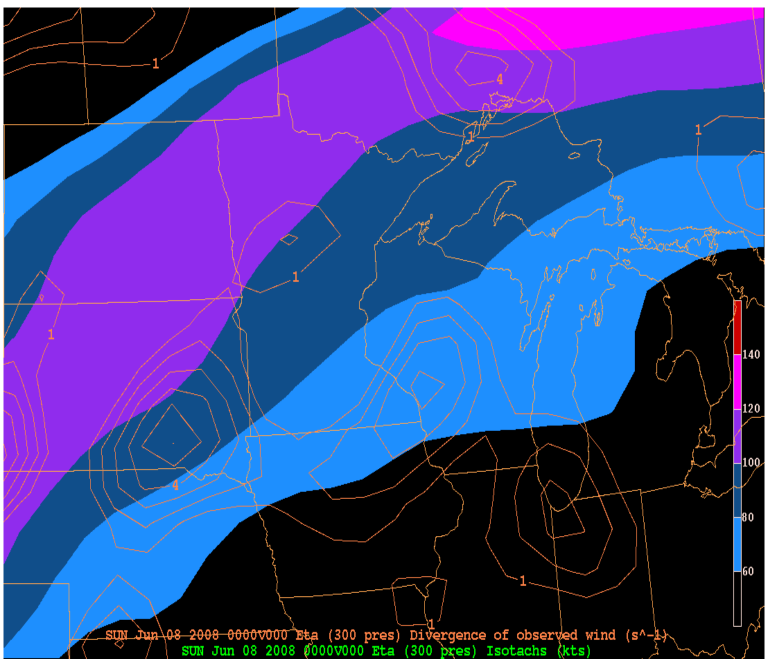

Figure 2: ETA model data from 300mb over the Upper Midwest valid at 00Z 08 June 2008. Wind (knots) is depicted in the color fills and the solid contours are divergence (s^{-1}).

Data were collected initially through GEMPAK plots, primarily using ETA model data, on the 211 grid, between 07 and 09 June 2008. Supplemental sources for data include the Storm Prediction Center's (SPC) mesoscale analysis archive, the SPC's upper air maps archive, and the Hydrometeorological Prediction Center's (HPC) surface analysis archive. Sounding data was collected from the University of Wyoming's radiosonde archive, except for the low-level jet sounding, which was generated in the GEMPAK Analysis and Rendering Program (GARP). GARP was also used to analyze NEXRAD radar data and compile rainfall estimates. The two hand-drawn diagrams were completed by the author.

Synoptic Analysis

The large-scale pattern over the central United States makes central and southern Wisconsin focal points for severe weather over the 07-09 June 2008 time span. A persistent jet pattern over the Upper Great Lakes during those two days provides the needed lift to spark thunderstorms. The 500 mb flow is also favorable for flooding based on the historical floods of 1993 along the Mississippi River. At 850mb, a thermal ridge stays in place over much of the eastern half of the country, keeping Wisconsin under its influence. Down at the surface, a strong, blocking high pressure system firmly affixes itself to the southeast United States. Meanwhile, a low pressure area tries to make its way into the Upper Midwest on 08 June, but did not progress very much, and the stalled warm front provides a triggering mechanism for sustained thunderstorm development in central and southern Wisconsin.

Upper-Level Pattern

At the initial point of analysis, 12Z on 07 June, the subtropical jet at 300mb extends from eastern Ontario to the Nevada-California boarder, where it curves around the trough axis. While there is no forcing for ascent over the Wisconsin area, it is important to note the position of the jet at this time, as it will remain in that general location over much of the analysis period. By 00Z on 08 June, the jet maximum has strengthened to over 125 knots in a small region to the north of Lake Superior (Figure 2). With all other flow over remaining virtually unchanged, this forces a large area of upper-level divergence over central Wisconsin, through southern Minnesota and into northern Iowa. In addition, there is some slight diffluence of the flow over southern and central Wisconsin which would amplify the divergence being caused by the newly formed jet maximum.

The way the 300mb pattern sets up puts parts of Wisconsin, Iowa, and Minnesota in the right entrance region of the canonical “four quadrant” jet streak. This local acceleration causes upper-level ageostrophic winds, which characterizes the overall wind vector's change over time. In the right entrance region, the ageostrophic wind is diverging from that area, leading to rising motions over that column. What this does with respect to severe weather is give the atmosphere the needed lift to overcome any type of impediment on air rising freely to convect. Most any type of surface inhibition, commonly a low-level temperature inversion, can be overcome by a synoptic forcing for rising air. In this case, the upper divergence evident over the tri-state area will provide the necessary lift for strong thunderstorm development in the hours after 00Z on 08 June.

Moving further into the day on 08 June, the mean flow over the Upper Midwest does not change very much in the way of direction. However, with respect to speed, the jet undergoes a change that will aid in more rising air. The previous jet maximum at 00Z has intensified from 125 knots to greater than 150 knots, with its position remaining just north of Lake Superior in central Ontario. This keeps much of the state of Wisconsin, along with eastern Minnesota and northern Iowa, under an area of upper-level divergence and a continued forcing for synoptic ascent. The diffluence over Wisconsin has also become more dramatic, leading to an enhancement of the vertical motion. Again, there is a favorable forcing for strong thunderstorm development in the regions of upper-level divergence.

By 00Z on 09 June, the jet maximum has weakened to around 125 knots once again, and the trough that the jet system has been circulating around finally progresses eastward. Regardless of those two facts, there is still some divergence at the 300mb level over central and southern Wisconsin. It is not, however, as strong as it had been the previous day. The story is the same at 12Z, as the jet starts to make its way eastward across Wisconsin and the region of synoptic

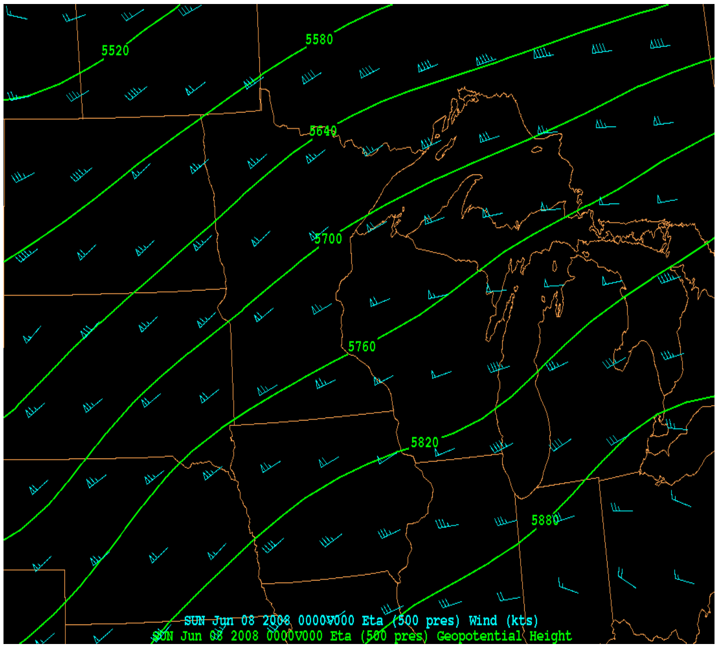

Figure 3: As figure 2, but at 500mb. The contours are geopotential heights in meters and the vectors are wind speeds in knots.

ascent is taken away from the analysis area. But, this does demonstrate that through 12Z on 09 June, the vertical motion from upper-level divergence is persisting over central and southern Wisconsin.

Mid-Level Pattern

The mid-level pattern, much like the upper-level pattern, does not shift much over the course of these two days. The most static layer of the bunch is at 500mb. Wisconsin is placed squarely in the middle of a ridge and trough at 500mb. The ridge axis is located around eastern Quebec and Northern Maine at 12Z on 07 June and does not move very much, if at all, over the next 48 hours. The trough is a little more dynamically inclined than the ridge. It is initially located over the Idaho and Oregon region, and slowly pivots itself over the Rockies and into the Plains by 09 June. With supergeostrophic flow at the crest of a trough and subgeostrophic flow at the base of a ridge, ageostrophic divergence is likely in between. The shorter the distance between the trough and ridge, as in this case, where the ridge remains stationary while the trough digs out from the west, means the divergence will be stronger and the rising motion will similarly increase as a result. What this means for Wisconsin is that there is yet another synoptic forcing for ascent over that area. Additionally, the flow over the Upper Midwest is uniformly out of the southwest (Figure 3). This has been found to be a persistent factor in the Great Floods of 1993 by Bell and Janowiak in their paper on atmospheric circulations associated with the

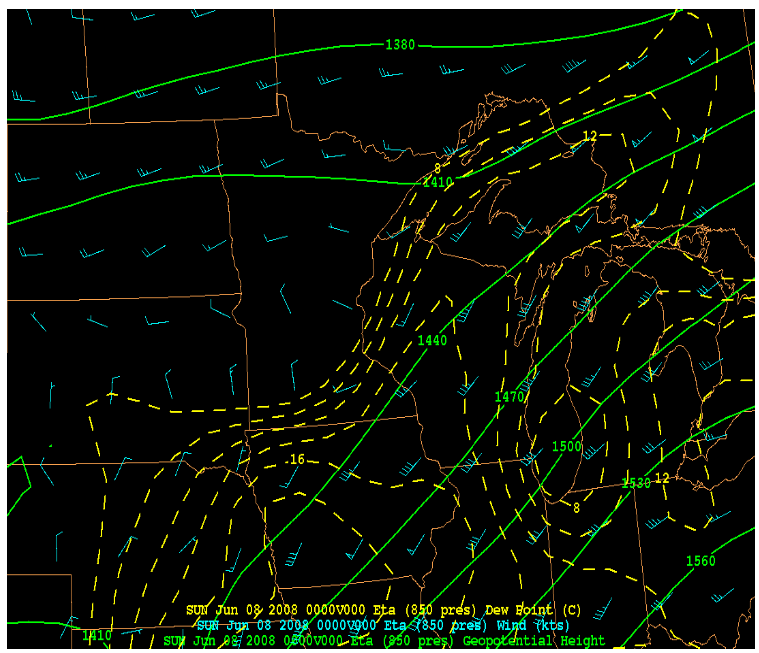

Figure 4: As figure 2 but at 850mb. The solid contours are geopotential heights in meters, the dashed contours are dew point temperatures in °C (>8 °C), and vectors are wind speeds in knots.

1993 Midwest Floods. Therefore, there is some historical significance to the continual southwesterly flow over Wisconsin that aids in the flooding.

Descending farther in the atmosphere, the 850mb level also plays a significant role in keeping portions of Wisconsin under the threat of severe weather. A strong ridge is in place over the eastern half of the United States at the initial analysis time on 07 June. The ridge extends as far west as central Kansas and Oklahoma and as far north as the New England-Canadian boarder. At that 12Z 07 June period, the air over central and southern Wisconsin is not very moist at 850mb. However, over the next 48 hours, there is a continual surge of moisture that keeps dew points above 12°C (Figure 4). What the ridge does is continually advect warmer air from the southern United States into the northern regions, including central and southern Wisconsin. In addition, the flow is situated so that even the Upper Midwest can receive moisture from the Gulf of Mexico. The ridge is serving a dual purpose: it heats and moistens the air in the region of concern, which gives it two important characteristics for severe weather. Its fixed position helps allow for this sustained severe episode in Wisconsin.

Surface Pattern

At the surface, synoptic-scale systems play a large role in this flooding event, as a stubborn high pressure center and a slow low pressure center focus much of the nation's active weather in the Upper Midwest. As was the case with the upper-level synoptic features, the stagnation of the surface systems makes for a prolonged event over Wisconsin.

The surface pattern at 12Z on 07 June reveals a large area of high pressure located over the southeastern United States. Initially, it has a central pressure of 1024mb, and that will weaken over the next 48 hours. However, it does not move off to the east as would be expected if another system was coming in from the west. Instead, it meanders into the interior portions of the southeastern United States from 12Z on 07 June to 12Z on 09 June. Its influence is felt from eastern Texas, through the Ohio River Valley, and even into central New England. This sets up as a blocking mechanism for any systems that are attempting to move eastward across the United States. It is this high that will cause the subsequent stalling of a front associated with a low coming off of the Rockies.

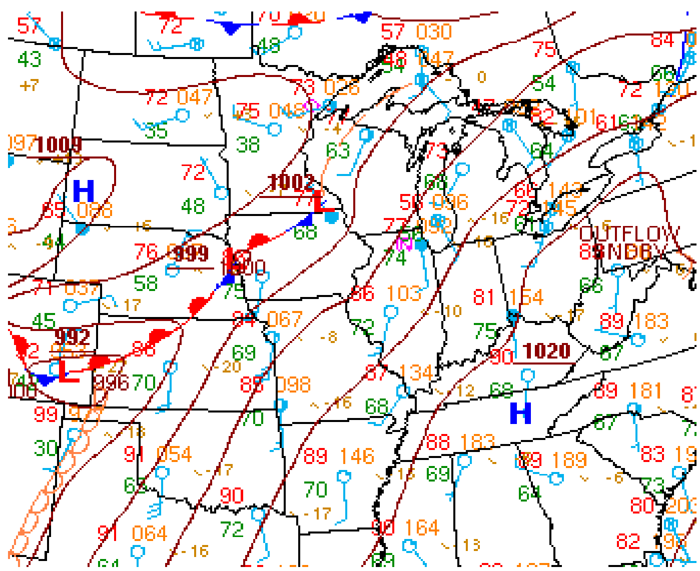

Figure 5: Surface analysis at 00Z on 08 June 2008. Image courtesy of HPC Archives.

With the high in place, a low is moving out of the Rocky Mountains in southern Colorado and Kansas at 12Z on 07 June. The warm front that is associated with that low extends north and east into western Iowa. By 00Z on 08 June, the low has not progressed very much, as it is still centered in southern Colorado (Figure 5). The front, however, is slowly advancing northeastward into western Wisconsin and southern Minnesota. It still retains its warm front characteristics as there is a distinct south-to-north wind shift across the front, in addition to a moisture and temperature increase behind the front. This front is providing another source of lift for the development of thunderstorms over the region. The low finally makes progress out of Colorado by 12Z on 08 June, but it only moves into north-central Kansas. What is more important is that the stationary front is still locked in place over Wisconsin and Iowa. This will keep southern and central Wisconsin under the threat of thunderstorms throughout much of the morning and early afternoon on 08 June.

The progression of the low increases during the day on 08 June. By 00Z on 09 June, the low looks well-structured in central Iowa and a cold front extends through to the Panhandle of Texas. The stationary front has not moved very much in the previous 12 hours. Since the center of low pressure has "caught up" to the front, it is no longer draped across the Midwest. It extends from the low in Iowa through southern Minnesota and north-central Wisconsin, into the Upper Peninsula of Michigan. This puts central and southern Wisconsin into the warm sector of the synoptic system, rife with the heat and moisture necessary for severe thunderstorms. The severe threat finally ends with the passage of the cold front around 12Z on 09 June, as the low moves off to the north over Lake Superior.

Miller Diagram

One tool to analyze the severe weather potential in the synoptic conditions is to complete a Miller Diagram. It allows forecasters to look at many levels of the atmosphere on one sheet of paper using different colors and patterns to represent various features at their respective levels. The main purpose of the Miller Diagram is to identify tornado potential, but it does not take much convincing to understand that severe weather would be likely in the same region that tornadoes are likely. A Miller Diagram over the Upper Midwest at 00Z on 08 June 2008 shows where conditions are favorable for severe development (Figure 6).

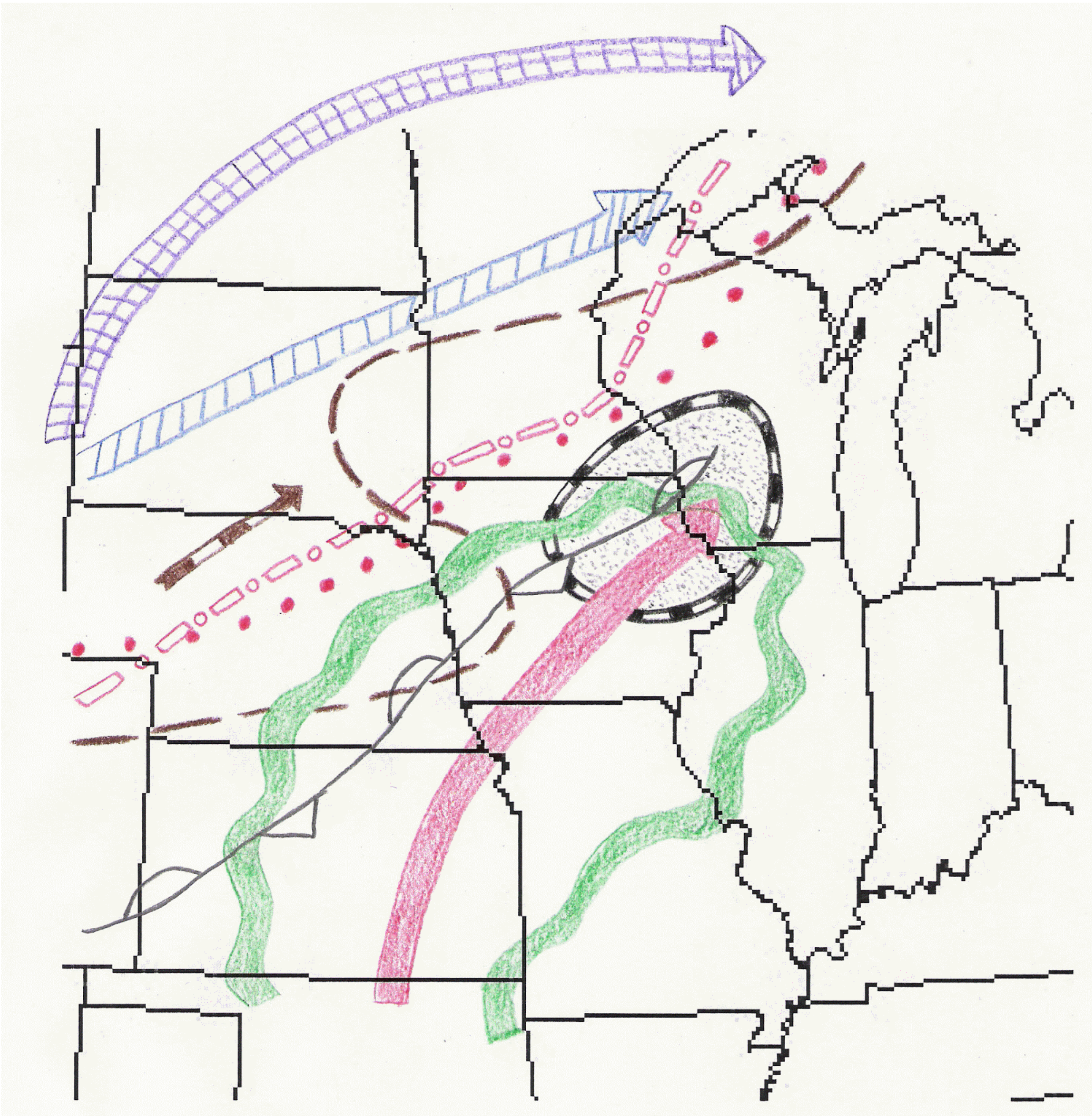

Figure 6: Miller Diagram over the Upper Midwest valid at 00Z on 08 June 2008. Features depicted: surface stationary front (pencil), 850mb jet (red arrow), temperature ridge (red dots), moist tongue (green wavy line), and dry line (unfilled red dashes and dots), 700mb dryline (brown dashes) and mean flow (brown dashed arrow), 500mb flow (blue striped arrow), and 300mb flow (purple hatched arrow). The speckled area enclosed by the black dashed circle indicates the region of probable tornado development.

Confirming the prior synoptic analysis, the Miller Diagram shows that central and southern Wisconsin, along with northeast Iowa and portions of Illinois and Minnesota, are in an area of probable tornadic development.

This pattern fits into the "Type C" synoptic pattern associated with Miller Diagrams.

The moist tongue at 850mb is overrunning the stationary front across Iowa and Wisconsin, producing the lift needed for thunderstorms. A dry tongue of air at 700mb is being advected towards the warned area by southwesterly flow—another characteristic associated with the Type C pattern. This pattern has been linked to overnight thunderstorm activity, which is what was observed throughout the case study period. The thunderstorm production by the Type C pattern will persist regardless of daytime insolation, providing a constant threat for severe weather until the synoptic conditions weaken or change altogether.

Mesoscale Analysis

Over the two days of this study, the type of severe weather events differs greatly. On 07 June, the majority of the storm reports are in the form of tornadoes over central and southern Wisconsin. Radar confirms that there are numerous discrete supercells over the region that correspond to the tornado reports between 18Z and 22Z. The next day, however, there are only wind damage reports that come at two discrete periods. The first occurs between 14Z and 18Z, and the latter between 23Z on 08 June and 02Z on 09 June. The goal of this section is to describe the mesoscale mechanisms that foster severe weather potential and distinguish which characteristics of the respective days led to their unique type of severe weather. Special attention will be paid to the mesoscale features that contribute to the large amounts of rainfall in the region.

CAPE/CIN

Two of the most scrutinized variables with respect to severe weather are convective available potential energy (CAPE) and convective inhibition (CIN). These two parameters give forecasters great insight into how explosive of a severe weather event cane be expected, if at all, based on the amount of energy in the atmosphere. Both variables can be interpolated by using a thermodynamic diagram, commonly a skew-T log-p diagram, as the area on that diagram is proportional to energy. CAPE is a measure of instability that is calculated by lifting a parcel from the surface (or any other level from which a measurement is desired) and looking to see if the lifted parcel is warmer than the environmental temperature. If the parcel temperature is warmer than the environment, it is positively buoyant and yields a positive CAPE value. However, if the lifted parcel is cooler than the environment, it is negatively buoyant and will return a negative value of CIN. A deep layer of CIN will prevent a parcel from lifting higher in the atmosphere, possibly to regions of very unstable air. In order for severe weather to occur, sometimes a balance is needed between the two variables so that all the energy is released at once, making a colossal thunderstorm. Other times, an environment with a high CAPE value and no CIN will result in powerful thunderstorms.

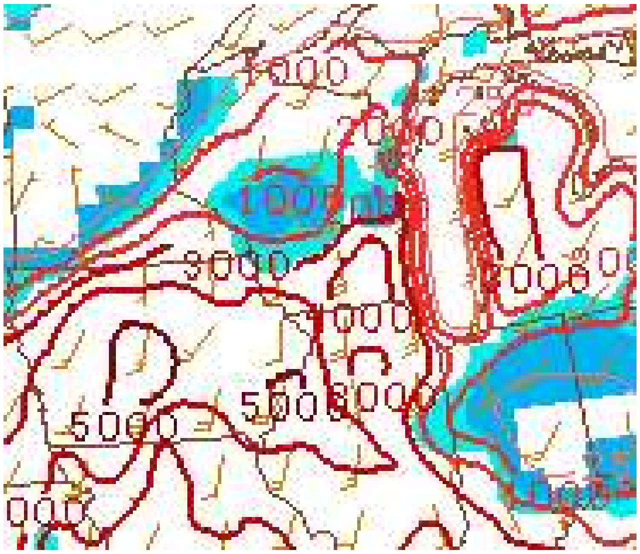

Figure 7: RUC model data from 07 June 2008 valid at 19Z over the Upper Midwest. Contours represent CAPE in J/kg and fills represent CIN in J/kg. The lighter CIN shading represents values from 25-100 and darker shading represents values >100. Image courtesy of the SPC mesoscale analysis archive.

On 07 June, the values for CAPE in southern Wisconsin are approaching 4000 J/kg in some locations, while others are exceeding that value (Figure 7). On top of that, the CIN values are very low, less than 3 J/kg. This shows that the environment over southern Wisconsin is quite unstable, and any lifting motion will likely result in thunderstorms. Recalling the synoptic situation at this time, upper-level divergence is prevalent over central and southern Wisconsin, meaning there is a lifting mechanism in place. This is the first characteristic of the 07 June storms that make them more prone to tornadic development.

The next day, the large values of CAPE, similar to the ones on 07 June, are held at bay in northern Illinois. That is not to say there is no CAPE in central and southern Wisconsin. In fact, at 22Z, a tongue of CAPE values greater than 1000 J/kg pokes into central Wisconsin. But, the CIN values are much higher than they were the day before, getting over 100 J/kg. This would be significant in preventing thunderstorm development, but, as was the case with the prior day, upper-level divergence is found over central and southern Wisconsin. Additional lift early in the day is provided by the stationary front that is stretched through Wisconsin before it moves slightly off to the north. However, from looking at just these variables, it seems unlikely that this environment is favorable for large thunderstorm growth as it was the day before.

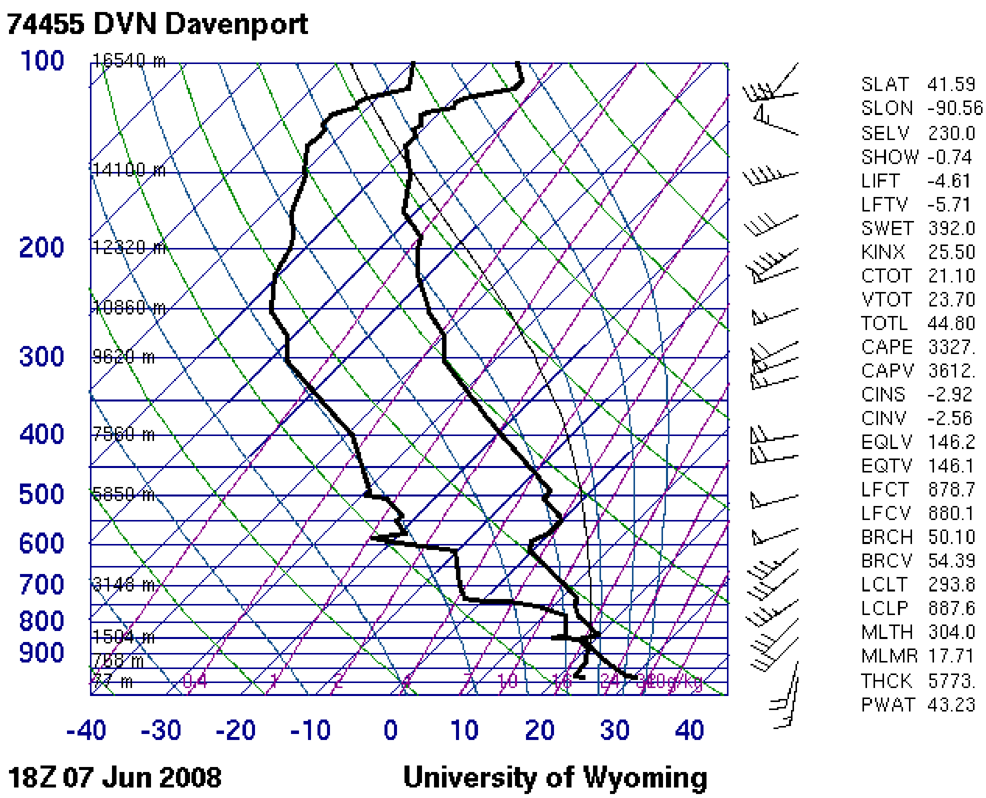

Figure 7: Atmospheric sounding from Davenport, Iowa valid at 18Z on 07 June 2008.

Wind Characteristics

The role CAPE and CIN play in severe storm development is equal to that of the variables calculated by the atmospheric winds. Instability and wind speed and direction have a delicate interaction that determines whether or not a thunderstorm will grow and if it will persist for a long time. In this case, if thunderstorms can maintain their structure for a sustained period, and if enough storms are being generated, that increases the likelihood for flooding rains. The factors that will be discussed in this section will be limited to helicity and shear (both directional and speed).

Helicity is the measure of how much the winds curve with height. It is used to explain why supercells have a splitting nature. The higher the helicity, the less likely cooler, drier air will entrain into the storm at mid and upper levels, ultimately leading to its demise. A storm can generate its own helicity via veering winds with height, but it is the background helicity of the environment that determines whether or not right or left moving supercells are favored. By creating a hodograph from the 18Z sounding on 07 June from Davenport, Iowa, there is a definite right curve to the diagram. The wind profile from the 18Z Davenport sounding corroborates with the wind speed and direction (Figure 8). Therefore, sustained right-moving supercells are favored in the environment; the airmass over

Davenport is likely very similar to the one over Wisconsin, as it is not far from the state, nor is there any synoptic feature to make the two airmasses different. Making another hodograph from 12Z on 08 June, again coming from the Davenport sounding, it reveals yet another environment favorable for right-moving supercells, as the hodograph generally curves to the right.

Similar to helicity, wind shear is a measure of how the winds change with height. Unlike helicity, wind shear is not directly used to determine the favoring of right or left moving supercells. The shear can be measured in both speed, how much the speed changes between given levels, and direction, the directional change between levels. It has been shown in literature that higher shear values are associated with longer living supercells. Specifically, as noted in Bunkers et al. (2006), the 0-8km bulk shear is much stronger in areas where long lived supercells are found. That paper also notes the balance that is involved between the shear and buoyancy (CAPE) in long lived supercells. In this case study, 0-8km bulk shear values of >40 knots are found throughout the study period. For supercells to be prevalent, the shear value needs to be around 40 knots, making this environment consistently favorable for supercell development.

Low-Level Jet

There is nearly consistent rainfall over central and southern Wisconsin from 12Z 07 June to 12Z 09 June. A typical summer day would see rain in the afternoon from convectively induced daytime heating thunderstorms, but those would disappear after sunset. In order to continue the threat of rain, or in this case the threat of severe weather, through the overnight hours, a feature needs to be in place that will advect the necessary heat and moisture into the region. This feature is the low-level jet.

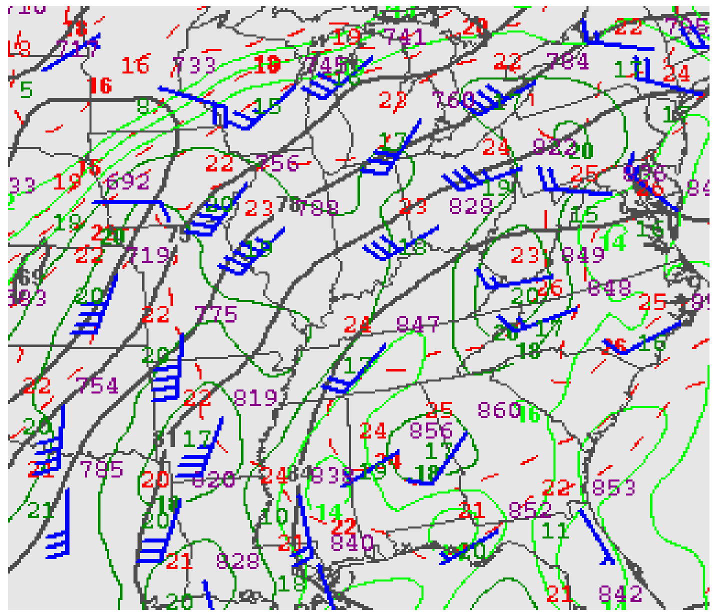

Figure 8: 925mb map depicting surface station data, mean wind flow (vectors), geopotential heights in meters (solid black contours) dew point temperatures in degrees C (solid green contours), and temperatures (dashed contours). Image courtesy of SPC Upper Air Analysis Archive.

For this case study, the low-level jet could be caused by one of two mechanisms, or a combination of the both. As mentioned earlier in the synoptic analysis, there is a stubborn high pressure system over the southeastern United States. The anticyclonic flow around the high is causing south to southwesterly flow over the southern Plains and into the Upper Midwest. However, the more traditional formation of the low-level jet occurs on the mesoscale level. A nocturnal inversion forms at the top of the planetary boundary layer. Below that level, the air is very turbulent and the winds could be coming out of any feasible direction. Just above the inversion, above the boundary layer, the air is suddenly frictionless and able to move at a considerably higher speed than the air below it.

At the 925mb level at 00Z on 08 June a plume of warm, moist air is being brought into the Upper Midwest (Figure 8). Dew points of 18°C are encroaching on southern Wisconsin and the mean flow is around 30 knots out of the south-southwest. The flow is uninterrupted from the Gulf of Mexico, and it is reflected in the expansive area of high dew points. This is again the situation at 12Z later that day, a more important time to have a low-level jet feature. The 18°C isodrosotherm (lines of constant dew point temperature) has been pared off to northern Iowa, but the low level moisture is still plentiful over southern Wisconsin. At 00Z on 09 June, the 18°C dew point again over takes the area of concern, but it is ushered out of the region by the cold frontal passage around 12Z.

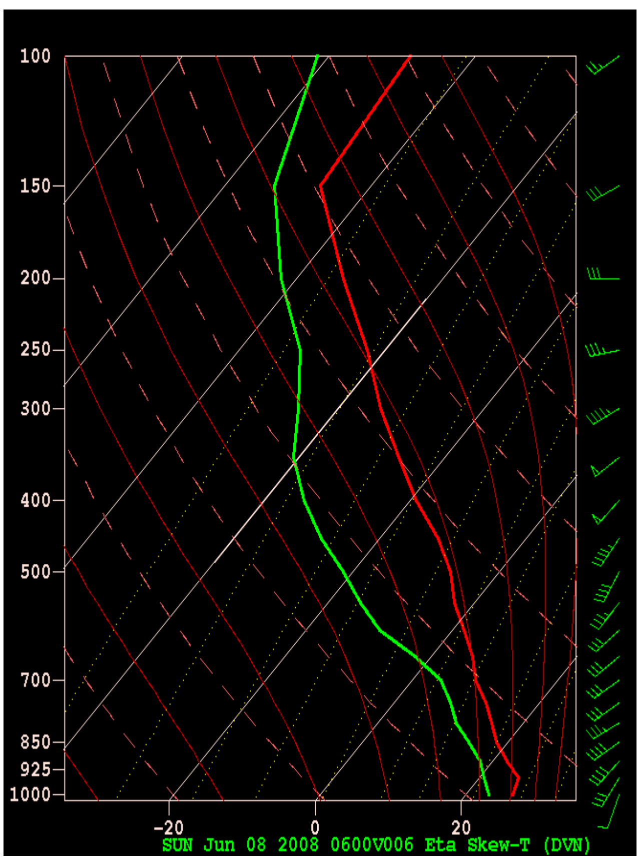

Figure 9: 06 hour forecast sounding using ETA model data valid at 06Z 08 June 2008 over Davenport, IA

Using a 6 hour sounding forecast from the ETA model at 00Z on 08 June, valid at 06Z, the probable cause of the low-level jet becomes clear (Figure 9). A nocturnal inversion is present and cuts off sharply around the 925mb level. The wind speed below this level is only 10 knots and is almost due southerly, but at 925mb the wind accelerates to 35 knots and is more south-southwesterly. This directly reflects the proposed origin of the low-level jet, and is likely the main mechanism behind it. The surface high is not to be discounted, however, as its circulation could be enhancing the flow generated by the jet.

850mb Moisture Transport

This variable is one that is valuable for predicting a heavy rainfall event over a region. It takes into account the wind speed and the mixing ratio at 850mb with an appropriate scaling factor. These two factors are necessary for widespread rainfall, but when it is coupled with the presence of severe weather, the heavy rainfall threat increases. Junker et al. (1999) indicated that the increased presence of 850mb moisture transport is a factor in heavy rainfall from convective systems. In the majority of their cases, the maximum rainfall values were found just to the north of the region of highest moisture transport. A high value for moisture transport would be around 20 units with anything above 30 being qualified as extreme.

During the day on 07 June, a large area of moisture transport values >30 are observed to be extending out of the southern Plains into the Upper Midwest. By 00Z on 08 June, the maximum values are marginally across the southern Wisconsin boarder, which would leave the area of high rainfall located over the central and southern portions of the state (Figure 10). At 12Z that same day, the maximum values have only retreated slightly into northern Illinois and Iowa. This continues the heavy rainfall threat over the same area. Advancing to 00Z on 09 June, the set-up is similar to how it was 24 hours prior, keeping maximum moisture transport over extreme southern Wisconsin and extending the heavy rainfall northward. By the time the cold front pushes across the state at 12Z, the moisture transport has been depleted nearly in full.

Between the time steps mentioned, there are plumes of moisture-rich air that extends into northern Wisconsin, sometimes even reaching the Upper Peninsula of Michigan. This is important to note, since the air in place over central and southern Wisconsin is still moisture laden, almost consistently. While the most extreme rainfall is going to be falling north of the 850mb moisture transport maximum, those areas under the maximum are still capable of receiving a great deal of rain. With respect to severe weather, the moisture transport at low levels will be an active ingredient in spawning strong thunderstorms.

Conclusions

The month of June 2008 will likely harbor resentment in the minds of many central and southern Wisconsin residents. That month, those regions accumulated over a foot of rain and, as a result, sustained record flooding. The events described in this study are only the first rounds of heavy rain to fall during June 2008. Another round of severe weather moved through on 12 June, bringing more tornadoes and an additional six inches of rain in some places. The most catastrophic damage occurred in Sauk County, where Lake Delton drained into the Wisconsin River via a weakened stretch of land on 09 June 2008. This wall of water instantly destroyed entire homes and businesses withing a matter of hours. Other memorable events included the closing of Interstate 94 in Jefferson County due to the threat posed by the Rock River and residents

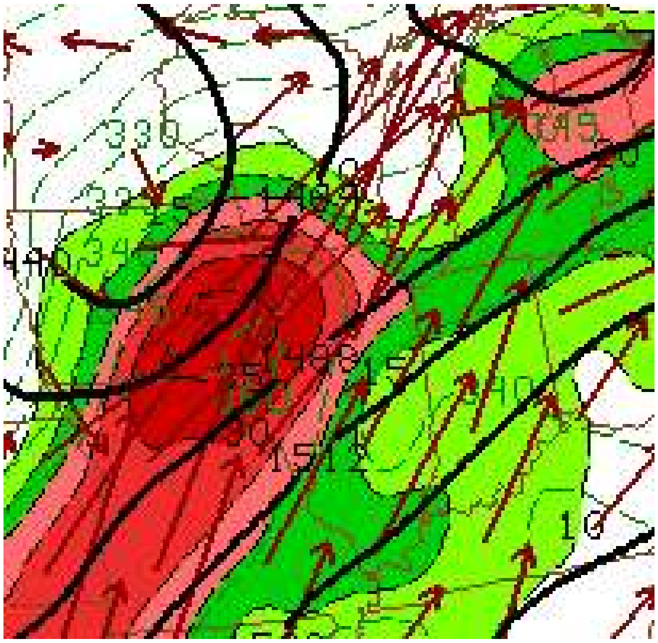

Figure 10: 850 moisture transport (in fills and vectors), geopotential heights (solid black contours), and theta-e in degrees Kelvin (dashed green contours).

frantically sandbagging around their homes and businesses in the hope of warding off the encroaching flood waters.

The synoptic forcings favored the prolonged event over such a focused region. With a stagnant 300mb jet pattern, the lower half of Wisconsin was in an area of upper-level divergence for nearly two consecutive days. 500mb flow structures mimicked the pattern associated with the even more cataclysmic 1993 Midwest Floods, while the 850mb ridge maintained warmer temperatures over the region. The two main culprits in this event were the large, blocking surface high pressure system over the southeastern United States and the surface low stalled in Colorado whose stationary warm front provided added instability and lift in a region already predisposed for severe weather.

At the mesoscale level, all of the necessary ingredients were in place to have long-lived and destructive supercell thunderstorms, capable of causing a large amount of precipitation. High amounts of CAPE were present over southern Wisconsin on 07 and 08 June, leading to the growth of the thunderstorms. These values were not negated by having large amounts of inhibition, which would have retarded the supercell growth. Environmental winds were sheared enough to foster and support the rotation of the thunderstorms and continued progression of right-moving supercells. The constant presence of the low-level jet at 925mb allowed for continuous moisture to be streamed into the region and the enduring creation of strong thunderstorms through the overnight hours. Likely the most important factor with respect to the flooding was the 850mb moisture transport variable. With maximum values located over the Wisconsin boarder for the majority of the 48 hour study, central and southern Wisconsin was a prime location for heavy rainfall.

This event provides numerous opportunities for further research and study. One area could be concerned with looking at the climatology in central and southern Wisconsin for the entire first half of the month of June 2008. The 07-09 June event was just one in a chain of severe weather events that led to the severe and prolonged flooding conditions. Another possibility, more geologically motivated, involves looking at a longer string of heavy precipitation events that affected this region over the year proceeding June 2008. This would include the 18-20 August 2007 rainfall event in southern Wisconsin and the incredible snowfall across the state that following winter. It is likely that watersheds were not able to recover after these continual events and June 2008 was the culmination. The research presented in this paper would be a fine supplement to any study in those areas.

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