Enhancement of the Downdraft
Wisconsin Derecho, May 30th-31st, 1998

Jason Harder
Atmospheric and Oceanic Sciences, UW-Madison, Madison, Wisconsin

ABSTRACT
Southern Wisconsin was pounded by a long lasting derecho on May 31st, 1998. The synoptic conditions were favorable for the development of severe storms. The set up was conducive to the formation of a bow echo and the derecho that would follow. Ingredients came together to enhance the downdraft of the derecho over south-central Wisconsin and produce wind gusts of up to 128 mph.

1. Introduction

In the early morning hours of May 31st, 1998, southern Wisconsin was subjected to a widespread, severe wind event, better known as a derecho. The night before, there was an outbreak of supercells in South Dakota, which through the night developed into a line of storms. Conditions were favorable for this line to develop into a bow echo, however once formed, the magnitude of this system grew and became a derecho that would travel roughly one thousand miles and lasted close to 15 hours. This storm became one of the most devastating derecho events in recorded history.

Hurricane force winds in excess of 120 mph sped through southern Wisconsin during the morning of May 31st. A line of storms developed over the Minnesota, South Dakota border earlier in the evening, with this line evolving into a long lasting derecho. The derecho entered Wisconsin just before 5z on the 31st and exited the state at about 9z. It sped through Wisconsin with a translation speed close to 60 mph.

Property damages were estimated up to $60 million and another $1.82 million in crop damage. One person was killed and thirty seven were injured from this derecho. A peak wind gust of 128 mph was recorded in Watertown, Wisconsin around 2:30 am, CDT on May 31, 1998 (**FIGURE 1**). The combination of the rear inflow jet, up-down draft and evaporative cooling enhanced the downdraft, achieving such intense surface wind speeds.

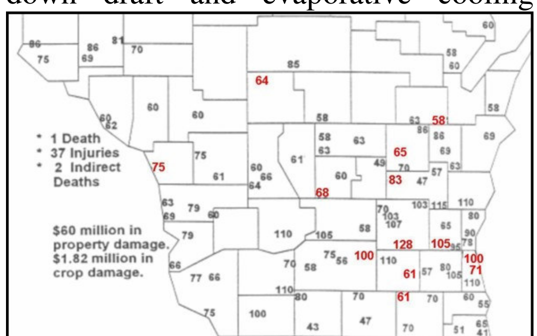

Figure 1 - Maximum wind gusts(mph) in red, estimated in black

2. Data

The conceptual model, Mesoscale-analysis, and cross section were all made by hand and finalized in the Paint program for Windows computers. The four-panel plot of the jet stream, lifted index/relative humidity, surface pressure and 850mb temperatures are courtesy of Unisys Weather. Radar reflectivity and velocity figures are courtesy of the SSEC/CIMSS

Summer Workshop Case Study Page. Progression of the derecho over the Upper Midwest and also the wind reports courtesy of the Storm Prediction Center.

3. Synoptic Overview

Synoptic conditions were favorable for the development of this derecho. There was a low pressure system located over the eastern Dakotas and western Minnesota (**FIGURE 2, top left**). Also present was a thermal gradient (**FIGURE 2, bottom left**) that the derecho followed during its journey through the Upper Midwest. With both the low pressure system and the thermal structure, this derecho fits into the serial and progressive derecho set up. Throughout the lifetime of the derecho it followed the thermal gradient, along with having the low pressure system right behind it the whole way through the Upper Midwest.

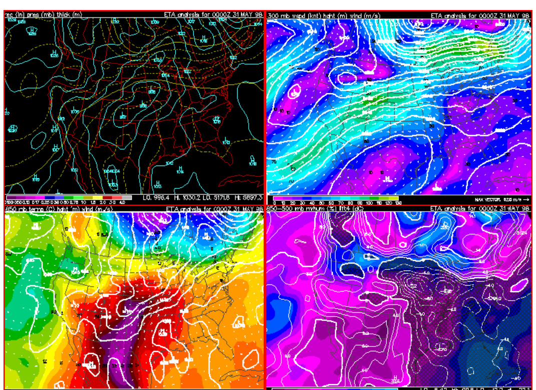

Figure 2 - (Top left) - Pressure and thickness lines (Top right) - 300mb winds and height contours (Bottom left) - 850 mb temperatures (Bottom right) - Relative Humidty and Lifted Index

The top right analysis in **FIGURE 2** shows the wind pattern and the associated jet streaks during the beginning hours of the derecho. With there being a small jet streak over the Heartland and also one just North of the Great Lakes region, there is an optimal set up for additional vertical motion. The area which the derecho formed in was simultaneously in a left exit region and right entrance region of the jet streaks. The bottom right-hand plot in **FIGURE 2** shows the low lifted indices over the derecho's path, which helped to produce the strong wind event on May 31st, 1998. Both of these created more vertical motion than already seen in the atmosphere, aiding in the development and evolution of the derecho. All of these conditions came together at the right time and right magnitude to produce and sustain such an intense derecho.

4. Mesoscale Analysis

There are two types of derechos: Serial and Progressive. A serial derecho is when there multiple bow echoes embedded in a relatively long squall line. They are associated with migrating low pressure systems and generally move in a northeasterly direction. The progressive derecho is normally linked with a shorter squall line, which will sometimes take the shape of a single bow echo. This type tends to form on the pole ward side of a stationary front and moves in southeasterly direction, migrating towards the warmer air south of the stationary front. The Wisconsin derecho, however, is a mix between these two, often called a "hybrid" derecho. There is both a low pressure

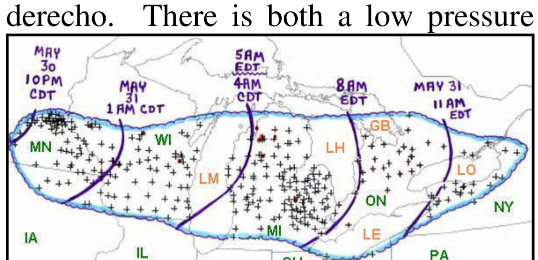

Figure 3 - Prgression of the derecho throughout the Upper Midwest. + indicate wind damage and red dots indicate tornadoes.

system and a thermal gradient associated with this derecho. It involves only one large bow echo, and moves southeast to begin with, but then turns and starts to move northeastward, reaching into Canada and parts of New York. **FIGURE 3** shows the progression of the derecho through the Upper Midwest.

As the derecho moved across Wisconsin a series of events came together to produce a small protruding extension of the bow echo where the gust of 128 mph was located. There is a rear inflow jet associated with most derechos. With most storms this is enough to cause extensive damage to property. **FIGURE 4** shows a conceptual model of this derecho where

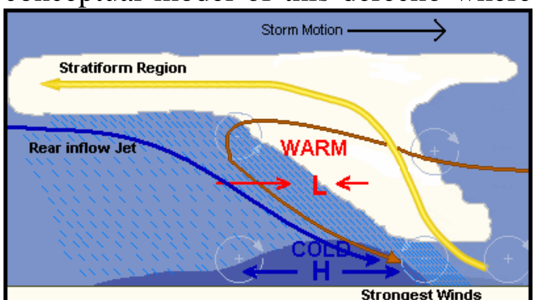

Figure 4 - Vertical cross section conceptual model of a derecho

there is the typical updraft pulling in warm, moist air from in front of the storm and lifting it up and over the cold pool and associated downdraft. **FIGURE 5** shows a vertical cross section through the derecho. The moisture plum is represented by Theta-e, contoured in green, and shows the tilted updraft and moisture flow towards the rear of the storm. Theta, contoured in red, shows the warm air rising in the updraft, and with the cold pool just behind the updraft, there is a sharp contrast in theta between the updraft and downdraft areas. The warm air aloft generates a Meso-low at mid levels and the cold pool at the surface creates a Meso-high at the surface. As the low and high begin to form the mid level air behind the storm is drawn in towards the front of the line, strengthening the

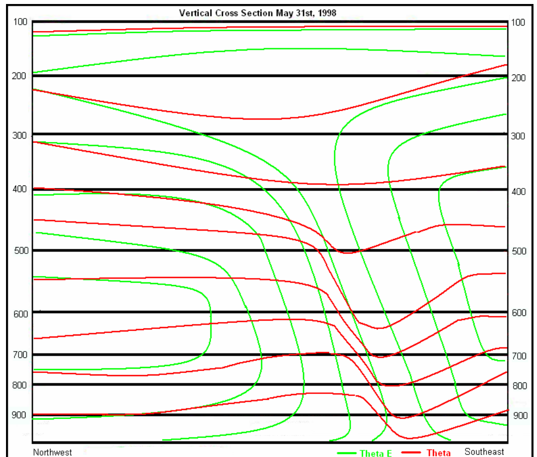

Figure 5 - Vertical cross section through the derecho

background wind flow, which can be seen in **FIGURE 6**. This is the beginnings of the rear inflow jet.

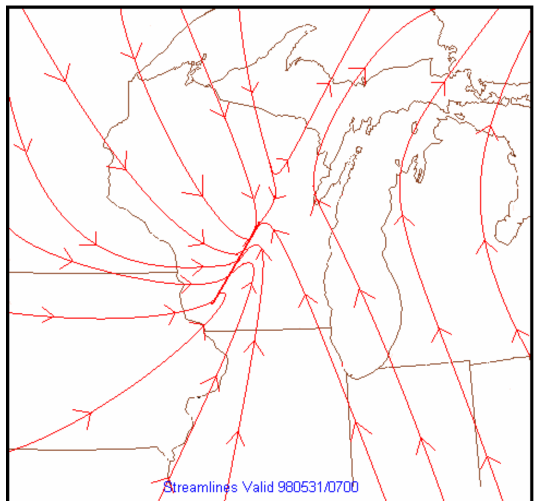

Figure 6 - Analysis of streamlines at 7z on May 31st, 1998

Depending on the speed of the derecho and also the speed of the rear inflow jet, it can be determined if the rear inflow jet is solely responsible for the damaging effects of the derecho, or if there are other aspects involved. This derecho travels at nearly 60 mph across southern Wisconsin. **FIGURE 7** shows the velocity of the winds associated with the derecho as it is going across Wisconsin. The lightest green areas are associated with velocities around 70 mph, which means the rear inflow jet is moving faster than the storm is

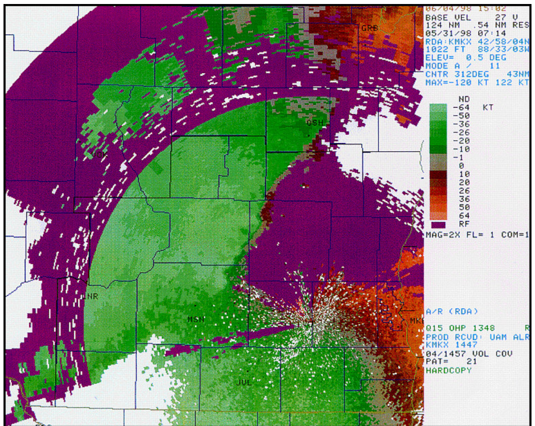

Figure 7 - Radar velocity at 2:14 am cdt where green values are coming towards the radar and red are values moving away from the radar

progressing. As the storm progresses towards the radar station, the appearance of the rear inflow jet diminishes (**FIGURE 8**). This is due to the fact the radar isn't reaching as high into the atmosphere, thus showing the rear inflow jet is in the mid levels of the atmosphere. With having a faster wind

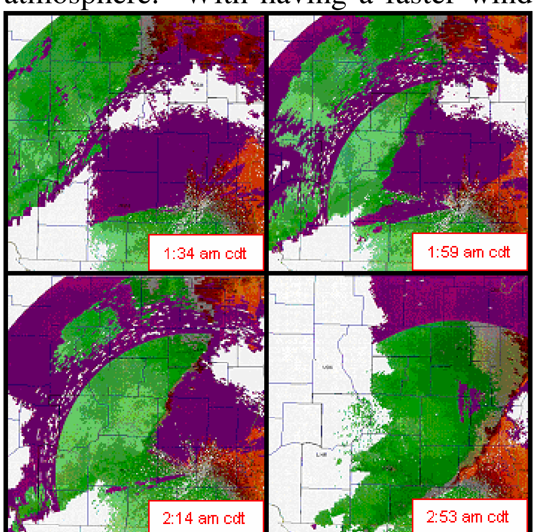

Figure 8 - Velocity progression of the derecho over southern Wisconsin

coming behind the leading edge, but having the storm move at its original speed, the excess momentum is used to "bow" out the leading edge. Where the storms bows the most is usually where the strongest winds are, as depicted in the conceptual model (**FIGURE 4**). In order to produce winds in excess of 100 mph, let alone the 128 mph gust in Watertown, Wisconsin, something else has to be aiding in the higher momentum.

When a rear inflow jet forms there are different signatures that can be seen to determine if there is one, and where it is. A good indication is a stratiform region of moderate rain behind the leading edge of convection.

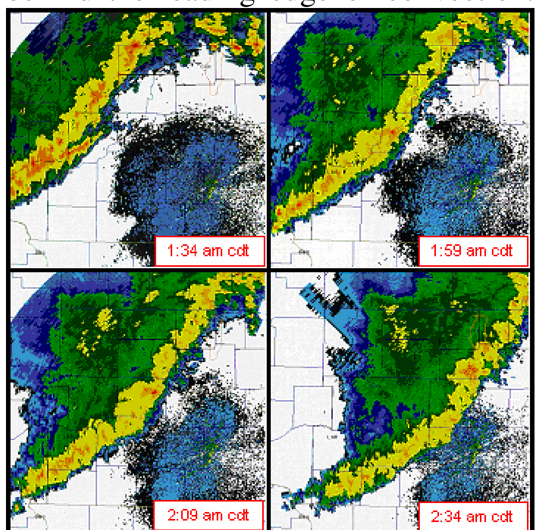

Figure 9 - Radar progression of the derecho over southern Wisconsin

FIGURE 9 is a four panel plot of radar reflectivity as the derecho progresses through southern Wisconsin. Starting at 1:59 am CDT there is a nice stratiform region associated with the part of the line that produces the highest wind gusts. The appearance of this stratiform region depicts the associated rear inflow jet because with the jet in place, the warm/moist air will slant up the descending air and reach further back than if there was not a significant rear inflow jet. Depending on the slant of the rear inflow jet and the associated downdraft, the front line of storms will be thinner and more intense with a jet staying higher aloft until it drops fast close to the front line. However, if there is more of a slant, the line of convection is wider and not quite as intense. With this derecho, there is a slanting downdraft that causes the convective line to be wider and not quite as intense. Consequently, even though the convection isn't as intense and the downdraft doesn't drop straight down, the winds are very intense.

The enhancement of this downdraft to produce such high wind gusts is twofold. The first way is with the stratiform precipitation impeding on the rear inflow where the downward motion coupled with the falling precipitation causes the flow to sink faster towards the surface. The addition of precipitation to this flow also creates some evaporational cooling in the inflow which in turn cools the downdraft and creates even more negative buoyancy. The second is similar to the first; however the elevated mixed layer in front of the derecho gets pulled in at mid levels and wraps around the updraft. This is possibly seen in the radar reflectivity in **FIGURE 9** at 2:09 am CDT. In the middle of the line there are two separate notches surrounding a wider and slightly further protruding region of the derecho. One thought is that with the pulling in of dry air around the updrafts, it interacts with the convective line and causes it to weaken in these two areas. More real-time data is needed to study this to determine if it is true or not.

When this dry air diverts around the updraft it gets pulled up slightly, but with the precipitation falling through it, there is evaporational cooling. With this cooling of the air, the flow drops back down, interacts with the downdraft and enhances the speed. The combination from all of these ingredients bows the derecho out even more, with a small protruding area seen in **FIGURE 9** at 2:09 am and 2:34 am CDT. This bowing signifies the intense winds that were seen across the southern part of Wisconsin (Refer back to **FIGURE 1**).

5. Conclusion

The synoptic conditions were favorable for the formation of some intense storms over the Dakotas. During the evening of May 30th, 1998 these storms formed into a bow and traveled east, hitting Wisconsin on its way. As the derecho progressed over southern Wisconsin, environmental surroundings helped the rear inflow jet to intensify, and along with the up/downdraft and the evaporative cooling generated a powerful downdraft. This downdraft produced a corridor of severe winds in excess of 100 mph, with the strongest gust reaching 128 mph in Watertown, Wisconsin.

6. References

- Storm Prediction Center
- Bridgette Eagan
- Emily Niebuhr
- Unisys Weather
- SSEC/CIMSS Summer Workshop Case Study Page
- National Climatic Data Center