The Labor Day Tornadoes of 02 September 2002: An In-Depth Analysis of the Synoptic and Mesoscale Dynamics of the Rusk and Taylor Counties, WI Tornado Events

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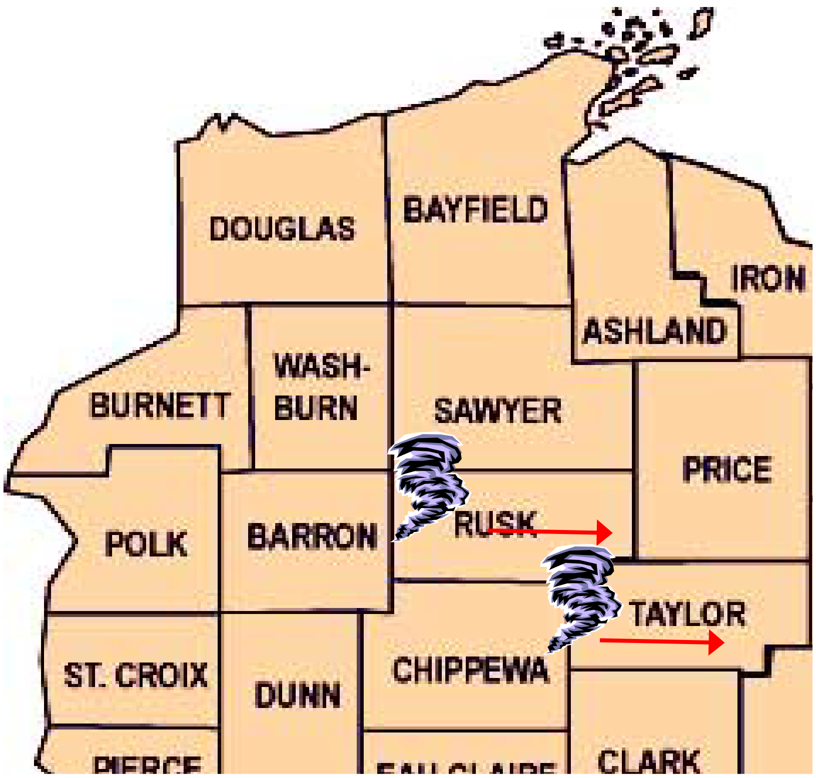


Image Courtesy of Progressive Democrats of Wisconsin

ABSTRACT

The tornadoes that struck the Village of Gilman, WI and the City of Ladysmith, WI on 02 September 2002 were events that the residents of those communities will likely never forget. The strong tornadoes spawned from powerful supercell thunderstorms, which developed oddly within a squall line preceding a strong cold front. Intense moisture flows from the Gulf of Mexico, incredible positive vorticity advection by the thermal wind and large wind direction and wind speed shears were the primary mechanisms in generating the strong thunderstorms and tornadoes, testing the power and determination of mankind. The following case study focuses on the synoptic and mesoscale processes and mechanisms that contributed to the "Labor Day tornadoes" event, an event that cost Rusk and Taylor Counties millions of dollars in property damage and injured many in the path of the storms.

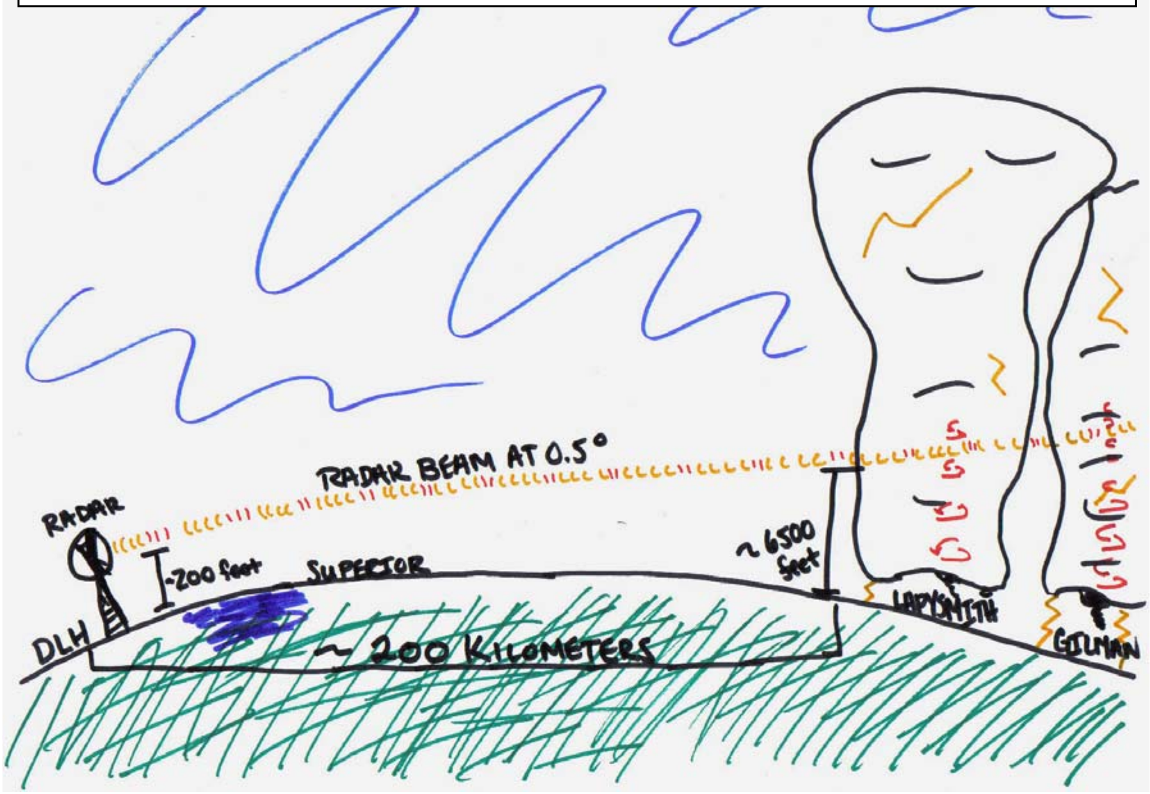
I. Introduction

The 02 September 2002 tornadoes in west-central Wisconsin were events that caught communities off-guard and tested man's strength and determination. Large supercell developed within a squall line ahead of a strong cold front, strengthening further as they passed from northeastern Minnesota into northwestern Wisconsin. In the end, two supercell thunderstorms produced tornadoes that caught the communities of Gilman, WI and Ladysmith, WI by surprise, giving the folks in those communities a taste of what furies Mother Nature can prevail. F2 and F3 tornadoes drove through the hearts of Gilman and Ladysmith, causing millions of dollars in damage and minor injuries. Though the atmospheric dynamics of a classic tornado and supercell thunderstorm are easily understood by a Meteorologist, the Labor Day tornadoes and thunderstorms' dynamics are not as easily understood, as it is known to be a rare occurrence for strong tornadoes to develop within squall lines. In the following case study, a synoptic overview of the Labor Day storm system was conducted, where specific processes and mechanisms were analyzed for their contribution to the "loaded gun sounding" that existed above the region that day. Then, the study was broken down into a mesoscale perspective, as atmospheric dynamics in the region were investigated for their contribution to supercell and tornado development. Finally, an overview of the events through the radar and satellite perspective was conducted, showing the mesoscale dynamics "at work" as the thunderstorms moved through the area. It is hypothesized that considerable directional and speed shear on 02 September 2002 accompanying the strong thunderstorms that developed and strengthened along the squall line were the primary reason for the birth and maturity of the strong tornadoes. Moisture at lower levels being transported upward by the updraft of the thunderstorms maintained their severity for an extended period of time, allowing the tornado to continue on a long path of destruction.

II. Data Used in the Case Study

For the 02 September 2002 case study of the Ladysmith, WI and Gilman, WI "Labor Day tornadoes", multiple data sets were used to completely understand the synoptic and mesoscale atmospheric dynamics. First, ETA model data was provided from 0000 UTC on 01 September 2002 to 0000 UTC 04 September 2006 for purpose of analyzing surface and upper air features. At similar time frames, Level III radar data from the National Weather Service offices in Duluth, MN and Chanhassen, MN was analyzed for thunderstorm structure and intensities over Rusk and Taylor Counties, WI. Radar data from the National Weather Service office in La Crosse, WI, the office responsible for the Gilman community, was unavailable after 0900 UTC on 02 September 2002 due to a direct strike by lightning to the WSR-88D radar the previous night, adding to the difficulty in scoping storm structures and features. The difficulty arises due to the curvature of the Earth, the distance from the Doppler Radar and inconsistency of the medium of propagation of the atmosphere, where the base reflectivity scan at 0.5 degrees above the ground measures 6500 feet in a thunderstorm 200 kilometers away, the approximate distance of Ladysmith and Gilman [See Figure "Conceptual Model"]. Finally, visible, IR and water

Figure "Conceptual Model" is a cartoon image that shows how the radar beam could only scan a minimum of 6,500 feet above the Earth's surface, making it difficult to detect storm intensity and rotation.

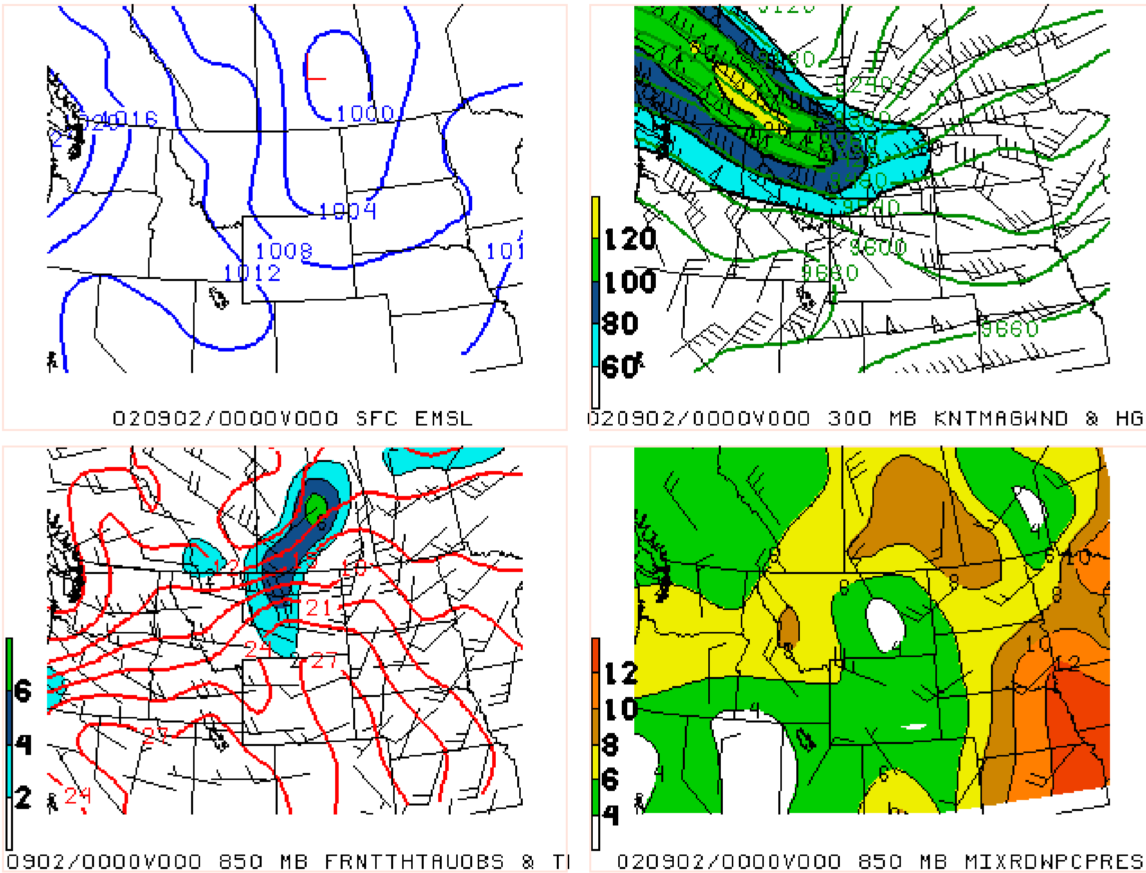


vapor data was given on the four and eight kilometer resolutions from the GOES East satellite over the United States from 0000 UTC 01 September 2002 to 0000 UTC 04 September 2002. All of the data was provided courtesy of the University of Wisconsin – Madison Atmospheric & Oceanic Sciences Department.

III. Synoptic Overview

The synoptic system responsible for producing the severe thunderstorms that caused the Labor Day tornadoes in west-central Wisconsin began as a typical North American mid-latitude cyclone. The storm was born the northern Rocky Mountains in the Canadian providences of Alberta and Saskatchewan, a result of a strong 300 millibar jet streak that caused an intense region of ageostrophic divergence at the left exit region [Figure 1.2]. The ageostrophic divergence area at upper levels created a local area of increased local relative vorticity at the surface, evacuating atmospheric mass continuously out of an imaginary column. Furthermore, the changing topography from the tall Rocky Mountains to the flat Canadian Plains resulted in the stretching of the imaginary vertical column of air, intensifying the relative vorticity of the column. With cyclogenesis occurring in full force, the processes and mechanisms that are a part of a mid-latitude cyclone (i.e. moisture flows, positive vorticity advection by the thermal wind, frontogenesis, etc.) started to play a major role in the maturing of the cyclone, setting up the atmosphere for a large severe weather outbreak.

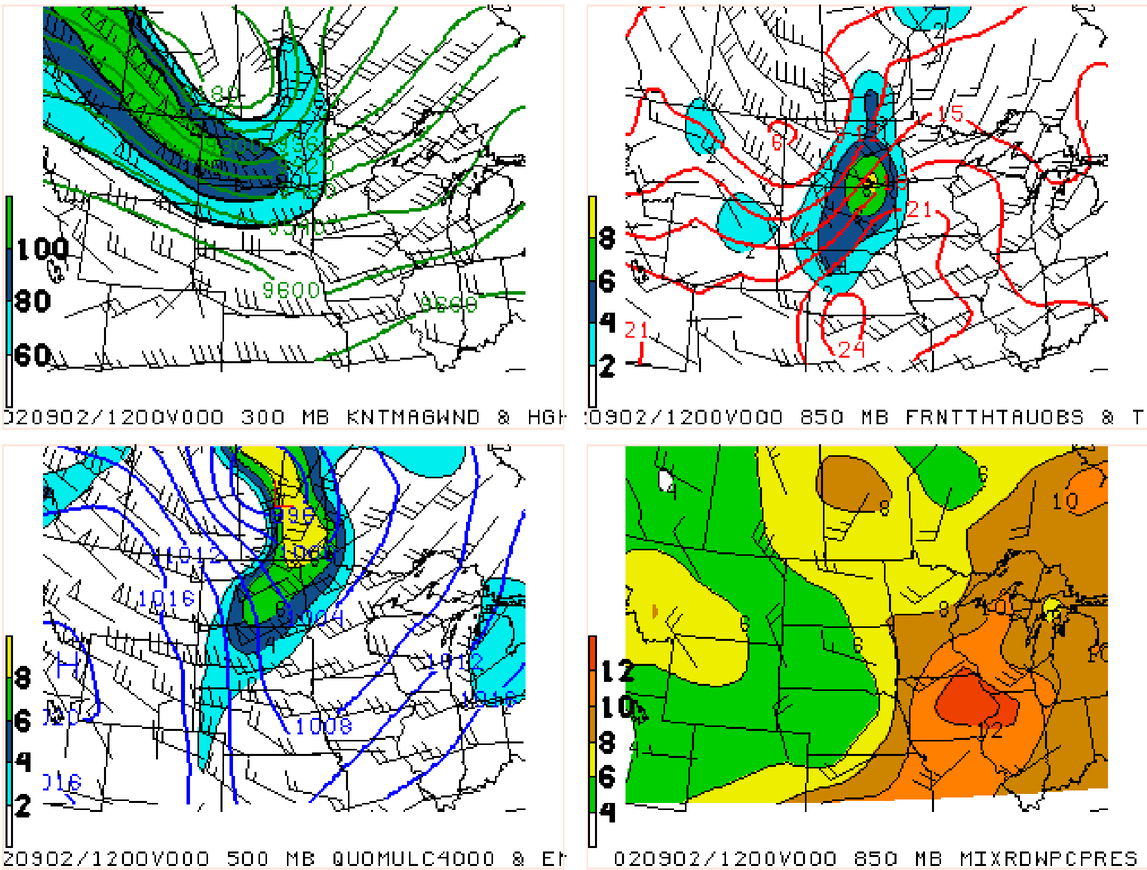
The genesis of the mid-latitude cyclone was on the evening hours of 31



The above figures are from the 0000 UTC 02 September 2002 ETA model forecast. Figure 1.1 (top left) is the surface pressure contoured every four millibars. Figure 1.2 (top right) is the 300 millibar heights and winds. Height is contoured every 60 meters and winds are contoured and color filled every 20 knots beginning at 60 knots. Figure 1.3 (bottom left) is the 850 millibar frontogenesis and 850 millibar temperatures. Frontogenesis is color filled and contoured every two Fahrenheit per meter per second while temperatures are contoured every three degrees Celsius. Figure 1.4 (bottom right) is the 850 millibar mixing ratios, contoured and color filled every two grams per kilogram of water vapor.

August 2002. By 2300 – 0000 UTC, the cyclone center was centered over central Saskatchewan, showing a strong presence with cloud top temperatures near the center of the storm approximately of 200 Kelvin. The cold cloud top temperatures were caused from the copious amounts of moisture drawn northward from the Gulf of Mexico and lifted by strong forcing mechanisms. Figure 1.3 indicates exactly where these forcing mechanisms occurred, as the forcing was a direct cause of strong frontogenesis. The positive vorticity in the frontogenesis zones indicated upward vertical motion, which resulted in condensation and eventually precipitation from the convective clouds. A Meteorologist should focus special attention at this time over eastern Minnesota and northwestern Wisconsin. He or she would notice how the thunderstorms developed in the area of slight frontogenesis, which was the cause of a weak, elongated cold front from a preceding synoptic system centered over Hudson Bay. Under normal conditions, the forcing mechanisms would produce cumulus clouds over the region; however, the strong inflow of moisture from the Gulf of Mexico [Figure 1.4] caused from the approaching cyclone is allowed the cumulus clouds to develop into strong thunderstorms. Hence, strong moisture presence ahead of the mid-latitude cyclone was shown to favor severe weather development. All that was needed was for considerable forcing to occur, which would allow this severe weather potential to turn into reality.

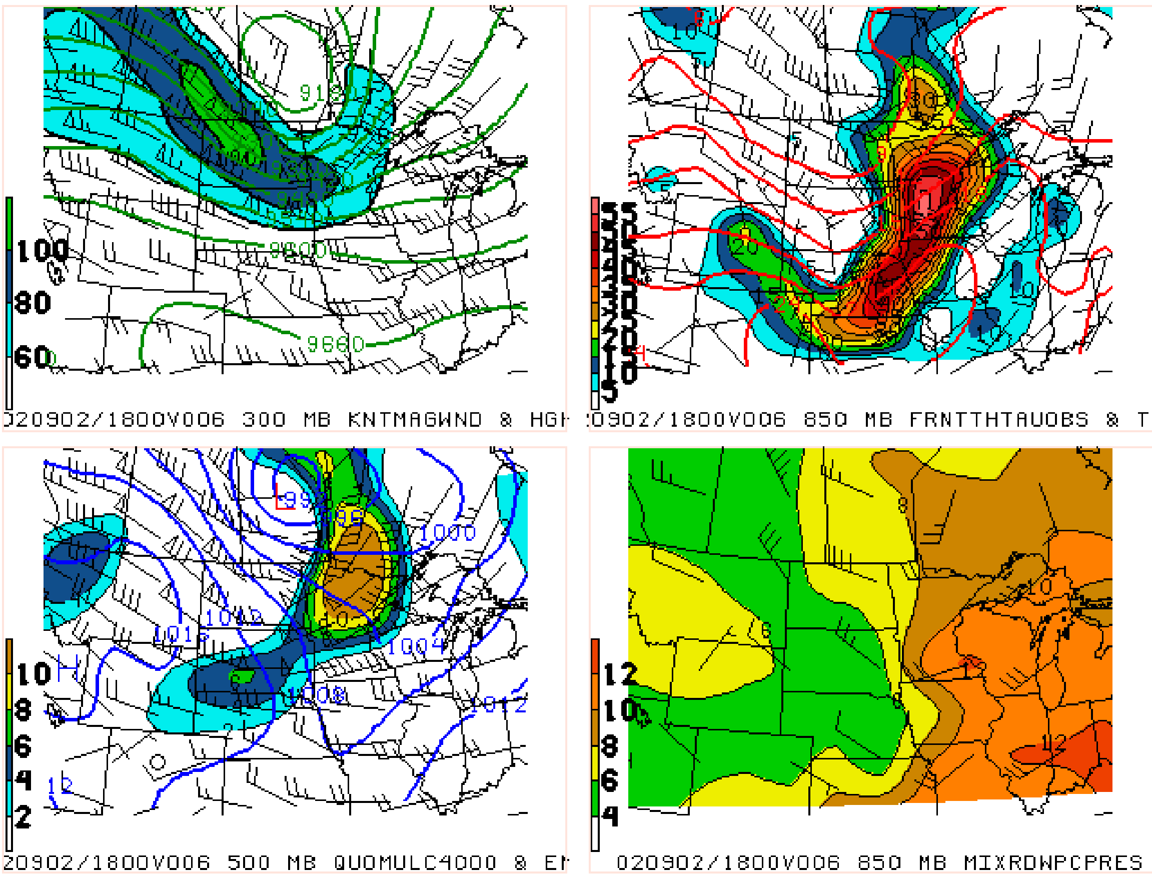
were frequent cloud to ground lightning strikes, which as aforementioned, decommissioned the WSR-88D radar at the National Weather Service office in La Crosse, WI. However, forecast model data was still being generated by large super computers across the country. By 1200 UTC on 02 September 2002, the center of the mid-latitude



The above figures are from the 1200 UTC 02 September 2002 ETA model forecast. Figure 2.1 (top left) is 300 millibar heights and winds. Heights are contoured every 60 meters and winds are contoured and color filled every 20 knots, beginning at 60 knots. Figure 2.2 (top right) is the 850 millibar frontogenesis and 850 millibar temperatures. Frontogenesis is color filled and contoured every two Fahrenheit per meter per second and temperatures are contoured ever three degrees Celsius. Figure 2.3 (bottom left) is the surface pressure and the positive differential vorticity advection by the thermal wind. Surface pressure is contoured every four millibars and positive differential vorticity advection is contoured and color filled every two units. Figure 2.4 (bottom right) is the 850 millibar mixing ratios contoured and color filled every two grams per kilogram of water vapor.

A line of thunderstorms rolled across Minnesota and Wisconsin on the evening of 01 September and into the morning hours of 02 September. Associated with these thunderstorms cyclone moved over central Manitoba, and showed a large presence in northern North America. Showers and thunderstorms developed along the strong cold front associated with the storm system, which were being fueled by considerable moisture flows from the Gulf of Mexico and intense frontogenesis. Figures 2.2 and 2.4 show the frontogenesis and mixing ratio values at 850 millibars at 1200 UTC on 2 September 2002. One should notice the strong inflow of moisture ahead of the cyclone. What makes the particular setup interesting is that the moisture flow occurred behind the cold front of rather weak from the Hudson Bay cyclone, giving the cyclone in study more potential to its fury on the Upper Midwest.

In addition to the abundant moisture present in Minnesota and Wisconsin, the same 300 millibar jet streak [Figure 2.1] responsible for the genesis of the synoptic system intensified and moved eastward with the cyclone. At 1200 UTC, the jet streak

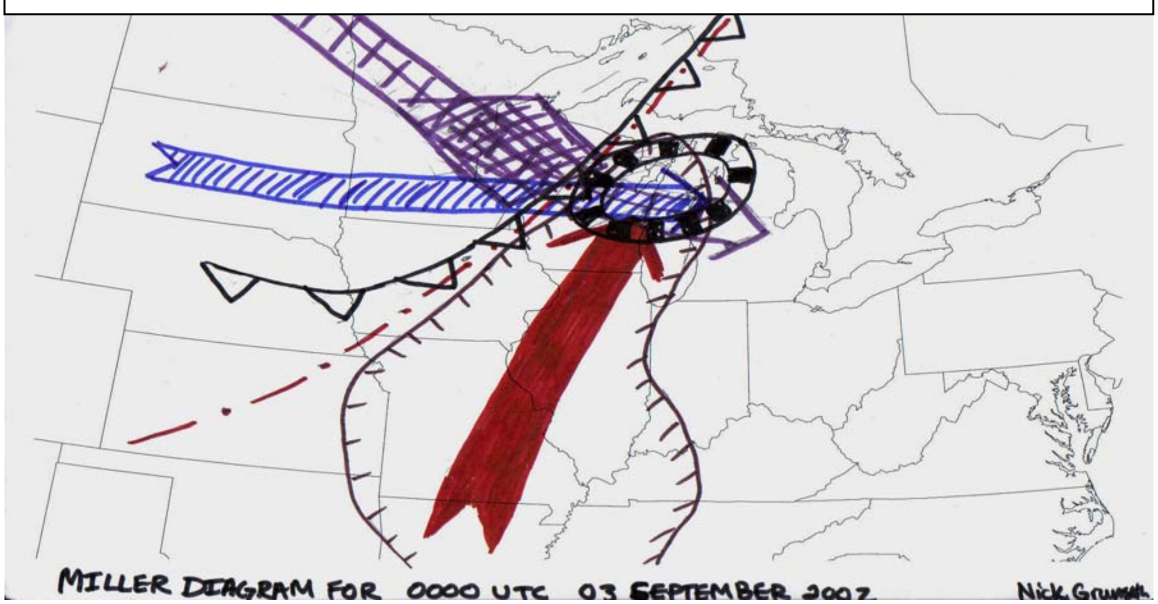


The above figures are from the 1800 UTC 02 September 2002 ETA model forecast. Figure 3.1 (top left) is 300 millibar heights and winds. Heights are contoured every 60 meters and winds are contoured and color filled every 20 knots, beginning at 60 knots. Figure 3.2 (top right) is the 850 millibar frontogenesis and 850 millibar temperatures. Frontogenesis is color filled and contoured every five Fahrenheit per meter per second and temperatures are contoured ever three degrees Celsius. Figure 3.3 (bottom left) is the surface pressure and the positive differential vorticity advection by the thermal wind. Surface pressure is contoured every four millibars and positive differential vorticity advection is contoured and color filled every two units. Figure 3.4 (bottom right) is the 850 millibar mixing ratios contoured and color filled every two grams per kilogram of water vapor.

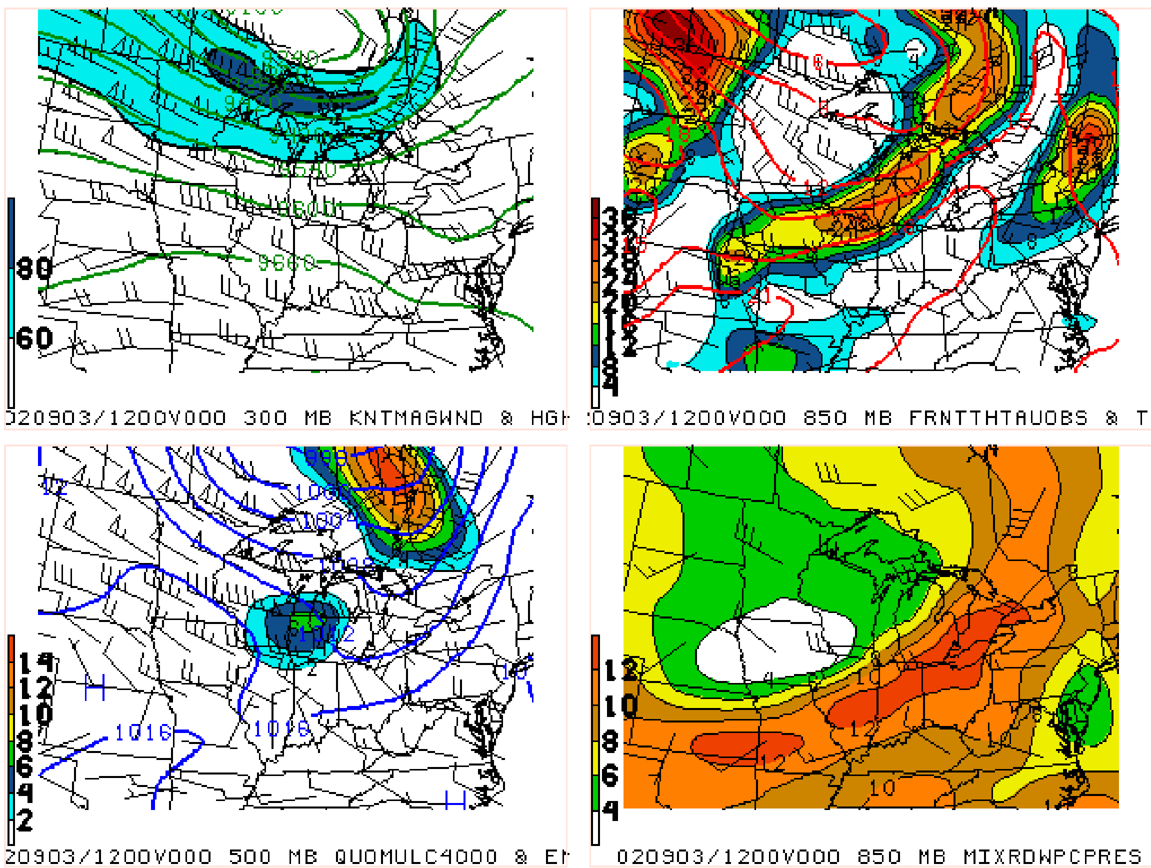
the Hudson Bay synoptic system. Thus, it was determined that the cold front was stretched from central Alberta into the central Dakotas, containing maximum wind speeds at the core of the jet near 120 knots [Figure 2.1]. Referring to the 300 millibar jet figure, two features were immediately noticed for their contribution to the synoptic system. First, a large gradient of wind speed exists on the northern side of the jet streak. The intense anticyclonic shear suggested that the jet was intensifying and supporting the cyclone as it progressed eastward across the continent. Second, the strong jet core and the sudden deceleration at the exit region of the jet indicated the increased potential for large positive vorticity advection by the thermal wind to occur downstream of the jet exit region. A region of positive vorticity advection by the thermal wind indicates that forcing from an upper level jet is causing upward vertical motion in an area downstream from the jet exit region. In fact, positive vorticity advection by the thermal wind occurred in parts of the eastern Dakotas and western Minnesota, indicative of the forcing from the 300 millibar jet [Figure 2.3]. As the jet and the cyclone moved eastward in the next six hour time frame, increased moisture content and stronger positive vorticity advection by the thermal wind played a large role in thunderstorm development and the production of tornadoes, a setup of the infamous “loaded gun sounding” over Minnesota and Wisconsin.

The 1800 UTC 02 September 2002 forecast was the last six hour increment in the ETA model before the supercell thunderstorms developed and hit the communities of Gilman and Ladysmith. At this time, the model run and the GOES East satellite showed that the cyclone had reached its mature stage, positioned in western Ontario. The intensity of the storm system was determined in many ways. First, the cloud top temperatures of the cloud head and the thunderstorms were very cold, ranging from 173 to 183 Kelvin. The cold temperatures of the cloud tops, inversely proportional with height, indicated that the height of the cloud reached 30,000 feet above the surface. Second, the strong southerly flow ahead of the cyclone that was transporting a tremendous amount of moisture from the

Figure “Miller Diagram” is a Miller Diagram over the north-central United States at 0000 UTC on 03 September 2002. The image features are as follows: Brown, moist tongue; red arrow, low level jet; red dash-dot, dryline; black, cold front; blue arrow, 500 millibar jet; purple arrow, 300 millibar jet; and circles, severe weather risk.



Gulf of Mexico had increased significantly [Figure 3.4], a sign of the intensity of the storm system. Furthermore, the 300 millibar jet streak at 1800 UTC [Figure 3.1] showed a comparable intensity to the prior 1200 UTC time frame, except the exit region was now located in central Minnesota and contained massive decelerations in the exit region. The strong jet was indicative of considerable positive vorticity advection by the thermal wind, which caused lifting to occur ahead of the exit region [Figure 3.3]. The result was a setup for severe weather to break out in massive proportions [See Figure "Miller Diagram"]. Indeed, thunderstorms began to fire along the cold front and on top of the region of strong frontogenesis, developing rapidly in the arrowhead of Minnesota and extending southward into northern Wisconsin by the later afternoon hours on 02 September 2002, indicated by the IR satellite images from the GOES East Satellite at 1915 UTC and 2115 UTC



The above figures are from the 1200 UTC 03 September 2002 ETA model forecast. Figure 4.1 (top left) is 300 millibar heights and winds. Heights are contoured every 60 meters and winds are contoured and color filled every 20 knots, beginning at 60 knots. Figure 4.2 (top right) is the 850 millibar frontogenesis and 850 millibar temperatures. Frontogenesis is color filled and contoured every four Fahrenheit per meter per second and temperatures are contoured ever three degrees Celsius. Figure 4.3 (bottom left) is the surface pressure and the positive differential vorticity advection by the thermal wind. Surface pressure is contoured every four millibars and positive differential vorticity advection is contoured and color filled every two units. Figure 4.4 (bottom right) is the 850 millibar mixing ratios contoured and color filled every two grams per kilogram of water vapor.

[Shown in Mesoscale Section].

Shortly after the thunderstorms moved through the arrowhead of Minnesota and the majority of Wisconsin, the mid-latitude cyclone reached its occluded stage, as dry air from the southwestern United States penetrated the storm's core. The system weakened considerably, noted easily by the pressure increase at the storm center and the warmer cloud top temperatures in the IR satellite imagery. Also, the 300 millibar jet weakened considerably over the course of 12-18 hours [Figure 4.2]. Some of the weaker attributes of the jet were a decreased jet core intensity by 40 knots and a decreased anticyclonic shear on the northern side of the jet streak. By 1200 UTC on 3 September 2002, the jet streak had a core speed of 80 knots and a an anticyclonic shear of 50 knots per 200 kilometers, indicative of less positive vorticity advection by the thermal wind mid-latitude cyclone itself. Moisture inflow at 850 millibars from the Gulf of Mexico slightly decreased significantly in the 12-18 hour time span [Figure 4.4], shown by the lower intensity moisture pockets at the 1200 UTC time compared to 1800 UTC on 02 September. By 1800 UTC on 03 September, the decaying mid-latitude cyclone had moved far away from the Upper Midwest and cooler and drier had moved into the Great Lakes states, providing residents with pleasant weather to start the clean-up process.

IV. Mesoscale Overview

The synoptic system that generated the two Labor Day tornadoes in west-central Wisconsin created a perfect setup for a severe weather outbreak to occur. As aforementioned in the synoptic overview, considerable moisture was

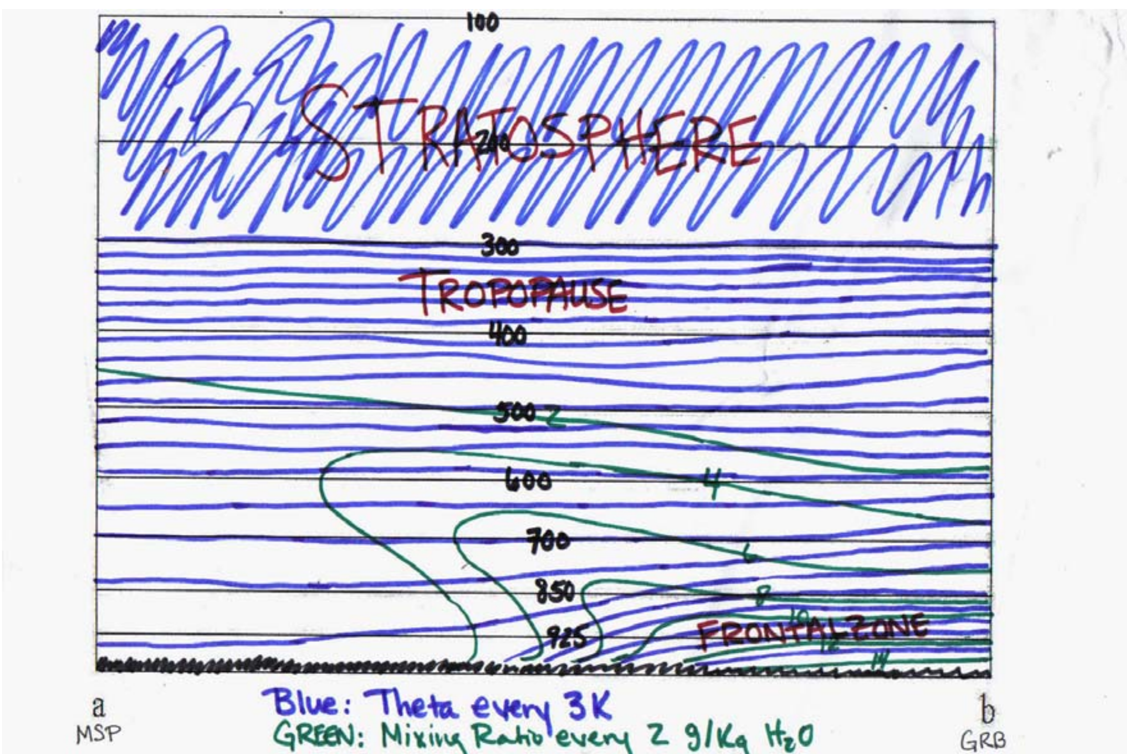


Figure "Cross Section" is a vertical cross section between Minneapolis, MN and Green Bay, WI at 0000 UTC on 03 September 2002. Blue lines are isotherms contoured every three Kelvin and green lines are isopleths contoured every two grams per kilogram of water vapor.

Mexico into the states of Minnesota and Wisconsin. At the surface over the Gilman and Ladysmith communities, mixing ratios were approximately 15 grams per kilogram water vapor [Figure "Cross Section"], which made the atmosphere like a sauna at lower levels if one included the day-time heating factors. However, the moisture was contained underneath a strong cap at 800 millibars, above which existed an extremely large elevated mixed layer. The Skew-T sounding from Green Bay, WI at 0000 UTC on 3 September 2002 [Figure 5] displayed many features that caught the interest of Meteorologists and was an accurate representation of the atmosphere for the region. First, one may notice the elevated mixed layer, which extends from 800 millibars to 280 millibars. The shape of the elevated mixed layer was very odd. In the sounding, it is evident that an elevated mixed layer was generated over the Rocky Mountains had moved eastward over the Great Lakes states. Then, subsidence from the 300 millibar jet injected drier, stratospheric air downward to the cap, noted by the very dry air in two portions of the elevated mixed layer. However, some mixing occurred within the elevated mixed layer between 700 and 520 millibars, suggesting that overturning took place due to a very unstable atmosphere.

The instability in the atmosphere was the second feature that may have caught the interest of the trained Meteorologist. At the surface, a nearly absolutely unstable layer existed to the cap at 800 millibars. Similarly, a nearly absolutely unstable layer existed from 740 millibars to the tropopause, excluding a few minor variations in the temperature profile. The resulting setup was an explosive situation, where as the cap eroded in the afternoon hours from the presence of the dryline and the cold

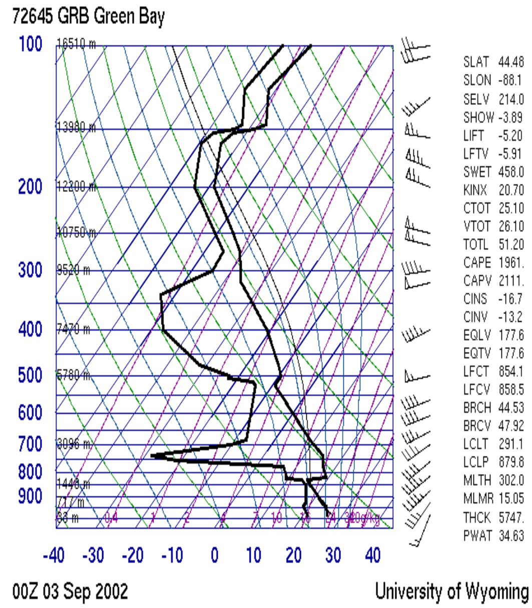
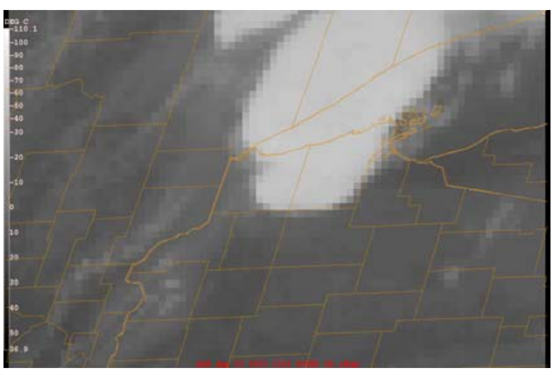


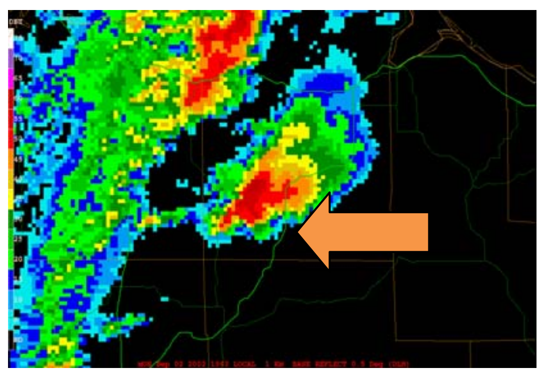
Figure 5 (above) is a Skew-T diagram from the National Weather Service office in Green Bay, WI at 0000 UTC on 03 September 2002. Plotted are temperature, dewpoint and wind barbs.

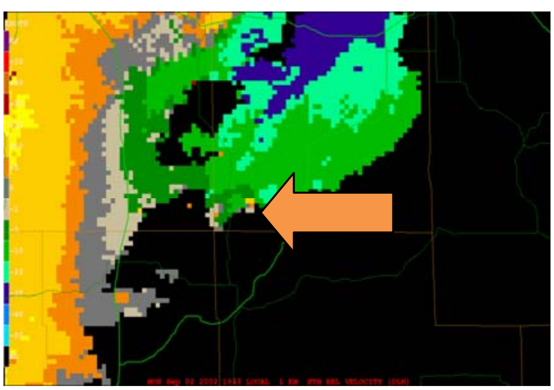
front approached the area, free convection occurred, creating a very large dynamical mesoscale system ahead of the front. CAPE values over the northern half of Wisconsin on the afternoon of 02 September averaged 2000 Joules per kilogram, and significant wind shear in both the vertical and directional perspectives increased the risk for supercell and tornado development. With the combination of lapse rate of temperature in the atmosphere, the dewpoint temperature throughout the depth of the tropopause, CAPE and wind shear, SWEAT (Severe Weather Threat) index values topped 450, suggesting a strong potential for the development of strong to severe thunderstorms with a large tornado threat. The strong jet core positioned over east-central Minnesota increased the thunderstorm probability, as positive vorticity advection by the thermal wind was forced lifting to take place in northern Wisconsin. With due time, the loaded gun sounding that had set up over Wisconsin made its move, as the cap deteriorated and free convection took place, causing the rapid development of thunderstorms.

The Storms

At approximately 1715 UTC on 2 September, the dryline had finally eroded the strong cap that was over the arrowhead of Minnesota and northern half of Wisconsin. Forcing from the cold front and the strong positive vorticity advection by the thermal wind triggered thunderstorms in northeastern Minnesota which moved quickly eastward into northwestern Wisconsin. By 1915 UTC, a line of strong thunderstorms exited Carlton and Pine Counties in northeastern Minnesota and moved through Douglas and Bayfield Counties in northwestern Wisconsin. The intensity of the thunderstorms was clearly indicated by the cloud top temperatures in the IR satellite and the base reflectivity scan from the National Weather Service office in Duluth, MN at 1931 UTC [Figures 6.1, 6.2]. One should carefully note the strong super cell thunderstorm in southwestern Douglas County and southeastern Bayfield County at 1931 UTC for the following reasons. First, the 55-60 dBZ reflectivities of the supercell storm, 15 dBZ stronger than 12 minutes previous, indicated that considerable convection and thunderstorm development was occurring, and that the potential for further development was not out of the question. Second, a slight hook shape feature was spotted in this cell by the base reflectivity scan, proposing the theory that the storm was a rotating supercell thunderstorm. Investigating further into the storm relative velocity perspective [Figure 6.3], a small gate-to-gate shear, +10 knots vs. -10 knots, was present at the time, implying that there was rotation within the storm and supporting the theory of the storm being



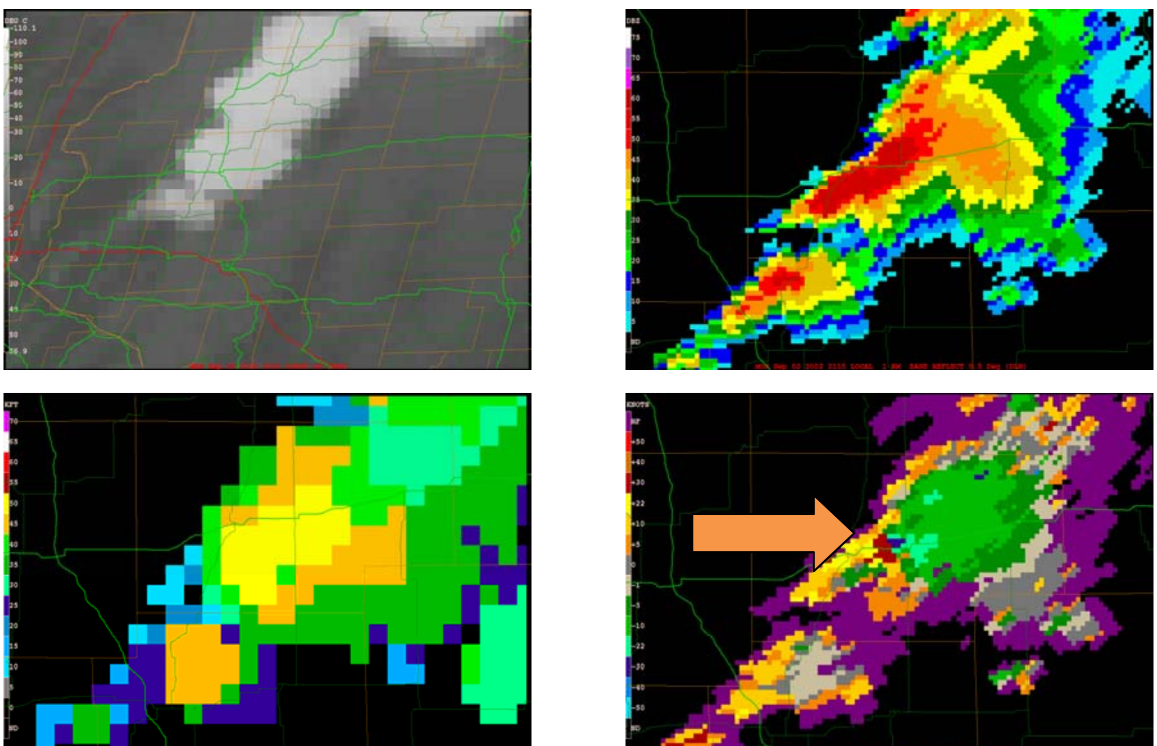




Figures 6 are of the Douglas/Bayfield County supercell thunderstorm. Figure 6.1 (top left) is an IR satellite image from GOES East at 1915 UTC on 02 September 2002 on the 10.7 micron channel with four kilometer resolution. Figure 6.2 (above) is the base reflectivity scan (0.5 degrees) from KDLH at 1931 UTC on 02 September. The orange arrow points to the storm and slight hook echo. Figure 6.3 (bottom left) is the storm relative velocity scan from KDLH at 1931 UTC on 02 September. The orange arrow points to the gate-to-gate shear couplet.

a mesocyclone. Even though this supercell thunderstorm was not the producer of the two tornadoes in Rusk and Taylor Counties, it did show that there was an increased risk of tornadoes in the region, and that residents of the area should have been on a tornado watch for the next few hours ahead.

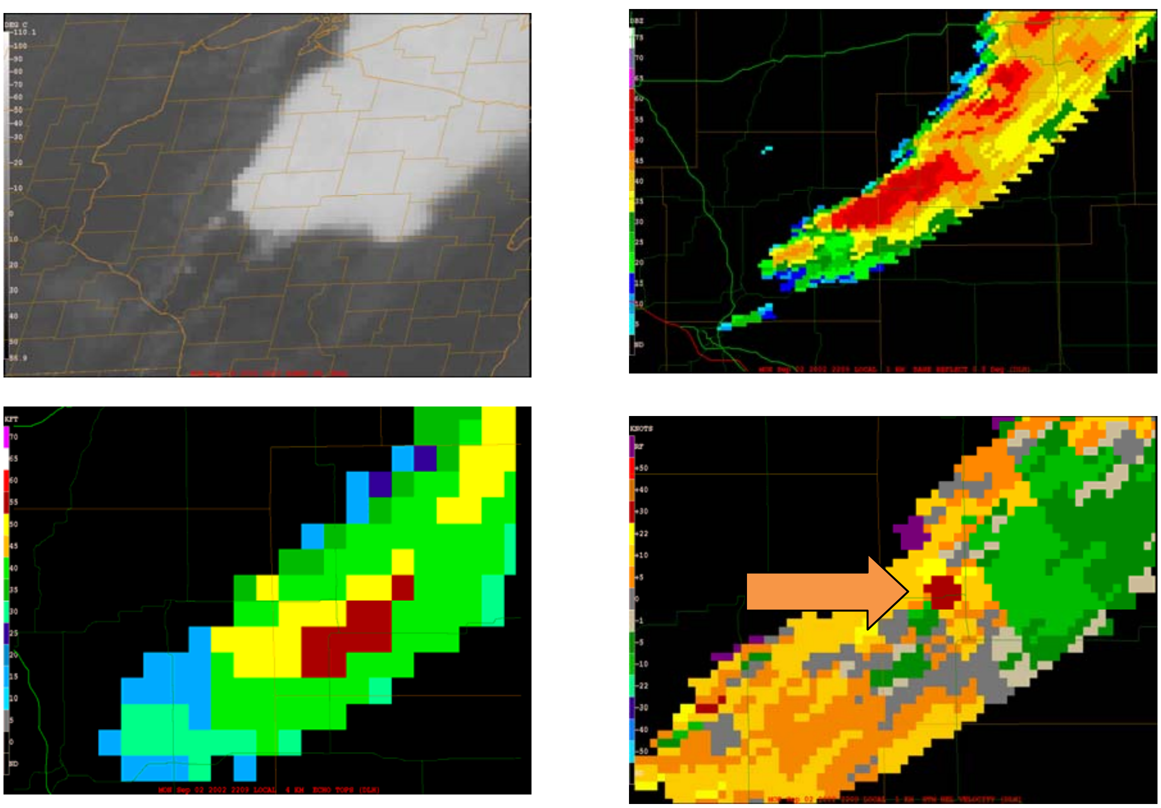
Because of the geography of the two communities and the orientation of the approaching cold front, Ladysmith was the first of the two communities hit by a tornado. The supercell thunderstorm responsible for the tornado made its first signature on National Weather Service Duluth, MN's Doppler Radar at 1907 UTC in eastern Polk County, WI, with a reflectivity of 35 dBZ. However, within the next hour, the storm exploded into a supercell with a maximum reflectivity of 55 dBZ, progressing through central Barron County and into western Rusk County. By 2115 UTC, the storm was on the doorstep of Ladysmith, as maximum reflectivity values were continuously measured at approximately 55 dBZ [Figure 7.2]. Echo tops estimated by the radar were above 50,000 feet, indicated also by the very cold cloud top temperatures in the IR satellite image [Figures 7.1, 7.3]. Furthermore, vertically integrated liquid values topped 50 kilograms of water per meter squared [Figure not shown], implying the extreme potential for large hail to play a major role with this storm. Finally, though the storm was roughly 200 kilometers from the radar and in velocity folding range, incredible gate-to-gate



Figures 7 are of the Ladysmith supercell thunderstorm and tornado. Figure 7.1 (top left) is an IR satellite image from GOES East at 2115 UTC on 02 September 2002 on the 10.7 micron channel with four kilometer resolution. Figure 6.2 (top right) is the base reflectivity scan (0.5 degrees) from KDLH at 2115 UTC on 02 September. Figure 6.3 (bottom right) is an image of echo top heights estimated by the KDLH radar in thousands of feet. Figure 6.4 (bottom right) is the storm relative velocity scan from KDLH at 2119 UTC on 02 September. The orange arrow points to the gate-to-gate shear couplet.

shear of -30 knots versus +30 knots was indicated [Figure 7.4], causing the National Weather Service in Chanhassen, MN to issue a tornado warning for Rusk County. Within minutes, the mesocyclone spawned a tornado ½ mile west of the City of Ladysmith, which drove through the heart of the community and continued on a fifteen mile path through central Rusk County. By 2151 UTC, the mesocyclone dissipated enough for the tornado's life to cease, lifting approximately five miles west of the Rusk-Price County border. Shingles and siding, along with a large Holiday® gas station sign fell from the sky up to 40 miles east of Ladysmith, displaying the true strength of the tornado and the supercell thunderstorm. The weakened storm had maintained a strong reflectivity of nearly 55 dBZ, but echo tops had reduced to 45,000 feet and gate-to-gate shear had vanished. Rusk County was through its scary ordeal, but another storm was brewing at this same time frame to the south, one that would produce another tornado and threaten other communities.

The supercell that produced the Gilman tornado on Labor Day 2002 was developed by forcing from the cold front, which was reinforced by the flanking line of the supercell that passed



Figures 8 are of the Gilman supercell thunderstorm and tornado. Figure 8.1 (top left) is an IR satellite image from GOES East at 2215 UTC on 02 September 2002 on the 10.7 micron channel with four kilometer resolution. Figure 7.2 (top right) is the base reflectivity scan (0.5 degrees) from KDLH at 2203 UTC on 02 September. Figure 7.3 (bottom right) is an image of echo top heights estimated by the KDLH radar in thousands of feet. Figure 6.4 (bottom right) is the storm relative velocity scan from KDLH at 2207 UTC on 02 September. The orange arrow points to the gate-to-gate shear couplet.

through Ladysmith. The storm was first indicated on National Weather Service Duluth, MN's Doppler Radar at 2007 UTC in eastern St. Croix County. The cell pushed through northern Dunn County and into northern Chippewa County, gathering strength from the low level moisture being transported aloft and strong directional and speed wind shear. By 2157 UTC, the supercell thunderstorm pushed into western Taylor County, its intensity being measured at 60 dBZ on the base reflectivity scan [Figure 8.2]. Additionally, echo tops reached 55,000 feet [Figure 8.3] and vertically integrated liquid values reached 55 kilograms of water per meter squared [Figure not shown], showing that strong updrafts were associated with the storm and the potential for large hail and damaging winds was a threat with the increased risk of tornadoes. At 2203 UTC, rotation was indicated in the storm velocity sweep by the Weather Service's radar, which denoted a gate-to-gate shear of +30 knots versus -10 knots west of Gilman [Figure 8.4]. Though the shear was very low, Meteorologists had to take into account the distance between the village and the radar as well as the structure of the thunderstorm. A tornado warning was issued for Taylor County by the National Weather Service office in La Crosse, WI. The tornado struck the northern part of the community 15 minutes later, and the gate-to-gate shear values increased and as the couplet moved over the village. The tornado intensified further after hitting the community, as echo tops of the supercell thunderstorm reached 60,000 feet and vertically integrated liquid values remained very high. Gate-to-gate shear values had intensified to +50 knots versus -50 knots shortly east of Gilman [Figure 9], as the tornado passed through the Chequamegeon National Forest, uprooting trees and damaging human establishments in the path. The tornado continued its track eastward for 17 miles, dissipating 6 miles west of Medford, WI. Pieces of the gymnasium roof and trees fell from the sky upon the City of Medford, as the storm dissipated rapidly with its eastward progression.

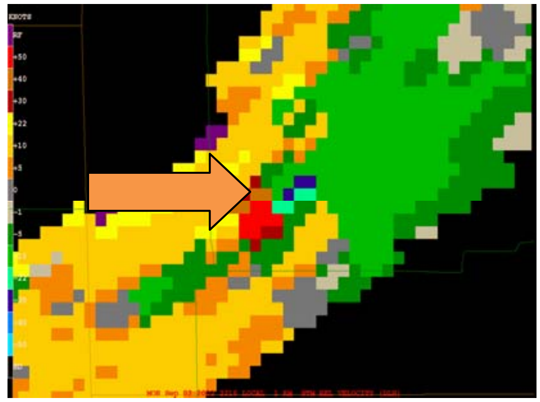


Figure 9 (above) is a storm relative velocity scan from KDLH at 2224 UTC on 02 September 2002. The orange arrow points to the intense gate-to-gate shear couplet.

V. Conclusions

The Labor Day tornadoes that ravaged the Gilman and Ladysmith communities are events that those residents will remember for many years ahead. The damage from the storms was tremendous. Downtown Ladysmith was left in utter ruin, as the tornado proceeded to destroy business and homes in its path, earning a F3 rating on the famous Fujita scale. The tornado that passed through Gilman achieved a F2 rating at its peak. However, it only acquired an unofficial F1 status for the time that it passed through the village, where it tore off the roof of the high school gymnasium that the author of the case study was practicing with his football team. In the end, over 20 million dollars in damage was caused by the "Labor Day tornadoes." But one may ask what processes and mechanisms contributed to cause such an event to occur. The answer is not simple; however, it can be summed up to three general statements. One, a large abundance of moisture trapped at lower levels of the atmosphere by a strong cap primed the area for a large severe weather outbreak. Two, the introduction of the synoptic dryline eroded the cap over the region, which allowed free convection to occur and thunderstorms to develop rapidly. Finally, strong speed and directional wind shear promoted the development of supercell thunderstorms through the tilted updraft concept, and eventually spawned tornadoes. Though the thunderstorms that caused the tornadoes fired ahead of a cold front in the orientation of a squall line, the storms were still mesocyclonic and rotating. The result was a heightened risk of tornadogenesis, a risk that turned into a reality on Labor Day, 2002.

VI. References and Acknowledgements

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