



Service Assessment

Tornado in Rogers, Minnesota September 16, 2006



U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Weather Service, Central Region Headquarters
Kansas City, Missouri

Cover: Damage caused by a tornado in Rogers, MN on September 16, 2006. Photo courtesy of Todd Krause, WCM, WFO Chanhassen, MN.



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November 2006

National Weather Service
Lynn Maximuk, Central Region Director

Preface

During the late evening of September 16, 2006, a tornado developed near Rogers, Minnesota. The tornado had an eight-mile long damage path across Hennepin and Anoka counties in eastern Minnesota. The Rogers tornado was rated F2 on the Fujita Scale (F0-F5 with F5 the strongest) resulting in one fatality and six injuries.

Due to the fatality and injuries with this tornado and the unique nature of this storm, NOAA's NWS Central Region Headquarters formed a team to evaluate the overall performance of the Weather Forecast Office in Chanhassen which had warning responsibility for the area. Team members were from three NWS Regions and national headquarters. The findings and recommendations from this assessment are offered with the goal of improving the quality of warning and forecast products and services, and to enhance the knowledge of storm structure and warning techniques for the protection of life and property to the citizens of the United States.

Lynn Maximuk
Director, Central Region

November 2006

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Service Assessment Team

The National Oceanic and Atmospheric Administration's (NOAA) National Weather Service (NWS) Central Region Headquarters activated an assessment team on September 19, 2006, to evaluate the NWS' performance as it related to the September 16 tornado in Rogers, MN. Team members worked in Minnesota from September 20 to September 22. The team continued to collect and review information through October 13. During its time in Minnesota, team members visited damage areas, and interviewed emergency managers, the media, public officials, and pertinent staff members at the Weather Forecast Office (WFO) in Chanhassen, MN.

The following members were on the team:

Steven Piltz	<i>Team Leader, Meteorologist-In-Charge (MIC), WFO Tulsa, OK</i>
Gary Szatkowski	MIC, WFO Mount Holly, NJ
Dr. Matthew Bunkers	Science and Operations Officer (SOO), WFO Rapid City, SD
Jim Keeney	Regional Warning Coordination Meteorologist (WCM), Central Region Headquarters, Kansas City, MO
Wayne Presnell	Service Assessment Program Manager, Office of Climate, Water and Weather Services (OCWWS), Silver Spring, MD

Other valuable contributors include:

Don Burgess	University of Oklahoma's Cooperative Institute of Mesoscale Meteorological Studies, Norman, OK
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Acronyms

AMEM	Association of Minnesota Emergency Managers
AWIPS	Advanced Weather Information Processing System
CDT	Central Daylight Time
CTA	Call-To-Action Statement
CWFA	County Warning and Forecast Area
FAA	Federal Aviation Administration
HWO	Hazardous Weather Outlook
LSR	Local Storm Report
NOAA	National Oceanic and Atmospheric Administration
NSSL	National Severe Storms Laboratory
NWS	National Weather Service
MIC	Meteorologist-In-Charge
OCWWS	Office of Climate, Water, and Weather Services
OAR	Office of Atmospheric Research
OST	Office of Science and Technology
OU-CIMMS	University of Oklahoma -Cooperative Institute of Mesoscale Meteorological Studies
SDM	Station Duty Manual
SKYWARN	Network of trained severe weather spotters for the NWS
SOO	Science and Operations Officer
SPC	Storm Prediction Center
SPS	Special Weather Statement
SVR	Severe Thunderstorm Warning
TDWR	Terminal Doppler Weather Radar
TOR	Tornado Warning
WarnGen	NWS Warning Generation Software
WES	Weather Event Simulator
WCM	Warning Coordination Meteorologist
WFO	Weather Forecast Office
WSR-88D	Weather Surveillance Radar, 1988 Doppler
VCP	Volume Coverage Pattern

Service Assessment Report

Executive Summary

On September 16, 2006, a tornado, rated F2 on the Fujita Scale (**Appendix A**), touched down three miles west of Rogers, MN, at 9:52 p.m. The tornado had an eight mile path and was on the ground for 12 minutes, first striking the city of Rogers at 9:54 p.m. Central Daylight Time (all times hereafter in CDT unless noted). The tornado crossed the Mississippi River into Anoka County and dissipated in the west section of Ramsey at 10:04 p.m. The tornado caused one fatality and injured six. In response to the event, the NWS' Central Region Headquarters formed a team to evaluate the warning service from the NWS, in particular the Minneapolis Weather Forecast Office (WFO) at Chanhassen, MN, which has warning responsibility for the area.

Residents of the area were provided with a heightened sense of awareness to the threat of severe weather as the Storm Prediction Center (SPC) in Norman, OK, issued a Tornado Watch for the Rogers area at 5:10 p.m. and indicated this was a "*particularly dangerous situation.*" WFO Chanhassen issued several warnings and statements as the storms were approaching the Rogers area and a Severe Thunderstorm Warning for the Rogers area (Hennepin County) was issued at 9:43 p.m. This warning included a statement that a Tornado Watch was in effect for the warned area. A Tornado Warning was issued for Anoka County at 10:04 p.m. WFO Chanhassen received the first report of damage in Rogers at 10:13 p.m. Local officials from Rogers and Hennepin County, and the three television station meteorologists from the Twin Cities area who were interviewed by the assessment team said the meteorological staff provided adequate products and services from WFO Chanhassen during this event. Severe weather information was being broadcast on the air and local emergency officials were alert to the approaching storms.

Issuing a timely Tornado Warning for the Rogers area was difficult, as the first definitive indicators on Doppler radar signatures of strong rotation became evident at the same time the tornado struck Rogers. In addition, there were no real time reports of the tornado. The WFO used proven scientific methods in their radar analysis and issued a Severe Thunderstorm Warning for the Rogers area 11 minutes before the tornado hit the community. A number of enhancements currently planned for NWS WSR-88Ds will provide more timely radar information which will assist forecasters in detecting tornados earlier in their life cycle.

The assessment team evaluated all aspects of WFO Chanhassen's products and services and identified areas for improvement. Specifically, the team focused on the process and timing of sectorizing WFO warning operations; the Tornado Warning product preparation process; and the call-to-action statement in the 9:43 p.m. Severe Thunderstorm Warning. The team has offered three findings and provided four recommendations to address these areas of the NWS warning service. All equipment functioned properly during the event.

Event Facts and Overview

During the afternoon of Saturday, September 16, 2006, a significant episode of severe thunderstorms, including tornado-producing supercells, occurred across eastern South Dakota. These thunderstorms spread into southern Minnesota during the evening in the form of supercells and multicell lines. Three tornadoes occurred in Minnesota during this event, however WFO Chanhassen received no reports of tornadoes in real time. The Rogers tornado developed at 9:52 p.m. at the west end of Sylvan Lake in northwestern Hennepin County (**Figure 1**), reaching its peak intensity of F2 on the Fujita Scale as it tracked across northwest sections of Rogers. Based on information from the Hennepin County Sheriff's Office, data from two home weather stations, and radar imagery, the worst damage in Rogers was occurring by 9:54 p.m. Damage to the home where the young female received fatal injuries occurred near 9:55 p.m.

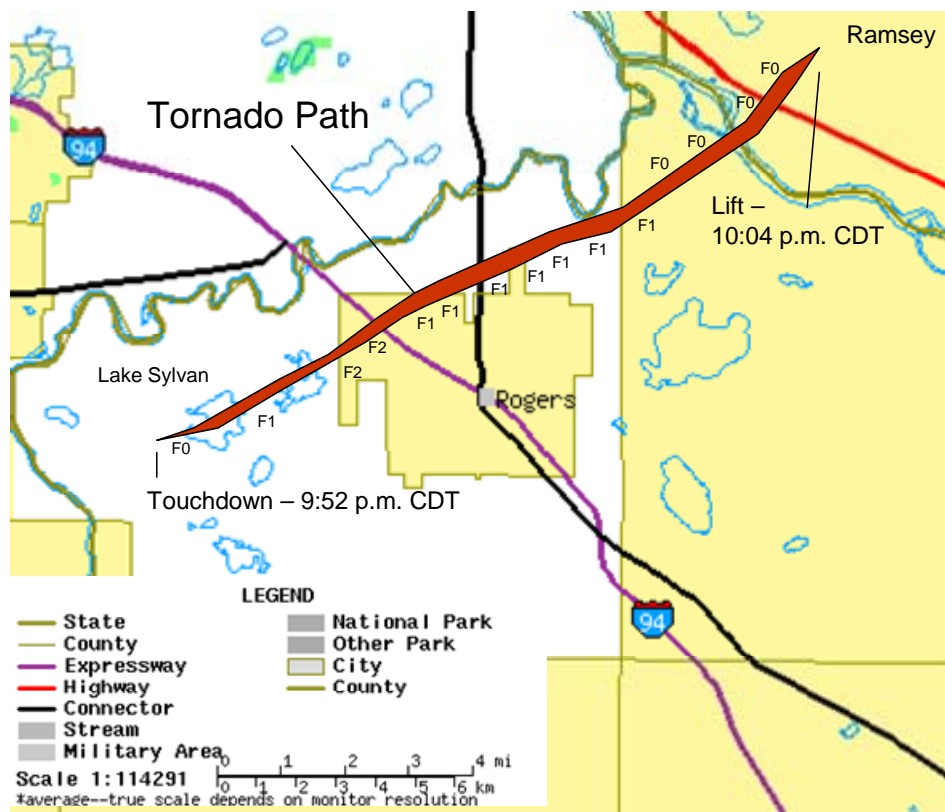


Figure 1. Rogers Tornado Track. Damage estimates related to the Fujita Scale noted. Taken from the Chanhassen WFO damage survey. Map background from the U.S. Census Bureau, modified to approximate the corporate limits of Rogers.

The overall weather pattern on September 16, 2006, supported the potential for tornado formation (**Figure 2**). The lower and upper jet streams (strong winds above the surface which move weather systems) were very strong for this time of year. The thunderstorm that produced the tornado in Rogers occurred ahead of a cold front, and near a subtle warm front that extended across central Minnesota. The combination of southeast winds at the surface with the much stronger winds several thousand feet above the ground led to very large wind shear (change in wind speed and/or direction with height)—a condition that favors tornado development in

supercell thunderstorms. The atmosphere was also very moist across most of southern Minnesota, with dew point temperatures (a measure of moisture compared to the actual temperature) at or above 65 °F. This low-level moisture helped produce the buoyancy necessary for strong thunderstorm development.

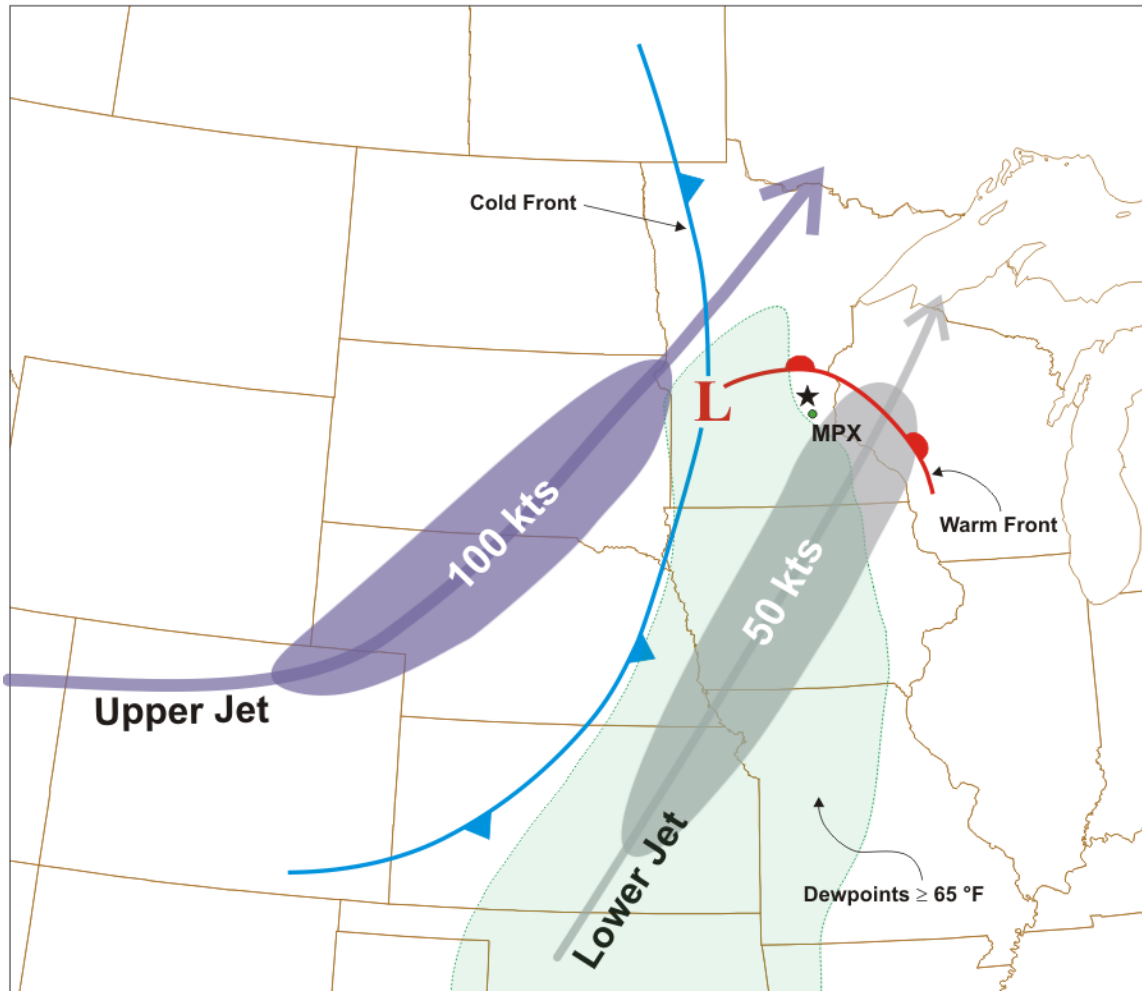


Figure 2. Composite synoptic weather pattern just prior to the tornado at Rogers, MN. Rogers is indicated by the black star, and MPX denotes the location of the Chanhausen WFO and WSR-88D.

National Weather Service Products and Services

The National Weather Service did an excellent job publicizing the potential for severe weather in Minnesota during the days preceding the Rogers tornado.

On Tuesday, September 12, WFO Chanhausen began mentioning in their Hazardous Weather Outlook (HWO) that a strong storm system would affect Minnesota on Saturday and Sunday with strong winds and large hail as the primary threats. The first graphical HWO was issued at 5:46 a.m. on September 14 and it identified frontal placement and general time lines for possible severe weather across their County Warning and Forecast Area (CWFA). On Saturday, September 16, the WFO Chanhausen HWO mentioned a moderate risk of severe weather. The

main threats were large hail and damaging winds, but a chance for “a tornado or two” was identified (See **Appendix B** for product timeline).

The SPC included all of Minnesota in a Slight Risk category of severe weather for Saturday at least three days in advance, and on Saturday upgraded to a Moderate Risk for most of west-central through southern parts of the state.

On Saturday, September 16, the SPC issued Tornado Watch 776 at 5:10 p.m. for northwestern Iowa and central and southern Minnesota, including Rogers and all of Hennepin County, effective until 1:00 a.m. Sunday, September 17. The Watch was headlined with “*This is a particularly dangerous situation.*” At 9:38 p.m., a Special Weather Statement (SPS) was issued by WFO Chanhassen for Wright and Hennepin Counties, including the Rogers area, valid until 10:30 p.m. The SPS stated, “*People in Hennepin and southeastern Wright counties should monitor the weather situation closely.*” A Severe Thunderstorm Warning for Wright and Hennepin Counties was issued at 9:43 p.m. mentioning the threat of large hail with damaging winds, and reminding those in the warned area that a Tornado Watch was in effect

The Severe Thunderstorm Warning issued for the Rogers area at 9:43 p.m. contained a call-to-action (CTA) statement indicating a Tornado Watch was in effect but did not contain a CTA statement explicitly indicating tornadoes are possible in severe thunderstorms. NWS Instruction 10-511 WFO Severe Weather Product Specification states: “*Severe Thunderstorm Warnings will include the possibility of tornadoes if a Tornado Watch is in effect.*” To ensure the intent of NWS Instruction 10-511 is met, the NWS should investigate the feasibility of developing a software enhancement to automate the required tornado potential statement in any Severe Thunderstorm Warning issued within a tornado watch area. (**Recommendation 3**).

The thunderstorm that spawned the Rogers tornado underwent a complex evolution beginning at 9:24 p.m. Within a line of thunderstorms moving across Wright County, a heavy-precipitation supercell rapidly developed (**Figure 3**). Key radar features typically associated with a rotating thunderstorm were difficult to discern because the storm was embedded within the line of thunderstorms. As a result, the Rogers storm did not exhibit classic supercell characteristics.

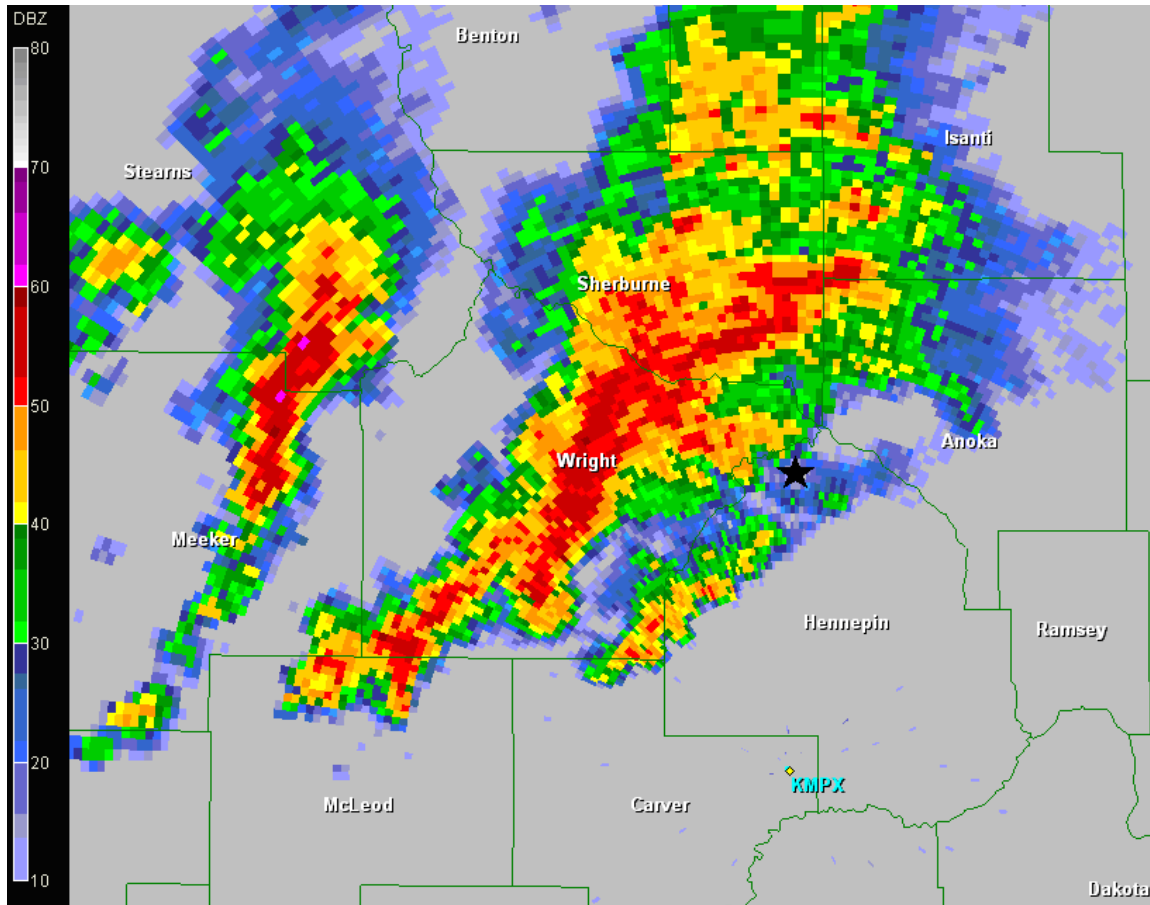
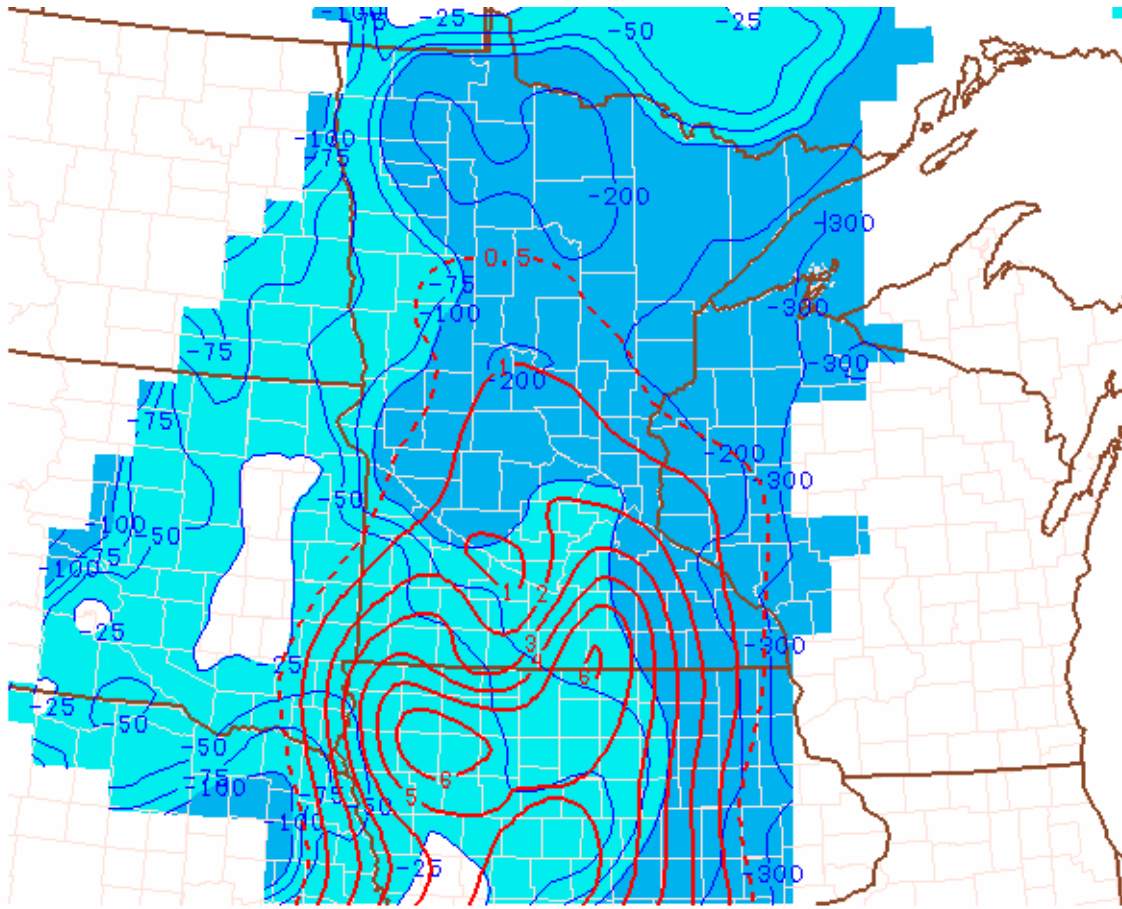


Figure 3. KMPX WSR-88D Radar Reflectivity from the lowest slice (0.5 degrees) at 9:37 p.m. The line of thunderstorms across eastern Wright County is the activity of interest and shows no discernable special low-level radar characteristics. Rogers is noted with the black star, with county names shown.

At approximately 9:40 p.m., 12 minutes before the tornado, WFO staff initiated the recommended action to “sectorize” their radar surveillance to increase the number of staff analyzing radar data from two meteorologists to three. To that point two forecasters worked as a warning team issuing products for the entire area of responsibility. While implementing sectorized operations, they considered the thunderstorms moving into the area northwest of Minneapolis and towards Rogers to have less tornadic potential than those moving into southern Minnesota. Therefore, a single forecaster was assigned warning responsibility for the Rogers area, while the existing two-forecaster warning team monitored the thunderstorms moving into far southern Minnesota where instability and shear parameters were greater (**Figure 4**).



060917/0100 Significant Tornado Parameter (STP) and 100 mb CIN

Figure 4. Significant Tornado Parameter (STP = red contours) at 8:00 p.m. as calculated by the SPC. The STP is a composite index containing both instability related and wind-shear related components. The majority of F2 or greater tornadoes studied by the SPC occurred with STP values greater than 1. Note the maximum values across southern Minnesota and northern Iowa.

The team believes two meteorologists assigned to analyze the information for the Rogers area would have been ideal, one to analyze all radar data, the second to assist with radar data interpretation, coordinate information, and evaluate environmental parameters. In addition to not having a second meteorologist to assist, the warning forecaster assigned to the Rogers sector entered the situation without knowing the details of the thunderstorm's evolution. This limited the forecaster's ability to assess trends (**Recommendation 2**). In spite of these limitations, a Severe Thunderstorm Warning for Hennepin County was issued at 9:43 p.m. The warning was composed and transmitted by the southern warning team as the warning forecaster assigned to the Rogers area was still configuring his workstation for warning operations. Sectorizing warning operations is a recommended practice during large or complicated warning situations. This process should be initiated early in the warning event, with a full hand-off not deemed complete until the new warning forecaster has configured his/her workstation and become familiar with the meteorology of the event.

The decision to issue the Severe Thunderstorm Warning was based on increased values of radar reflectivity aloft that suggested a more potent storm updraft, and stronger low-level

velocity implying an increased threat for wind damage. What was not detected was the development of radar reflectivity and velocity signatures indicative of a heavy-precipitation supercell (**Figure 5**).

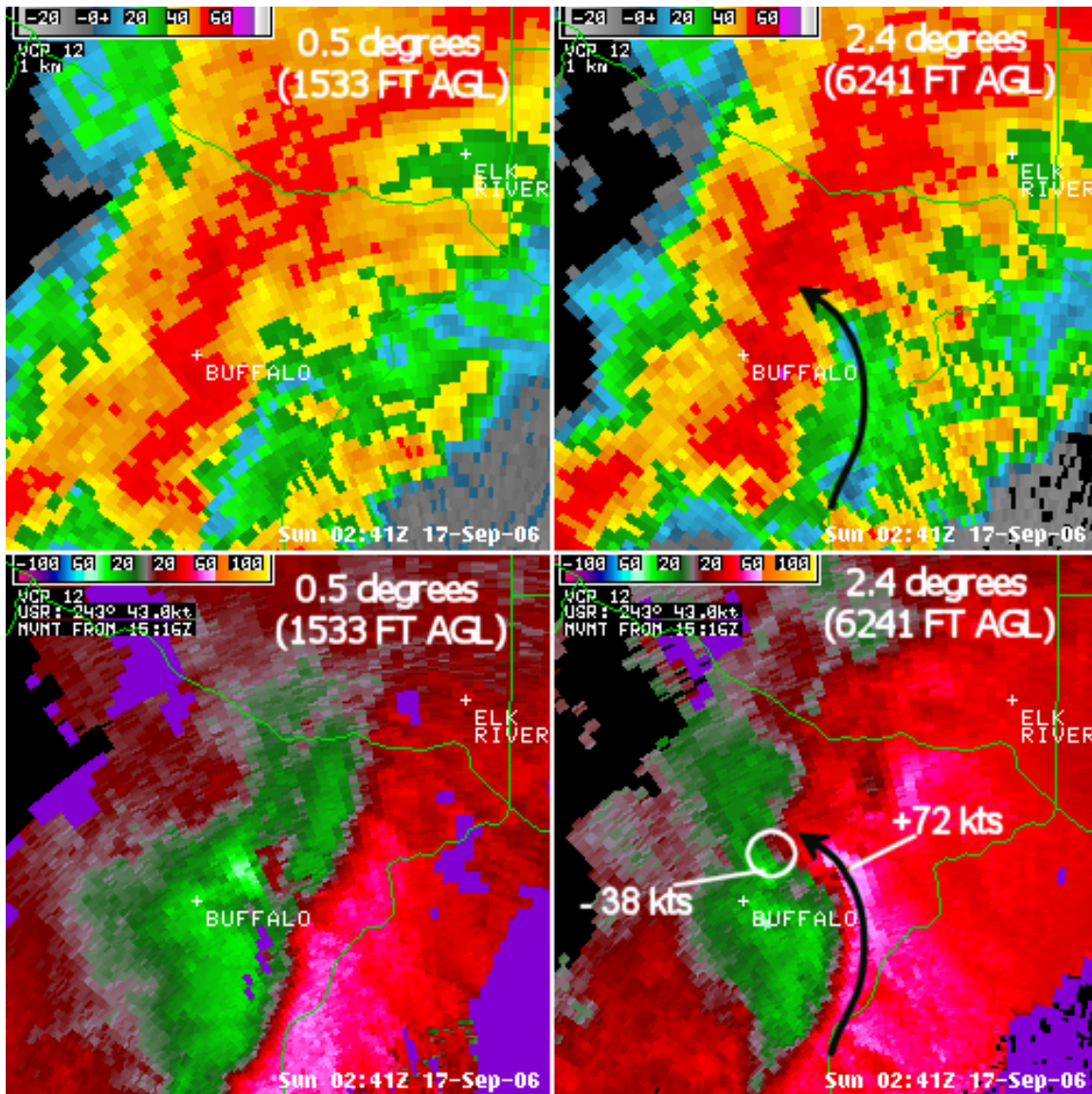


Figure 5. KMPX WSR-88D four panel display from the 9:41 p.m. volume scan radar reflectivity is on top and storm-relative radar velocity display is on bottom (Storm motion was set for 243 degrees at 43 knots). The left column is from the lowest data slice, 0.5 degree antenna elevation with the image center approximately 1500 feet above ground level. The right column is from the data slice at antenna elevation 2.4 degrees, with the image center approximately 6200 feet above ground level. Note the reflectivity inflow notch at 2.4 degrees and the mesocyclone in both storm-relative velocity displays. These features are indicative of a supercell. The values displayed in white in the lower right image are storm-relative velocity magnitudes. Negative values are shown in green and indicate air motion toward the radar. Values in red mark air motion away from the radar which is located off the image to the south.

The assessment team determined that under ideal circumstances, a Tornado Warning for Hennepin County (Rogers area) could have been issued as early as 9:52 p.m. based on information from the WSR-88D's 9:50 p.m. volume scan (**Figure 6**). However, data from the

9:54 p.m. radar volume scan gave stronger indications of the likelihood of a tornado near Rogers (Figures 7a and 7b). Based on this information it is the belief of the assessment team that a Tornado Warning could have been issued on this storm by 9:56 p.m. This would have been after the fatal injuries to the young female in Rogers.

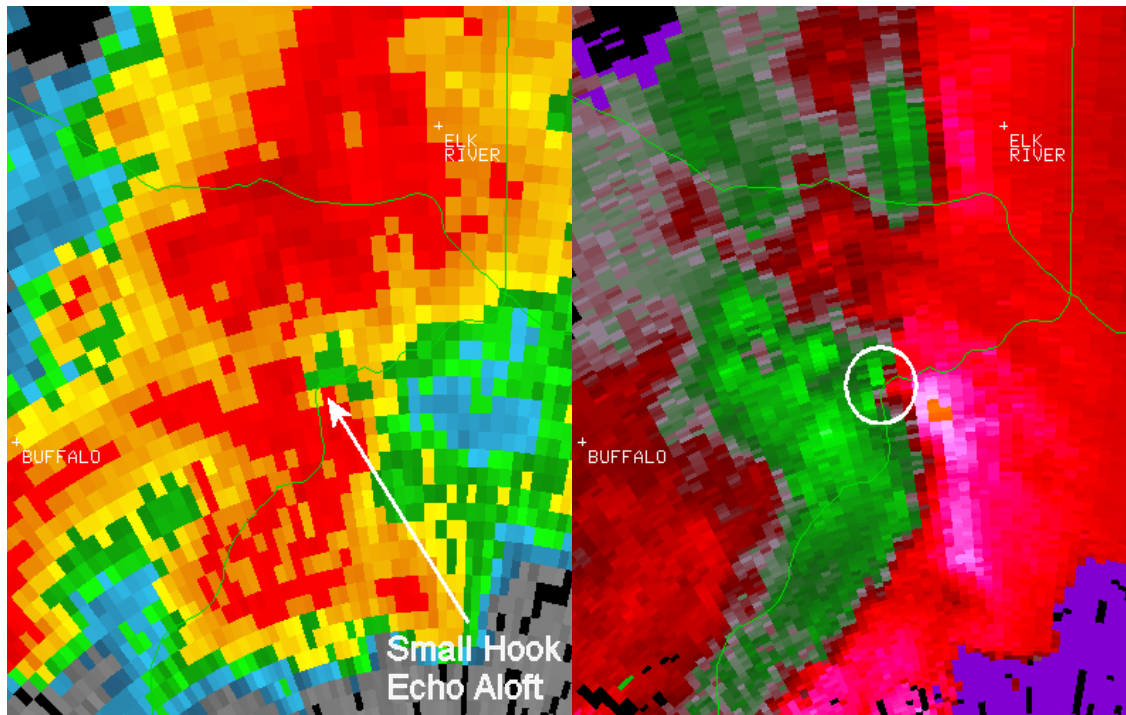


Figure 6. KMPX WSR-88D data from the 9:50 p.m. volume scan shows a small hook echo and associated storm-relative velocity couplet at the 2.4 degree elevation scan. The image center is 5619 feet above ground level.

Based on the warning forecaster's desire to assess additional environmental and radar information, and given the lack of storm reports received in the office, the decision to issue a Tornado Warning on the storm near Rogers was held until the volume scan from the WSR-88D was completed at 9:58 p.m.

After the warning decision was made at 9:59 p.m., the team believes the warning forecaster spent too much time drawing the warning area using warning generation software in the AWIPS workstation, to ensure the list of cities in the warning text was correct. The warning forecaster's diligence stemmed from a response to past criticism that some Tornado Warnings issued by the Chanhassen WFO were too broad in area and included unnecessary locations. In addition, the absence of tornado reports following previous Tornado Warnings during the evening cast some doubt in the forecaster's mind as to whether a tornado would actually develop. The initial process to prepare the warning lasted from 9:59 p.m. to 10:02 p.m. when the next low-level radar data became available. At 10:02 p.m., the radar indicated that the rapidly moving circulation was crossing the Mississippi River into Anoka County, and therefore Hennepin County was no longer needed in the warning.

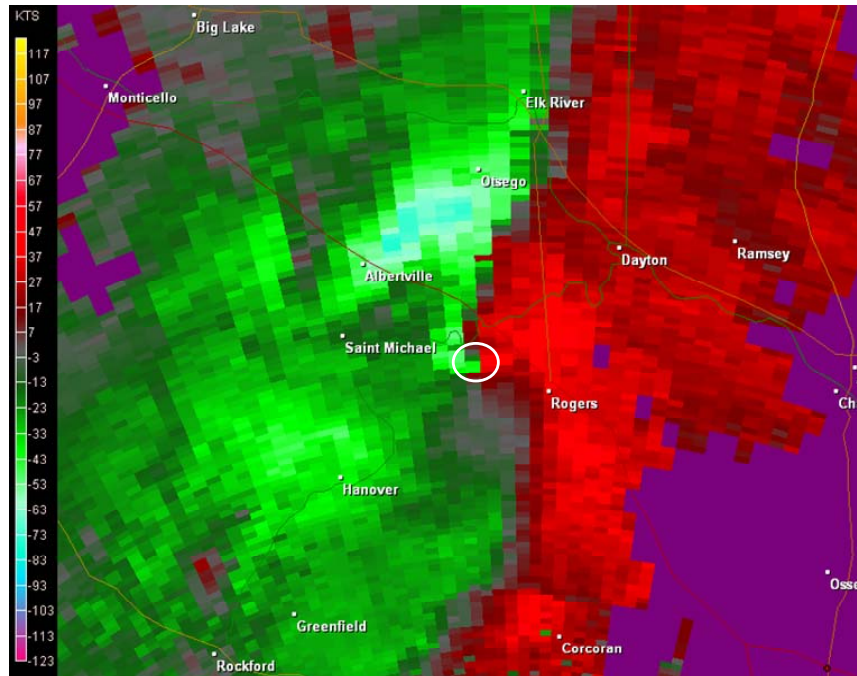


Figure 7a. KMPX WSR-88D storm-relative radar velocity data from the 0.5 degree elevation slice at 9:54 p.m. The white circle denotes the strong low-level rotation near Rogers. Data near the white circle shown in green indicates air motion toward the radar. Those data near the white circle shown in red indicates air motion away from the radar (located off the image to the south). This opposing air motion is used to infer the existence of the storm's rotation.

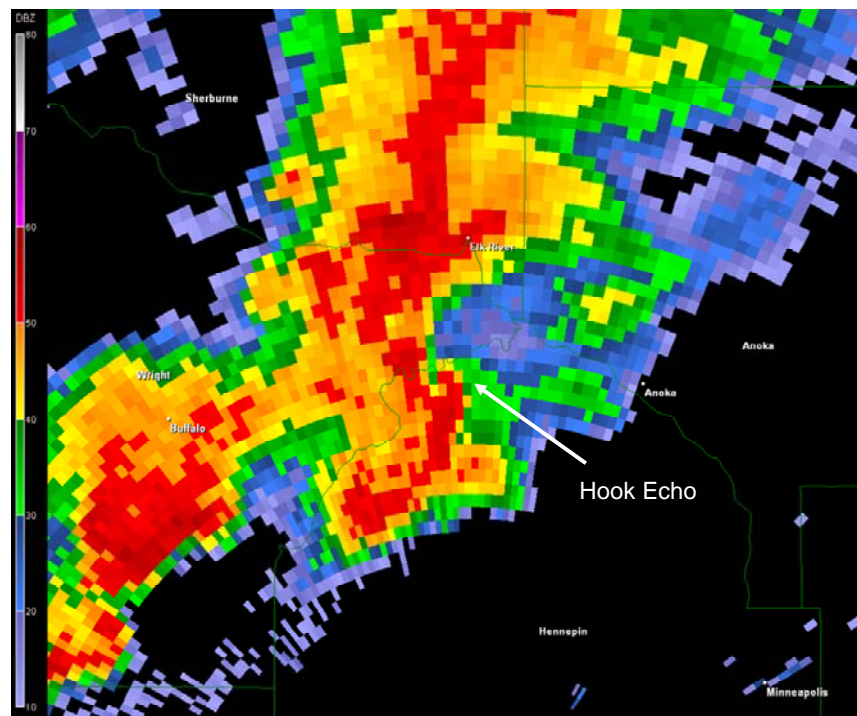


Figure 7b. KMPX WSR-88D reflectivity data from the 0.5 degree elevation slice at 9:54 p.m. The hook echo is noted.

Once the decision to remove Hennepin County was made, the warning forecaster restarted the warning generation process. The Tornado Warning for Anoka County was issued at 10:04 p.m. A total time of 10 minutes elapsed between the first strong WSR-88D indication of the likelihood of a tornado near Rogers and the issuing of a Tornado Warning for Anoka County. The team believes the Tornado Warning for Hennepin and Anoka Counties could have been issued within two minutes of the 9:54 p.m. WSR-88D volume scan, which indicated a tornado was likely near Rogers. The NWS is developing a storm-based (polygon) warning concept, which moves away from the traditional county-based approach. If the polygon warning concept were in place during the Rogers, MN event, the warning would have been issued several minutes sooner. **(Recommendations 1a and b).**

The Tornado Warning issued at 10:04 p.m. was based solely on radar data and environmental considerations. The first report of damage from the Rogers area was received from a storm spotter via a cellular phone call to the WFO at 10:13 p.m. In the telephone conversation, a hail report near Albertville was correctly logged as having occurred at 9:55 p.m. In the same call, it was reported that a sign was wrapped around a pole and pieces of lumber were scattered on Interstate 94 in Rogers. An accurate time of the wind damage report was not provided during the call. WFO staff inaccurately estimated the event time for the wind event as 9:45 p.m. That information was released in a Local Storm Report. Upon further clarification, it was determined that the damage was actually observed at 10:07 p.m. The mobile spotter who made this report did not observe the damage occurring, but was providing information on the impact of the storm.

WFO Chanhassen Staffing

Staffing was adequate to handle the event until a second warning sector was established **(Recommendation 2)**. The WFO warning output of 18 Severe Thunderstorm and Tornado Warnings issued during the nearly eight-hour Tornado Watch period was not excessive. However, a single forecaster working the northern sector was not efficient, and there should have been an additional meteorologist to help work the sector. Also, one of the original warning forecasters already familiar with the severe storm meteorology of the day should have been assigned the northern warning sector, while the forecaster spinning up on warning operations should have been assigned to the southern warning team. The staffing pattern at the time of the tornado was three warning forecasters, a person dedicated to communications, and a forecaster maintaining a basic weather watch and issuing public and aviation forecast products. There were a total of five WFO Chanhassen staff members on duty at the time of the tornado.

The public/aviation forecaster and three warning forecasters were monitoring the environmental conditions pertinent to severe thunderstorms and tornadoes during this event. They used hourly analysis graphics posted on the Internet by the SPC, and local data including the vertical atmospheric information from the evening instrumented balloon launch. They further monitored trends using local objective analyses of surface weather observations from area airports, and the vertical wind profile created each volume scan by the WSR-88D. The staff members on duty at WFO Chanhassen during the tornado were aware of the pertinent severe weather parameters in place across their region, and particularly aware of the wind-shear related parameters.

Three amateur radio operators were in place at the Chanhassen WFO during the Rogers tornado. The assessment team was impressed with the organization of the SKYWARN system in metropolitan Minneapolis-St. Paul, and with the knowledge of the principle amateur radio operator that was interviewed. It was noted that the absence of storm reports was likely related to the darkness of night, rolling terrain that makes spotting difficult, and the placement and number of storm spotters.

Emergency Management / Media Satisfaction and Response

The assessment team met with seven community leaders from Rogers and Hennepin County, and conducted telephone interviews with three Twin Cities television station meteorologists. The team concluded that WFO Chanhassen has a strong relationship with these key partners, and the NWS is well respected. A letter from the President of the Association of Minnesota Emergency Managers (AMEM), written on September 22, 2006, also confirms the success of these excellent working relationships.

“AMEM has a long history of working with the Chanhassen Forecast Office, and has been repeatedly impressed by the high degrees of professionalism and dedication of the men and women who provide us forecasts and severe weather warning.”

A local television station conducted an interview while the team was at the WFO in Chanhassen, and the resulting story was broadcast later in the day was complimentary of the WFO. In addition, the *Minneapolis Star Tribune* newspaper developed an online poll asking if the people of Rogers were adequately warned. The majority of the respondents indicated they felt the severe weather warnings and watches were adequate.

The team interviewed the on-air meteorologists at the Minneapolis-St. Paul television stations that provided coverage of the severe weather event on the evening of September 16. They indicated the mechanics of the warning process that evening were adequate. The television stations used crawlers to broadcast NWS warning text information along the edge of the screen, displayed graphics of the warned areas, and cut in to routine programming to provide live updates and show radar images.

Radar Data

The Rogers tornado occurred approximately 24 miles north of the Chanhassen WSR-88D (KMPX). The assessment team, with the help of Don Burgess of the University of Oklahoma’s Cooperative Institute of Mesoscale Meteorological Studies (OU-CIMMS), determined the radar was configured appropriately by the WFO staff, and the radar performed as designed. The staff at the Chanhassen WFO was using VCP 12, the fastest VCP, collecting data at any one slice approximately every four minutes and 15 seconds. VCP 12 also emphasizes data collection closest to the ground, which made it the most appropriate choice for the situation that evening.

Planned improvements to NWS WSR-88Ds will help in more timely detection of tornadoes. Below is a discussion of these radar enhancements and their relation to the Rogers tornado event.

1. **3-Dimensional Displays** – The tornadic storm exhibited rapid changes in rotation. Experimental 3-D radar data displays being developed at the National Severe Storms Laboratory (NSSL) provide very useful ways to see and understand the mid-level and low-level evolution of the evolving circulations that led to the Rogers tornado. The NWS Office of Science and Technology (OS&T), working with NSSL, is developing 3-D radar displays for the NWS's Advanced Weather Information Processing System (AWIPS). [Implementation with AWIPS Build 8.2, November 2007]

2. **Super Resolution** – The observed low-level velocity and reflectivity signatures were small in size. Super Resolution data (0.5 degree azimuth and 250 meter gate spacing) would have been helpful to better define the signature intensities and locations. [Implementation date: WSR-88D Build 10, April 2008]

3. **Dual Polarization** – A dual-polarization debris signature has been seen in WSR-88D data with strong tornadoes (F3+) that destroy structures and loft debris. It is not possible to know if the Rogers tornado lofted enough debris to produce such a signature. Dual-polarization outputs would have certainly provided more accurate and detailed information on the severe hail that was reported. [Implementation date: FY2010]

4. **Fast Volume Coverage Patterns** – Low-level rotation and signature strength increased rapidly prior to and during tornado development. The radar was operated in the fastest Volume Coverage Pattern (VCP) currently available (VCP 12; 4 minute updates). VCP 13 (under development; 2 minute updates) would have provided more frequent low-level data. However, the fast VCPs being developed for the WSR-88D have limitations. For example, VCP 13 (6 elevation angles topping at 6.5 deg) does not cover the full volume around the radar, including loss of flight level data. In addition, fast antenna rotation rates cause loss of data quality and enhanced wear and tear on radar hardware. Multifunction Phased Array Radars, being developed by the National Oceanic and Atmospheric Administration (NOAA) Office of Oceanic and Atmospheric Research (OAR) / National Severe Storm Laboratory (NSSL), can produce even faster scans (1 minute or less) without the limitations of the fast VCPs. [Implementation date to be determined.]

The WFO at Chanhassen does not have access to data from the FAA's Terminal Doppler Weather Radar (TDWR) at the Minneapolis-St. Paul International Airport (TMSP). The data from the TMSP system revealed a low-level cyclonic velocity signature at 9:51 p.m. over northwest Hennepin County, to the west of Rogers (see white circle in Figure 8). The TDWR signature is similar to that seen in the WSR-88D data three minutes later. This faster detection by the TDWR results from the 60 second low-level scanning strategy used by the TDWR as opposed to the four minute strategy used by the fastest VCP in the WSR-88D. Access to these data, used in combination with the WSR-88D information, would have given additional confirming evidence of rotation near Rogers, and could have sped up the warning decision

process. Yet, using 9:51 p.m. as a decision time for a Tornado Warning, the best possible warning issuance time would be at 9:53 p.m. (allowing time for radar analysis and warning preparation). The tornado was already occurring at that time.

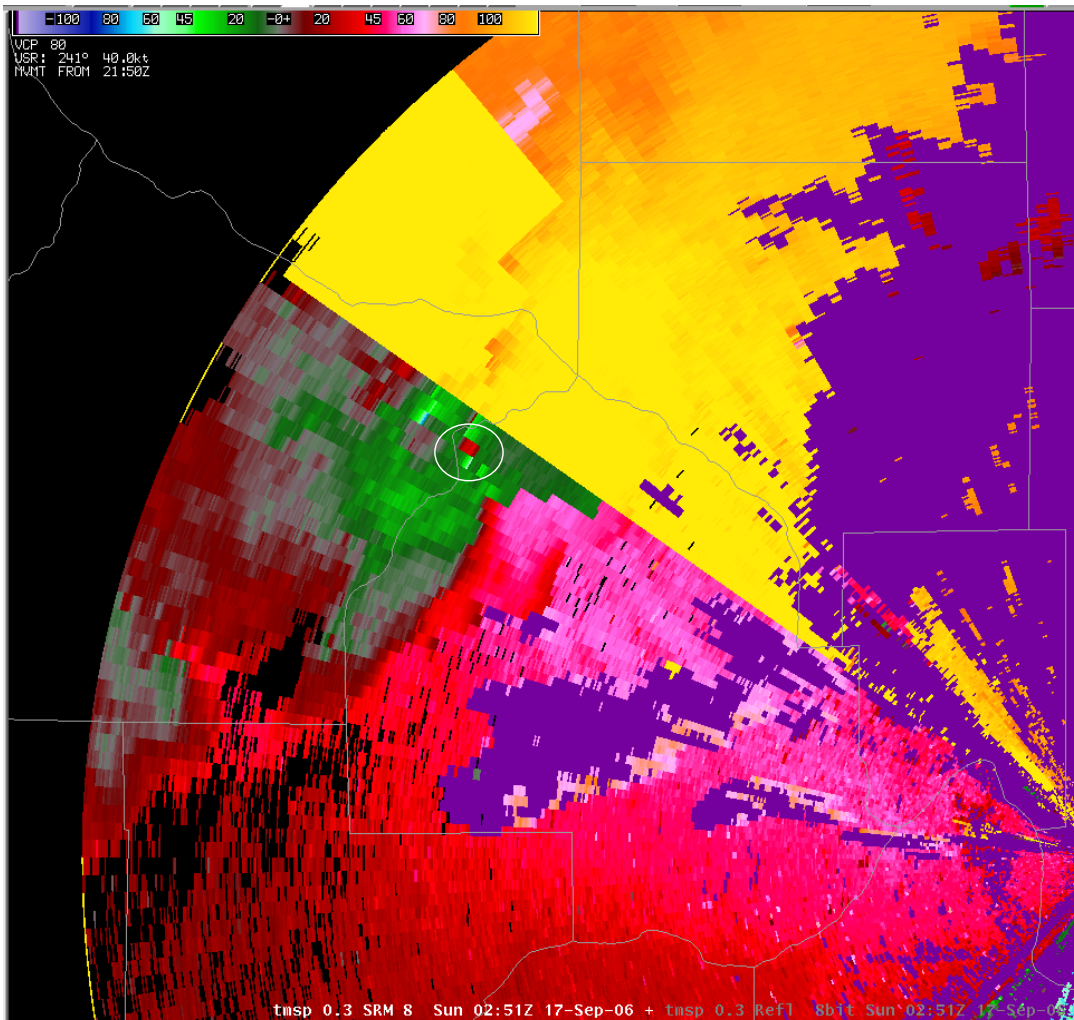


Figure 8. TMSR TDWR storm-relative radar velocity data from the lowest radar slice at 9:51 p.m. A low-level cyclonic rotation signature is seen inside the white circle. This signature is similar to that seen in WSR-88D data three minutes later. The broad area of data shown in yellow represents incorrectly displayed velocity data.

Conclusion

The Chanhassen WFO warning team operated within the established parameters of typical NWS severe weather operations. Under the absolute best circumstances, a Tornado Warning for Hennepin County (Rogers) could have been issued at 9:52 p.m. based on data from the 9:50 p.m. volume scan of the WSR-88D. However, data from the 9:54 p.m. radar volume scan were more conclusive, depicting rotation near Rogers, and thus it is the belief of the assessment team that a Tornado Warning realistically could have been issued by 9:56 p.m. Given that the fatal injuries in Rogers occurred near 9:55 p.m., an effective Tornado Warning,

one that is issued with sufficient lead time for dissemination and response, was not achievable. Officials from the city of Rogers and Hennepin County, along with media in the Minneapolis-St. Paul area, were satisfied with the service from the WFO.

A Severe Thunderstorm Warning for the Rogers area (Hennepin County) was issued by the WFO at 9:43 p.m., nine minutes before the tornado began. That warning message stated that a Tornado Watch (issued by the SPC at 5:10 p.m.) was also in effect for the warned area. The Severe Thunderstorm Warning did not contain an explicit call-to-action statement indicating the possibility of tornadoes occurring in severe thunderstorms. NWS Instruction 10-511 states this type of statement should be included with Severe Thunderstorm Warnings when a Tornado Watch is in effect.

The WFO Chanhassen staff began sectorized warning operations shortly before the line of severe thunderstorms moved into the Rogers area. This change to their operations was to increase the number of meteorologists analyzing radar data, however the timing of the process briefly impacted the efficiency of their warning operations. This, combined with the difficulty of discerning the storm characteristics suggestive of a tornado, impacted the production of a timely tornado warning. An additional meteorologist on duty would have made their operation more efficient. Absent an additional person, lower priority duties should have been delayed or shed.

The lack of real time storm reports had an impact on the warning decision process. However, due to the time of night and the local topography, it is not uncommon for storm reports to be delayed.

Future improvements planned for all NWS WSR-88Ds have the potential to provide information that would have been beneficial in the warning process for the Rogers tornado. These improvements include Super Resolution, Faster Volume Coverage Patterns, Dual Polarization, and 3-Dimensional Displays. Access to local Terminal Doppler Weather Radar data from the FAA could also have been beneficial.

Findings and Recommendations

Finding 1: Under optimum circumstances, given data available to forecasters at the time, the earliest a Tornado Warning could have been issued for the storm which struck Rogers, MN, on September 16, 2006, would have been concurrent with its development, approximately 9:52 to 9:53 p.m. Subsequent data, available after 9:54 p.m., could have contributed to issuance of a tornado warning anytime after approximately 9:55 p.m., depending on operational efficiency. Decisions by WFO Chanhassen staff on distributing forecaster analysis tasks (“sectorizing”) and warning product preparation resulted in a warning not being issued until 10:04 p.m.

Recommendation 1a: The NWS Severe Storm Program Leader and the Warning Decision Training Branch should develop a training exercise based on the Rogers event to reaffirm best practices associated with “sectorizing” warning operations. Emphasis should be placed on issues such as making early decisions to sectorize and maintaining forecaster continuity with ongoing

storms as much as possible. The case study should be distributed to all field offices by February, 2007.

Recommendation 1b: As part of its effort to transition from county-based to storm-based Tornado Warnings during 2007 and 2008, the NWS Severe Storm Program Leader should incorporate lessons learned from the Rogers event into forecaster training for production of storm-based warnings.

Finding 2: Staffing at WFO Chanhasen was adequate to handle this event, however, the need to sectorize operations resulted in a less than optimum staffing situation. An additional forecaster, especially one who had been involved with ongoing events, would have been beneficial.

Recommendation 2: The Regional Director will reemphasize in the upcoming December regional meeting of Meteorologists and Hydrologists in Charge the importance of adequate staffing for potential high-impact events and the operations concept of “load sharing,” whereby lower-priority duties can be passed to neighboring WFOs during warning operations.

Finding 3: A Severe Thunderstorm Warning was issued for the Rogers area at 9:43 p.m., nine minutes before the storm produced a tornado. The warning did contain a statement that a Tornado Watch was also in effect for the area, but it did not contain the required statement (NWS Instruction 10-511), when a tornado watch is in effect, that a severe thunderstorm can produce a tornado. Such a statement must be “toggled” on during warning product preparation.

Recommendation 3: The NWS Severe Storm Program Leader should investigate the feasibility of developing a software enhancement to automatically include the required tornado potential statement in any severe thunderstorm warning issued within a tornado watch area.

Appendix A

Fujita Tornado Intensity Scale

The Fujita Tornado Intensity Scale is a scale of damage intensity in which wind speeds are inferred from an analysis of wind damage.

Category	Definition	Effect
F0	less than 73 mph	Light Damage – Some damage to chimneys; break branches off trees; push over shallow-rooted trees; damage to sign boards.
F1	73 to 112 mph	Moderate Damage - Peels surface off roofs; windows broken; trailer houses pushed or overturned; trees on soft ground uprooted; some trees snapped; moving autos pushed off the road.
F2	113 to 157 mph	Considerable Damage - Roof torn off frame houses leaving strong upright walls standing; weak structures or outbuildings demolished; trailer houses demolished; railroad boxcars pushed over; large trees snapped or uprooted; light-object missiles generated; cars blown off highway; block structures and walls badly damaged.
F3	158 to 206 mph	Severe Damage - Roofs and some walls torn off well-constructed frame houses; some rural buildings completely demolished or flattened; trains overturned; steel framed hanger-warehouse type structures torn; cars lifted off the ground and may roll some distance; most trees in forest uprooted, snapped or leveled; block structures often leveled.
F4	207 to 260 mph	Devastating Damage - Well-constructed frame houses leveled, leaving piles of debris; structures with weak foundation lifted, torn, and blown some distance; trees debarked by small flying debris; sandy soil eroded and gravels fly high in the wind; cars thrown some distance or rolled considerable distance finally to disintegrate; large missiles generated.
F5	261 to 318 mph	Incredible Damage - Strong frame houses lifted clear off foundation and carried considerable distance to disintegrate; steel-reinforced concrete structures badly damaged; automobile-sized missiles fly through the distance of 100 yards or more; trees debarked completely; incredible phenomena can occur.

Appendix B

Warning/Watch/Statement Product Timeline from WFO Chanhassen September 16, 2006

Time	Product	Issued for	Expiration
5:10 pm	Tornado Watch*	Northwest Iowa and Central and Southern Minnesota	1 am (17 th)
5:18 pm	Tornado Warning (TOR)	Swift/Chippewa Counties, MN	6 pm
6:58 pm	Severe Thunderstorm warning (SVR)	Yellow Medicine / Renville/ Redwood Counties, MN	8 pm
7:43 pm	SVR	Kandiyohi County, MN	8:30 pm
7:51 pm	TOR	Southeast Yellow Medicine and Redwood Counties, MN	8:15 pm
8:02 pm	TOR	Renville County, MN	8:45 pm
8:23 pm	SVR	Meeker County, MN	9:15 pm
8:33 pm	SVR	Mcleod County, MN	9:30 pm
8:48 pm	SVR	Wright and Carver Counties, MN	9:30 pm
9:27 pm	SVR	Martin County, MN	10:30 pm
9:32 pm	SVR	Blue Earth and Faribault Counties, MN	10:30 pm
9:37 pm	Special Weather Statement – Significant Weather Alert	Wright and Hennepin Counties, MN	10:30 pm
9:43 pm	SVR	Wright and Hennepin Counties, MN	10:30 pm
10:02 pm	SVR	Waseca County, MN	11:00 pm
10:04 pm	TOR	Anoka County, MN	10:30 pm
10:29 pm	SVR	Chisago/Anoka/Washington/Hennepin Counties, MN	11:30 pm
10:56 pm	TOR	Anoka and Hennepin Counties, MN	11:30 pm
11:15 pm	SVR	Polk County, WI	12:15 am
11:28 pm	SVR	Chisago County, MN	12:00 am
11:44 pm	SVR	Waseca/Steele/Freeborn Counties, MN	12:45 am

*: The Storm Prediction Center issues Tornado Watches