The Benson, MN Tornado of June 11, 2001

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ABSTRACT

A severe weather outbreak over the three days of June 11-13, 2001 helped set a record number of tornadoes for the annual total of 32. Throughout the morning of the 11th, surface conditions became favorable for a severe weather event. Recent rainfall increased soil moisture across Iowa, Illinois, and Missouri readily evaporated in the clear conditions prior to the 11thhelping to raise surface moisture levels. The peak of the agricultural season added the process of transpiration to increase the moisture content also. As the moisture advected into central Minnesota it collided with a surface warm front and upper level short wave to produce a synoptic lifting mechanism. The increasing instability of atmosphere allowed for a strong F2 tornado to break out in Benson, MN as with a string of smaller tornadoes in the three days period as the low pressure system moved across the central part of the state.

Introduction

2001 was a record year for tornado outbreaks across Minnesota. Between the three days of June 11-13, 2006 there were 32 tornadoes reported, accounting for nearly half of the annual reported tornadoes witnessed in Minnesota that year. On June 11, 2001 around 3:00pm a strong F2 tornado ripped through Benson, MN causing over ten million dollars in damage. The eight mile long path damaged 71 structures, leaving four homes and seven businesses condemned. No deaths occurred possibly due to the public knowledge of the threat for severe weather from the SPC, but seven people were injured during the storm.

Several days prior to the 11th, the National Storm Prediction Center recognized the potential threat for severe weather in Iowa, Minnesota and Wisconsin. As the 11th approached the potential for severe weather was only increased, and warnings were issued. After a week of quiet weather a surface warm pressure center moved toward Minnesota, situating a warm front through the central part of the state. The location of the front and moist, warm air advection from the Corn Belt States provided ample instability in the atmosphere over central Minnesota. As soon as a lifting mechanism was initiated the instability of the atmosphere caused the storms to become severe rather than convective rainshowers. The Benson tornado was the largest tornado spawned of the nine touchdowns in Swift County alone.

Data

The University of Wyoming site provided observational soundings and was used to determine the actual conditions across Minnesota throughout the day of the 11^{th} of June 2001. Since observations were only documented on the 0z and 12z hours (with the exception of 18z run on this particular day with weather occurring) the Eta model run is used to evaluates times in-between missing data at times right before and after the tornado. The largest tornado is documented to have occurred at approximately 3:07 pm in Benson. Most data evaluated is from 20z on the 11^{th}, just before the tornado touched down. Nearly all data was processed using the program of GARP. Hand analysis of potential temperature and equivalent potential temperature on cross sections across the warm front and moisture gradient provides knowledge of location of convective plumes and where the tornado likely formed.

A conceptual model of the dynamics of a tornado and a miller diagram of the Midwest area plainly illustrate the most important features contributing to the severe weather outbreak. Radar functions of base reflectivities and velocity data are used from outside sources since GARP data was unavailable to determine radar signatures of severe weather and forecasting ability. The exact location of the tornado can be observed with the radar and satellite data as well. Following the radar returns will show the series of tornadoes associated with the outbreak.

Mesoscale Analysis

The large synoptic flow patterns across the Midwest were favorable to support a severe weather outbreak. The National Storm Prediction Center evaluated the risk up to two days prior to the string of tornadoes across Minnesota and Wisconsin from the 11-13. Figure 1 shows the large scale flow of the atmosphere at several different levels. The 850mb temperature and height fields show the warm air advection from the south/southwest into Minnesota at 12z on the 11^{th}, about eight hours prior to the outbreak. The low pressure in the Dakota's have a warm front associated with it which stretches into Minnesota. At upper levels, the 300mb polar jet is north of Minnesota involved with a shortwave. Throughout the next 12 hours the jet marches eastward. The right exit region of the shortwave jet is positioned over central Minnesota provided a slight synoptic scale lifting mechanism for later in the day. The lifted index values and relative humidity shown in the lower left corner of Figure 1 show the air over Minnesota near saturation and LI values near -3, and only decreasing as the time of the storm approaches.

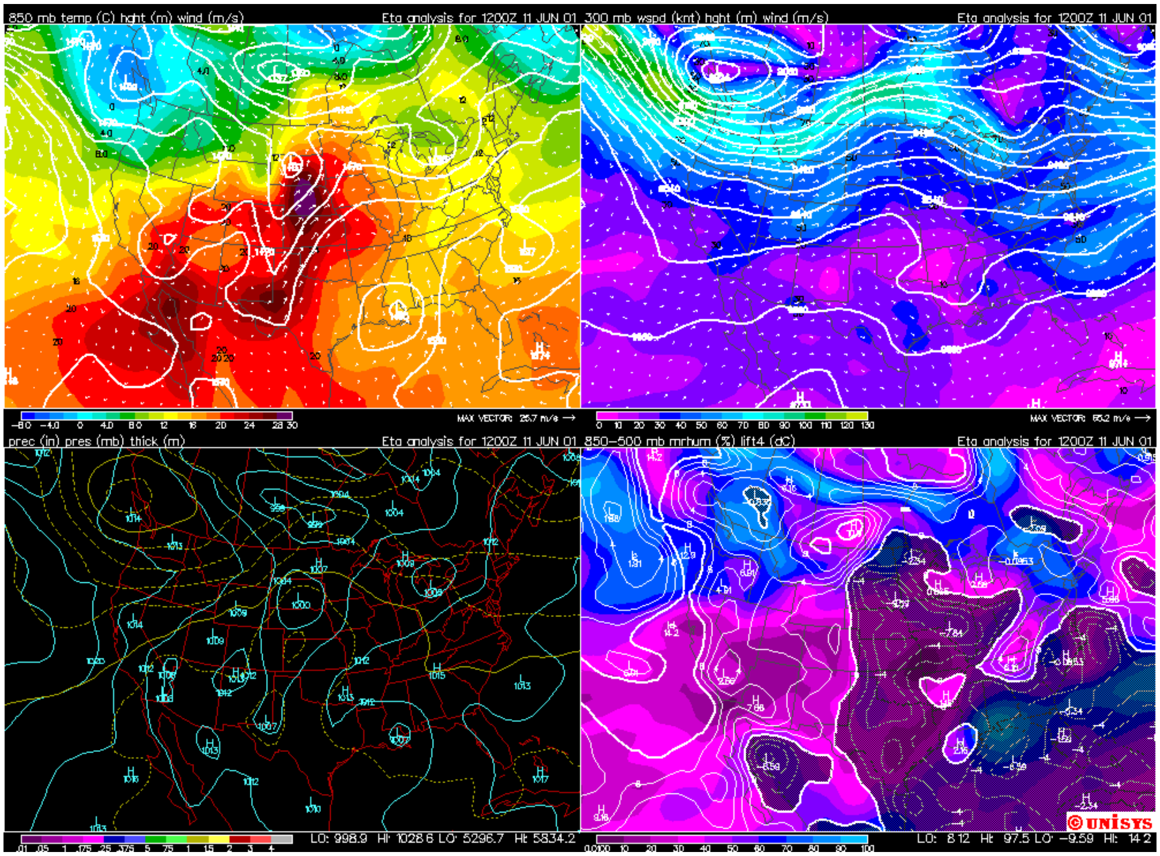

Fig. 1 four panel plot valid 12z on June 11, 2001 courtesy of Unisys

A zonally oriented warm front associated with a surface low pressure region in South Dakota stretched across the middle of Minnesota and into Wisconsin. During the early morning of the 11th, the southern part of Minnesota experienced clear skies. Surface temperatures rose into the mid-nineties due to the intense solar radiation and strengthened the warm frontal boundary already present, while the cloud covered northern part of the state only reached into the mid-sixties; this is seen in the surface observations in Figure 2 showing the surface temperature gradient and moisture gradient off to the west of Minnesota approaching. This stark contrast in temperatures and dewpoints create yet another surface boundary.

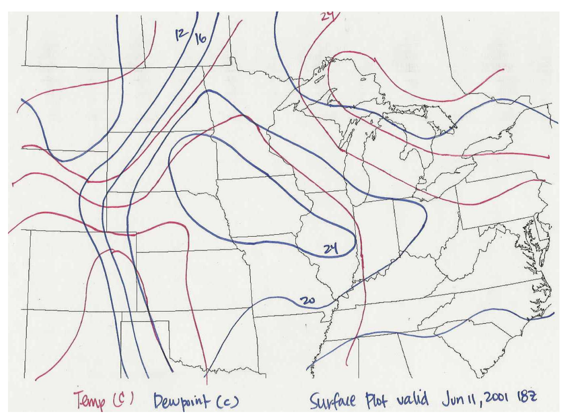

Fig 2 Surface temps and dewpoint valid 11 June 2001 20z

Throughout the day, surface winds from the south increased as the low pressure region and pressure gradient moved closer to Minnesota. The increase in surface wind intensity brought forth the hot, moist air from the Iowa, Missouri, and Illinois. Since winds along the Gulf coast were northerly, due to a tropical storm system, it has been suggested by Cheresnick and Basara, 2005, that the high moisture content in the Central Plains State's is a combination of both evaporation from recent rainfall and transpiration from the agricultural fields of the area. The dewpoint temperatures increased so the dewpoint depression across the warm front section was a few degrees. In the Dakota's the surface winds came from the north, bringing cooler, dry air in behind the moist air. Figure 2 shows the apparent moisture gradient from different sources. This surface boundary, along the warm front, helped assist as a lifting mechanism for the convection in Minnesota on the 11th through the 13th. The entire period of time as the low pressure system moved across the state the moisture gradient was present.

Mesoscale Analysis

After evaluating the importance of the synoptic flow moist air advection from the Corn Belt States, a closer look into the dynamics near Benson, MN at 20z on the 11th is assessed. Surface observations taken from the west of Benson at Aberdeen, SD and east of Benson at Chanhassen, MN at 18z on the 11th are seen in Figures 3 and 4. By 18z the surface front had passed over Aberdeen, bringing southerly winds at the surface behind the front. The progression of the front can be seen in a cross section of theta and theta e taken from the same two stations on Figure 5. The surface boundary layer is still saturated and a dry layer is evident at 800mb. The sounding of the wind

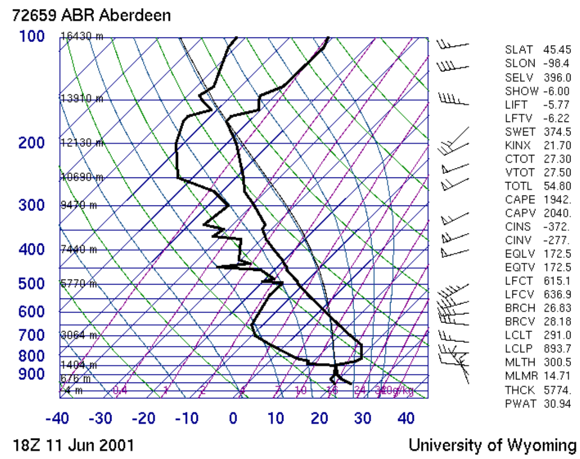

Fig 3 Skew T valid 18z on the 06-11-01

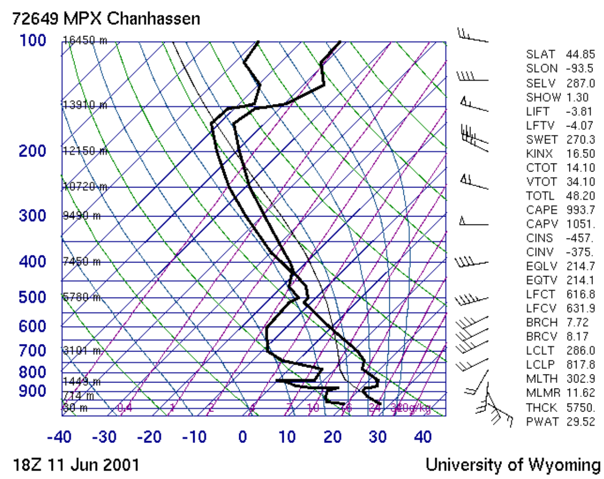

Fig 4 Skew T valid 18z on the 06-11-01

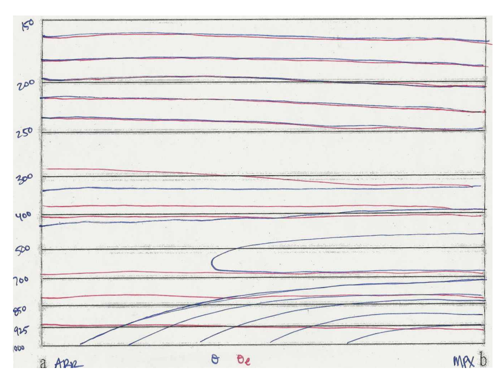

Fig 5 theta and theta e cross section from Aberdeen to Chanhassen valid 18z on the 06-11-01

profile at Chanhassen, MN is similar to what Benson would be experiencing close to 20z when the tornado happened. The surface layer was near saturation, and a small inversion was present at low levels between 900mb and 800mb. This inversion helped to create a substantial cap, which in turn created a large layer of CAPE. The cap was not too strong, but just strong enough for the conditions, so when it was breeched it was the trigger to the loaded gun sounding and deep convection was allowed to happen.

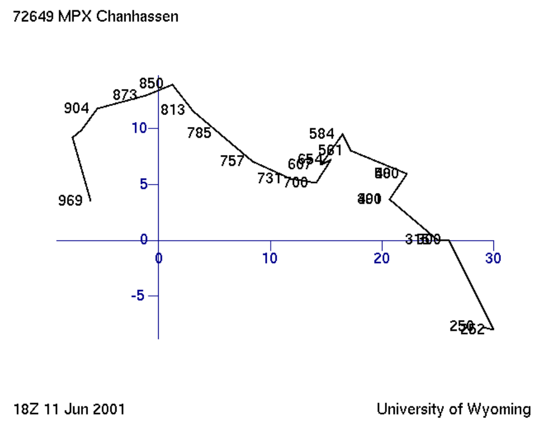

Fig 6 hodograph valid 18z on the 06-11-01

The drier air from the west behind the front provided instability over the very warm moist air. The LFC layer was as low as 770mb, and the EL was under 200mb provided a very significant amount of CAPE. The CAPE, reaching as high as 4000 J/Kg around the time of the tornado was estimated in a special sounding of the Benson area. The vertical wind shear is evident in the sounding profile. A hodograph, figure 6, displays the increasing vertical shear with height. Veering with height is also shown and creates an environment favorable of severe weather due to an increase in helicity. A conceptual model is shown in Figure 7 to demonstrate the inflow into the storm by the moist air and the outflow. Under the right conditions, as it was in Benson, a tornado can be produced.

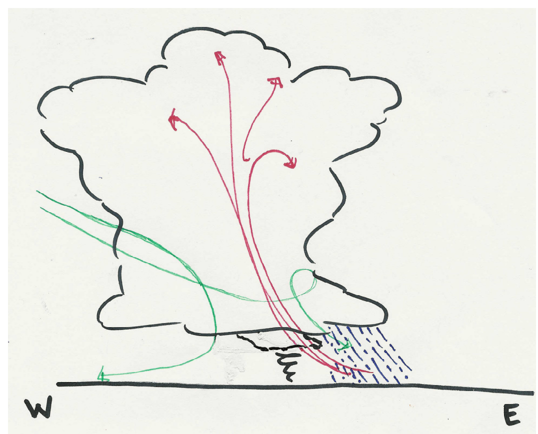

Fig 7 conceptual model of tornadic supercell

Satellite imagery near the time of 20z show the cold convective cloud tops of the mesoscale convective complex that would soon move through Benson as it becomes more developed (Figure 8). Radar data shows more of the MCC structure than the satellite data. The cell had a developed structure all the way up to 200mb. Velocity data showed some rotation evident before hitting Benson in Figures 9-10. In reality the system did not look impressive until later that afternoon when a strong bow echo region developed. Multiple tornadoes were produced but none at the strength of the F2 Benson tornado. The rotational aspect of the storm allowed the National Weather Service to issue a warning to the Benson area.

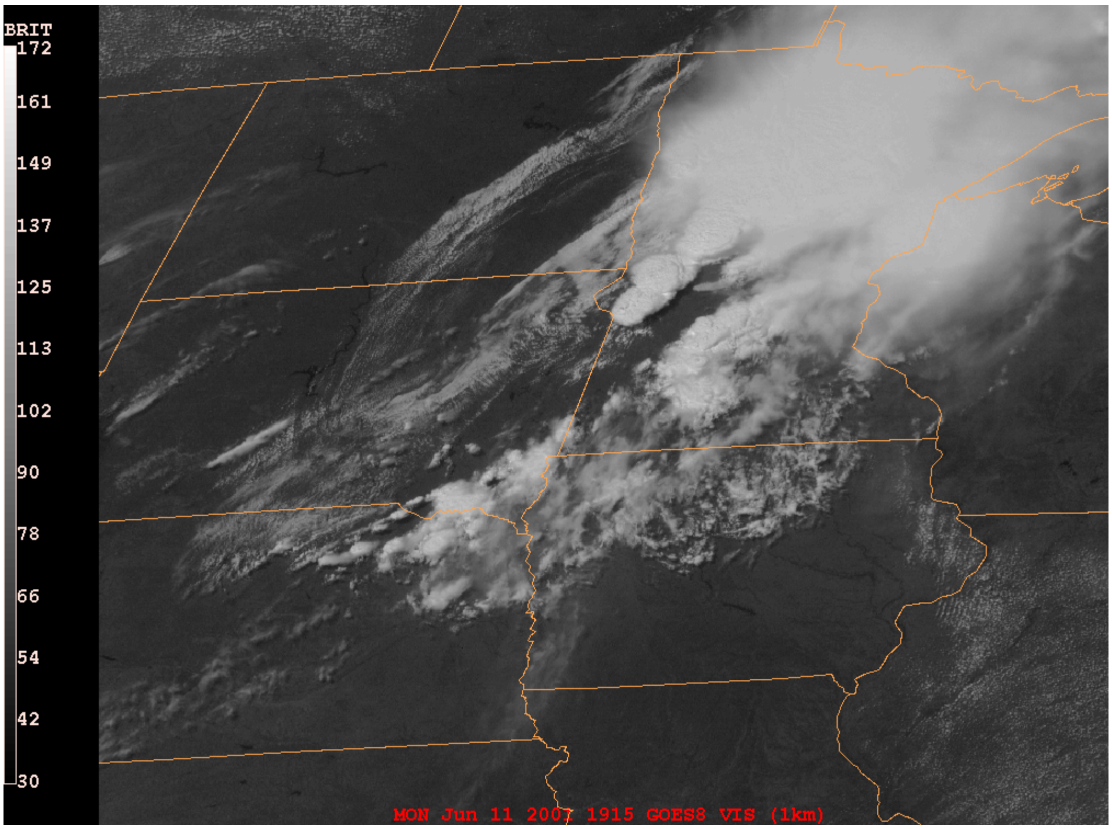

Fig 8 satellite image valid 06-11-01 at 19:15

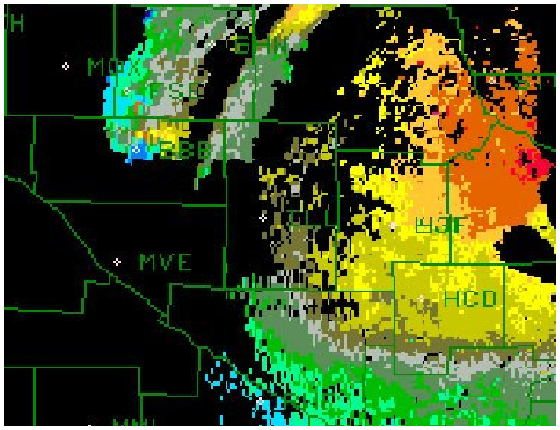

Fig 9 velocity image valid 06-11-01 at 20z

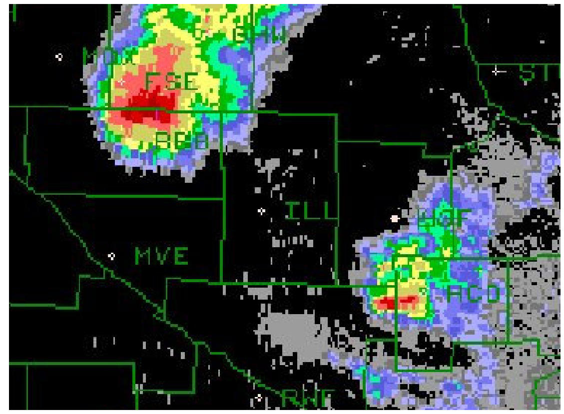

Fig 10 radar image valid 06-11-01 at 20z

Conclusion

Synoptic conditions around Minnesota through the days of June 11-13, 2001 allowed for a severe weather outbreak across the center of the state. Two distinct air masses, a warm moist surface layer advected from the south, and a cooler, dry mass from the west clashed along a warm front on the 11th creating a sizable amount of instability. The source of the low level moisture was extremely important for the production of severe weather in mid-June. Because of the tropical storm system in the Gulf at the time, the usual moisture flow provided by the southerly flow from the Gulf was absent. Surrounding local conditions from the agricultural season made transpiration and evaporation possible and added significant moisture to the air to be advected into Minnesota.

The synoptic weather pattern provided a lifting mechanism to initiate convection in central Minnesota. A loaded gun sounding was produced, and a large F2 tornado ripped through Benson, MN shortly after 3pm on the 11th. Unstable conditions continued throughout the week as the low pressure region drifted eastward allowing for a large tornado outbreak along the progressing warm front. Knowledge of the instability was acknowledged and assessed by the SPC to prevent numerous injuries to the entire central part of Minnesota.

References

Cheresnick, D and Basara, J: 2005. *The Impact of Land-Atmosphere Interactions on the Benson, Minnesota, Tornado of 11 June 2001*. BAMS, 637-624.