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The Greensburg, KS Tornado

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1. Background

The tornado that moved through Greensburg, KS the evening of 4 May 2007 destroyed much of the town. The damage was so massive that it earned the first ever EF-5 rating. The tornado damage was the first to be rated a 5 since the Oklahoma City, OK tornado of 3 May 1999.

This paper will review the synoptic set up for this particular outbreak that produced 18 tornadoes in the Dodge City Forecast Area and 47 tornado reports in Kansas, Nebraska and Missouri. The outbreak resulted in thirteen fatalities and at least 70 injuries while destroying 90% of the town of Greensburg.

Since the year 2000, only 0.4% of all tornadoes were considered violent with damage ratings of F4 or F5. No tornado damage was considered to be F5 since the Moore/Oklahoma City, OK on 3 May 1999. Much of the reason for this was that the tornado that extended from Bridge Creek, OK through southwest Oklahoma City into Del City, OK may have set the standard for F5 damage. Another part could be that the FEMA Building Assessment Report (2000) analyzed thoroughly how homes and buildings sustained damage in the 3 May 1999 event.

After that report, many years were spent training Storm Assessment Teams to evaluate the structural integrity of the damage and learn how to assess the strength of structures in order to better estimate tornado winds (Marshall, 2002).

Many tornadoes since 2000 resulted in widespread damage, i.e. Hallam, NE which had a 2-mile maximum path width resulting in F4 damage, and the Marmaduke, AR tornado which had a 45-mile path length and destroyed 176 homes and buildings with damage rated at F3. But, very few F4 damage reports were made, and no damage achieved F5 criteria.

2. Enhanced Fujita Scale

In February, 2007, the National Weather Service implemented the Enhanced Fujita Scale (McDonald and Mehta, 2006) in order to improve damage assessments from tornadoes. The EF-Scale has 28 Damage Indicators (DI). Each Damage Indicator has Degrees of Damage (DOD) ranked from the weakest to the

strongest with a lower bound and upper bound of the expected wind speed associated with the damage. Wind speed estimates with the EF-Scale are made using a 3-sec wind rather then a ¼-mile wind in the legacy scale. Table 1 shows a comparison of the wind speeds between the two scales.

The EF-Scale makes assessment more consistent from one geographic region to the next. With the numerous DIs and the ratings ranging from the weakest to the strongest structural integrity, evaluating the damage and estimating the associated tornado wind speed makes the task easier for meteorologists to perform damage surveys.

3. Synoptic Conditions

A strong middle- to upper-level system was digging southeast over Nevada at 00 UTC on 5 May 2007. Figure 1 shows tight thermal gradient in the southwest quadrant of the trough coincident with the strong 60-70 kt jet streak. The exit region of the upper level jet was over south central Colorado with an area of well defined diffluent flow over northeast Colorado and western Kansas.

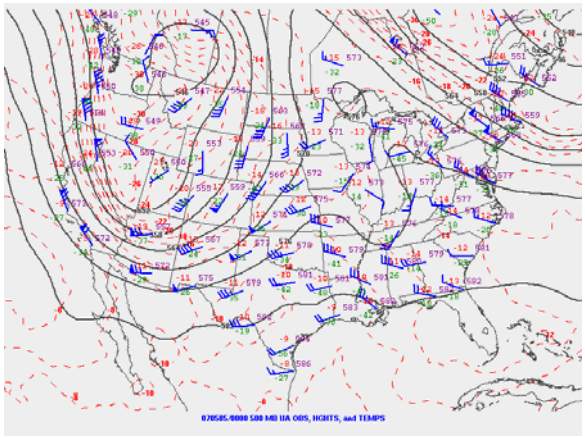

Figure 1: 5 May 07 500 hPa analysis.

With the middle- and upper-level low over the Great Basin, low level flow was being drawn northward from the Rio Grande River Valley into western Oklahoma and central Kansas into south central Nebraska along and east of a strong dry line boundary. By 2000 UTC, surface dew points (not shown) ranged from the low to middle 60s across central Kansas to around 70 degrees across central Oklahoma. Figure 2 shows the DDC thermodynamic plot showing the passage of the dryline by 00 UTC.

Figure 2: Thermodynamic plot at DDC 5 May 07 at 00 UTC. Lighter purple plot is the data from4 May 07 at 12 UTC.

Also quite evident is the evening well mixed layer with steep low- to mid-level lapse rates and deep layer shear. A look at the OUN sounding (Fig. 3) shows the deep moist layer that was advecting northward into central Kansas ahead of the dryline the evening of 4 May 2007. This led strong credence to the forecast soundings valid for 03 UTC 5 May 2007 from the NAM and the RUC for Pratt, KS (Fig. 4) showing a quite favorable sounding to support

Figure 3: Thermodynamic diagram for OUN 5 May 07 at 00 UTC. Purple plot is data from 12 hours prior.

supercell storms with a strong hodograph.

The Storm Prediction Center uses a tool called the Sounding Analog System which analyzes a database of historical data to find similar thermodynamic profiles. In this case, the program equated the profiles to such cases as 3 May 1999, 30 May 2004 and 25 April 2003.

Figure 4: Point Forecast Sounding valid 03 UTC from the 00 UTC run of the Rapid Update Cycle model.

The Significant Tornado Parameter which takes into account 0-1km helicity, mixed-layer CAPE, 0-6km shear and mixed layer LCL height, indicated values of 7. Minimal conditions for a significant tornado occur with a parameter value of 1.

4. Storm Development

Initial storm development occurred over the northern Texas panhandle/Oklahoma border on 4 May 2007 at 2210 UTC. Infrared satellite imagery (not shown) indicated the exit region of the southern branch of the middle- to upper-level jet to be extending eastward through central New Mexico into the southeast Texas panhandle. Surface analysis from 05 May 2007 at 2100 UTC (Fig. 5) showed this location to be in a favorable location on the surface dry line. As the mid- to upper-level flow increased, and the low level jet (Fig. 6) increased to 40-50 kt from north central Texas through eastern Kansas, enhancing moisture flux convergence through western Oklahoma into south central Kansas just east of the dryline.

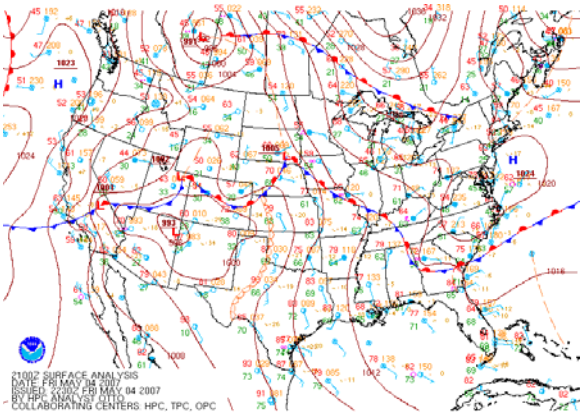

Figure 5: HPC Surface Analysis at 2100 UTC 4 May 2007.

Several cells developed over northwest Oklahoma, a tornado at

2321 UTC around Arnett, OK damaged a house, a garage and a barn. New storm developed over Harper County in northwest Oklahoma becoming a supercell as it crossed over the Kansas/Oklahoma border at 0045 on 5 May 2007.

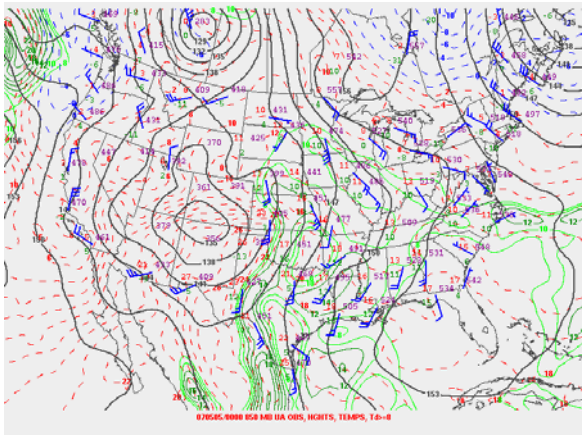

Figure 6: 00 UTC 5 May 07 analysis at 850 hPa.

The cell that eventually produced the Greensburg, KS tornado developed over north central Harper County, Oklahoma at approximately 0050 UTC moving north-northeast at 40-45 kt. The cell first developed its hook signature by 0106 UTC over south central Clark County prompting a tornado warning for Clark and Comanche counties at 0113 UTC.

This storm seemed to recycle between 0130 UTC and 0148 UTC as radar continued to indicate a strong middle-level mesocyclone. By 0200 UTC, reflectivity was near 70 dBz up to 44000 feet and still showing a persistent mesocyclone circulation with nearly 50 kt of shear. A tornado warning was issued at this time for Kiowa County. The storm rapidly developed a second hook signature much stronger that the last time. By 0225 UTC, radar showed its second TVS signature with maximum shear to 80 kt! Figure 7shows a plot

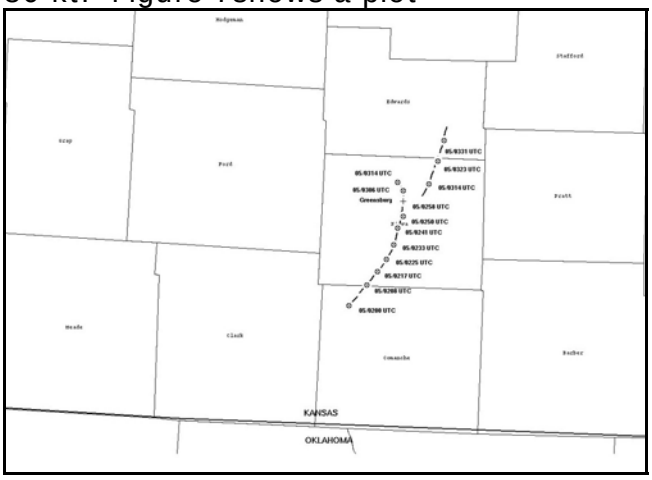

Figure 7: Plot of the mesocyclone centroid associated with the supercell that produced the Greensburg, KS tornado.

of the mesocyclone signature associated with the Greensburg, KS tornado and the development of the second tornado that developed coincident with the end of the Greensburg tornado just northeast of town.

The 30-minute lead time provided by the NWS DDC Weather Forecast Office allowed broadcast media, emergency and city management to broadcast the warning and sound the sirens in Greensburg.

5. Damage Survey

Much of the town of Greensburg was destroyed by the tornado that had a 1.7 mile maximum path width and a 22 mile path length. The damage clearly showed how the tornado moved northeast into the southwest part of town before turning northward, seemingly down Main St. Greensburg.

Many of the homes along and west of Main St. were swept off their

foundations. Included in the damage was the water tower above the "World's Largest Hand-Dug Well," which was estimated to be holding 55000 gallons of water at the time of the tornado.

The rating of EF-5 was merited along this area of Main St. that included Greensburg High School built in 1939. The walls to the high school were built with two layers of brick and mortar for the outside wall and a layer of concrete block and mortar for inside wall support. In addition, a ¾-inch layer of plaster made up the inside layer of the wall (Fig.8). Many of these walls crumbled in the tornado damage. The elementary school located just southeast of the high school also sustained significant damage with only part of the west wall remaining.

Figure 8: Damage to southwest wall to Greensburg High School. (Larry Ruthi, 2007)

It is estimated that 85% of the structures in Greensburg sustained severe damage. It was difficult to research original locations of automobiles and other projectiles as the town was totally evacuated for safety reasons. Fig. 9 is a photograph looking north from US 54 illustrating the heavy stripping of trees and homes through Greensburg.

Figure 9: Looking north through Greensburg, KS from the western end of U.S. 54.

Using the EF-Scale, the NWS Quick Response Team worked with the NWS DDC staff to determine the scale related to the damage from the tornado. Using the EF-Scale documentation and EF-Kit, a software program to use to evaluate storm damage, it was determined that the structure at the elementary and high schools was at least EF-4 damage.

However, given the structure of the high school and the hospital, it was thought that the descriptions in this particular case may have been insufficient. The Damage Indicator for an institutional building given that these buildings had masonry walls indicated that slightly stronger winds, or multiple vortices, enhanced the damage. Plus, the number of homes swept clean with little trace of debris led the team to the EF-5 rating with winds estimated between 200 mph and 210 mph.

6. Conclusions

The large tornado that tracked through Greensburg, KS the evening of 4 May 2007 was the most significant tornado event in the last eight years. The tornado is recorded as having a maximum path width of 1.7 miles and a path length of 22 miles causing surmountable damage to a town that had a population of nearly 1600 people.

The message highlighting the threat for severe weather in the Greensburg, KS area began with the Day 4-8 Outlook issued by the NOAA Storm Prediction Center the morning of 1 May 2007. The Hazardous Weather Outlook issued by the NWS office in Dodge City also conveyed the threat for severe weather seven days in advance. By the morning of 4 May 2007, a moderate risk of severe storms was issued with a 15% probability for tornadoes as well as at least a 10% probability that tornadoes could produce EF-2 to EF-5 Damage.

The tornado watch for the area was issued at 1815 UTC and included the wording announcing a particularly dangerous situation. Then, the tornado warning for Kiowa County was issued at 0156 UTC on 5 May 2007, 32 minutes before the tornado entered the southwest parts of the county.

While ten people in the town lost their lives while 70 people were listed as injured, the small number of fatalities from such a significant storm is a tribute to the cooperation between NWS personnel, broadcast media, emergency officials and the people of Greensburg to respond properly and quickly to keep the loss of life minimal.

References

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