OVERVIEW OF THE 24 MAY 2011 TORNADO OUTBREAK

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ABSTRACT

On 24 May 2011, 12 tornadoes impacted different parts of the state of Oklahoma. Three of these tornadoes were violent and impacted the greater Oklahoma City-metro area. The highlight of the event was the low death toll given the violent tornadoes proximity to dense populations. Damage surveys following the event revealed a number of stories from impacted citizens of a heightened awareness to the weather, even with limited information of the on-going threat. This presentation will provide an overview of the event, the proceeding damage surveys, stories from impacted citizens and other highlights of the event, including collection of mobile radar data on two of the day's tornadoes.

1. Introduction

Severe weather was widespread on 24 May 2011. Severe weather occurred from Western Kansas to Northern Texas and began early in the morning and continued until late in the evening (Fig. 1). This paper will focus on the portion of the event which occurred within the Norman weather forecast office county warning area (CWA).

The event within the Norman CWA yielded

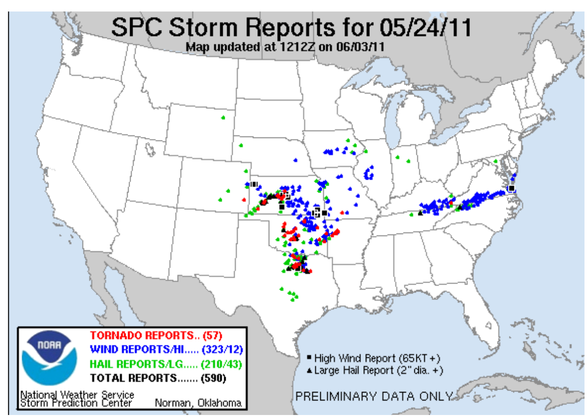

Figure 1: Storm reports map from 24 May 2011 (Courtesy Storm Prediction Center; http://www.spc.noaa.gov)

a total of 12 tornadoes produced by 5 main supercell thunderstorms. These tornadoes spanned the EF-scale with the subsequent

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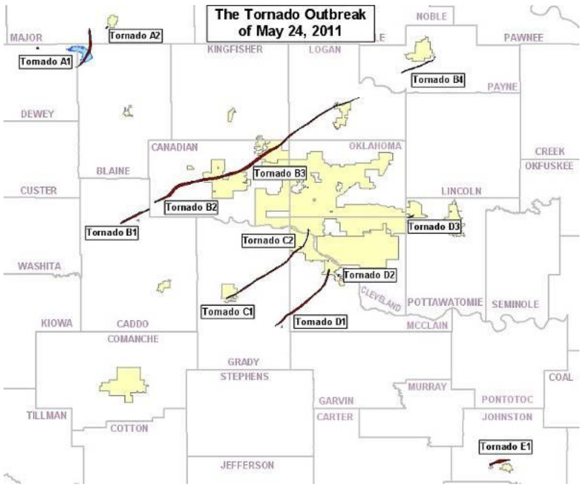

Figure 2: Overview map of the tornado paths on 24 May 2011 (Courtesy WFO Norman; http://www.srh.noaa.gov/oun/?n=events-20110524)

ratings of the damage caused: 1 EF-5, 2 EF-4, 2 EF-3, 2 EF-2, 2 EF-1 and 3 EF-0 (Fig. 2).

The 24 May 2011 event was noteworthy for several reasons. First, this event was only a few days following the Joplin, MO, tornado and almost 1 month following the outbreak of 27 April. Second, 3 of the violent (EF-4+) tornadoes on the day occurred near the Oklahoma City-metro area and yet only 11 fatalities occurred among all tornadoes (though, 293 people were injured). Third, the reason for this low fatality count may be the incredible reaction of the community to not only watches and warnings, but also to the forecast of severe weather on this day.

This paper will summarize different aspects of this day mostly through a story telling approach to highlight some good, and some bad, aspects of this outbreak concerning the response by the public. The paper will also summarize meteorological aspects of the event, such as the collection of mobile radar data and discussions about the EF-scale following damage surveys.

2. Weather summary

A potent mid-level shortwave was translating across the US Southwest. The trough axis moved from approximately from the Arizona/New Mexico border at 12Z to Eastern Texas Panhandle at 00Z (Fig. 2). This led to significant mid-level height falls across Oklahoma. The approach of this shortwave also contributed to strong shear and incredibly high values of storm-relative helicity; the observed 00Z hodograph from FWD had over 500 m^2s^{-2} of 0-3 km storm-relative helicity (Fig. 3). The surface was characterized by mid 80°F (27°C) temperatures with dew points near 70°F (21°C), leading to strong instability across

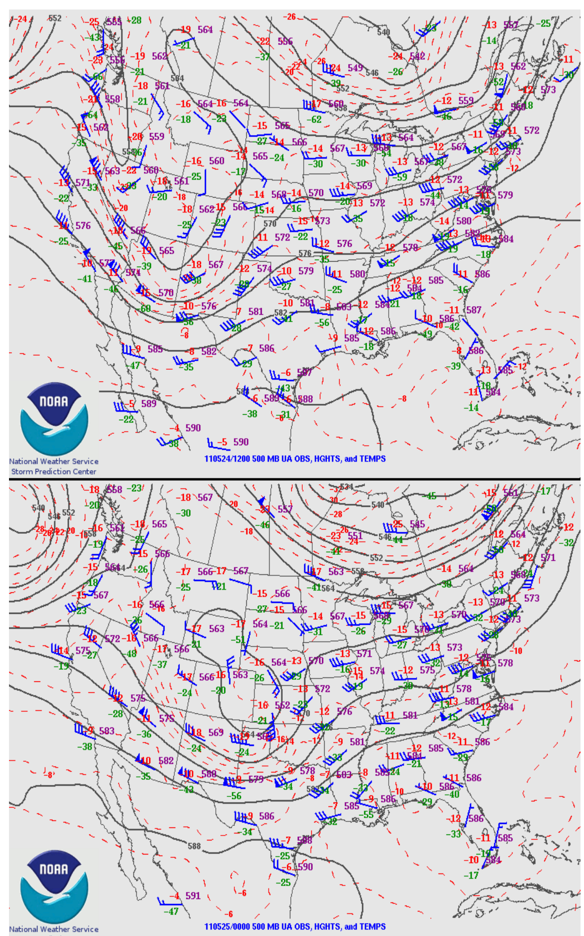

Figure 3: 12Z 24 May 2011 500 mb chart (top) and 00Z 25 May 2011 500 mb chart (bottom; courtesy SPC).

Oklahoma (Fig. 4).

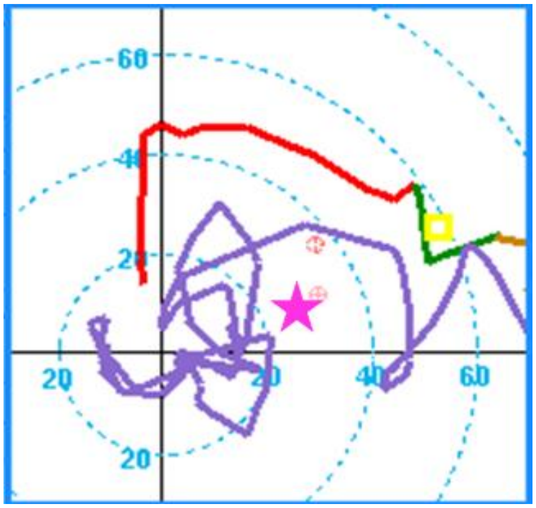

Figure 3: 00Z 25 May 2011 FWD hodograph. El Reno storm motion denoted by pink star.

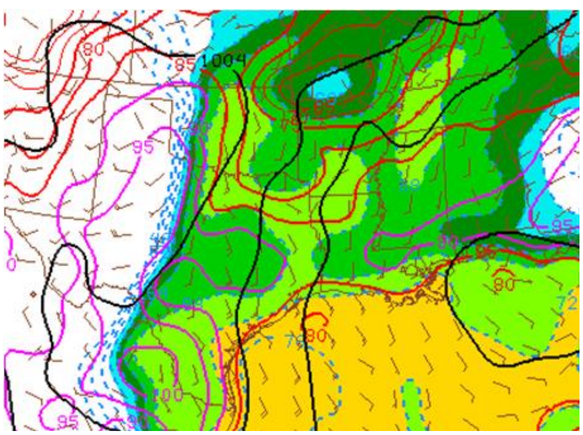

Figure 4: SPC Mesoanalysis at 21Z 24 May 2011. Surface pressure contoured with solid black lines; temperatures contoured with solid red/magenta lines; dew points solid fill and dashed lines.

3. Canton Lake Tornado

a. Canadian Campground

The Canadian Campground is located on the southwestern part of Canton Lake (Fig. 1; tornado A1) and is the largest campground

Figure 5: Remains of a concrete bathhouse which sheltered approximately 10 individuals during the tornado.

at Canton Lake comprising of 132 campsites and 69 trailer sites. The campsite is a pay site with a gate house for tracking entrances and exits of campers, thus allowing for tracking of how many campers were in the camp.

On the morning of 24 May 2011, 80 of the of the campsites and all of the trailer sites were occupied. Approximately 50% of the campers in the campground exited the camp prior to noon local time on 24 May—before a watch or warning was even issued. Another 20% left the campground before the first tornado warning for the location was issued (2000Z). When the tornado warning was issued, another 13% of the campers evacuated the camp, leaving approximately 20 people in the camp. Between 2000Z and when the tornado struck the camp, 2025Z, the remaining 20 or so campers took shelter at different locations in the camp: 1 individual slept as the tornado approached and was thrown with his camper (sustaining serious injuries), approximately 10 took shelter in a permanent residence on the west side of the camp while the rest sheltered in a concrete bathhouse (Fig. 5). The bathhouse was completely filled and had no more room to shelter more individuals.

Figure 6: Aerial photograph of the Canadian Campground at Canton Lake. North is towards the top of the image. Image courtesy Oklahoma Highway Patrol.

The camp was heavily damaged with a maximum EF-rating of EF-3 occurring on the grounds of the camp, yet with the exception of the 1 individual who was thrown with his camper, most injuries were minor (cuts and bruises sustained by those in the bathhouse and cuts from glass sustained by the gatehouse attendant; Fig. 6) and no fatalities occurred at the camp. This was the result of preparations by the individuals who left in the morning and prior to the first warning, the response of the individuals remaining at the camp to take shelter and a little luck (thrown camper and enough room in the bathhouse).

b. NOXP Data Collection

The National Severe Storms Laboratory (NSSL) operates a mobile, X-band, dual-polarimetric radar—NOXP; specific details on the radar can be found in Burgess et al. (2010).

NOXP deployed approximate 11 km east-southeast from the Canadian Campground. At the time the Canadian Campground was being struck, NOXP recorded peak winds within the tornado near 70 ms^{-1} (Fig. 7), while exhibiting a tornado debris signature (TDS; Ryzhkov et al. 2005).

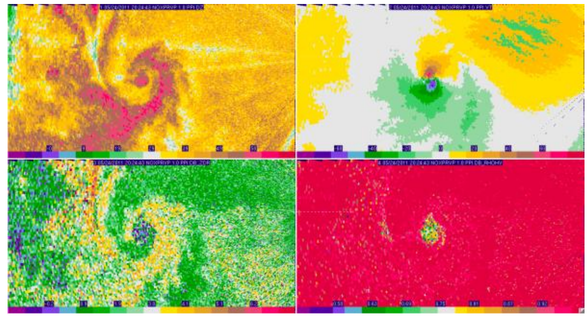

Figure 7: Radar data from NOXP at 202443Z 24 May 2011. Top-left: reflectivity; top-right: velocity; bottom-left: differential reflectivity; bottom-right: correlation coefficient.

4. EF-Scale Discussions

Following a week of several damage surveys, including multiple trips to multiple sites a number of discussions on the Enhanced Fujita (EF; McDonald et al. 2006) scale occurred among some of the authors and surveyors. Four major issues were discussed:

- EF-4 vs. EF-5 for wood frame homes
- Consistency of high-end ratings from the Fujita scale-era and consistency of other high-end EF-scale ratings
- Non-traditional, or not included in the EF-scale, damage indicators (DIs)
- Use of mobile radar data for use in rating tornadoes

a. Wood frame homes and consistency

The three tornadoes near the Oklahoma City-metro area (B2, C1, D1; Fig. 2) all had examples of homes in which the home was wiped clean from the foundation. Some of the homes were fairly new with construction having taken place within the previous 5 years. The EF-scale specifies a DI 2 (One- and two-family residences), degree of damage (DOD) 10 as "destruction of engineered and/or well constructed residence; slab swept clean."

The majority of the discussion was on the idea of "well constructed residence." There is no guidance explicitly stated within the EF-scale on well- versus poorly-constructed residences (McDonald et al. 2006). Doswell (2003), Marshall (2002) and Marshall et al. (2003) give assorted guidance and suggestions in surveying homes and in determining the quality of construction, and pitfalls in trying to determine F4 versus F5 (which could be used to help determine EF4 versus EF5).

In the discussions following the damage surveys, it was suggested that the 90 MPH Exposure B Guide of the Wood Frame Construction Manual (American Forest & Paper Association 2006) be used as a guide in rating residences (Mike Foster and Tim Marshall, personal communication). However, this brings about the problem of consistency with past F-scale or other EF-scale ratings. For example, houses which are built upon slabs-on-grade (i.e., concrete slabs poured on the ground directly) have a suggested spacing between bolts of 24 inches and that the bottom plates be secured with 3 inch by 3 inch plate washers, which would cover the entire width of the bottom plate. The obvious issue with this type of construction being used as the new standard for homes to be rated EF-5 is whether homes previously rated F- or EF-5 were not built to this standard. Given the WFCM was published in 2006, it would seem that there would have been homes rated F-/EF-5 that did not meet this standard. This then causes problems in either greatly fracturing the tornado climatology or causing the need for past tornadoes to be reevaluated with this new standard.

There were several discussions of specific homes and whether they could be considered for an EF-5 rating. Most of the homes seemed to have been easily disqualified for any number of reasons: older construction with poor, critical load paths (connections from the foundation to the roof), wide spacing between foundation anchor bolts, lack of top-plate to roof straps or clips and straight nailing of wall studs to bottom plates are among the more common reasons. However, one home at the end of Goldsby (D1; Fig. 1) path provided an interesting dilemma for those post-analyzing of the damage (Fig. 8).

Figure 8: Aerial and ground photographs of a home which was removed from its foundation towards the end of the Goldsby tornado path.

Two architects designed the home with improvements to make the home more tornado-resistant. The home was completely removed from the foundation (Fig. 8). It was determined that small washers (0.5 inch) were used on the anchor bolt-bottom plate connection, allowing for the home to be pulled off its foundation. These are all valid reasons for lowering the estimate of the damage intensity from EF-5 to EF-4. However, it is unknown if consistent reasons were considered in past surveys of "slabbed" homes that ended up with F5/EF-5 ratings. Also, it seems to suggest the need for a centralized database containing documentation (photographs with descriptions of the damage, construction and reasons for rating) of structures which were rated highly on the EF-scale.

b. Non-traditional Damage Indicators

The El Reno tornado (B2; Fig. 1) struck a very interesting structure: a 1.9 million lb natural gas drilling derrick and rig with over 200,000 lbs of down force on the drilling pipe (Fig. 9). The Cactus 117 site was, more or less, completely destroyed. The workers at the site took shelter in the site's bunkhouse, which was anchored to the ground through the use of 4 10,000 lb-rated straps and anchors (Jason Jordan, personal communication). One strap broke and a large objected landed on the bunkhouse causing a significant dent in the roof. The derrick itself was moved from its position and possibly rolled 2 or more times. The blowout preventer, which was underneath the rig and at its base, was bent at a significant angle.

Figure 9: Cactus Rig 117. The base of the rig can be seen in the middle of the image, with the mast lying towards the left and behind the tank on the left. The blowout preventer is seen in the foreground just to the right of the rig. Photo courtesy Derrick Brown

The El Reno tornado (which continued on to impact Piedmont), and the Chickasha and Goldsby tornadoes (B2, C1 and D1, respectively; Fig. 1), threw cars considerable distances. The furthest a vehicle was thrown was approximately 780 yards (Fig. 10). If research were completed to add vehicles as EF DIs, it would all for important new information to be used in the rating process.

Figure 10: An SUV which was thrown approximately 780 yards and landed in a thicket.

c. Using Mobile Radar Data in Ratings

The RaxPol radar (Pazmany and Bluestein 2011) was deployed near the El Reno tornado as it approached Interstate 40 (Fig. 11). Scans every 3 seconds for a several minute period from RaXPol showed radial velocities exceeding 100 ms^{-1} (Fig. 12).

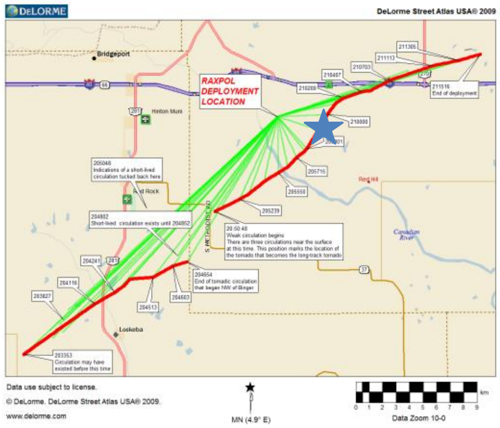

Figure 11: Map of the RaxPol deployment and approximate track of the tornadoes. The data shown is from the spot marked by the blue star.

However, the mobile radar data was only a small piece of what went into rating the El Reno tornado EF5. The measurements did occur near the Cactus 117 rig. Also, just to the west of Cactus 117 was a scrap yard which also had several buildings on site, including an auto repair shop, large garage and 2 buildings comprising a small grain storage facility. The repair shop and garage were destroyed, while the grain facility was damaged beyond repair. Further, several shipping containers were being used on site as storage and these were thrown over 100 yards. Across the street from the scrap yard, an older farmhouse was completely destroyed. The tornado also threw several vehicles (which unfortunately led to 5 fatalities) from Interstate 40 as it crossed the interstate east of where RaXPol deployed.

The mobile radar data were used in conjunction with the nearby damage of completely destroyed buildings, Cactus 117 and thrown vehicles and other large objects, to assign an EF-5 rating for the El Reno tornado.

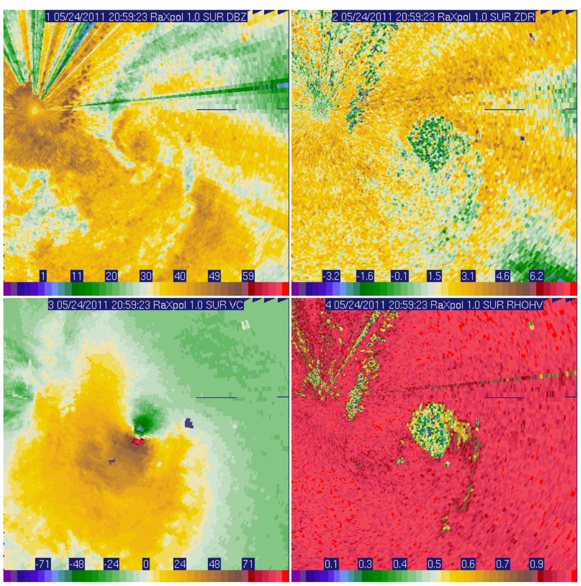

Figure 12: Radar data from RaXPol at 205923Z 24 May 2011. Top-left: reflectivity; top-right: differential reflectivity; bottom-left: velocity; bottom-right: correlation coefficient.

5. Societal Response

The preparation by the public and response to forecasts, watches and warnings was quite amazing. In question is whether the response was in reaction to earlier tornado events (27 April and Joplin) or only to the certainty and severity of the 24 May forecasts or to both. Many businesses and government agencies within Oklahoma City and the surrounding metro-area shut down early on the afternoon of the 24th. Tinker Air Force Base instructed their 2nd shift not to report for duty. Activities at schools and churches in the evening were cancelled, prompting local news stations to list these on their webpages (as is the case common for winter storm closings).

However, there were problems caused by these preparations by the public. "Rush hour" was moved from near the 5 o'clock hour to several hours earlier. While this would be expected, it was occurring just as storms were forming. If storms had moved faster or formed closer to the metro, there could have been thousands of people on the road as the storms were producing significant tornadoes.

Designated (and undesignated) public shelters were filling up many hours before even the first warning was issued. There were stories of individuals breaking into locations after they were turned away due to the shelter already being filled. Individuals would also show up with their pets, which caused problems at many locations. The National Weather Center on the University of Oklahoma's campus served as a shelter to almost 1,000 people even though it is not a designated public shelter (Fig. 13).

These issues need to be carefully considered as operational meteorology in the United States moves towards a warn-on-forecast

Figure 13: Photo from inside the main lecture hall in the National Weather Center during the 24 May 2011 tornado outbreak. Photo courtesy Bethany Hardzinski.

concept for high impact weather (Stensrud et al. 2009). Further, there's a need to understand how high-end events, such as 27 April and Joplin, affect the decision making for individuals who may not have been physically affected on later events—like the citizens of Oklahoma on 24 May.

During damage surveys of two of the tornadoes (B4 and D1 on Fig. 1) individuals stated that they were not receiving warning information via TV for the storm which ended up impacting them. Instead the TV stations were focused on the tornado nearest to Oklahoma City or those tornadoes which at the moment had live video associated with them. Several individuals along the Goldsby tornado path stated that they took shelter based on a visual spotting of the tornado and not due to another source, such as sirens or media. This problem might point out an opportunity to explore what are the best ways to gather information on storms and warnings, and for media, best practices when dealing with a multiple storm event. For instance, should individuals only tune into one station or continuously flip stations, or use other sources, to gather information?

24 May 2011 presents an interesting day of study. There are several unique datasets, including the availability of mobile radar data. For meteorology and social sciences, the day opens a wide set of questions and areas of exploration: how much did recent events affect the response, how do people turn the forecast into actionable information and how do people react to a lack of information during an event?

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