P3.4 THE MAYFEST HIGH-PRECIPITATION SUPERCELL OF 5 MAY 1995 – A CASE STUDY

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1. INTRODUCTION

The most damaging non-tornadic severe thunderstorm in the United States, and perhaps world history, occurred in the Dallas/Fort Worth Metroplex (DFW) during the late afternoon and evening of 5 May 1995. A high precipitation (HP) supercell (Moller et al. 1990) produced significant severe weather over Parker and Tarrant Counties, including hail varying in size from 4.5 to 11.5 cm, along with winds exceeding 30 m s^{-1}. The supercell struck the Mayfest outdoor festival just south of downtown Fort Worth; 60 people were hospitalized, four critically, from injuries received from very large hail (Storm Data 1995; NOAA 1995). The HP supercell later merged with a bowing squall line over eastern Tarrant County. Extreme rainfall ensued over eastern Tarrant County and much of Dallas County, with portions of northern Dallas receiving rainfall rates approaching 23 cm hr^{-1}. In all, this event claimed 20 lives, with 17 fatalities attributable to flash flooding. Hundreds more were injured, and total economic losses approached $2 billion (Moller 2002).

This extreme severe weather event provided several meteorological and sociological challenges to the outcome of the Integrated Warning System (IWS; Leik et al. 1981), some of which are discussed below. In Section 2, we describe the meteorological environment prior to and during the severe weather event of 5 May 1995. Section 3 is devoted to Doppler radar observations and ground truth supplied by amateur radio and other spotters. The National Weather Service (NWS) warning process and differing levels of situational awareness shown by warning officials and the public are discussed in Section 4. Lastly, we summarize the event in Section 5.

2. METEOROLOGICAL SITUATION

Diagnostic scrutiny of observational data is essential to IWS forecast and warning success (Doswell et al. 1993; Moller 2002). This was particularly true with the Mayfest storm. At 0000 (all times UTC; subtract five hours for local time) on 5 May, a cold front became stationary about 160 km south of DFW area. Numerical models initialized at 0000 on 5 May showed the front to return slowly northward through north Texas late on the 5^{th} through the 6^{th} in response to an upstream shortwave trough over the western U.S. Numerical model data initialized at 1200 on 5 May showed the warm front to remain south of DFW by 0000 on the 6^{th}, and model-derived precipitation forecasts suggested that the greatest threat of thunderstorms would arrive in the DFW area after local midnight on 6 May. Consequently, convective outlooks from the National Severe Storms Forecast Center and public forecasts issued by the NWS Fort Worth office (FTW) valid at 1200 on 5 May called for the threat of severe storms to be confined closer to the warm front and well south of the DFW area.

However, observational data later in the day revealed a differing solution to that offered by the numerical models. A 250 hPa jet streak approaching from the southwest and an upstream 700 hPa shortwave trough over southwest Texas were evident at 1200 on 5 May (Fig. 1). These features translated north and northeast, respectively, over north Texas during the day (Fig. 2). Low level thermal and wind field adjustments in response to these features during the afternoon of 5 May favored a faster northward warm frontal translation, and by 1800

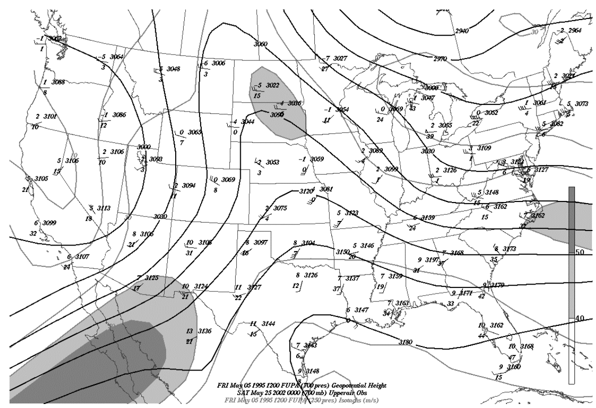

Figure 1. 5 May 1995 1200 UTC 700hPa Heights and 250hPa isotachs (m s^{-1}).

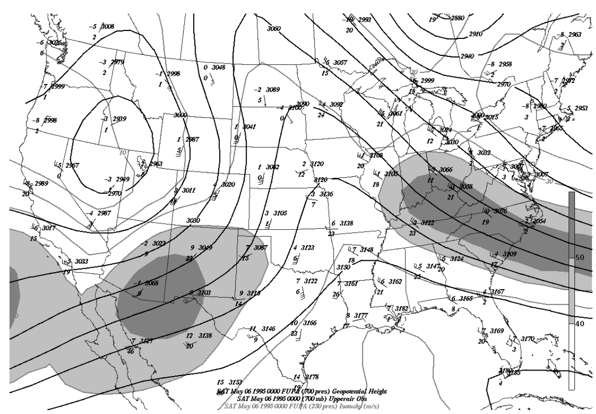

Figure 2. 6 May 1995 0000 UTC 700 hPa Heights and 250hPa isotachs (m s^{-1}).

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the warm front was located south of the DFW area (Fig. 3), well to the north of what was depicted by numerical models. Further northward translation of this boundary was hampered, however, by the presence of rain-cooled air over far north Texas. This area of rain-cooled air, supplied from a mesoscale convective system (Maddox, 1980) over Oklahoma, likely caused the front to become stationary just south of the DFW area by 0000 on the 6th (Fig. 4).

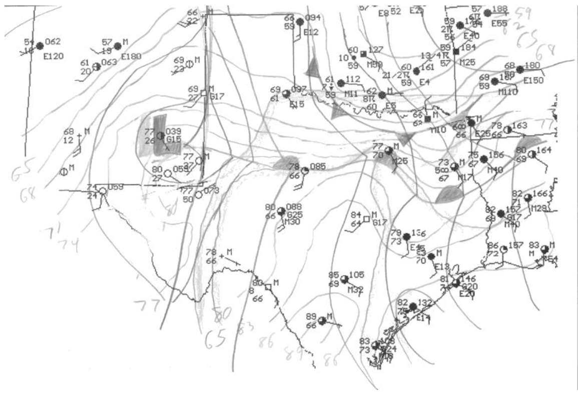

Figure 3. 5 May 1995 1800 UTC Surface Data Hand Analysis.

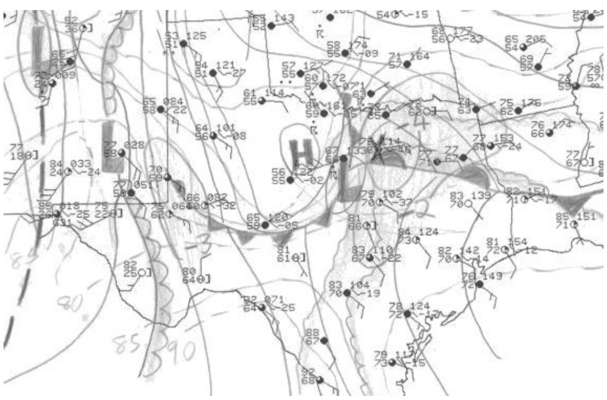

Figure 4. 6 May 1995 0000 UTC Surface Data Hand Analysis.

Meanwhile, a squall line developed during the early afternoon hours of the 5th along a dryline situated along the Texas-New Mexico border. This squall line translated east during the afternoon hours toward the DFW area. By mid afternoon of the 5th, forecasters at FTW recognized that numerical model solutions did not capture the threat of severe weather over north Texas. The airmass along and south of the warm front was unstable, with CAPEs near 2000 J kg^{-1}. The approach of the 250 hPa jet streak and an acceleration of mid-tropospheric winds associated with the approaching 700 hPa shortwave trough increased deep layer shear over north Texas. At the surface, backing storm relative winds associated with a mesolow at the intersection of the warm front and the squall line increased environmental helicity along and north of the warm front.

Based on these observations, it became obvious to the forecasters at FTW that the severe weather threat to the DFW area was increasing rapidly as the environment became more supportive for supercellular thunderstorms. Public forecasts issued on the afternoon of the 5th specifically mentioned the threat of high winds and large hail to the DFW area. With most of these events becoming apparent during the mid and late afternoon hours of the 5th, Doppler radar observations and storm spotter reports became crucial to both situational awareness and the success of the warning process.

3. WSR-88D RADAR AND GROUND TRUTH OBSERVATIONS

The HP supercell formed in southwestern Parker County, at the south end of a cluster of storms, about 65 km east of the eastward translating squall line (not shown). This storm exhibited a hook echo over southeastern Parker County (Fig. 5).

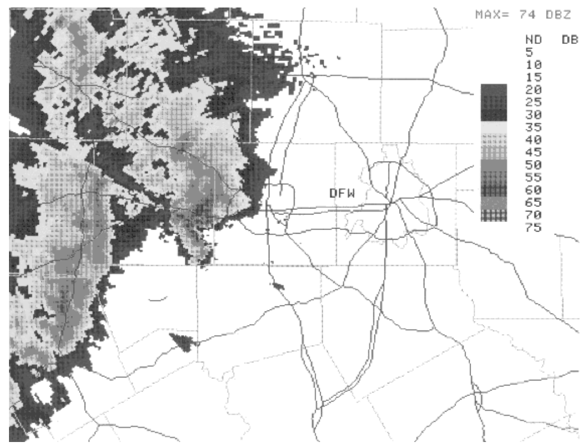

Figure 5. 5 May 1995 KFWS 2350 UTC Base Reflectivity Image

Low level reflectivities greater than 70 dBZ and a strong, deep mesocyclone were present at this time. A reflectivity cross section (Fig. 6) indicated the presence of a mid level bounded weak echo region in the storm's forward flank.

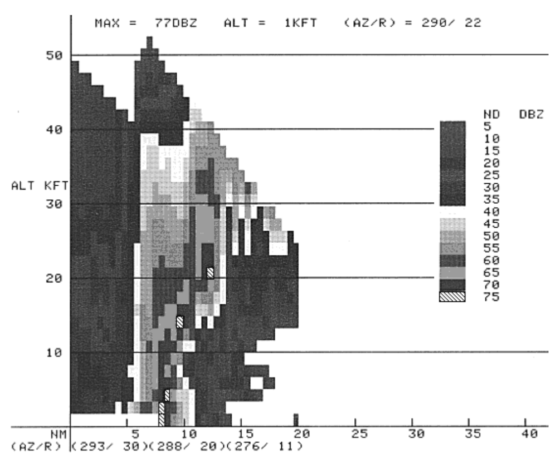

Figure 6. 5 May 1995 KFWS 2338 UTC Reflectivity Cross Section.

A pronounced high reflectivity overhang was present over this mid level feature. Time-height cross sections of mesocyclone depth and strength (Fig. 7) suggested that storm intensity remained constant as the storm moved into Tarrant County.

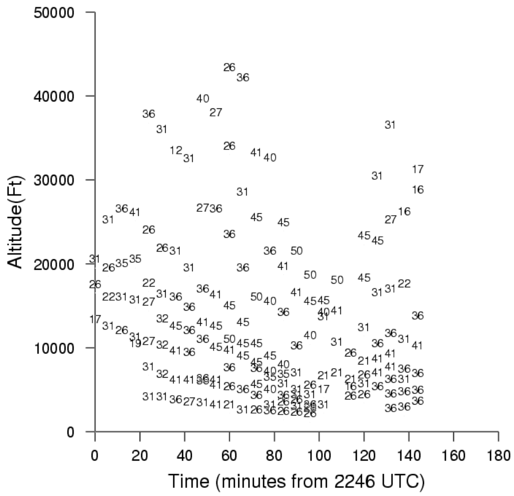

Figure 7. Mesocyclone Rotational Velocity time-height graph. Zero corresponds to 5 May 1995 2246 UTC.

A pronounced hook echo persisted with this supercell as the storm moved over downtown Fort Worth (Fig. 8). At this time, the associated mesocyclone on the storm's forward flank began to occlude while another mesocyclone intensified to its immediate south (Fig. 9).

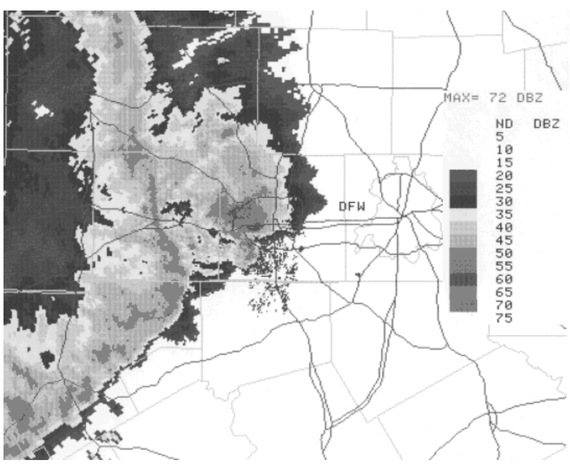

Figure 8. 6 May 1995 0013 UTC KFWS Reflectivity Image.

While the HP supercell was moving into Tarrant County, the squall line to the west began to exhibit classic bow echo characteristics, including development of a weak echo channel on the rearward side of the high reflectivity core (Fig. 8). The bow echo complex overtook the supercell over eastern Tarrant County (Fig. 10), slowing as it moved into western Dallas County. The mesocyclones associated with the HP supercell began to diminish in both depth and intensity after merger.

Ground truth, particularly that relayed into FTW by amateur radio spotters, confirmed radar indications that the HP supercell was extremely severe. A devastating

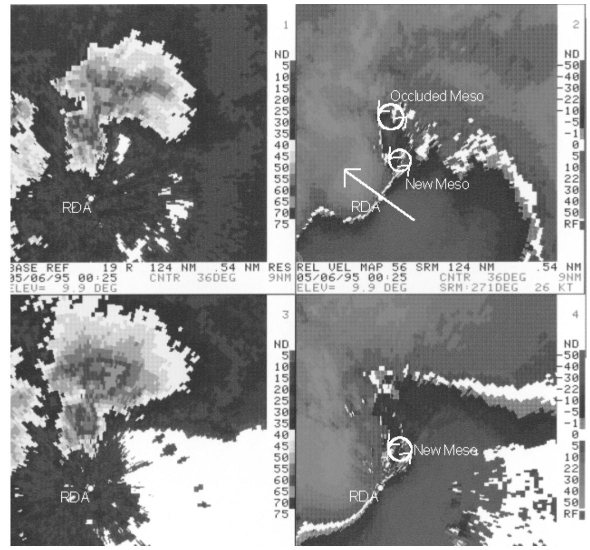

Figure 9. 6 May 1995 0025 UTC. Left Panels reflectivity, Right Panels storm relative motion. Top two panels 9.9°; bottom two panels 4.3°.

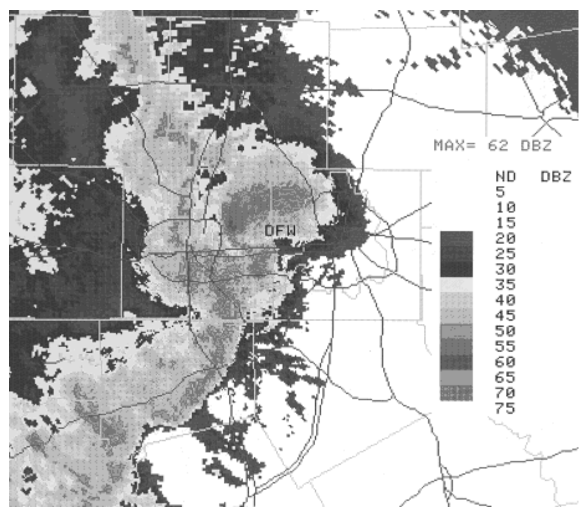

Figure 10. 6 May 1995 0100 UTC Reflectivity image.

hailfall occurred over southern Parker County, with hail in excess of 6.5 cm in diameter accompanied by winds over 25 m s^{-1}. The area was described as "looking like the dead of winter, with vegetation totally stripped from trees and shrubs and the ground white as if covered by snow" (Storm Data, 1995). The swath of extremely large hail continued through central Tarrant County, including the Mayfest area immediately west of downtown Fort Worth. Hail to 11.5 cm in diameter was reported in downtown and eastern Fort Worth. Numerous windows and skylights were destroyed in downtown Fort Worth and most of the injuries took place at the Mayfest event. A second devastating hail swath, associated with the mesocyclone that developed over south central Tarrant County, began over southern Fort Worth and continued east across Arlington. Copious amounts of large hail over 6 cm in diameter and driven by winds near 40 m s^{-1} caused extensive damage in this area. Some homes and buildings were virtually destroyed from wind driven large hail. No known tornadoes were reported in Tarrant County, however. In all, amateur radio spotters provided over 80 reports of large hail and wind from Tarrant County alone.

After the bow echo merged with the HP supercell, spotter reports of wind and hail were suggestive of an overall decrease in the severe weather threat. Spotter reports of rotating wall clouds in Dallas County, however, continued to be received by forecasters at FTW. The threat of flash flooding began to increase immediately after the merger. The forward speed of the complex slowed appreciably after merger; this slower movement, combined with increased precipitation efficiency, likely resulted in tremendous rainfall rates over Dallas County (Smith et al. 2001). Radar derived rainfall rates of 7.5 cm hr^{-1} were indicated over north Dallas, but rain gage data (not available in realtime to forecasters at FTW) showed that these rainfall rates were underestimated by nearly a factor of three (NOAA, 1995). The extreme rainfall that occurred after merger and over an urban watershed caused catastrophic flash flooding in northern and central Dallas. A few reports of flooding came into the Dallas Emergency Management (EM) office between 0130 and 0200, but because of tornado concerns and workload, these reports were not immediately relayed to FTW (NOAA, 1995). After FTW issued a flash flood warning at 0158, however, a deluge of reports came into the FTW office. Many reports of flash flooding, including reports of people being rescued from stranded automobiles, were subsequently received by FTW through 0240.

4. DISCUSSION

The 5 May 1995 severe weather event posed significant challenges to the IWS in several ways. First, the HP supercell produced the greatest amount of combined hail and wind damage in U.S. history. Although tornadoes were a distinct threat throughout the event, none occurred. The HP supercell contained a persistent strong mesocyclone throughout most of its life; however, it should be remembered that only about 20 percent of observed mesocyclones produce tornadoes (Moller 2002). Regardless, the combined effects of hail and wind were comparable to tornadic damage. This suggests a need for continued education regarding the threats of non-tornadic supercell storms.

The Mayfest outdoor festival in Fort Worth, with several thousand people in attendance, bore the brunt of the hail and wind storm. Hail to the size of softballs caught both event organizers and attendees unaware. As a result, over 400 people were injured, with 60 requiring hospitalization (Storm Data 1995). Prior to this event, Mayfest officials did not contact either FTW or local EMs for severe weather assistance (NOAA, 1995). Since 1995, however, Mayfest organizers have actively monitored severe weather potential. Amateur radio spotters coordinate with FTW and relay weather information to event officials. In doing so, the Mayfest organizers can halt the event and evacuate the site before weather problems arise. Unfortunately, many outdoor celebrations and sporting events nationwide lack adequate means to receive and act upon severe weather information.

Secondly, this event may be viewed as a barometer of the extreme sociological impact that such storms have when they occur in a metropolitan area. It is unknown to what effect different warnings (tornado, severe thunderstorm, or flash flood) have on public response. Based on anecdotal evidence, we believe that public response to severe weather warnings varied based on the perceived threat. Warnings alone may not cause people to take necessary action; rather, it is their assessment of personal danger that prompts the appropriate response (Gruntfest 2000). For instance, tornado warnings may elicit a stronger public response to take precautionary action than either a severe thunderstorm or a flash flood warning, perhaps in large part to oftentimes graphic depictions of tornadic damage. Clearly, additional research is needed to determine what the actual public response is to various severe weather warnings and to determine what efforts, if any, are needed within the IWS to elicit the appropriate public response.

Third, as the supercell storm moved through Tarrant County, local media understandably committed much of their time and resources to coverage of the hail and its impacts. As noted in Section 3 above, the concern about large hail and tornadoes continued for all agencies (NWS, media, and EM's) as the squall line merged with the supercell over eastern Tarrant County. Although FTW issued a flash flood warning prior to receiving reports of flooding in Dallas County, the catastrophic impact of the torrential rainfall and subsequent flash flooding was only realized after the fact as reports of rescues were received by FTW. This serves as a reminder of the need for keen situational awareness (Bunting 1998) and realtime ground truth reports during severe weather events.

Lastly, the runoff from the extreme rainfall over Dallas and Tarrant Counties quickly overwhelmed existing drainage systems. Flash flooding claimed 17 lives, with 16 of the fatalities in Dallas County and one in Tarrant County. The extreme rainfall rates over Dallas County caused flooding of streets and highways in areas that were not previously known to be flood prone. Other flood events in urban areas (e.g., Kansas City, 1979; Fort Collins, CO, 1998) suggest that while the Dallas County flash flood was a significant event, it certainly was not unique. As metropolitan areas continue to grow, and as a resulting increase in paved areas affects the drainage, the threat of catastrophic flash floods will continue to increase. Extreme rainfall events, such as what occurred in eastern Dallas County on 5 May 1995, should prompt urban governments nationwide to consider the impact of very heavy rainfall and stormwater drainage on public safety. The Mayfest event also re-emphasized the continuing need for flash flood education and preparedness in and near vulnerable areas.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

The authors will provide references upon request.