P2.5

SEVERE LOCAL STORM WARNINGS: CHALLENGES FROM THE 04 MARCH 2004 EVENT

Gregory R. Patrick * and Gary R. Woodall, NOAA/NWS, Fort Worth, TX

1. INTRODUCTION

A powerful low pressure center at 500 hPa moved from northeastern Sonora, Mexico at 1200 UTC 04 March 2004, into west Texas by 0000 UTC 05 March. An infrared satellite presentation of the upper low's movement is depicted in Fig. 1. Extremely strong wind fields accompanied the upper low from the surface to 200 hPa. Surface cyclogenesis helped bring low level moisture north across most of Texas and Oklahoma. Moderate instability developed in the warm sector of the surface cyclone, with 100 hPa mean-layer Convective Available Potential Energy (MLCAPE) values (see Doswell et al. 1982) analyzed around 1500 J kg^{-1}. Fig. 2 is a surface mesoanalysis from 1800 UTC 04 March 2004. The extremely strong environmental wind shear, with 0 - 1 km storm relative helicity values over 500 m^2 s^{-2}, is depicted in the wind profiler from Palestine, TX in Fig. 3.

A line of severe thunderstorms developed across west Texas during the morning of 04 March, and spread quickly east during the day. Severe thunderstorms are defined as storms which produce hail 19 mm (3/4 in) or larger or wind gusts 26 m s^{-1} (50 kt) or stronger. The event was well forecast by the Storm Prediction Center (SPC) and local Weather Forecast Offices (WFOs); SPC posted a moderate risk of severe storms across much of Texas. A map showing preliminary severe weather reports is shown in Fig. 4.

A summary of the event, from pre-storm planning to verification and storm surveys, is presented from the perspective of forecasters at WFO Fort Worth/Dallas (FWD).

2. WFO FORT WORTH/DALLAS ACTIVITIES

On the afternoon of 03 March, the WFO leadership team assembled to assess the threat to the area of responsibility and to determine staffing availability for 04 March. Two outreach programs were planned for the day and the evening of 04 March, both of which needed to be postponed to ensure adequate staffing at the WFO. On the morning of 04 March, the FWD staff sent e-mail notification to all emergency managers on their mailing list emphasizing the threat and the severe weather products that FWD would be issuing. As the convection approached the western part of the County Warning Area (CWA), the Forecaster-in-Charge (FIC) assigned the duties and roles for the event. Those duties are detailed in Table 1.

Table 1. FWD Roles and Duties during the 04 March 2004 Severe Weather Outbreak

Role	Duties
Warning Coordinator	Oversee Severe Weather Operations
2 Warning Forecasters	Severe Thunderstorm and Tornado Warnings
Statement Writer	Issue Severe Weather Statements
Long-Range Forecaster	Public Forecasts for days 1-7
Short-Range Forecaster	Aviation Forecasts and Mesoanalyses
2 Communications Officers	County Briefings and Spotter Activations
Weather Radio Monitor	Weather Radio Programming Management

The Warning Coordinator directed the severe weather operations of the WFO. The staff quickly decided on a sectorized warning approach and subdivided the County Warning Area of responsibility into two parts. The Statement Writer produced all follow-up Severe Weather Statements once warnings were issued. The Long-Range forecaster prepared the scheduled forecasts using Interactive Forecast Preparation System (IFPS). The Short-Range Forecaster performed periodic mesoanalysis, monitored aviation forecasts, and issued Airport Weather Warnings for Dallas-Fort Worth International Airport and Dallas Love Field. The Communications Officers conducted informational briefings, spotter group activations, and report logging. The Weather Radio Monitor ensured that programming on the 13 NOAA Weather Radio transmitters operated by FWD was as concise and up to date as possible.

As thunderstorms approached the FWD area of responsibility, the staff engaged in an extensive coordination and briefing program. This program featured contacting, via telephone or other pre-

* *Corresponding author address:* Gregory R. Patrick, National Weather Service, 3401 Northern Cross Blvd, Fort Worth, TX 76137; e-mail gregory.patrick@noaa.gov

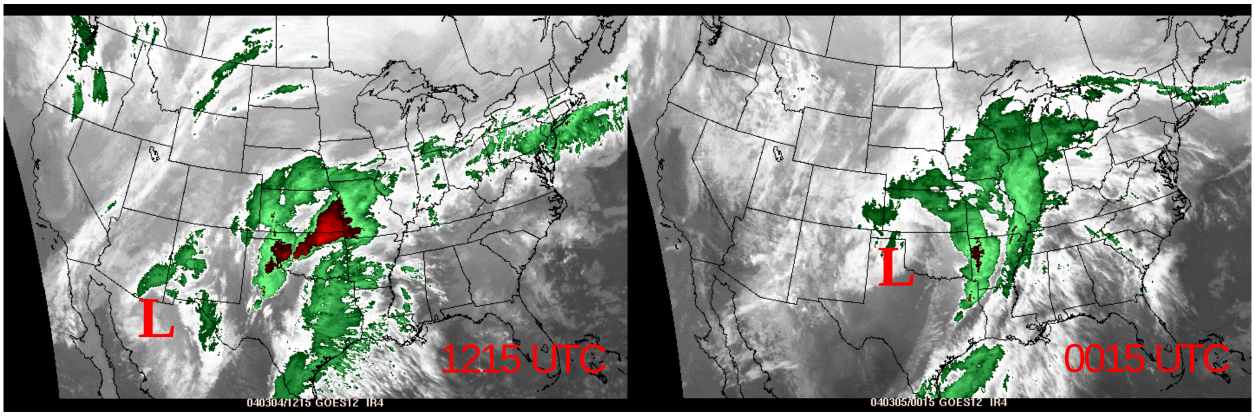

Fig. 1. GOES infrared satellite imagery at 1215 UTC 04 March 2004 (left) and 0015 UTC 05 March 2004. Red L on each image marks the approximate location of the 500 hPa circulation.

determined methods, emergency managers and warning point officials in the counties that would be threatened. The FWD staff performed over 65 county briefings and spotter group activation requests before the storms entered threatened counties. As the storms moved across the FWD CWA, the staff participated in over 100 follow-up contacts providing updated radar information or receiving storm reports.

Early in the morning of 04 March 2004, contact was made with the office's amateur radio liaison team. As a result of the early planning, 4 members of the team were in the office and monitoring amateur radios as the storms moved across north Texas. In addition to assisting with county briefings and providing updated storm locations and warning decisions, the volunteer amateur radio operators logged several hundred reports from spotters in the field. The combination of amateur radio communications and contacts made by the FWD staff resulted in a torrential flow of information into and out of the WFO.

As storms moved across north Texas, the FWD staff utilized several new text product and product formats that were developed locally in late 2003 as part of a new short term weather suite. The new products and new product formats were intended to supplement the existing national baseline text products, including Severe Thunderstorm Warnings and Tornado Warnings, issued by all NWS Forecast Offices. The newly formatted products included an expanded Short Term Forecast, which served as a plain-language mesoscale discussion. The staff also utilized the new Area Weather Update as a Warning Decision Update product, discussing storm-scale evolution and near-storm environments. An example of a Warning Decision Update issuance from 04 March 2004 is shown in Fig. 5. Customer feedback indicates that the new products and new product formats were beneficial in providing a constant flow of information regarding storm evolution.

Media coordination was a minor factor before and during the event. A Dallas television station camera crew came to the WFO before the storms entered the FWD area and did a short interview on our preparations and operations. As the event unfolded, announcers from three radio stations called for briefings and updates. Once the storms exited, reporters from four newspapers called to request early storm reports and their impacts.

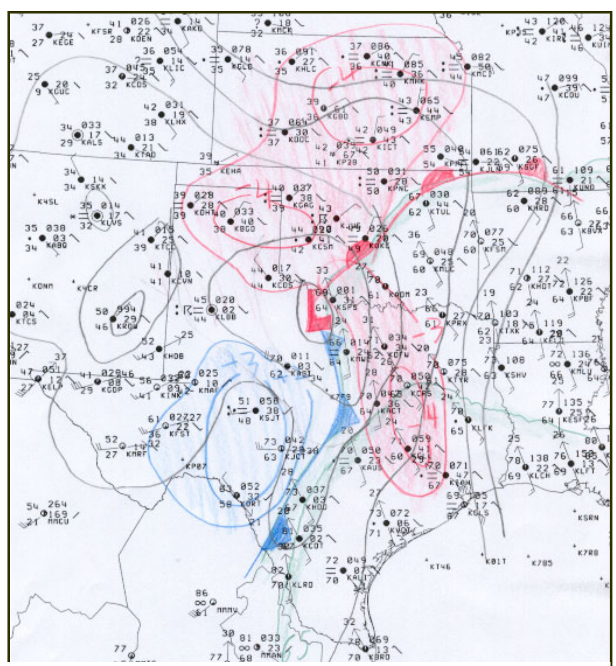

Fig. 2. Surface Analysis valid at 1800 UTC 04 March 2004. A low pressure center was analyzed near Wichita Falls, TX, with frontal systems across OK and central TX. Red and blue shading areas show significant pressure falls and pressure rises, respectively.

Despite the large number of forecast staff who worked this severe weather outbreak, this proved to be a taxing event. Operationally, the event of 04 March 2004 was an outbreak that maximized the workload for all WFO FWD personnel involved. The squall line affected all 46 counties of the FWD warning area, and moved at a forward speed averaging 23 m s^{-1} (45 kt). The rapid movement meant that the Communications Officers had to contact counties when storms were still 1-2 counties to the west to allow sufficient time for spotter group activation. Since this was a linear event, and did not feature isolated discrete convection, the Communications Officers were often required to notify several county warning points almost simultaneously.

3. WARNING DECISION CHALLENGES

3.1 Convective Mode

A linear convective mode was dominant across north Texas partially as a result of forcing along the advancing cold front. Reports of damaging winds were numerous along a large part of the squall line, possibly as a result of very strong environmental winds in a deep layer associated with the upper level shortwave. However, there were several instances where supercells embedded within the line became intense and produced tornadoes. Fig. 6 shows a radar image at 1900 UTC with several supercells embedded within the line of storms. Fig. 7 shows an example of a strong mesocyclone that developed within the line and eventually contributed to two confirmed tornadoes across southern Ellis County.

There was also at least one instance of a long-lived, small-scale circulation that persisted in a relatively weak convective cell. Based on storm surveys and a study of radar archives, it appears that a weak tornado occurred once the cell with the circulation merged into the main squall line. The circulation associated with the tornado is shown in the KFWS (Dallas/Fort Worth WSR - 88D) imagery in Fig. 8.

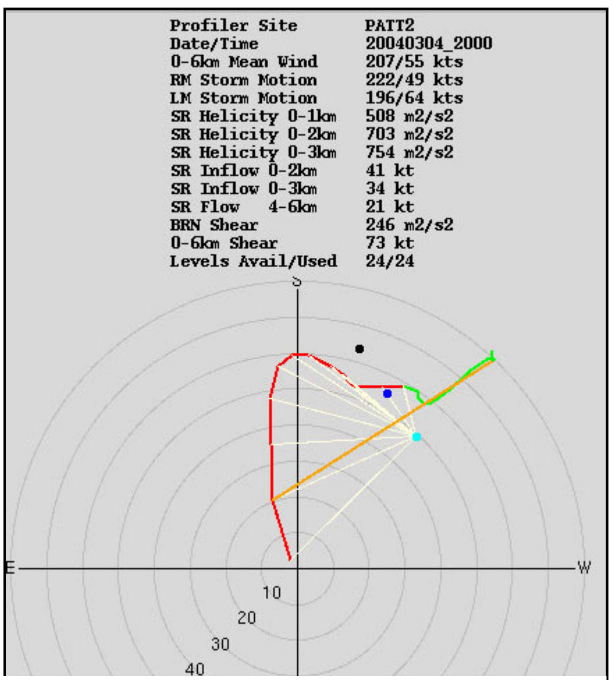

Fig. 3. Hodograph from the Palestine TX (PATT2) NOAA Wind Profiler at 2000 UTC 04 March 2004. The 0 - 6 km mean wind is the blue dot; the black and green dots indicate forecast storm motions for left-moving (LM) and right-moving (RM) supercells, respectively. For the supercells on 04 March, the observed storm motion was from approximately 230 degrees at 27 m s^{-1} *(52 kt), which was close to the RM Storm Motion in this hodograph. Note the extremely high values of 0 – 1 km helicity (508 m^2/s^2) and 0 – 6 km Shear (37.5 m s^{-1} or 73 kt).*

3.2 Rapid Movement

The mean eastward progression of the squall line across the FWD County Warning Area was 23 m s^{-1} (45 kt). Individual storm cells within the line moved to the northeast at 26 m s^{-1} to 31 m s^{-1} (50 to 60 kt). Given the rapid storm movement and the intensity of the convection, numerous warnings were issued in a 5 h time span. Fig. 9 gives a breakdown of the severe weather product issuances from WFO FWD on 04 March 2004.

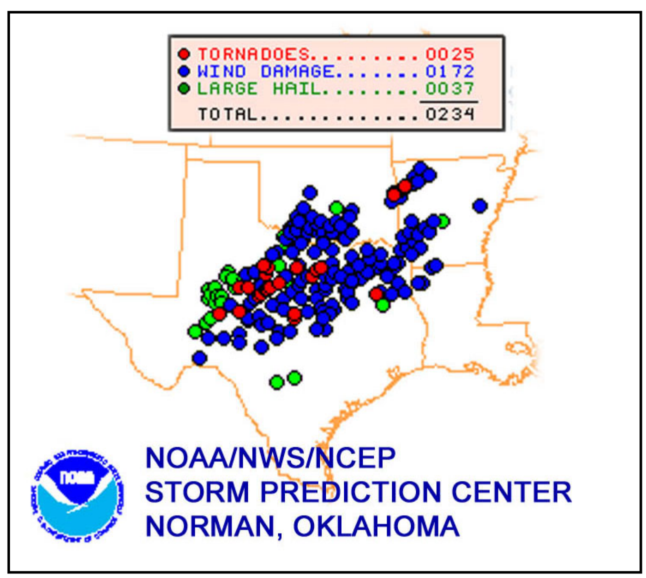

Fig. 4. Preliminary Severe Weather Reports from 04 March 2004, courtesy Storm Prediction Center.

```
AREA WEATHER UPDATE
NATIONAL WEATHER SERVICE FORT WORTH TX
310 PM CST THU MAR 4 2004

...WARNING DECISION UPDATE FOR NORTH TEXAS...

LINE CONTINUES EAST AROUND 40-50 MPH. LINE HAS TWICE TRIED TO BREAK DOWN
INTO DISCRETE CELLS. LATEST CYCLE RESULTED IN TORNADOES OVER PARKER/DENTON
COUNTIES. OVERALL LINEAR STRUCTURE CONTINUES...BUT CELLS OVER SOUTHERN
DALLAS AND SOUTHERN ELLIS MAY BE TRYING TO ACQUIRE CIRCULATION. MID-50S
OUTFLOW BEHIND LINE SUGGESTS PRIMARY LINEAR CONVECTION SHOULD CONTINUE AND
MOVE QUICKLY INTO E COUNTIES OF WARNING AREA.
```

Fig 5. Warning Decision Update product issued by WFO FWD at 2110 UTC 04 March 2004.

Data from several WSR-88Ds were utilized as the storms moved across a large geographic area in a short period of time. Warning forecasters often had to rely on two or even three separate 88Ds to optimize data input for warning decisions. The three primary 88D systems used by WFO FWD during the outbreak were KDYX (Dyess AFB) for the western part of the CWA, KFWS (Dallas/Fort Worth) for the central and northern part of the CWA, and KGRK (Fort Hood) for the central and southern part of the CWA.

The rapid storm motion meant that upper-level radar signatures were displaced several km downstream of the low-level features. This displacement required the warning forecasters to mentally correlate the signatures rather than rely solely on algorithm output. The combination of strong vertical shear and modest instability did, however, likely create tilted updraft and downdraft columns. This was particularly noted in eastern Collin County, where a tornado track was several kilometers removed from the 0.5 degree circulation signature.

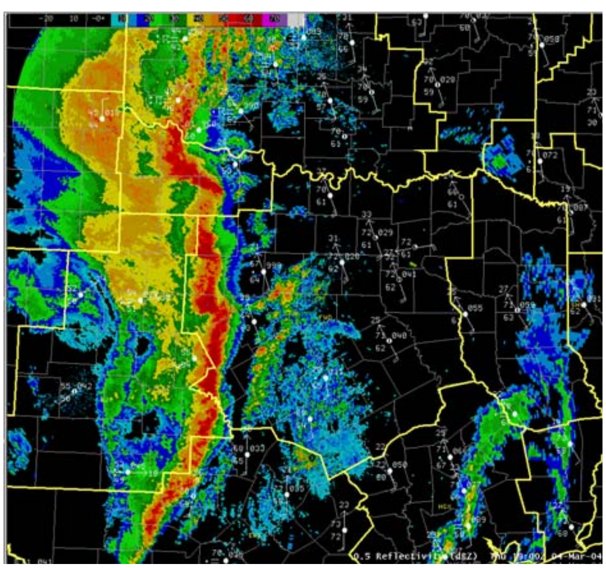

Fig. 6. WSR-88D Reflectivity Mosaic at 1900 UTC 04 March 2004. Note the numerous kinks in the main line of storms caused by mesocyclonic circulations. Yellow lines outline the CWA of NWS Forecast Offices.

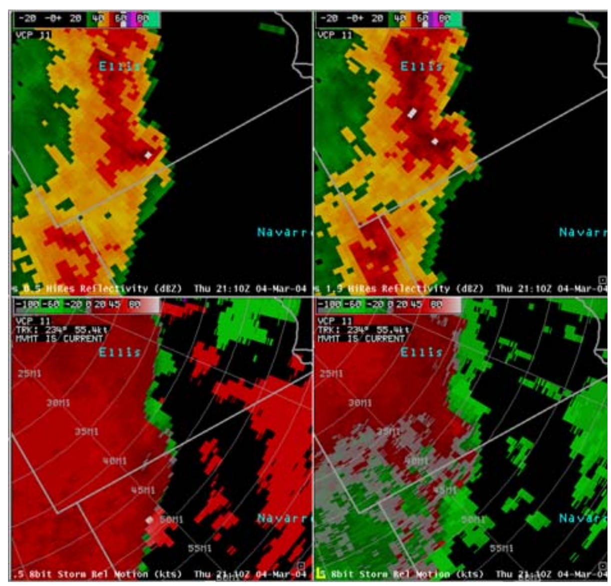

Fig. 7. Base Reflectivity (Z) and Storm Relative Base Velocity (SRM) from KFWS at 2110 UTC 04 March 2004. Top images are Z from 0.5 degree slice (left) and 1.5 degrees (right). Bottom images are SRM at 0.5 degrees (left) and 1.5 degrees (right). The storm of interest in Ellis County is 67 km (36 n mi) southeast of the KFWS 88D. The intense supercell along the line of storms produced two tornadoes across southern Ellis County.

3.3 Line Redevelopment

As the squall line approached the Dallas-Fort Worth Metroplex, new convective cells began developing in the area about 50 - 100 km ahead of the line. As shown in Fig. 10, the line effectively redeveloped just east of Fort Worth. The discontinuous line propagation led to a relative minima in severe weather reports around Fort Worth; the original squall line dissipated west of Fort Worth and the new squall line developed from the convective cells just east of Fort Worth. Study of archived radar reflectivity animations suggests that the line redevelopment was NOT the result of new convection developing on outflow from the original line; rather, new cells developed in the area of very strong large-scale scale lift ahead of the original line and gradually evolved into a linear formation.

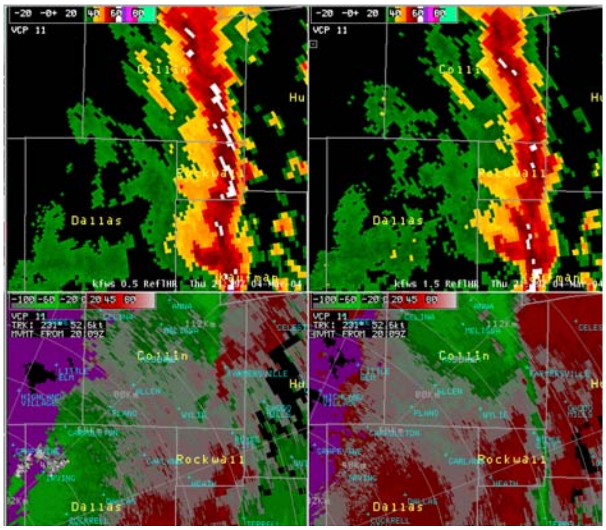

Fig. 8. Same as Fig. 7, except the time is 2139 UTC 04 March 2004. The storms in Ellis County are 109 km (59 n mi) northeast of the KFWS 88D. The relatively strong circulation at 0.5 degrees elevation in the lower left panel was associated with an F1 tornado near Farmersville.

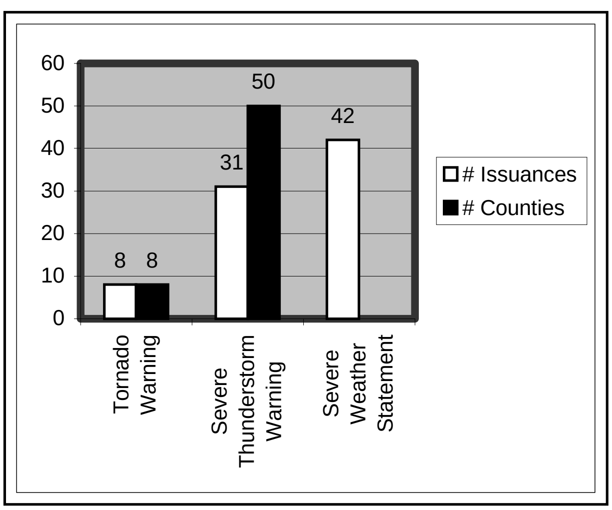

Fig. 9. Severe Weather Product issuances by WFO FWD on 04 March 2004. All of the issuances were during a 5 h period between 1830 UTC and 2330 UTC.

4. STORM SURVEYS AND VERIFICATION

On 05 March 2004, two teams from FWD surveyed selected damage areas. There were many locations in the FWD warning area that were worthy of survey, however, time and resource limits restricted the FWD survey teams to areas where there were significant questions about the nature of the damage. These locations were in southern Ellis County, central Kaufman County, and eastern Collin County. In other areas, the FWD staff relied on follow-up information from storm spotters and local emergency management staff to document the event.

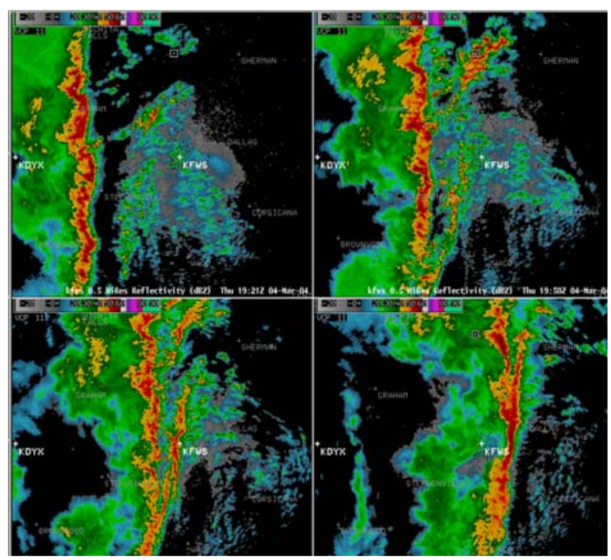

Fig. 10. KFWS 88D Reflectivity images over a 1.5 h period depicting the redevelopment of the squall line as it approached KFWS 04 March 2004. Upper left image (1921 UTC) depicts a nearly solid line of storms with weak development ahead of the line. The upper right image (1950 UTC) and lower left image (2015 UTC) indicate that the original line was weakening as a new line formed near KFWS. The lower right image (2055 UTC) shows that the line of storms has completely redeveloped just east of KFWS.

The tornadic supercells were fast moving and generally linear in nature; thus, there is very little photographic documentation of the tornadoes. The tornadoes' fast movement meant that there was little indication of "return flow" on the north sides of the circulations. Survey teams were required to use convergent and divergent damage patterns (NWS 2003) as the primary method of identifying tornadoes and downbursts, respectively.

Fig. 11 is typical of the damage that was documented in southern Ellis County. A tornado moved through southern sections of the city of Ennis and partially unroofed a warehouse building. Interestingly, while much attention was focused on the tornado tracks, the downbursts (generally associated with supercell rear flank downdrafts) were typically stronger and caused more significant damage than did the tornadoes.

Table 2 gives a breakdown of verification statistics for the warnings issued by FWD on 04 March 2004.

Table 2. Verification statistics for WFO FWD on 04 March 2004.

ALL SEVERE EVENTS	
Number of County Warnings	58
Verified Warnings	49
False Alarm Rate	0.16
Total Severe Events	68
Warned Events	68
Probability of Detection	1.00
Average Lead Time	17.2 min
TORNADO DATA ONLY	
Number of County Warnings	8
Verified with Tornadoes	6
False Alarm Rate	0.25
Total Tornado Events	9
Events with TOR in effect	6
Events with SVR in effect	3
Probability of Detection (TOR)	0.67
Average TOR Lead Time	8.0 min

5. SUMMARY

The intense squall line that moved across much of Texas on 04 March 2004 presented many challenges to the Weather Forecast Offices involved. A line of convection, fueled by moderate instability and extremely strong environmental wind shear, was responsible for several tornadoes and over 200 reports of damaging thunderstorm wind gusts. The rapid movement of the squall line and the presence of numerous embedded supercells within the line presented the most significant challenges to those forecasters making warning decisions.

Fig. 11. Tornado damage to a warehouse boulding in southern Ellis County near Ennis, TX. The convective cell associated with the tornado is depicted in Fig.7.

With effective planning and by utilizing all available resources, the Fort Worth WFO was able to efficiently handle the demanding workload and maximize the two-way flow of information between the WFO and customers. In addition to the standard suite of severe weather issuances, the Fort Worth forecast office utilized the Area Weather Update product to provide real-time information on storm-scale evolution and near-storm environments.

6. ACKNOWLEDGMENTS

The profiler hodograph shown in Fig. 3 was created using an AWIPS application developed by Brian Walawender.

REFERENCES

Doswell, C. A. III,, J. T. Schaefer, and D. W. McCann, 1982: Thermodynamic analysis procedures at the National Severe Storms Forecast Center. Preprints, *Ninth Conf. on Weather Forecasting and Analysis,* Seattle, WA, Amer. Meteor. Soc., 304–309.

National Weather Service, 2003: A Guide to F-Scale Damage Assessment. U.S. Dept of Commerce, NOAA, Silver Spring MD, 94 pp.