RADAR-BASED ANALYSIS OF THE DALLAS COWBOYS PRACTICE FACILITY COLLAPSE OF 2 MAY 2009

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ABSTRACT

The Dallas Cowboys indoor practice facility in Irving, TX, collapsed on 2 May 2009. The 26-m tall, gable-roofed steel frame and fabric structure succumbed to severe thunderstorm winds, injuring several people, one seriously. The facility was fortuitously located just 2.4 from a Terminal Doppler Weather Radar (TDWR). Analysis of the TDWR and surface data indicates that maximum surface wind gusts were likely in the 63-79 mph range, while gusts at the top of the facility likely reached 78-96 mph, with an upper limit of 101-126 mph.

1. OVERVIEW

The Dallas Cowboys Practice Facility (PF) was destroyed by thunderstorm wind gusts on the afternoon of 2 May 2009. It was a 26-m tall gable-roofed steel frame structure with a tensioned fabric covering. The goal of this study is to determine the likely magnitude of those wind gusts. An important question concerns whether the winds at the top of the PF could be considered extraordinary or within the realm of reasonable possibility.

A number of data sources and reports are examined here, including: National Weather Service (NWS) bulletins issued by the Fort Worth office and Storm Prediction Center (SPC); NWS Automated Surface Observing System (ASOS) observations; radar data from both NEXRAD and Federal Aviation Administration (FAA) Terminal Doppler Weather Radars (TDWR). Additionally, the National Institute of Standards and Technology (NIST) produced a report on the incident the following year.

2. NWS BULLETINS

SPC at 1:55 pm CDT issued a Tornado Watch for north-central Texas through 7 pm. The watch noted the potential for tornadoes, hail to 3 inches in diameter, and thunderstorm wind gusts to 70 mph. The NWS Fort Worth office at 3:06 pm issued a Severe Thunderstorm Warning for Dallas County. The warning concerned a line of severe thunderstorms capable of producing nickel-size hail and damaging winds in excess of 60 mph through 3:45 pm.

The only relevant storm report was a high wind report regarding the PF collapse, with the time given as 2030 UTC (3:30 pm). There was no wind speed estimate with this report. No tornado or large hail reports were received regarding this event.

The Fort Worth NWS office issued a Public Information Statement on the evening of the event regarding the damage:

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PUBLIC INFORMATION STATEMENT
NATIONAL WEATHER SERVICE FORT WORTH TX
842 PM CDT SAT MAY 2 2009

...RESULTS OF VALLEY RANCH DAMAGE
SURVEY...

BASED ON A SURVEY OF THE ON-SITE
DAMAGE...RADAR IMAGERY...AND EYEWITNESS
REPORTS...THE NATIONAL WEATHER SERVICE
DETERMINED THAT A MICROBURST IMPACTED THE
VALLEY RANCH AREA OF FAR NORTH IRVING.
MAXIMUM WINDS NEAR THE GROUND WERE
ESTIMATED NEAR 70 MPH.

RESEARCH HAS INDICATED THAT WIND SPEEDS
IN HIGH WIND EVENTS OFTEN INCREASE
CONSIDERABLY IN THE LOWEST FEW HUNDRED
FEET ABOVE THE GROUND. THEREFORE...IT IS
QUITE POSSIBLE THAT WINDS GREATER THAN 70
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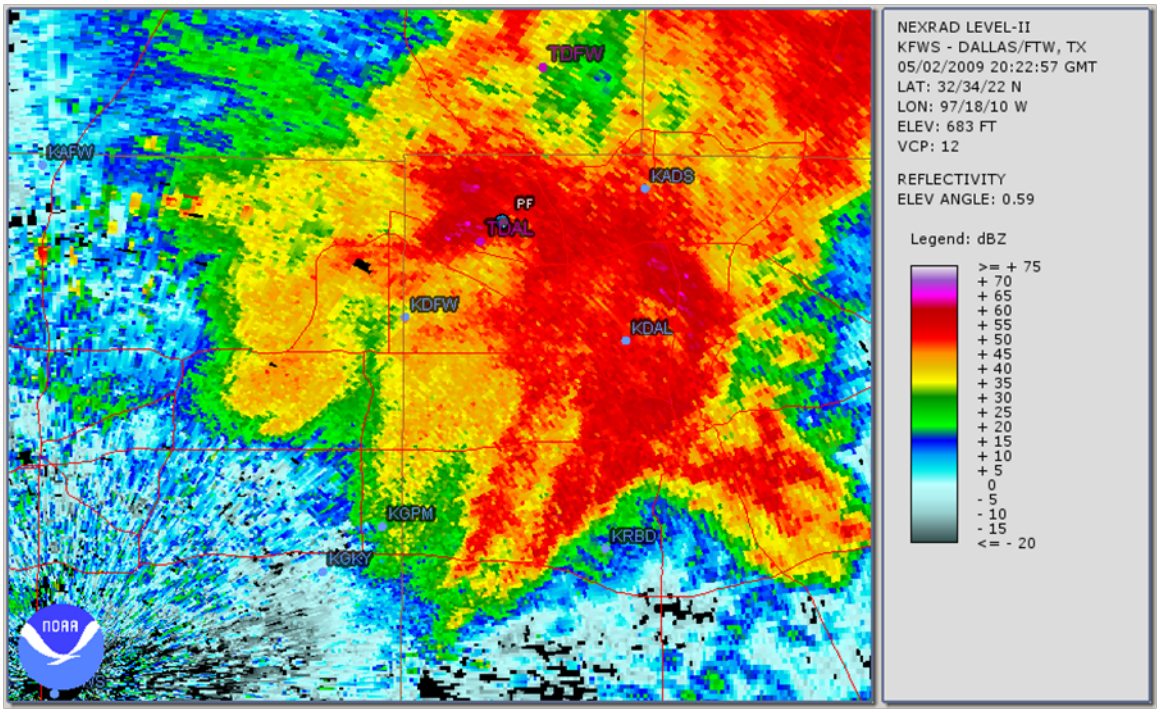

Figure 1. High-resolution (Level 2) radar reflectivity from the Fort Worth NEXRAD (KFWS), lowest scanning angle, at 2023 UTC (3:23 pm CDT) 2 May 2009. In this and subsequent radar images, the location of the Practice Facility is indicated by "PF", radars (KFWS, TDAL, TDFW) are indicated by purple dots, and NWS ASOS stations (KDFW, KDAL, etc.) are indicated by blue dots.

MPH AFFECTED THE UPPER PORTIONS OF THE DAMAGED STRUCTURES.

A MICROBURST IS A SMALL...INTENSE DOWNDRAFT WHICH RESULTS IN A LOCALIZED AREA OF STRONG THUNDERSTORM WINDS. IN EXTREME CASES... MICROBURSTS CAN HAVE WINDS WHICH EXCEED 100 MPH.

3. NIST REPORT

The following year, the National Institute of Standards and Technology (NIST) issued a report (Gross et al., 2010) that considered damage surveys by NIST and the City of Irving; ASOS observations; TDWR data; and theoretical maximum microburst wind calculations.

Based on damage surveys and ASOS observations at Dallas-Ft. Worth International Airport (KDFW), they concluded that (a) the wind direction at the PF at the time of damage was from the west or slightly south of west; (b) the peak surface (10 m) wind gusts were 55–65 mph (25–29 m s^{-1}); and (c) that the stagnation point (center of the microburst) was about 1 mile (1.6 km) southwest of the PF, based on TDWR data. Aside from the PF, damage consisted largely of snapped tree limbs and minor structural damage.

Additionally, NIST applied McCann's (1994) thermodynamic calculation to estimate microburst wind gust potential. Using that evening's 0000 UTC Fort Worth rawinsonde data and adjusting to match the pre-storm environment, they calculated that the maximum expected microburst winds gusts would be about 60-65 mph (27–29 m s^{-1}) at the surface.

The PF structure consisted of steel truss gable frames covered with a tensioned fabric. NIST performed structural analysis and concluded that at the 90 mph design wind speed (gust), the building would have been greatly overloaded (design-capacity ratio [DCR] as high as 6). Even in 60 mph winds, the DCR would have been as high as 2.

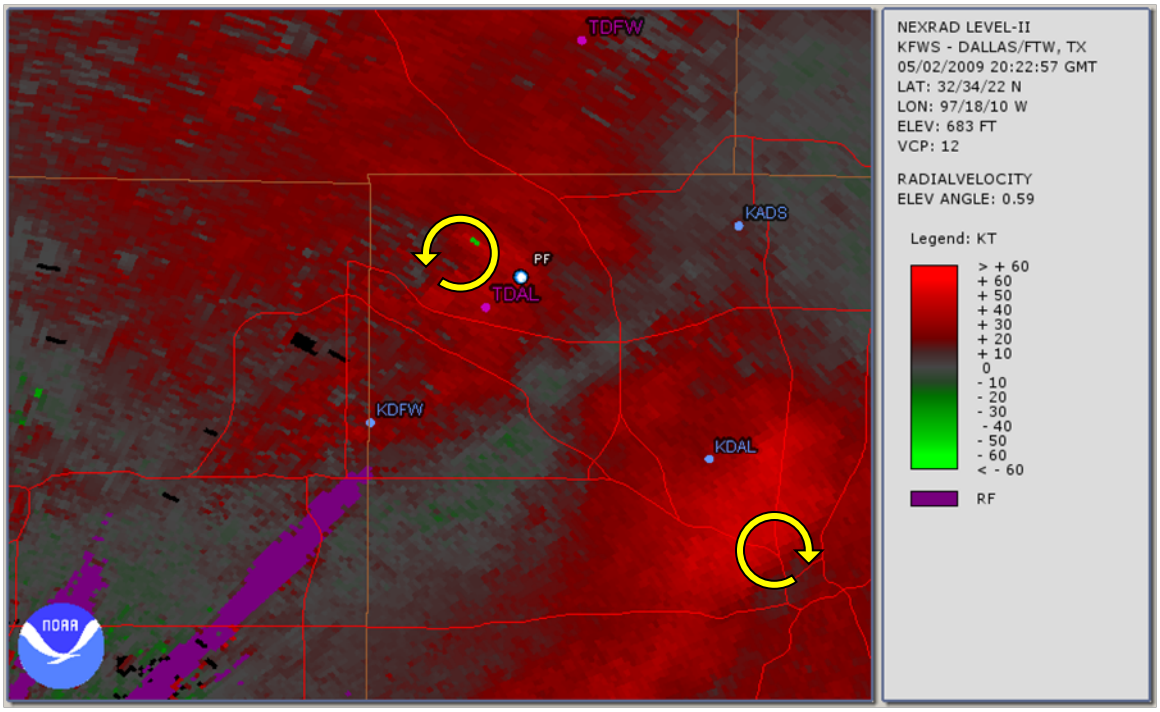

Figure 2. High-resolution (Level 2) radial velocity from the Fort Worth NEXRAD (KFWS), lowest scanning angle, at 2023 UTC (3:23 pm CDT) 2 May 2009. Circular arrows indicate the location of counter-rotating vortices at the ends of the bow echo.

4. SURFACE OBSERVATIONS

ASOS observations taken at two nearby airports were examined. Dallas-Ft. Worth International Airport (KDFW), located 6 miles southwest of the PF reported a maximum wind gust of 44 mph from the W at 3:18 pm (Table 1). Dallas/Love Field (KDAL), located 8.6 miles southeast of the PF, reported a maximum wind gust of 33 mph at 3:21 pm (Table 2). Cooperative observing station data were also examined but no suitable nearby station was found.

Time (UTC/CDT)	Weather	Wind Direction, Speed / Gust (mph)
2000 / 3:00 pm	Light drizzle	210° 9 / -
2008 / 3:08 pm	Thunderstorm, light rain	320° 18 / -
2018 / 3:18 pm	Thunderstorm, heavy rain	280° 29 / 44 Peak wind 44 mph from 280° and wind shift at 2018
2029 / 3:29 pm	Thunderstorm, heavy rain	360° 15 / 32
2036 / 3:36 pm	Thunderstorm, light rain	30° 11 / 25

Table 1. Observations for Dallas-Ft. Worth International Airport (KDFW). Sustained wind speeds are 2-minute averages, while wind gusts are peak instantaneous speed during the preceding 10 minutes. Peak wind speeds are the maximum wind gust since the last routine report.

Time (UTC/CDT)	Weather	Wind Direction, Speed / Gust (mph)
2009 / 3:09 pm	Light rain	230° 5 / -
2024 / 3:24 pm	Thunderstorm, heavy rain	230° 15 / 33 Peak wind 33 mph from 270° (W) at 2021
2048 / 3:48 pm	Light rain	110° 13 / -

Table 2. Observations for Dallas/Love Field (KDAL)

5. RADAR DATA

Data from the Fort Worth NEXRAD radar (KFWS) and two nearby TDWR radars were

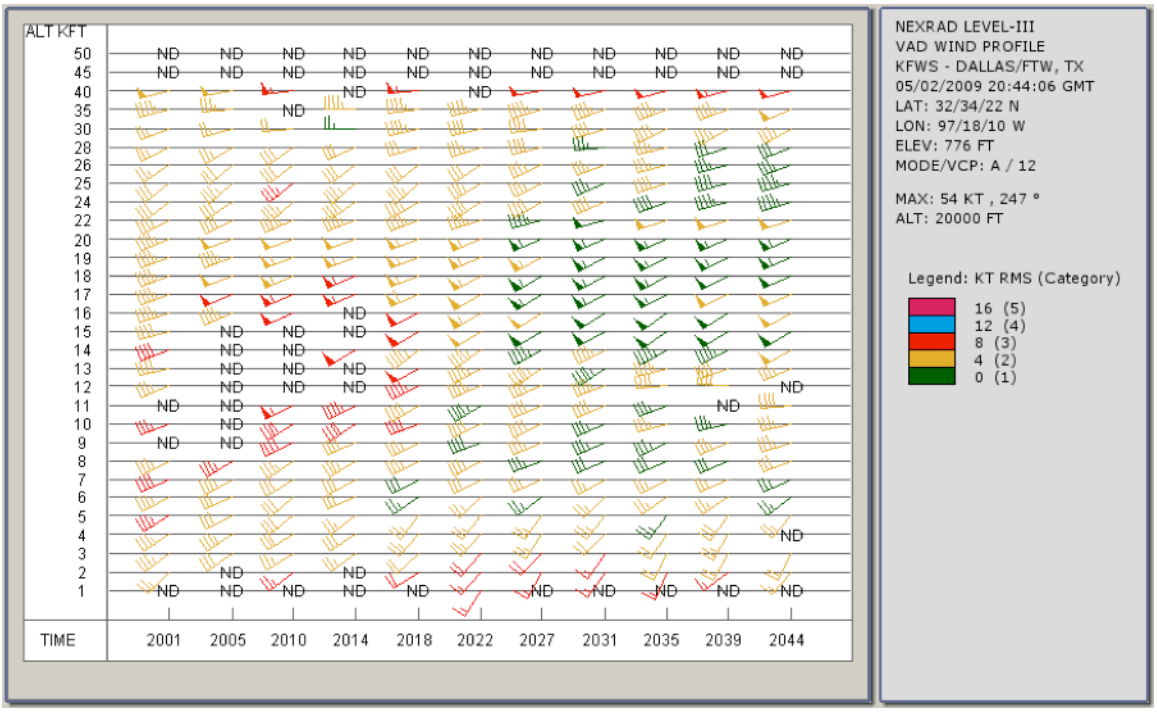

Figure 3. Velocity Azimuth Display (VAD) from the Fort Worth radar for the period 2001–2044 UTC (3:01–3:44 pm). Elevation above mean sea level is indicated in thousands of feet, and wind barbs are in knots.

examined. All data were obtained from the NCDC archive at 5-minute intervals. (TDWR data is generated at 1-minute intervals but only stored at NCDC in 5-minute intervals.) The data were viewed using NCDC's Weather and Climate Toolkit (WCT) and the National Severe Storms Laboratory's (NSSL) Warning Decision Support System—Integrated Information (WDSS-II).

5.1. Fort Worth NEXRAD Radar (KFWS)

The Fort Worth NEXRAD radar (KFWS) is located 33 miles southwest of the PF. At 2023 UTC (3:23 pm), it showed the leading edge of a thunderstorm complex over the PF moving rapidly northeast (Fig. 1). Examinations of reflectivity and radial velocity data at multiple times and scanning angles revealed that the leading arc of the storm was a small bow echo with counter-rotating "bookend" vortices at either end. Such features are often associated with microbursts.

Owing to pre-existing thunderstorm activity, this thunderstorm complex was somewhat irregular in appearance, but key features could be readily identified when looking at animations. The bow echo became organized and began to rapidly intensify around 3:00 pm, and continued to maintain its strength and appearance as it moved over and beyond the PF.

Radial velocity data at 2023 UTC (3:23 pm), which is likely the time nearest the event, are shown in Figure 2. Radial winds are indicated as away from (reds) and toward (greens) the radar. Individual radars cannot detect the tangential (cross-beam) component of the winds, so actual winds speeds will be equal to or higher than the radial component. At the lowest scanning angle (0.59°), the center of the radar beam is 745 m (2,444 ft) above ground level. The highest radial winds in the vicinity of the PF were 43.7 knots (50 mph).

The location of bookend vortices, commonly found on the ends of a bow echo, are indicated on the figure. The location of these vortices is confirmed by examining higher scanning angles (not shown). Owing to the overall motion of the thunderstorm complex to the

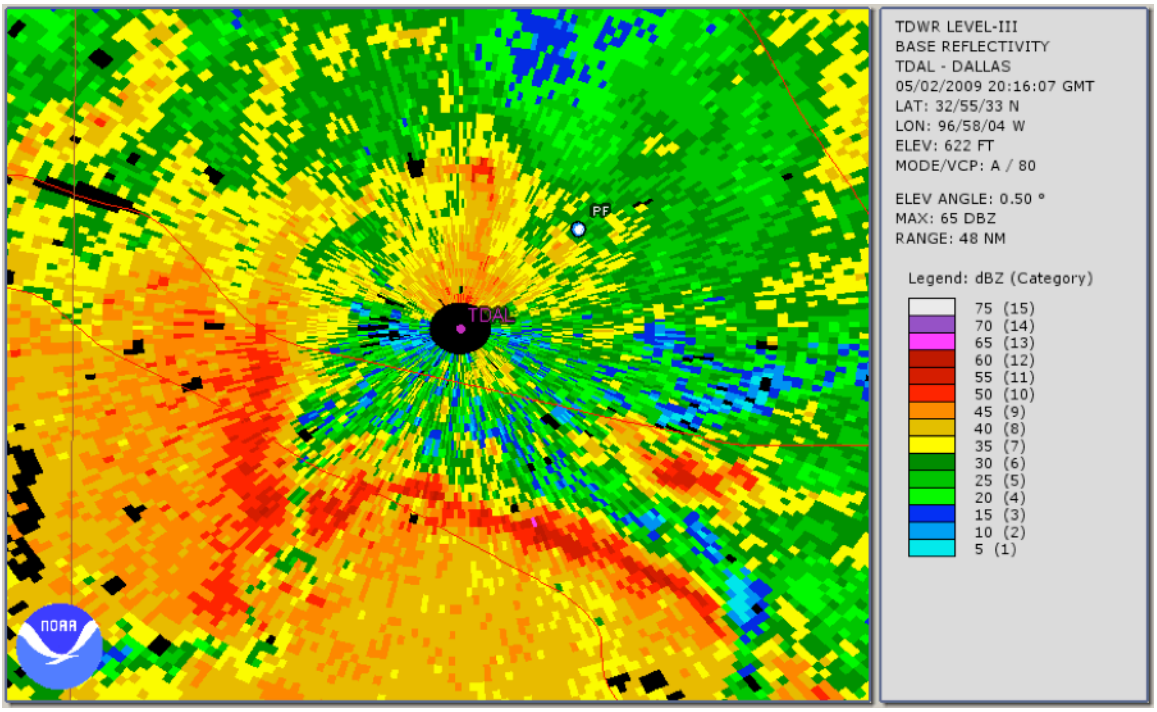

Figure 4. Reflectivity from the Dallas/Love TDWR (TDAL), lowest scanning angle, at 2016 UTC (3:16 pm CDT) 2 May 2009.

northeast, the vortices are manifested by high outbound (away from the radar, red) velocities and near-zero (gray) inbound velocities. The data do not show evidence of a tornadic circulation.

Wind speed and direction at multiple altitudes, representative of the large-scale environment surrounding the radar, are computed by averaging the winds from all radar scanning angles and directions. A time series of the resulting profile, called a Velocity Azimuth Display (VAD), is shown in Figure 3. Winds in the lowest several thousand feet above the radar at 2022 UTC (3:22 pm) averaged 15-25 knots (17-29 mph) from the SW, with the highest winds of 50-55 knots (58-63 mph) from the WSW being located about 14,000 to 19,000 ft above sea level. This wind profile is supportive of severe thunderstorms with high winds.

5.2. Dallas (Love Field) TDWR Radar (TDAL)

The Dallas/Love Field TDWR (TDAL), located just 1.5 miles southwest of the PF, provides a close-up view of the event. Reflectivity data from 2016 UTC (3:16 pm) show the bow echo south of the radar location moving rapidly toward the radar and the PF (Fig. 4).

Radial velocity data from the time closest to the event, 2022 UTC (3:22 pm) are shown in Figure 5. The maximum radial wind approaching the PF is 44.7 kt (51 mph). The figure also shows notional wind vectors and the likely location of the microburst center. (In comparison, NIST found higher peak radial winds of 58–62 mph at 3:24 pm. They likely had access to higher resolution 1-minute data, not available for this report.)

5.3. Dallas-Ft. Worth TDWR Radar (TDFW)

Radial velocity data from the Dallas-Ft. Worth TDWR (TDFW), located 14 km (8.7 miles) north-northeast of the PF, for the time closest to the event, 2022 UTC (3:22 pm), are shown in Figure 6. At the lowest scanning angle, the center of the radar beam is 119 m (390 ft) above the surface. The maximum radial wind in the vicinity of the PF is 41 kt (47 mph), which is consistent with the TDAL data.

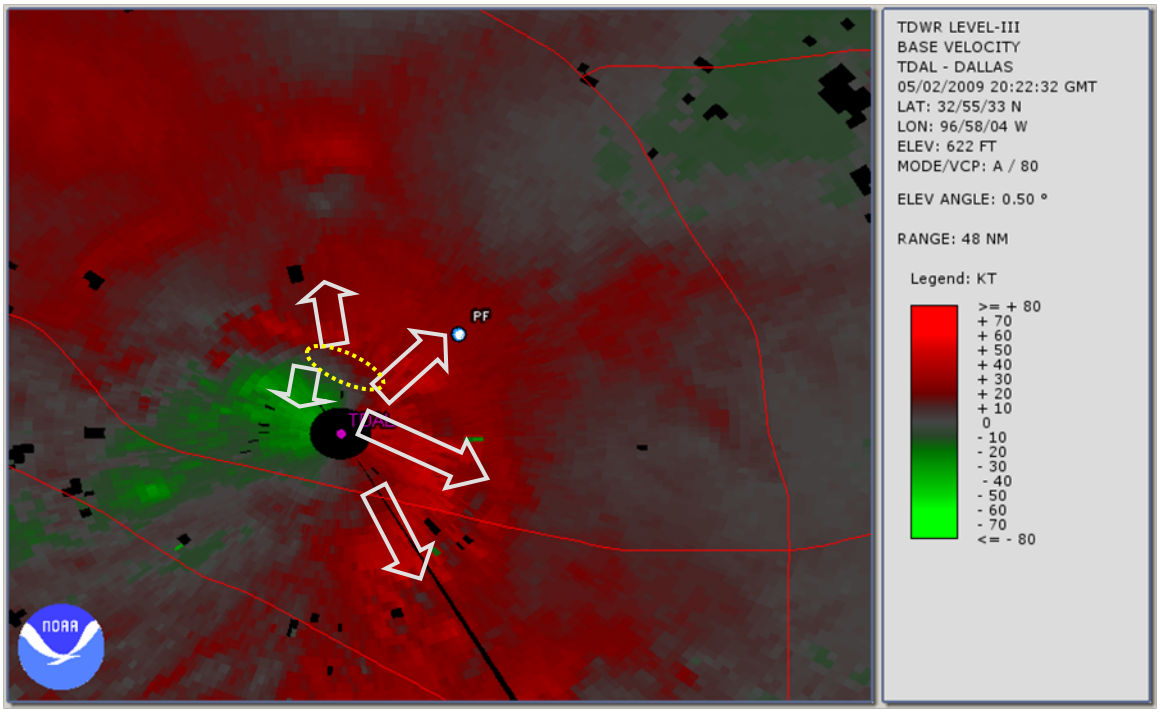

Figure 5. Radial velocity from the Dallas/Love TDWR (TDAL), lowest scanning angle, at 2022 UTC (3:22 pm CDT) 2 May 2009. Arrows indicate notional wind vectors that can be reasonably inferred, while the dotted yellow oval indicates the possible center of the microburst.

6. PEAK WIND GUST CALCULATION

We obtain a value for the maximum likely wind gust by applying to the TDWR radial data a series of adjustments: for wind direction, for reduction to lower atmospheric levels, and for instantaneous wind gusts.

The wind direction at the time of the event likely was from the west, as indicated by the KDFW ASOS observation at 2018 (3:18 pm), the NIST report, and the damage surveys cited therein. Given the location of the TDAL radar to the southwest (215°) of the PF, we make a geometric correction for the wind speed by dividing by the cosine of 45°, which is the angle between the radar, the PF, and a due westerly wind (cf. Fig. 2-5 of NIST). The wind speed thus obtained based on the TDAL radar data examined here is 51 mph ÷ 0.707 = 72 mph. NIST, using a peak radial wind of 58–62 mph, computed a 90-mph wind when correcting for wind direction.

Wind speeds in the lowest portion of the atmosphere tend to decrease with altitude owing to frictional effects with the ground. In a study of thunderstorm gust fronts, Eilts (1987) found a wind speed reduction factor of 1.6 from the Doppler radar wind estimates at heights of 50–600 m to the surface (nominally 10 m or 33 ft above ground). Applying this reduction yields surface-level winds of 56 mph.

The reduction in wind speed from the center of the beam to the top of the PF (a distance of 53 m or 174 ft; Figure 7) is less certain. We will take no reduction as an upper bound, and half the reduction (i.e., reduction factor of 1.3) as a likely value. The TDWR-indicated wind speeds at the top of the PF are therefore determined to be 69 mph (likely) to 90 mph (upper bound). [NIST conservatively estimated that the TDWR winds, linearly extrapolated to the top of the PF, would be only 30 mph (sustained wind) or 42 mph (maximum gust).]

The wind speeds thus obtained represent averages over a volume of the atmosphere approximately 24 m (79 ft) tall, 44–54 m (144–177 ft) wide, and 600 m (1,969 ft) long. We therefore may consider the radar winds as analogous to the sustained winds reported in

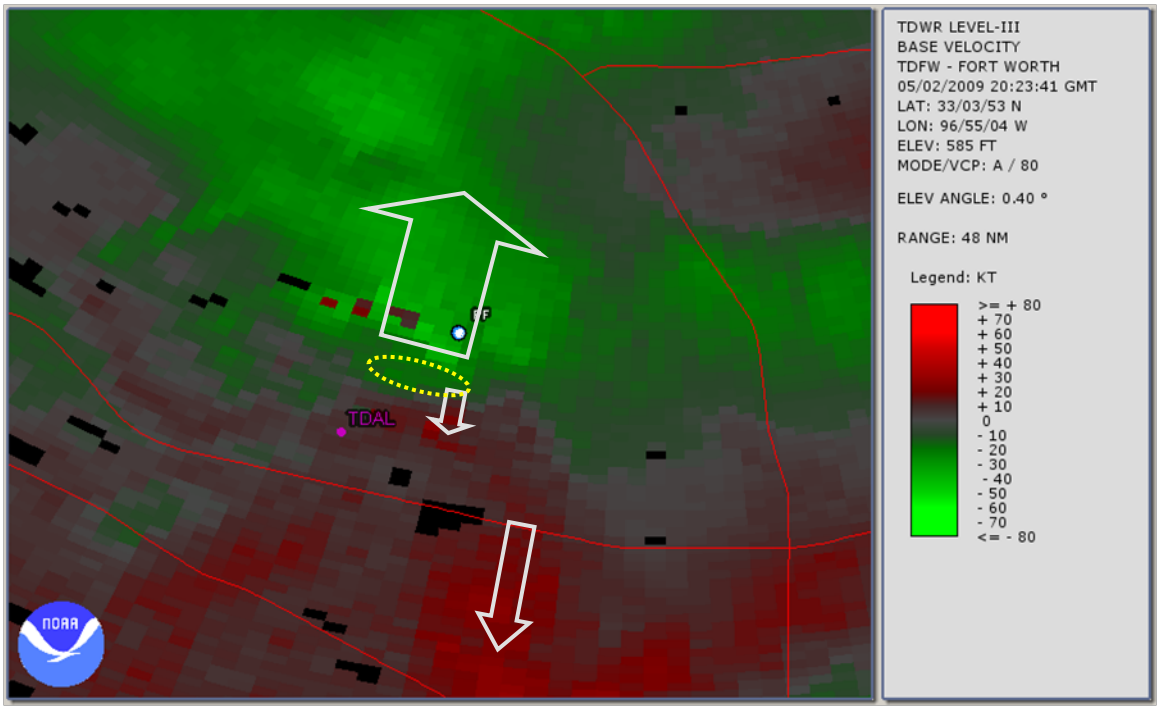

Figure 6. Radial velocity from the Dallas-Ft. Worth TDWR (TDFW), lowest scanning angle, at 2023 UTC (3:23 pm CDT) 2 May 2009. Notional wind vectors that can be reasonably inferred are indicated by arrows, while the possible center of the microburst is indicated by the dotted yellow oval.

surface observations, which are 2-minute averages. Momentary wind gusts may be estimated by multiplying by a standard 1.4 factor (following NIST; see Durst, 1960). We obtain wind gusts at ground level of 78 mph. Near the top of the PF, gusts range from 97 mph (likely) to 126 mph (upper limit). This is summarized in Table 3 below.

Location	Max sustained wind (mph)	Max gust (mph)
Lowest radar scan	90	126
Top of PF	69 (likely) 90 (upper bound)	97 (likely) 126 (upper bound)
Ground level (10 m)	56	78

Table 3. Estimates of maximum sustained wind speeds and wind gusts at various vertical levels based on TDWR data.

7. SUMMARY AND CONCLUSIONS

A microburst struck the Dallas Cowboys Practice Facility on the afternoon of 2 May 2009. The Dallas/Love Field TDWR was fortuitously located just 1.5 miles southwest of the PF, and the stagnation point (center of the microburst) was determined to be about 1 mile southwest of the PF. Based on damage surveys, thermodynamic calculations, and TDWR data, the maximum surface wind gust was variously estimated by NIST and NWS to be in the 55-70 mph range.

The question arises whether these surface-level winds are representative of winds at the top of the 26-m tall PF. Upon adjusting the TDWR radial wind speed for wind direction, for reduction to lower atmospheric levels, and for instantaneous wind gusts, we find that the maximum gust at the top of the PF may have been 97 mph (likely value) to 126 mph (upper bound). Using the same methodology, the maximum surface level gusts are determined to be 78 mph, somewhat higher than the range estimated previously. It may be that the lowest

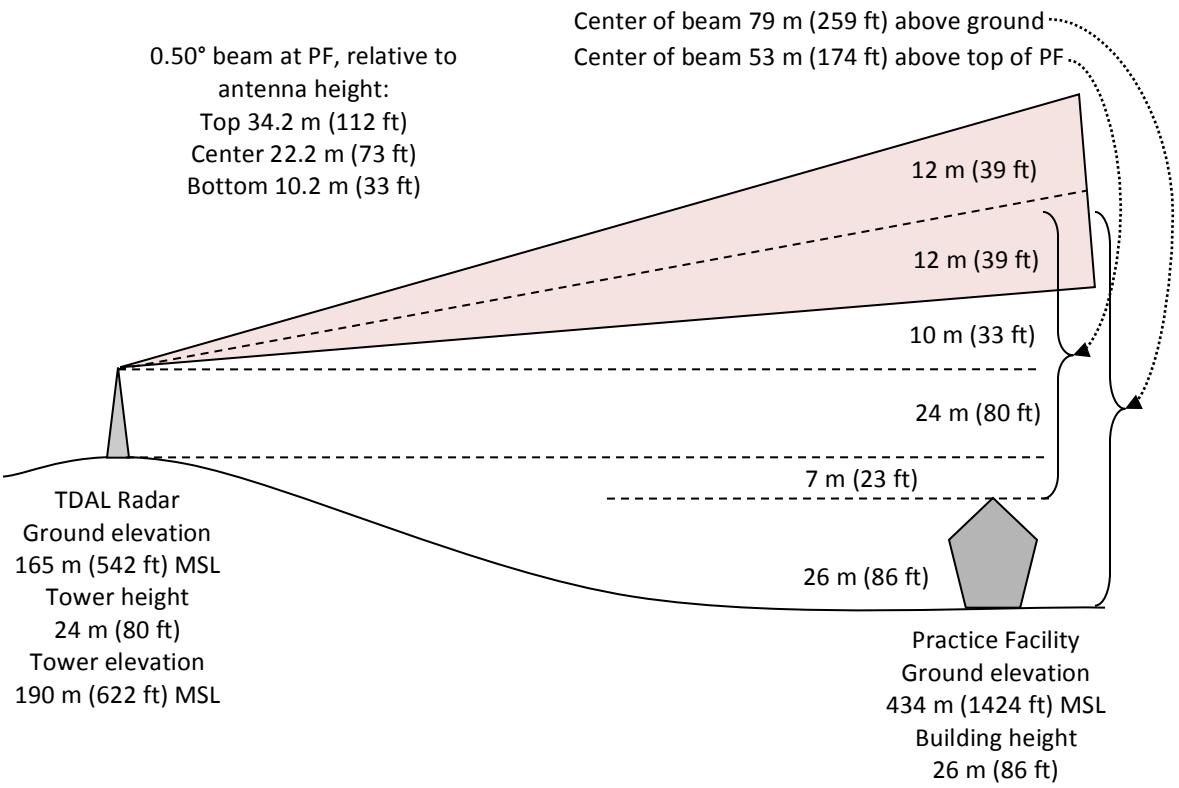

Figure 7. Geometry of lowest scanning angle (0.50°) radar beam from TDAL TDWR with respect to the PF. Values were obtained using the WCT and WDSS-II software. Building height is from NIST. MSL = Height above Mean Sea Level.

levels of the atmosphere had sufficiently stabilized such that higher momentum at the height of the radar beam could not be transported downward.

Clearly there is uncertainty in the adjustment factors applied here (and in the NIST report). Numerical simulation is offered as a potential technique for reducing this uncertainty.

Acknowledgement. I thank Ben Baranowski and Chris Porter for their assistance with interpreting the radar data.

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