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COMPARISON BETWEEN DOW OBSERVED TORNADOES AND PARENT MESOCYCLONES OBSERVED BY WSR-88Ds

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1. INTRODUCTION

The typical inter-radar spacing and operational volumetric coverage patterns of about 30 WSR-88Ds across the approximately 1.5 million square km of the United States plains often precludes observations in the lowest kilometer of tornadic supercell thunderstorms. Only about 35% of the plains are covered by WSR-88D observations in the lowest km decreasing to about 12% for observations in the lowest half-km (Fig. 1).

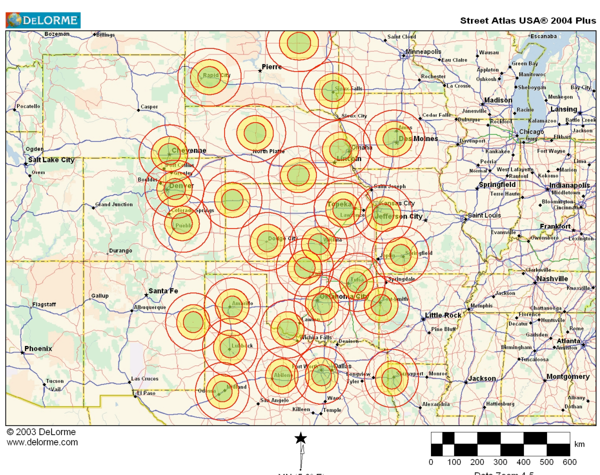

Fig. 1 The elevation of the 0.5° beam in the WSR-88D network across the plains, showing regions below 0.5 km (green), below 1.0 km (yellow and green), and below 2.0 km (outermost red-rings).

The Mesocyclone Detection Algorithm (MDA), Tornado Vortex Signature (TVS), and more recently the Tornado Detection Algorithm (TDA) are all used operationally with WSR-88Ds to assist with the tornado warning process in supercells (Zrnic et al. 1985; Crum et al. 1993; Mitchell et al. 1998; Stumpf et al. 1998). While these algorithms can identify and track the evolution of storm-scale shear present in supercell thunderstorms, the aforementioned radar horizon problem, limits of sample volume size (1.0° x 1.0° x 250 m), and 5 min volume updates, leave most tornadoes produced by parent mesocyclones either unresolved or unobserved.

The Doppler On Wheels (DOWs) mobile 3-cm X-band radar systems have collected high-resolution data in nearly 100 tornadoes between 1995 and 2004 (Wurman et al. 1997; Wurman and Gill 2000; Burgess et al. 2002; Wurman 2002; Alexander and Wurman 2004; Wurman and Alexander 2004a, 2004b). Many of these DOW-observed tornadoes are sampled between 20 and 100 m AGL with typical sample volume sizes around 50 m x 50 m x 50 m and volume updates every 60 s. In a few tornadoes, the sampling resolution is on the order of 3 m x 3 m x 12.5 m.

A subset of the DOW tornado database is selected containing observations of strong to violent tornadoes (Doppler velocities in excess of 60 $m\ s^{-1}$) observed by the DOWs within about 300 m AGL. These radar observations are compared with the corresponding level II and III WSR-88D observations including the MDA and TVS algorithm (or TDA) output (Table 1).

TABLE 1. List of strong or violent DOW-observed tornado cases including the available WSR-88D level II or III data. All radar data is classified by the height above ground level of the lowest beam in the tornado or parent mesocyclone. The * indicates ground-based Doppler velocity estimates of the tornado intensity where the official damage survey is either unavailable or indicates a weaker intensity due to a lack of damage descriptors.

Date	Location	F-Scale(s)	Radar Lowest Elevation			
			< 0.5 km	< 1 km	< 2 km	< 4 km
2 Jun 1995	Dimmitt, TX	F3*	DOW1		KLBB	
8 Jun 1995	Kellerville, TX	F4	DOW1		KAMA	KFDR
30 May 1998	Spencer, SD	F4	DOW3	KFSD		KABR
3 May 1999	Oklahoma City, OK	F5	DOW3, KTLX			KINX
3 May 1999	Mulhall, OK	F4	DOW3		KTLX	KICT, KINX
3 Jun 1999	Almena, KS	F3	DOW3		KUDX	KGLD
9 May 2003	Oklahoma City, OK	F3	DOW3, KTLX			KFDR, KINX, KVNX
15 May 2004	Stratford, TX	F3*	DOW3			KAMA
12 May 2004	Harper, KS	F4	DOW3	KICT, KVNX		KDDC
29 May 2004	Geary, OK	F3*	DOW3		KTLX, KVNX	KFDR

2. METHODOLOGY

The comparison between DOW observed tornadoes and WSR-88D observed parent mesocyclones is an attempt to find any correlation between the shear across the parent mesocyclone and that of the near surface tornado wind field. Of particular interest is any relationship between MDA/TVS/TDA performance and the evolution of the tornado near the ground.

The DOW and WSR-88D comparisons are constructed using two different approaches. For each DOW tornado case, one or more WSR-88D observations are available for various elevations (and corresponding ranges) in a supercell. The WSR-88D observations are grouped into elevation bins of 0.0 - 0.5 km AGL, 0.5 - 1.0 km AGL, 1.0 - 2.0 km AGL, and 2.0 – 4.0 km AGL.

For each comparison between a DOW observed tornado and a WSR-88D MDA/TVS/TDA observation, several quantities are compared including peak Doppler velocity difference (Delta-V) and shear (defined here as Delta-V divided by distance between peak Doppler velocities). For a few cases where the level III MDA/TVS/TDA data is either unavailable or does not include the Delta-V observations of the TDA, the level II data is used in the comparison.

The first approach isolates each DOW tornado case and examines multiple WSR-88D observations at various elevations in the same supercell. This comparison avoids any assumption about the similarity of mesocyclone to tornado evolution in different supercells, but usually limits the WSR-88D observation height comparison to one or two elevation bins.

The second approach examines the relationship of the WSR-88D mesocyclones at fixed elevation bins as they compare to DOW observations of various tornadoes. Under the assumption that the relationship between mesocyclone evolution and tornado evolution is identical for different supercell storms, this comparison provides an objective method to characterize the effect of increased height and range of WSR-88D observations on the MDA/TVS/TDA performance.

A dramatic example of this comparison is shown with the Spencer, SD supercell of 30 May 1998 where the observed Delta-V within 50 m AGL is nearly three times higher than that observed in the lowest scan of the WSR-88D across the mesocyclone at about 900 m AGL (Fig. 2). At the same elevation as the 88D, the DOW observes a Delta-V about twice as high as the 88D. This not only demonstrates the effect of increased range and decreased azimuthal sampling, but also the extreme variability of the tornado strength in the lowest few hundred meters.

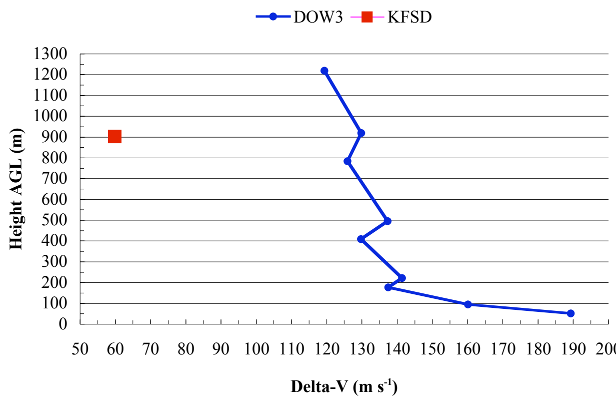

Fig. 2 The Delta-V across the Spencer, SD tornado around 0139 UTC on 30 May 1998 (tornado is in the town) as observed by DOW3 at 4 km range, and the Delta-V across the mesocyclone viewed by the 0.5° scan from the WSR-88D KFSD at about 72 km range.

3. PRELIMINARY RESULTS

Two tornadic supercell cases are analyzed using the DOW and surrounding WSR-88D observations including Spencer, SD on 30 May 1998 (Alexander and Wurman 2004; Wurman and Alexander 2004) and Geary, OK on 29 May 2004.

A comparison of the shear observed at low-levels by the DOW and the WSR-88D KFSD and KABR MDA/TVS algorithms (Fig. 3) shows the shear across the tornado observed by the DOW remaining nearly an order of magnitude higher than that observed by either the MDA or TVS algorithm from KFSD and KABR.

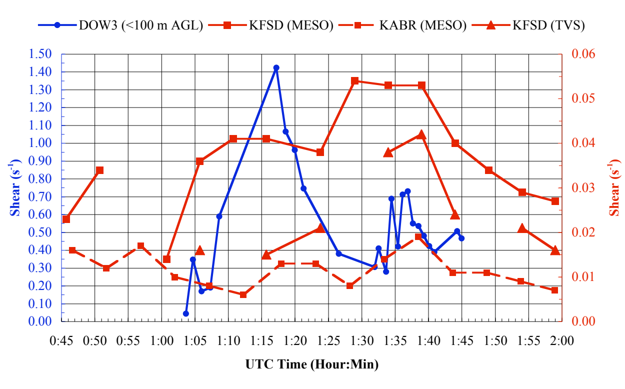

Fig. 3 The shear across the 30 May 1998 Spencer, SD tornado and supercell mesocyclone as viewed by DOW3 (blue) or the WSR-88D MDA/TVS algorithms (red). The KFSD observations are near and above 1 km AGL, while the KABR observations are near and above 3 km AGL.

The shear values for both the MDAs and the TVS reach a maximum around 0.04 s^{-1} to 0.05 s^{-1} during the time when the tornado near surface wind field is most intense between 0130 and 0140 UTC (Fig. 4). The DOW observed shear has decreased from earlier as the tornado rapidly increases in size while slowly increasing its Delta-V. The Delta-V of the mesocyclone, as viewed by KFSD, also reaches a maximum amplitude between 0135 and 0140 UTC which is the same time as the DOW peak Delta-Vs of over 190 m s^{-1} near the surface and around 140 m s^{-1} at 1 km AGL. However, as previously discussed, the peak KFSD Delta-V remains almost three times lower than the peak Delta-V in the near-surface tornado (Fig. 4).

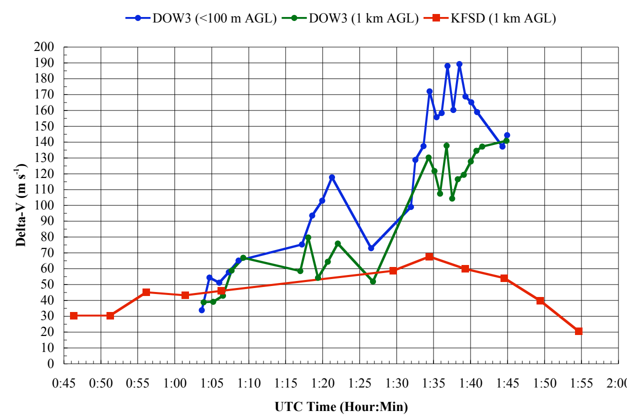

Fig. 4 The Delta-V across the 30 May 1998 Spencer, SD tornado and supercell mesocyclone as viewed by DOW3 near the surface (blue) and at 1 km (green). The WSR-88D KFSD Delta-V is also shown (red) based upon the level II data.

The comparison of the Geary, OK supercell and tornado observations on 29 May 2004 reveals some slightly different results (Wurman and Alexander 2004b). In this case, the location of the supercell and tornado observations by the DOW are in a region where all WSR-88D observations are near and above 2 km AGL as opposed to 1 km in the Spencer, SD case.

The DOW observed shear across the tornado reaches a brief maximum amplitude of about 0.30 s^{-1} between 0130 and 0140 UTC while the MDA/TDA show a nearly constant value around 0.045 s^{-1} for KTLX and 0.025 s^{-1} for KFDR which are both about an order of magnitude lower than the DOW observations (Fig. 5).

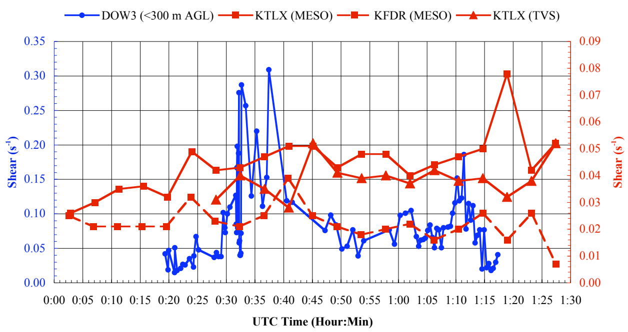

Fig. 5 The shear across the 29 May 2004 Geary, OK tornado and supercell mesocyclone as viewed by DOW3 (blue) or the WSR-88D MDA/TDA (red). The KTLX observations are near and above 2 km AGL, while the KFDR observations are near and above 3 km AGL.

The Delta-V comparison shows little change in intensity for the WSR-88D observations with typical values near 50 to 60 m s^{-1} for KTLX TDA maximum and low-level Delta-Vs, while the DOW observations show a pronounced two-fold increase in Delta-V between 0125 and 0140 UTC. Similar to the Spencer, SD case, the peak 88D Delta-V lies between two and three times less than the peak DOW Delta-V observations (Fig. 6).

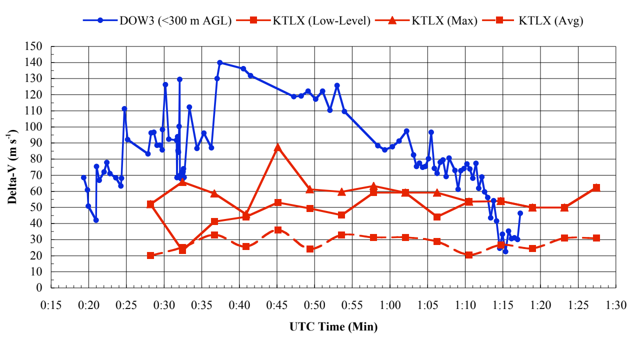

Fig. 6 The Delta-V across the 29 May 2004 Geary, OK tornado and supercell mesocyclone as viewed by DOW3 near the surface (blue) and near or above 2 km based upon the KTLX TDA (red).

The analysis of the remaining cases in this study will help to determine if signal detection of rapid tornado intensification has a functional relationship to the height (range) and magnitude of the 88D mesocyclone observations. This work may also provide some aspect ratio corrections to 88D shear and Delta-V values as a function of observation height both to help characterize tornado intensity and possibly further efforts lead by Wood and Brown (1997, 2000) and Wood et al. (2001).

4. ACKNOWLEDGMENTS

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5. REFERENCES

Alexander, C. and J. Wurman, 2004: The 30 May 1998 Spencer, South Dakota Storm. Part I: The Structural Evolution and Environment of the Tornadoes. Submitted to Monthly Weather Review.

Burgess, D. W., M. A. Magsig, J. Wurman, D. C. Dowell, and Y. Richardson, 2002: Radar Observations of the 3 May 1999 Oklahoma City tornado. *Wea Forecasting*, **17**, 456-471.

Crum, T. D. and R. L. Alberty, 1993: The WSR-88D and WSR-88D Operational Support Facility. *Bull. Amer. Meteor. Soc.*, **74**, 1669-1687.

Mitchell, E. D., S. V. Vasiloff, G. J. Stumpf, A. Witt, M. D. Eilts, J. T. Johnson, and K. W. Thomas, 1998: The National Severe Storms Laboratory Tornado Detection Algorithm. *Wea Forecasting*, **13**, 352-366.

Stumpf, G. J., A. Witt, E. D. Mitchell, P. L. Spencer, J. T. Johnson, M. D. Eilts, K. W. Thomas, and D. W. Burgess, 1998: The National Severe Storms Laboratory Mesocyclone Dectection Algorithm for the WSR-88D. *Wea Forecasting*, **13**, 304-326.

Wood, V. T., and R. A. Brown, 1997: Effects of radar sampling on single-Doppler velocity signatures of mesocyclones and tornadoes. *Wea. Forecasting.*, **12**, 928–938.

Wood, V. T., and R. A. Brown, 2000: Oscillations in mesocyclone signatures with range owing to azimuthal radar sampling. *J. Atmos. Oceanic Technol.*, **17**, 90-95.

Wood, V. T., R. A. Brown, and D. Sirmans, 2001: Technique for improving detection of WSR-88D mesocyclone signatures by increasing angular sampling. *Wea. Forecasting.*, **16**, 177-184.

Wurman, J., J. Straka, E. Rasmussen, M. Randall, and A. Zahrai, 1997: Design and deployment of a portable, pencil-beam, pulsed, 3-cm Doppler radar. *J. Atmos. Oceanic Technol.*, **14**, 1502–1512.

Wurman, J., and S. Gill, 2000: Finescale radar observations of the Dimmitt, Texas (2 June 1995), tornado. *Mon. Wea. Rev.*, **128**, 2135–2164.

Wurman, J., 2002: The Multiple-Vortex Structure of a Tornado. *Wea. Forecasting.*, **17**, 473–505.

Wurman, J., and C. Alexander, 2004a: The 30 May 1998 Spencer, South Dakota Storm. Part II: Comparison of Observed Damage and Radar-Calculated Winds in the Tornadoes. Submitted to Monthly Weather Review.

Wurman, J., and C. Alexander, 2004b: Scales of motion in tornadoes, what radars cannot see, what is a tornado. Preprints, *22nd Conf. on Severe Local Storms*, Hyannis, MA, Amer. Meteor. Soc.

Zrnic, D. S., D. W. Burgess, and L. D. Hennington, 1985: Automatic detection of mesocyclonic shear with Doppler radar. *J. Atmos. Oceanic Technol*, **2**, 425-438.