5.5 Highlights from the Texas Tech Ka-band Mobile Doppler Radar and StickNet Data Collection During VORTEX2

Christopher C. Weiss*
Texas Tech University, Lubbock, Texas

David C. Dowell
National Center for Atmospheric Research

1. INTRODUCTION

Described below are details of Verification of the Origin of Rotation in Tornadoes Experiment 2 (VORTEX2) observations made by two types of platforms developed by Texas Tech University. These observations include in situ tripod-based measurements from a suite of 24 "StickNet" stations and mobile Doppler radar data collected by two Texas Tech Ka-band (TTUKa) radars. Each of these platforms is charged with obtaining information about the supercell thunderstorm in its pre-tornadic and tornadic state. All combined, there were nearly 800 instances of StickNet and TTUKa deployments during the VORTEX2 field phase.

2. STICKNET OVERVIEW

In 2005, faculty and students from the Texas Tech Atmospheric Science Group and the Wind Science and Engineering Research Center developed two prototype StickNet observation systems. These platforms feature a suite of meteorological instrumentation mounted on rugged engineering tripods. The primary purpose of these probes is to make simultaneous measurements – with adjustable station density – of atmospheric phenomena. In the case of supercell thunderstorms, these samples are often taken in regions near the updraft, where it is too hazardous to carry out observational strategies with manned instrumentation.

Following prototype development and testing (Schroeder and Weiss 2008), more probes were constructed and deployed *en masse* for the first time on thunderstorms during the 2007 and 2008 incarnations of the Multiple Observations of Boundaries in the Local-Storm Environment Project (Weiss and Schroeder 2008). It was found that each of the probe types ("A" probes featuring independent measurements of state variables, "B" probes relying on a single Vaisala WXT510 for all measurements (less pressure)) had advantages over the other. Consequently, a roughly equal number of each type was constructed to arrive at the current total of 24 probes (Fig. 1).

During the VORTEX2 project in 2009 and 2010, StickNet instruments were tasked with the in situ sampling of target thunderstorms. The default deployment strategy was one in which two arrays of 12 probes were dropped (e.g., deployment near Dumas, TX on 18 May 2010 (Fig. 2)). The probes in each of these arrays were spread, as best as possible given the available road network, in the direction normal to storm translation. In most cases, a wider net of probes (~5 km spacing) was deployed first (~60 minutes of lead time) to capture storm-scale variability in thermodynamic and kinematic state. In 2009, this ~25-30 km-wide coarse array was centered on the low-level mesocyclone of the target storm. In 2010, the center was shifted to the left of the anticipated mesocyclone track to better sample thermodynamic gradients within the area forward (i.e., downshear) of the updraft. Nested within the broader array was a finer scale deployment of probes (~1 km spacing) focused specifically on the sampling of sharp gradients on the scale of the principal low-level mesocyclone.

In total, 650 StickNet probes (221 in 2009, 429 in 2010) were dropped during the two years of the VORTEX2 field campaign. The priority of cases (Table 1) is largely determined by factors such as tornado production within the target, the proximity of tornadogenesis to the array and the number, density and proper function of deployed probes. Deployments on 13 case days (five in 2009, eight in 2010) are considered to be in the upper tier, that is, holding the potential to satisfy multiple key project objectives.

3. TTUKA OVERVIEW

The Texas Tech Vice President for Research awarded a $1M competitive grant in 2006 to the Atmospheric Science Group and the Wind Science and Engineering Research Center

* *Corresponding author address: Christopher C. Weiss, Texas Tech University, Atmospheric Science Group, Department of Geosciences, Lubbock, TX, 79409; e-mail: Chris.Weiss@ttu.edu*

for the development of two mobile Doppler radar systems in the Ka frequency band. The high transmit frequency and the introduction of a non-linear pulse compression technique allows these systems to prioritize three-dimensional resolution and sensitivity. Though initially developed for the purpose of visualizing clear-air flows (e.g., boundary layer circulations, wind turbine wake), the radars excelled in field testing on precipitating structures, and were thus proposed for inclusion in VORTEX2.

The first of the radars was completed late in 2008 and had the opportunity (on pilot funds) to assist the VORTEX2 project in achieving goals related to the low-level wind field of tornadoes (Fig. 3). Though there were limited opportunities to obtain such samples through the first field season, the signature tornado event in Goshen County, WY on 5 June 2009 permitted the first TTUKa data of a tornado vortex, albeit from well outside the optimal range (Weiss 2009, Metzger and Weiss 2010).

The second of the TTUKa radars was completed early in 2010 and the National Science Foundation supported both systems for the second VORTEX2 field phase. The 2010 season allowed more opportunities for data on tornadoes, though all were weak (TABLE 2). Owing to the transience of these weak vortices, dual-Doppler objectives were not met on the tornadoes themselves. However, a number of quality non-tornadic and pre-tornadic dual-Doppler deployments were executed (TABLE 2). Foremost of these, perhaps, is the dual-Doppler case west of Dumas, TX on 18 May 2010, in which multiple RFGF structure was resolved and related to short-lived vertical vorticity maxima (Skinner et al. 2010a)

4. ONGOING ANALYSES AND FUTURE PLANS

i. StickNet

One of the principal goals of StickNet measurements is to elucidate the distribution of baroclinity within the flanks of supercell thunderstorms. Many numerical modeling studies have identified regions where horizontal density gradients contribute horizontal solenoidal vorticity to air parcels heading inbound to the low-level mesocyclone. Yet, a fair number of observational studies (e.g., Shabbot and Markowski 2006) have diminished the importance – or failed to identify – any such zones in areas traditionally expected to contain such baroclinity (e.g., the forward-flank reflectivity gradient), though some cases in recent research using StickNet and mobile mesonet probes (e.g., Skinner et al. 2010b) have reaffirmed the presence of baroclinic zones potentially relevant to the vorticity budget of the low-level mesocylone.

StickNet, mobile mesonet and mobile Doppler radar data are currently being compiled to form a composite of baroclinty within VORTEX2 supercells. Bulk characteristics of observed cold pools are being investigated to reveal whether the magnitude of these deficits have some bearing on the modulation of vertical vorticity and buoyancy within the low-level mesocyclone (Charboneau and Weiss 2010). Further, the ability of current single- and dual-moment microphysics packages to properly replicate observed cold pools is being investigated using the Weather Research and Forecasting Model / Data Assimilation Research Testbed (Reinhart et al. 2010).

ii. TTUKa Radars

As the TTUKa radars prioritize resolution and sensitivity in sampling, research objectives are focused on the fine-scale structure of tornado vortices, particularly in the boundary layer / corner flow region, which is too shallow to visualize with many lower-frequency radar systems. The best attempt at resolving this inflow region was during the 2009 Goshen County, WY deployment (Weiss 2009, Metzger and Weiss 2010) where two separate areas and scales of convergence are identified within the surface layer of the tornado. Analysis is ongoing on this case.

The 13 June 2010 tornado north of Booker, TX (Fig. 4), though weak, provided a second opportunity to assess the vertical structure of the tornado vortex at high resolution (Metzger and Weiss 2010). Further, tools such as the Ground Based Velocity Track Display (Lee et al. 1999) are being employed to resolve the horizontal (axisymmetric) radial and tangential components of the tornado vortex. Other weak tornadoes near Limon, CO (11 June 2010) and Tribune, KS (25 May 2010) are also slated for similar study.

In a few VORTEX2 cases, routine PPI and RHI scanning of storm-generated boundaries revealed some interesting structure. Specifically, a couple of these cases identify regions of horizontal vorticity within the RFGF zone that appear to translate vertically (both upwards and downwards in time (Fig. 5)). The existence/production of horizontal vorticity in these areas demands further scrutiny for any relevance to the vorticity budget of low-level vertical vorticity maxima.

5. ACKNOWLEDGEMENTS

The authors are grateful to the National Science Foundation, which has supported the StickNet and TTUKa data collection and research through grants ATM-0800542 and AGS-0964088, respectively. We also thank Pat Skinner, Anthony Reinhart, Brad Charboneau and Ryan Metzger for their contributions to the images presented in this paper. Robin Tanamachi is acknowledged for her assistance in GBVTD analysis. Finally, these observations would not have been possible without the hard work of Jerry Guynes, John Schroeder and the many students at Texas Tech University and the University of Michigan that helped in the field for twelve weeks of data collection.

6. REFERENCES

Charboneau, B., and C. C. Weiss, 2010: Thermodynamic and kinematic analysis of a tornadic supercell using high resolution in situ data from Texas Tech StickNet instrument systems., *Preprints, 25th Conference on Severe Local Storms*, paper 8A.3.

Lee, W.-C., B. Jou, P.-L. Chang, and S.-M. Deng, 1999: Tropical cyclone kinematic structure retrieved from single-Doppler radar observations. Part I: Interpretation of Doppler velocity patterns and the GBVTD technique., *Mon. Wea. Rev.,* **127**, 2419-2439.

Metzger, R. S., and C. C. Weiss, 2010: An examination of the vertical structure of two tornadoes using Ka-band mobile Doppler radar., *Preprints, 25th Conference on Severe Local Storms*, paper 16A.6.

Reinhart, A. E., C. C. Weiss, D. C. Dowell, 2010: Verification of supercell cold pools in high-resolution WRF simulations using StickNet in situ data., *Preprints, 25th Conference on Severe Local Storms,* paper 8A.5.

Schroeder, J. L., and C. C. Weiss, 2008: Integrating research and education through measurement and analysis., *Bull. Amer. Meteor. Soc.*, **89**, 793-798.

Shabbott, C. J., and P. M. Markowski, 2006: Surface in situ observations within the outflow of forward-flank downdrafts of supercell thunderstorms., *Mon. Wea. Rev.*, **134**, 1422-1441.

Skinner, P. S., C. C. Weiss, A. E. Reinhart, W. S. Gunter, J. L. Schroeder and J. Guynes, 2010a: TTUKa mobile Doppler radar observations of near-surface circulations in VORTEX2., *Preprints, 25th Conference on Severe Local Storms,* Denver, CO, paper 15.3.

Skinner, P. S., C. C. Weiss, J. L. Schroeder, L. J. Wicker, M. I. Biggerstaff, 2010b: Observations of the surface boundary structure within the 23 May 2007 Perryton, Texas supercell., *Mon. Wea. Rev.* (in review)

Weiss, C. C., 2009: The TTUKa mobile radar: Coordinated radar and in situ measurements of supercell thunderstorms during Project VORTEX2., *Preprints, 34th Conference on Radar Meteorology*, paper 11B.2.

Weiss, C. C., and J. L. Schroeder, 2008: The 2007 and 2008 MOBILE Experiment: Development and testing of the TTU StickNet platforms., *Preprints, 24th Conference on Severe Local Storms,* Savannah, GA, paper 5.1.

TABLE 1 – Top StickNet cases from VORTEX2, in chronological order

Date	Event Description
6/4/2009	Supercell near Cheyenne, WY
6/5/2009	Tornadic supercell near Lagrange, WY
6/7/2009	Supercell near Oregon, MO
6/9/2009	Supercell near Greensburg, KS
6/11/2009	Merging supercells near La Junta, CO
5/10/2010	Tornadic supercell near Seminole, OK
5/18/2010	Supercell near Dumas, TX
5/19/2010	Supercell near Cimarron City, OK
5/25/2010	Tornadic supercell near Tribune, KS
6/6/2010	Merging supercells near Ogallala, NE
6/7/2010	Tornadic supercell near Mitchell/Bridgeport, NE
6/11/2010	Supercell with ancillary updraft interaction near Limon, CO
6/13/2010	Tornadic supercell near Booker, TX

TABLE 2 – TTUKa case days in VORTEX2 featuring tornado deployments, in chronological order

Date	Event Description
6/5/2009	Lagrange, WY - PPI/RHI of tornado from far range
5/18/2010	Dumas, TX - Dual Doppler of low-level mesocyclone , RFGF spinups, single Doppler of tornado
5/25/2010	Tribune, KS - Single Doppler of three weak tornadoes
6/11/2010	Agate, CO - Single Doppler of two weak tornadoes, multiple vortex structure
6/13/2010	Booker, TX - RHIs of weak tornado

Figure 1 – A photograph of a StickNet mass test on 22 May 2010.

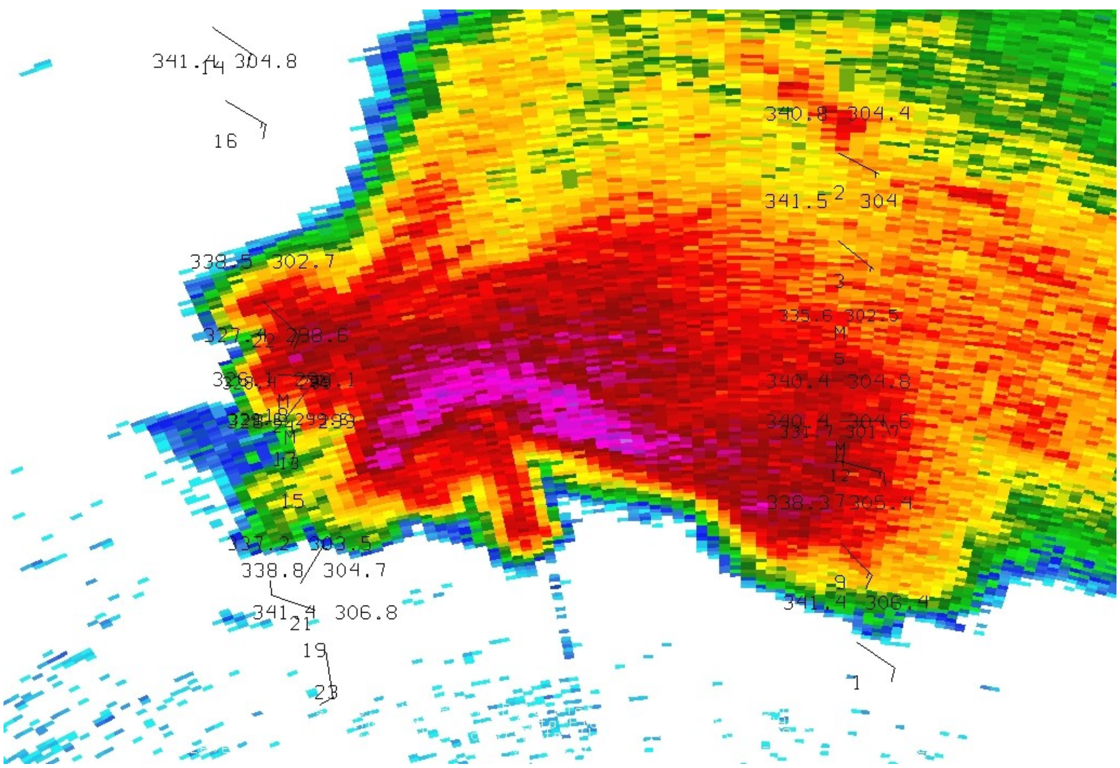

Figure 2 – Reflectivity (colored) from the KAMA WSR-88D on 18 May 2010 at 2350 UTC overlaid with StickNet observations (surface station model with equivalent potential temperature (upper left), virtual potential temperature (upper right) and probe ID (below)).

Figure 3 – A photograph of the TTUKa-1 radar scanning a supercell near Greensburg, KS on 9 June 2009.

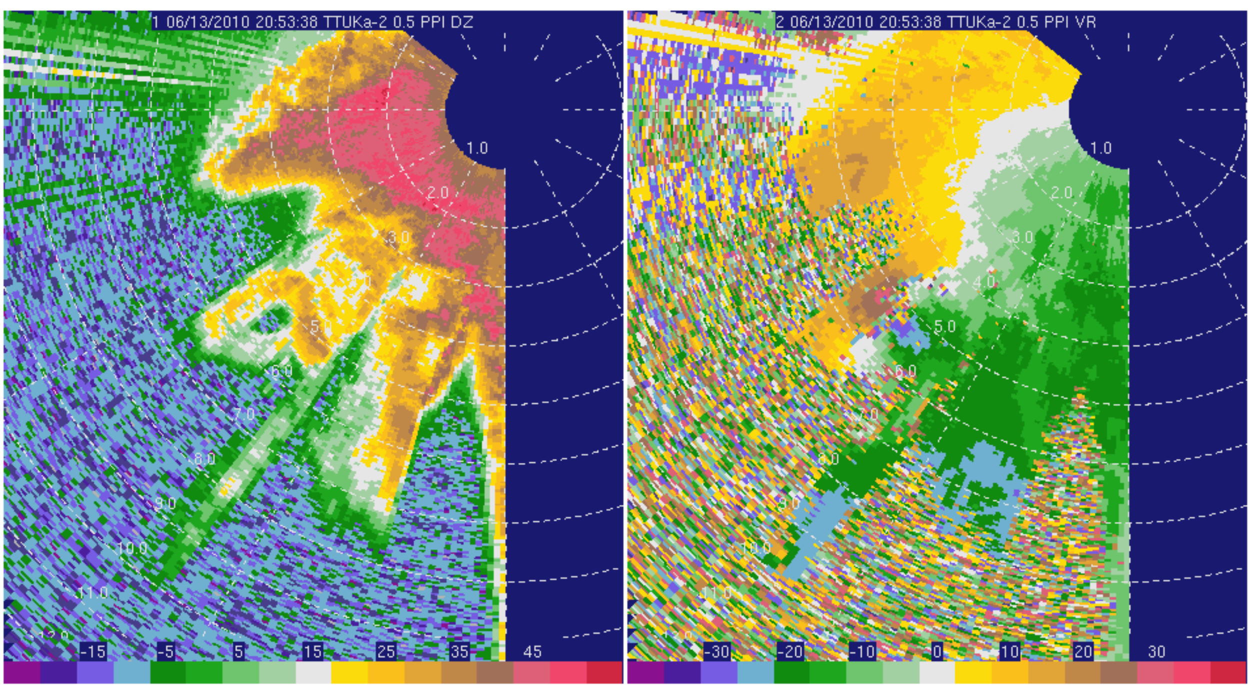

Figure 4 – TTUKa-2 reflectivity (left, dBZ) and radial velocity (right, m s^{-1}) of a weak tornado north of Booker, TX on 13 June 2010 at 2053 UTC.

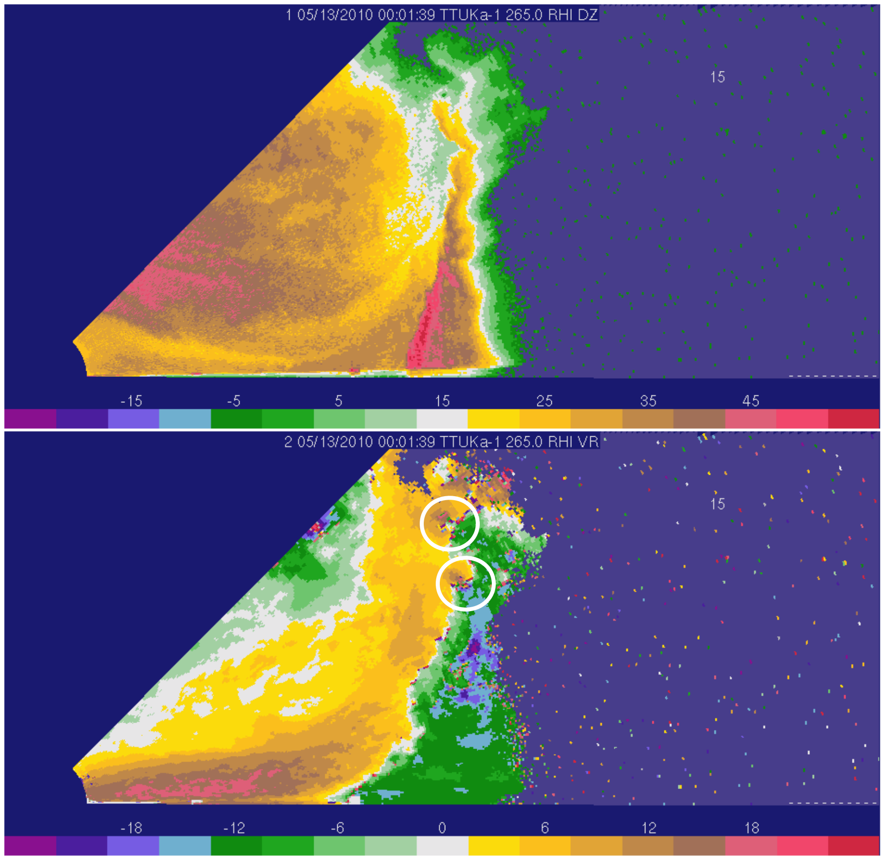

Figure 5 – TTUKa-1 RHI reflectivity (top, dBZ) and radial velocity (bottom, m s^{-1}) of vertical vorticity maxima above the rear flank gust front of the 12 May 2010 near Willow, OK. The data were obtained at 0001 UTC (13 May 2010). Areas of strong horizontal vorticity are shown with white circles (discussed in text), and are ascending with time.