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THE VDAC TECHNIQUE: A VARIATIONAL METHOD FOR DETECTING AND CHARACTERIZING CONVECTIVE VORTICES IN MULTIPLE-DOPPLER RADAR DATA

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1. Introduction

The severe thunderstorm and tornado warning process becomes particularly challenging when forecasters do not have time to thoroughly interrogate all available radar data or when observations and model forecasts are only marginally supportive of severe weather prior to its onset. The former scenario is common during severe weather outbreaks, especially if the county warning area (CWA) exists within several Doppler radar domains. Lowered forecaster situational awareness in the latter scenario likely explains the documented increase in zero-lead-time warnings on the first tornado of the day, particularly if it is the only tornado in/near the CWA that day (Brotzge and Erickson 2010). Radar-based detection algorithms become particularly important in these cases, serving to alert forecasters to important features they may otherwise have missed.

Since the implementation of the Weather Surveillance Radar 1988-Doppler (WSR-88D) network, several algorithms have been developed to aid forecasters in real-time identification of intense convective vortices. These include the Tornado Vortex Signature (TVS) algorithm (Crum and Alberty 1993), the National Severe Storms Laboratory (NSSL) Mesocyclone Detection Algorithm (MDA; Stumpf et al. 1998) and the NSSL Tornado Detection Algorithm (TDA; Mitchell et al. 1998). Unfortunately, since these techniques rely upon thresholds of gate-to-gate shear, they are particularly sensitive to noise in the velocity data and to azimuthal offset of vortices from the radar beam. This results in a sharp tradeoff between the false alarm rate (FAR) and probability of detection (POD).

The Velocity Track Display (VTD) technique and its variants (Lee et al. 1994; Roux and Marks 1996; Lee et al. 1999; Liou et al. 2006) fit radial velocity data to a vortex model in order to recover key characteristics of the vortex flow. This approach is less sensitive to noisy velocity data than are shear-based techniques. However, the VTD techniques are not designed to

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retrieve the vortex center, which instead must be predetermined using another method. This makes the retrieval of the remaining vortex parameters particularly sensitive to errors in the specified vortex center when the vortex being retrieved is small relative to the observational resolution.

The Vortex Detection and Characterization (VDAC) technique described herein also adopts a vortex-fitting approach. More specifically, radial wind observations from two or more close-proximity Doppler radars with overlapping domains are fit to an analytical low-order model of a vortex and its near-environment. The ability of the technique to use data from multiple radars makes it comparable to the dual-Doppler Extended Ground-Based VTD (EGBVTD; Liou et al. 2006). However, the model parameters in the VDAC method include the vortex center, making *a priori* knowledge of the location of the vortex unnecessary. This allows the technique to function as both a vortex detection algorithm and a vortex characterization algorithm. The VDAC technique is designed primarily for use in Collaborative Adaptive Sensing of the Atmosphere (CASA; McLaughlin et al. 2005; Brotzge et al. 2007) and CASA-like radar networks, whose high observational resolution and overlapping coverage should permit more accurate detection and characterization of tornado- and mesocyclone-scale vortices than is possible with the WSR-88D network. However, it will be shown that the technique may reliably detect and characterize vortices > 1 km in diameter even when velocity data from only one radar are available.

A complete description of the original VDAC methodology as well as tests of the technique using analytically-generated, numerically-simulated and one observed tornadic wind field were presented in Potvin et al. (2009). In the current study, important improvements to the technique as well as tests with additional radar observations of convective vortices are shown. The rest of this paper, available at http://dl.dropbox.com/u/8728461/VDAC_092310.doc, is organized as follows. The updated low-order model is described in section 2. The retrieval methodology, including the cost function computation and the selection of analysis domains, is described in section 3. Section 4 describes the new detection criteria. In sections 5-7, the technique is tested using Shared Mobile Atmospheric Research and Teaching (SMART; Biggerstaff et al. 2005) radar observations of the 30 May 2004 Geary, Oklahoma tornadic supercell, Doppler-On-Wheels (DOW; Wurman et al. 1997) observations of a tornado that occurred near Attica, Kansas on 5 June 2001, and CASA observations of the 14 May 2009 Anadarko, Oklahoma tornado. The ability of the technique to detect and characterize vortices > 1 km in diameter is explored in section 8. A summary and conclusions follow in section 9.