P4.5 TORNADO WARNING SERVICES FOR MISOSCALE CIRCULATIONS IN QUASILINEAR CONVECTIVE SYSTEMS

Kevin Scharfenberg[1]
NOAA/NWS Office of Climate, Water, and Weather Services
Norman, OK

David L. Andra, Jr.
NOAA/NWS Forecast Office
Norman, OK

Patrick T. Marsh and Kiel L. Ortega
University of Oklahoma Cooperative Institute for Mesoscale Meteorological Studies
NOAA/National Severe Storms Laboratory

Jerry Brotzge
University of Oklahoma Center for Analysis and Prediction of Storms
Center for Collaborative Adaptive Sensing of the Atmosphere

1. INTRODUCTION

Observations of misoscale (Fujita 1981) circulations in convection (~40 m to ~4 km diameter) have been well-documented in the literature (e.g., Kessinger et al. 1988, Brotzge et al. 2010). While many non-damaging misocyclones have been observed, a few are known to have strengthened and produce tornado-like damage, or at least areas of enhanced wind damage at the surface.

Historically, observations of misocyclones have been possible generally only with research radars with higher temporal and spatial resolutions than the National Weather Service (NWS) Weather Surveillance Radar – 1988 Doppler (WSR-88D). In recent years, however, these resolution constraints have been somewhat mitigated in the NWS operational environment. WSR-88D scanning strategies have been implemented that provide greater temporal, azimuthal, and range resolution. The improved resolution results in greater ability to detect important features in severe thunderstorms (Brown et al. 2005). Due to their small and shallow nature, misocyclones are still only resolved on WSR-88Ds near the radar site. Even with 4-minute volume scan frequency, misocyclones may go undetected on the WSR-88D because their life cycle is typically very brief.

Federal Aviation Administration Terminal Doppler Weather Radar (TDWR; Michelson et al. 1990) data have also been made available to NWS forecasters over the last few years. TDWRs have shorter range than the WSR-88D, but can provide low-altitude reflectivity data at a temporal frequency as high as once per minute. The higher temporal resolution has allowed increased detection of misocyclones on TDWRs, particularly close to the radar site.

Sufficient bandwidth and computer processing now exist to share limited research radar data with forecasters in real-time for evaluation. One such research program, from the Center for Collaborative Adaptive Sensing of the Atmosphere (CASA; McLaughlin et al. 2009), includes low-power research radars capable of collecting data at very high spatial and temporal resolution in the lowest 3 km of the atmosphere. CASA radars are well-suited to resolve misocyclones and depict their often-rapid evolution.

The more frequent operational detection of misocyclones presents a new warning problem. Specifically, what is the appropriate warning philosophy when a nascent misocyclone is detected (e.g., tornado or severe thunderstorm warnings)? The warning problem is particularly difficult when faced with a large convective system with rapid and seemingly random misocyclone evolution.

Complicating the warning issue, due to the short life cycle and small-scale nature of these events, it is sometimes not clear in post-event assessment whether the damage associated with a radar-indicated misocyclone is due to a “tornado”, enhanced “straight-line” winds, or some combination of both. Due to the lack of complete information, this study does not attempt to make such distinctions.

2. CASE EXAMPLES

Before exploring the warning philosophy issue, a few representative examples of misocyclones in quasilinear convective systems are presented. The

---

[1] *Corresponding author address:* Kevin Scharfenberg, NOAA/OCWWS, 120 Boren Blvd., Suite 2300, Norman, OK 73072. E-mail: Kevin.scharfenberg@noaa.gov

data presented were available to forecasters in real-time. In each of these cases, the near-storm environment was characterized by moderate to strong low-level shear, sufficient bulk shear for storm organization, and sufficient convective instability for thunderstorms. Also in each case, the convection was already formed into a short quasilinear system at the time of misocyclone detection.

a. Case 1: TDWR / WSR-88D

Figure 1 (top) depicts a series of misocyclones in a quasilinear convective system at various stages of development as detected by a TDWR at close range. Figure 1 (bottom) shows the northern two circulations at the same time from a WSR-88D, also nearby but at a different viewing angle. Both of these circulations moved across a metropolitan area, lasted about 10-15 minutes, and were associated with minor wind damage (a few trees, signs, and power poles downed), suggesting slightly higher wind speeds than in the rest of the line.

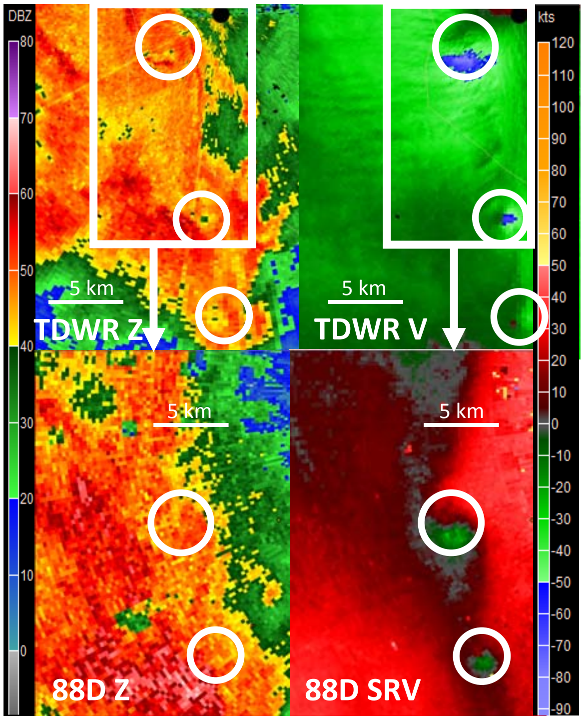

Figure 1. *(Top) Terminal Doppler Weather Radar (TDWR) view at close range of a series of misoscale circulations (circled) in a quasilinear convective systems at various stages of development.*
(Bottom) WSR-88D view of the northern two circulations, also at close range but from a different viewing angle.

b. Case 2: WSR-88D

Figure 2 shows a misocyclone detected along the leading edge of a short line of convection, as detected at close range by a WSR-88D. This detection was not associated with any damage, but was located in an area of open fields with few objects likely to be damaged. The circulation was only detected for one WSR-88D volume scan before dissipation. Radar-detected ground-relative wind speeds suggested little damage potential.

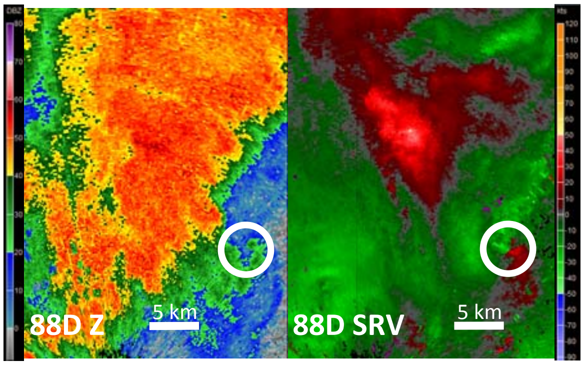

Figure 2. *WSR-88D view at close range of a misocyclone (circled) along the gust front of a quasilinear convective system.*

c. Case 3: CASA

Figure 3, from CASA, depicts a larger misocyclone that moved across the edge of a small town. The circulation had started several minutes earlier as a much smaller and weaker feature. The forward motion of the system was northeastward at almost 25 ms^{-1}. The left half of the circulation path (relative to storm movement) was not associated with any wind damage, but the right half of the circulation was associated with significant wind damage, including damage to structures, trees, power poles, and the generation of a few debris missiles. Even though it was 2-4 km across and lasted about 15 minutes, this feature was also not easily resolved by the nearest TDWR or WSR-88D.

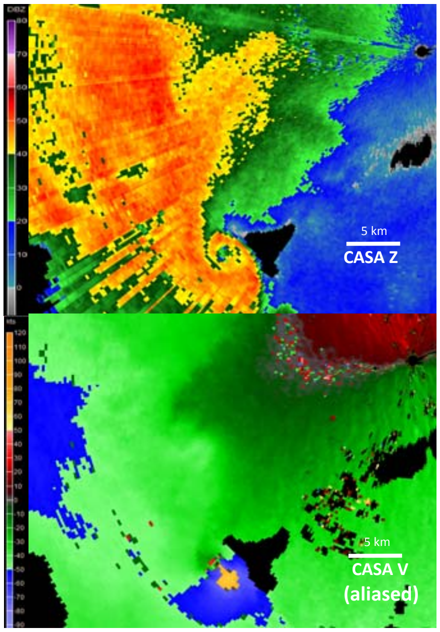

Figure 3: *Collaborative Adaptive Sensing of the Atmosphere (CASA) radar view (top - reflectivity; bottom - aliased velocity) of a large, mature, intense misoscale circulation along the leading edge of a quasilinear convective system. The system was moving northeast toward the radar site at a forward speed of nearly 25 m s-1. Peak radial speeds (< 100 m AGL) detected by the radar exceeded 40 m s-1 on the right side of the circulation and were near 0 ms-1 on the left side of the circulation.*

d. Case 4: CASA

Case 4, also from a CASA radar, occurred near in time and space to Case 3. Figure 4 shows a distinct, very small circulation detected along the leading edge of a line of convection. This circulation was not resolvable by either the nearest WSR-88D or TDWR. The circulation quickly dissipated, lasting less than 5 minutes, and was not associated with any known wind damage.

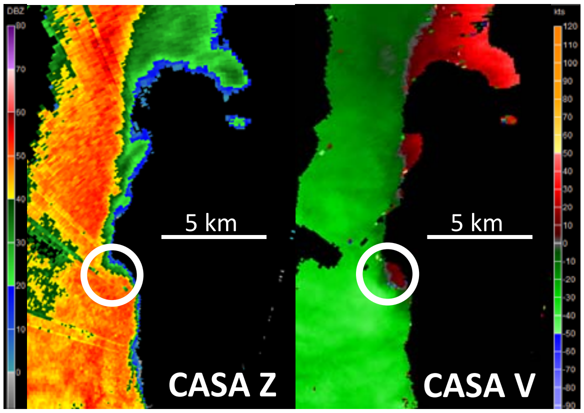

Figure 4. *CASA radar view of a misoscale circulation along the leading edge of a narrow squall line.*

3. DISCUSSION ON WARNING PHILOSOPHY

The increased ability to detect misoscale circulations in real time suggests a strategy is needed for public warning services. The public warning dissemination cycle is designed to work on the order of 10 or more minutes, even in the age of instant communication. Most observed misocyclones, even the ones strong enough to produce damage, have been observed to dissipate within about 10 minutes of formation.

In addition, experience suggests most misoscale circulations do not grow strong enough to produce damage. It is unclear what percentage can be expected to grow into damaging circulations, though it is likely dependent on both the speed and shear magnitude of the environmental low level winds. A more thorough climatology needs to be developed as more cases are observed.

Cases 2 and 4 were of circulations that appeared and disappeared within just a few minutes, with no damage reported and no tornadoes sighted. Similar, initially-minor circulations grew a little more significant in Case 1, in a series along a line, producing minor damage in isolated spots. In Case 3, another circulation that began minor grew very significant, produced substantial damage, and quickly dissipated. The near-storm environments were similar in each case, so it is not clear how a forecaster could know which circulation(s) would intensify.

The authors question whether tornado warnings are appropriate for misoscale circulations due to the large percentage that will quickly dissipate, the unpredictable nature of the few that will strengthen, and the expected brief remaining life span of any detected strong misocyclones relative to the warning dissemination cycle. Any benefit that may be gained from very short lead time seems likely to be outweighed by the large number of additional false alarms that would necessarily result from adopting an aggressive tornado warning philosophy. Perhaps storm-scale prediction model runs in the future will detect (with useful lead time) environments favorable for misoscale circulations to become damaging, and severe thunderstorm warnings can be enhanced to include predictions for isolated pockets of more significant damage.

4. SUMMARY

Misoscale circulations in organized convective systems, with diameters between 40 m and 4 km, have been frequently observed in research radar data, and more recently in operationally-available radar data. Most of the time, these circulations are quite transient, dissipating within a few minutes with little or no damage. However, these circulations can sometimes grow strong enough to produce tornadoes and/or enhanced areas of wind damage.

Early experience using “super resolution” WSR-88D data, information from the TDWR, and data from research CASA radars, suggests that we have little operational skill anticipating which of these circulations will grow strong enough to produce significant impacts. The authors believe their short life cycle and unpredictable nature makes tornado warnings inappropriate for these features, as the false alarm rate would have to rise significantly to achieve any useful lead time.

More observations are needed from research radars such as CASA, and operational radars such as the TDWR and WSR-88D, to develop a climatology of these features, and better define which environments are favorable for particularly strong misocyclones. Storm-scale “warn on forecast” models should be put to the test with both damaging and null misocyclone events, so that significant impacts can be better anticipated with useful lead times, and appropriate public warnings can be developed.

DISCLAIMERS

This work is supported in part by the Engineering Research Center Program of the National Science Foundation under NSF award number 0313747. Additional partial funding was provided by NOAA/Office of Atmospheric Research under NOAA-University of Oklahoma Cooperative Agreement #NA17RJ1227

REFERENCES

Brotzge, J., K. Hondl, B. Phillips, L. Lemon, E. J. Bass, D. Rude, and D. L. Andra, Jr., 2010: Evaluation of Distributed Collaborative Adaptive Sensing for Detection of Low-Level Circulations and Implications for Severe Weather Warning Operations. Wea. Forecasting, **25,** 173 - 189.

Brown, R. A., B. A. Flickinger, E. Forren, D. M. Schultz, D. Sirmans, P. L. Spencer, V. T. Wood, C. L. Ziegler, 2005: Improved Detection of Severe Storms Using Experimental Fine-Resolution WSR-88D Measurements. *Wea. Forecasting,* **20,** 3-14.

Fujita, T., 1981: Tornadoes and downbursts in the context of generalized planetary scales. *J. Atmos. Sci.,* **38,** 1511 - 1534.

Kessinger, C. J., D. B. Parsons, and J.W. Wilson, 1988: Observations of a Storm Containing Misocyclones, Downbursts, and Horizontal Vortex Circulations. *Mon. Wea. Rev.,* **116,** 1959 - 1982.

McLaughlin, D. and coauthors, 2009: Short-wavelength technology and the potential for distributed networks of small radar systems. *Bull. Amer. Meteor. Soc.*, **90**, 1797–1817.

Michelson, M., W. W. Shrader, and J. G. Wieler, 1990: Terminal Doppler Weather Radar. *Microwave J.,* **33,** 139 - 148.