**SIMULATED TORNADIC VORTEX AND REFLECTIVITY SIGNATURES OF NUMERICALLY MODELED TORNADOES HAVING WEAK ECHO HOLES**

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### Tornado Vortex Signature (TVS)
- TVS – a degraded Doppler velocity shear signature – with peak Doppler velocity values about one beamwidth apart – that occurs when the core diameter of a tornado is smaller than the radar’s beamwidth.

### The TVS Simulation
- This figure shows that although the TVS associated with a given tornado decreases in magnitude as the radar beam becomes broader, the peak values of the TVS remain essentially the same distance apart – about one beamwidth apart for uniform reflectivity across an assumed Rankine tornado vortex.

### Union City TVS
- To confirm that the TVS represents a tornado, a simulated radar scanned past Rankine vortices that were smaller than the radar beamwidth, assuming that reflectivity was uniform across the vortices.
- The above figure presents Doppler velocity measurements (dots) through the center of the Union City, OK tornado of 24 May 1973 using an NSSL research Doppler radar.
- Three theoretical TVS curves are produced by scanning the radar past three Rankine vortices having different sizes (ratio of beamwidth BW to core radius CR) and peak tangential velocities (V_{max}).
- Doppler velocity data points nicely fit the simulated TVS curves that represent tornadoes having various sizes and strengths.
- The TVS strength does not reveal the strength or size of the tornado itself.

### TVS in WSR-88D Velocity Data
- When a radar scans as it collects the number of pulses needed to compute the mean Doppler velocity, the radar beam is effectively widened, -- the widened beam is called “effective beamwidth” (EBW).
- For example, when a WSR-88D collects data at 1.0° azimuthal legacy intervals (ΔAZ = 1.0°), the beamwidth effectively increases from 0.9° to 1.4°.
- For 0.5° azimuthal super-resolution data collection, the EBW broadens to only 1.0°.
- With uniform reflectivity across the simulated tornado vortex, the TVS peak values are separated by about one EBW.
- For legacy resolution (with ΔAZ = 1.0° and EBW = 1.4°), TVS peak values therefore are expected to be separated by ΔAZ = 1.0°.
- For super-resolution (with ΔAZ = 0.5° and EBW = 1.0°), TVS peak values also are expected to be separated by ΔAZ = 1.0°.
- However, recent WSR-88D observations indicate that some super-resolution TVS peaks are separated by ΔAZ = 0.5° → WHY?
- To answer this question, we ran new Doppler radar simulations using a more realistic vortex model (instead of the Rankine model) and a more representative reflectivity distribution having a weak-reflectivity eye across the vortex.

### Vortex and Reflectivity Models
- Doppler radar simulation results indicate that using 2 different reflectivity profiles in which the Burgers-Rott vortex is embedded, there is a significant difference in TVS diameter when the EBW is less than 2.5 times larger than the tornado’s core diameter.
- With the presence of a reflectivity eye, it is possible for the distance between the peak Doppler velocity values to be separated by 0.5° for super-resolution data collection.
- However, when the EBW is greater than 2.5 times the core diameter, the peak values are expected to have an azimuthal separation of 1.0° for both legacy-resolution (one azimuthal increment) and super-resolution (two azimuthal increments) data collection.

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AMS 35* Conference on Radar Meteorology
Pittsburgh, PA, 26-30 September 2011

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**Conclusions**
- Doppler radar simulation results indicate that using 2 different reflectivity profiles in which the Burgers-Rott vortex is embedded, there is a significant difference in TVS diameter when the EBW is less than 2.5 times larger than the vortex’s core diameter.
- With the presence of a reflectivity eye, it is possible for the distance between the peak Doppler velocity values to be separated by 0.5° for super-resolution data collection.
- However, when the EBW is greater than 2.5 times the core diameter, the peak values are expected to have an azimuthal separation of 1.0° for both legacy-resolution (one azimuthal increment) and super-resolution (two azimuthal increments) data collection.