TDWR Detection of QLCS Tornadoes

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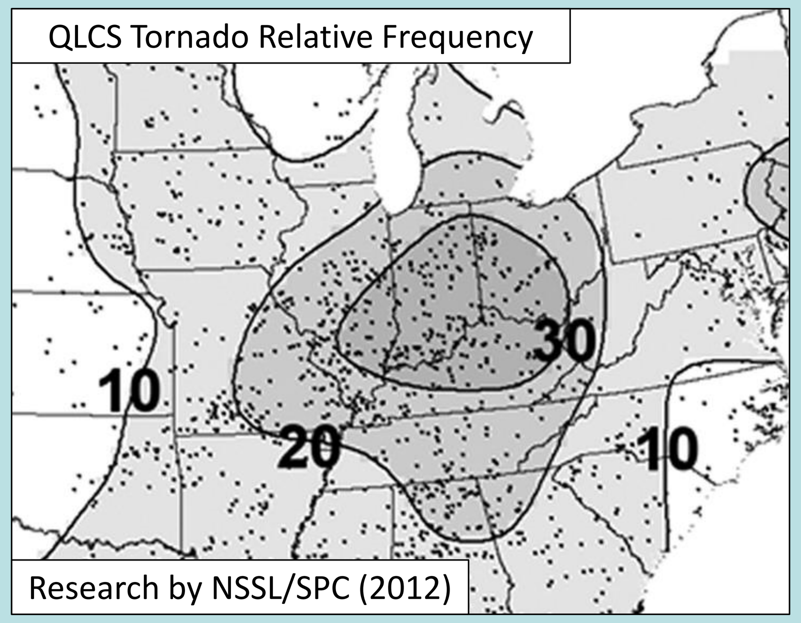
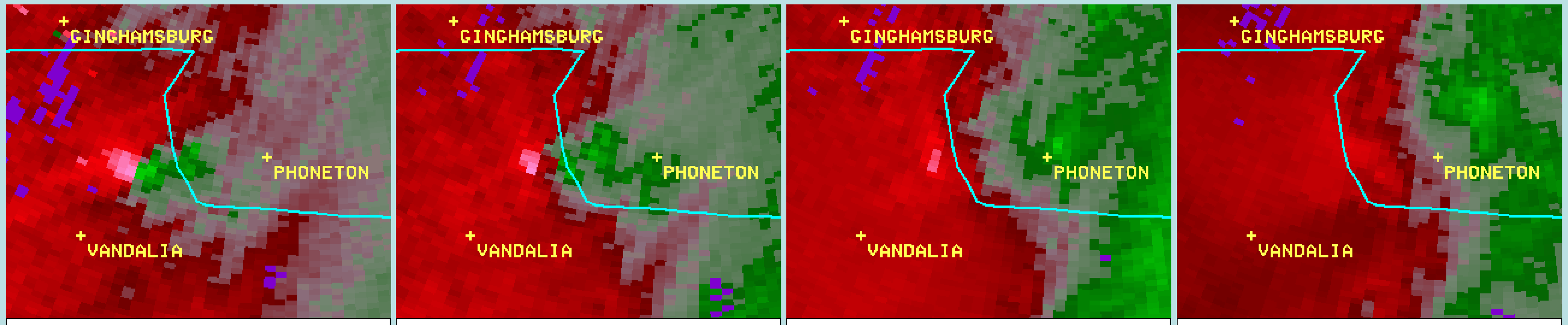
About QLCS Tornadoes



Quasi-Linear Convective Systems (QLCSs) are a class of convection that includes bow echoes, line segments, and squall lines. Though usually associated with straight-line winds, QLCSs can also develop tornadoes. NSSL/SPC research suggests that the relative frequency of QLCS tornadoes is higher in the central Ohio Valley than anywhere else in the United States. QLCS tornadoes are typically characterized as transient and shallow, making their detection via traditional radar methods very difficult.

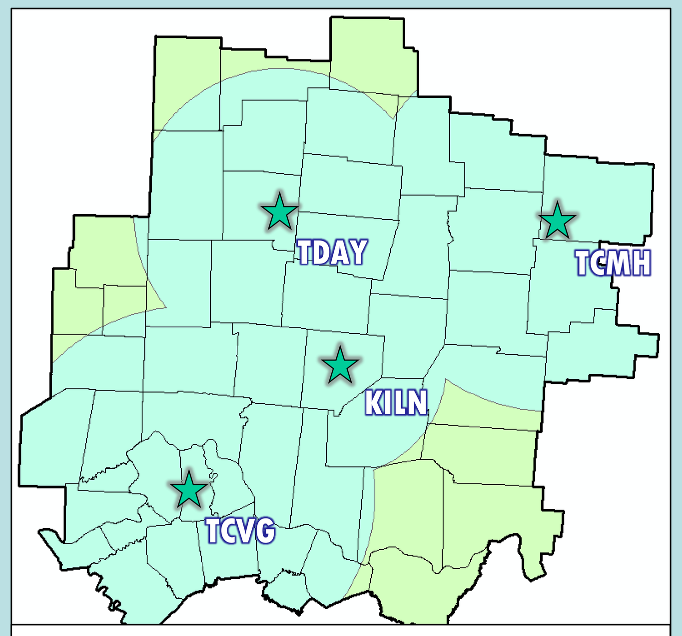
The Vandalia Case

On 31 October 2013, a strong QLCS moved east through the NWS ILN forecast area, producing four tornadoes. The strongest tornado (EF1 / 110 MPH) hit a commercial area near Vandalia, Ohio, blowing out the windows of a restaurant and injuring eight patrons. This tornado occurred at close proximity to the Dayton TDWR site, which provided an exceptionally detailed view of the circulation. The 40-knot gate-to-gate circulation on the 0.3° elevation angle was the strongest *Vr* measurement in the entire study and is convincing evidence of an ongoing tornado. Further aloft, the broader, weaker appearance of the circulation provided few clues of what was occurring at the surface. Though pronounced in this case, a similar evolution with height was found with many other QLCS tornadoes in the study.



Vr = 40 knots — TDAY 0.3° Base Velocity / 400 feet AGL
Vr = 36 knots — TDAY 1.0° Base Velocity / 1000 feet AGL
Vr = 27 knots — TDAY 2.4° Base Velocity / 2100 feet AGL
Vr = 10 knots — TDAY 4.9° Base Velocity / 4100 feet AGL

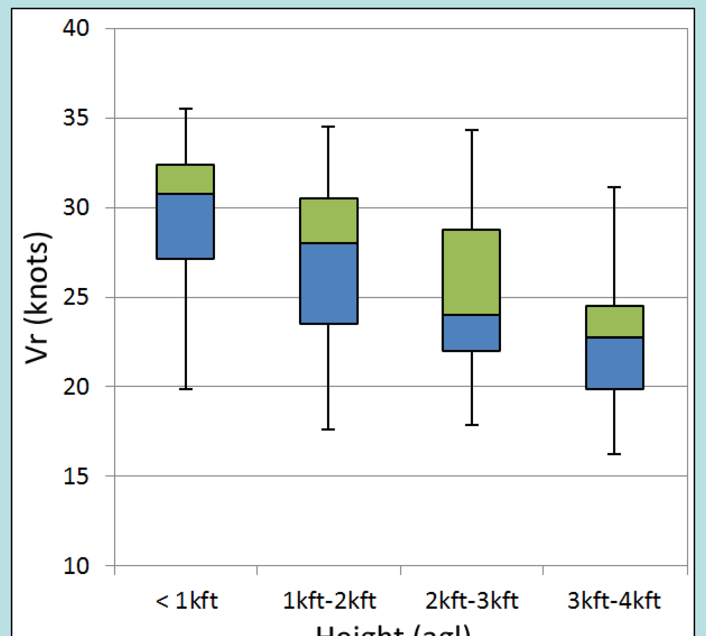
About TDWR



NWS ILN / Radar Coverage < 2kft (blue)

Terminal Doppler Weather Radars (TDWRs) are operated by the Federal Aviation Administration, with operational implementation for the NWS in 2008. TDWRs use a 5cm wavelength, providing a higher resolution than the 10cm WSR-88D radars. Their lowest angles (typically 0.1°-0.3°) provide data very close to ground level. Forty-five TDWRs are installed across the US, with three well-spaced TDWRs within the NWS Wilmington Ohio (ILN) forecast area. Along with the WSR-88D, 80% of the ILN forecast area is covered by radar within 2000 feet of ground level. This makes the ILN forecast area an excellent location for detecting and studying shallow QLCS tornadoes.

The Study

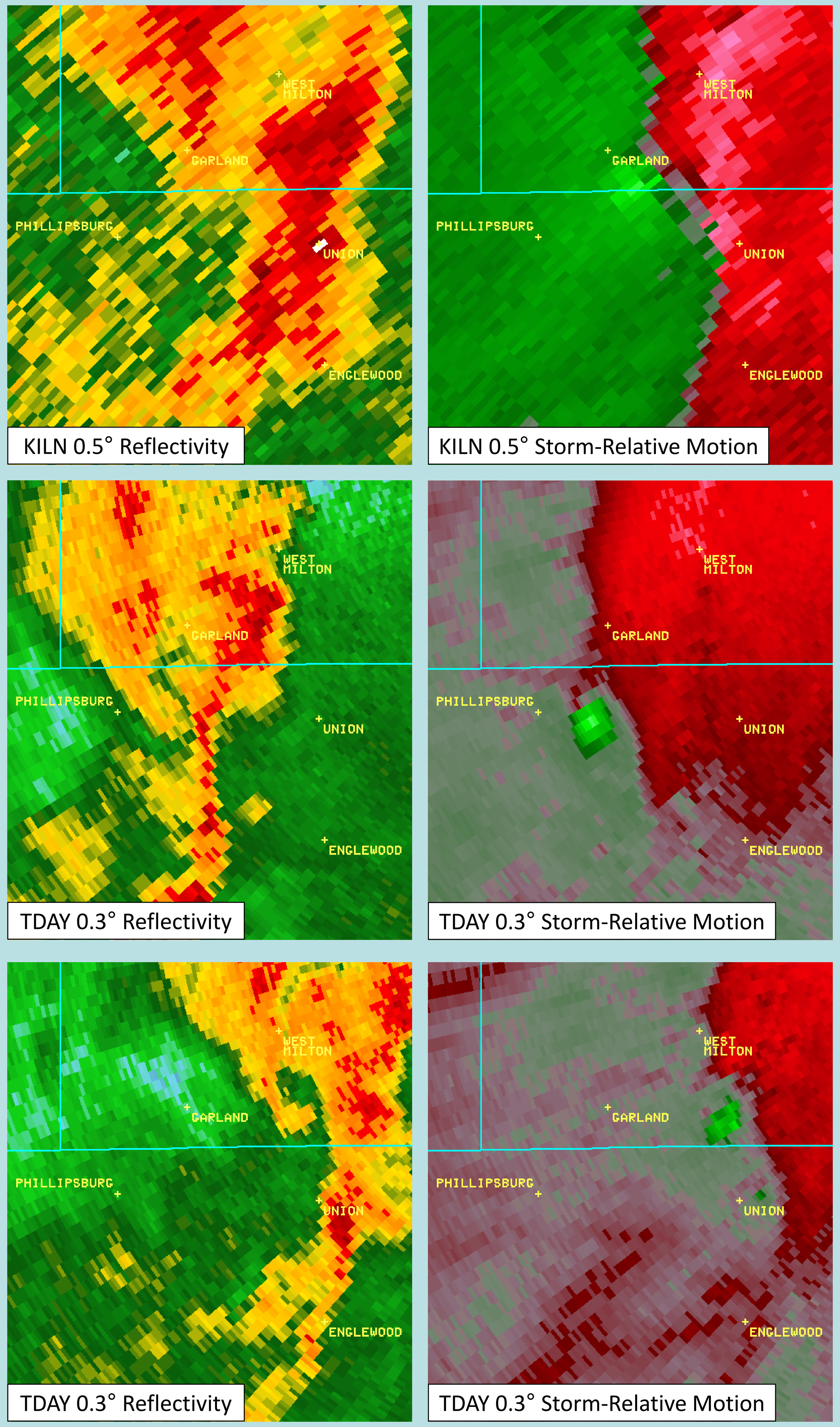


Plot of Vr values for each 1000-foot layer

This research included 33 QLCS tornadoes within the NWS ILN forecast area. During the time that each tornado was assessed to be occurring, values for rotational velocity (*Vr*) were determined, along with a reading of the beam height. These *Vr* values were classified into 1000-foot layers above ground level, allowing for an analysis of the typical strength of tornadic QLCS circulations at varying heights. Unsurprisingly, given the shallow nature of QLCS tornadoes, it was found that circulations closest to ground level exhibited the greatest strength: a median *Vr* of 30.8 knots for circulations sampled below 1000 feet. This median value decreased markedly with each step up in height.

The Phillipsburg Case

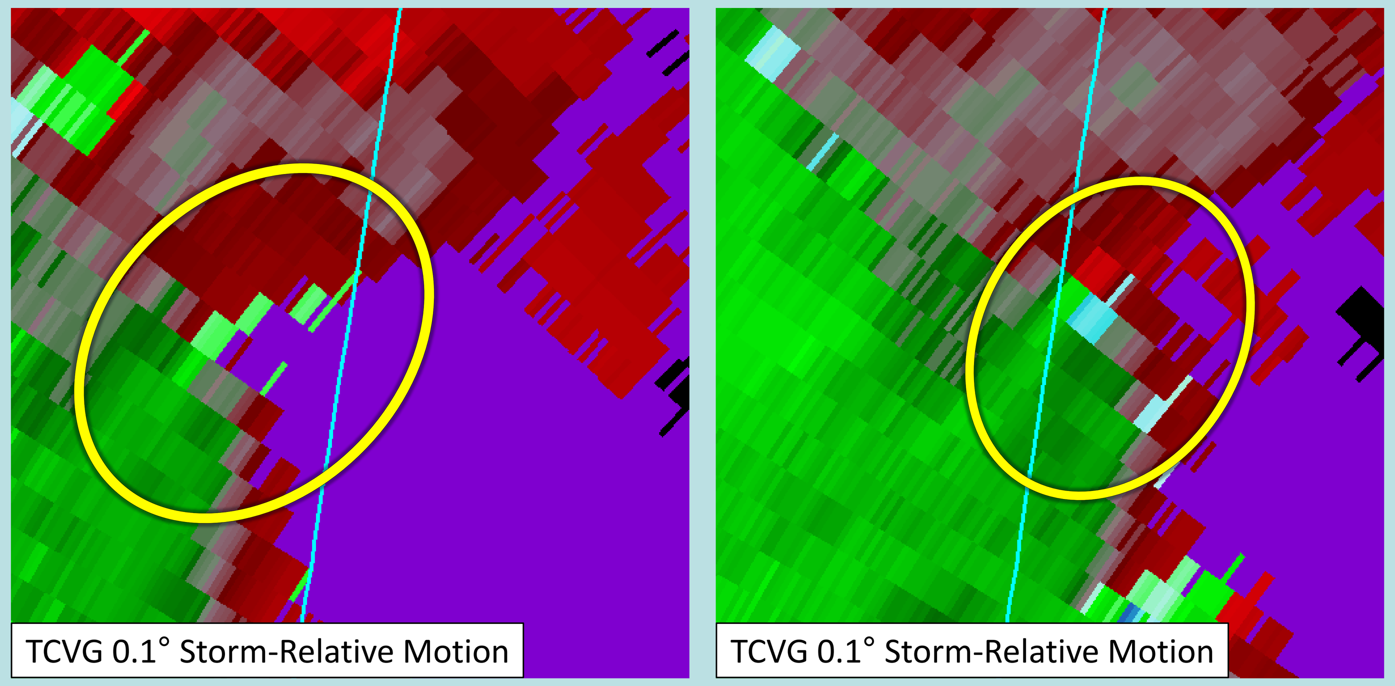
During the late evening of 20 February 2014, a QLCS produced three tornadoes in the NWS ILN forecast area. One tornado (EF0 / 85 MPH) struck near Phillipsburg, Ohio, damaging several residences and barns. The NWS Wilmington Ohio WSR-88D radar depicted a classic “Broken-S” radar signature: a weakness in reflectivity coincident with a broad circulation at a kink or S-shaped section of the gust front. Compared to the WSR-88D, the Dayton TDWR provided a significantly higher amount of detail for this tornado. The break in reflectivity was much better resolved, showing a hook-shaped reflectivity appendage attached to the back segment of the “Broken-S” signature. Velocity data indicated that the tornado was located about two miles behind the forward segment’s gust front, occluded from the inflow. This stands in contrast with several other tornadoes in the study, which formed along the leading edge of the gust front. Instead, this tornado hit an area that had already experienced outflow winds from the passage of the gust front, along with several minutes of heavy rainfall.



KILN 0.5° Reflectivity — KILN 0.5° Storm-Relative Motion
TDAY 0.3° Reflectivity — TDAY 0.3° Storm-Relative Motion
TDAY 0.3° Reflectivity — TDAY 0.3° Storm-Relative Motion

TDWR Dealiasing Failures

In comparison to the 10cm wavelength used by NWS WSR-88Ds, the 5cm wavelength used by FAA TDWRs provides data at a higher resolution (0.55° per radial, 150 yards per range bin). However, this smaller wavelength frequently results in the production of several data-quality issues. One common problem is known as the *dealiasing failure*, as shown in this example from Sunman, Indiana (EF0) on 23 May 2011.



TCVG 0.1° Storm-Relative Motion — TCVG 0.1° Storm-Relative Motion

Due to their shorter wavelength, TDWRs have a smaller Nyquist velocity than the WSR-88D. This results in a greater probability that velocity values will be ambiguous, requiring dealiasing to assign a proper velocity. In areas where winds change rapidly in short distances, such as tornadoes and mesocyclones, dealiasing failures become more likely. This can result in clusters or swaths of bins depicting clearly erroneous values. Although far from ideal, dealiasing failures within QLCSs can sometimes be used beneficially, as a sign that significant shear or rotation is occurring.

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