The Impacts of Global Regression Clutter Filtering on RaXPol Observations of a Significant Tornado

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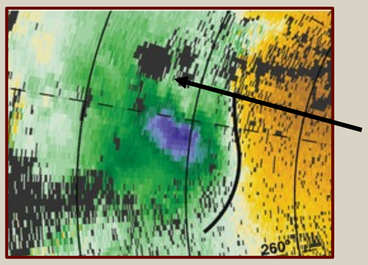
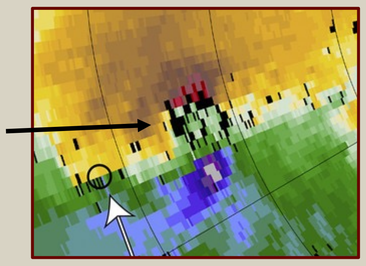
Motivation

Ground clutter contamination is a well-known issue for mobile radar studies of tornadic winds near the ground. Many previous mobile radar studies manually remove gates obviously contaminated by clutter or employ a censor to mask it out, typically based on low radial velocity and spectrum width.



Kosiba et al.(2013)

Manually removed ground clutter



Bluestein et al.(2018)

Global Regression Filtering (GRF)

Hubbert et al. (2025) introduced GRF, which operates on the I/Q signal in the time domain and removes ground clutter contamination without performing an FFT or windowing the time series. GRF can operate in real time and was found to have 25—50% less error than comparable spectral filters like GMAP, which is used for the NEXRAD system.

While GRF was shown to work well for NEXRAD, parameters such as the polynomial order are sensitive to the azimuthal sampling, adding complexity to employing GRF on high-resolution observations. In this study, we test if GRF is useful for RaXPol observations of a tornado.

05 June 2025 Morton, TX Tornado

A large tornado occurred near Morton, TX was rated EF2 by NWS Lubbock. Observed by the Rapid X-Band Polarimetric (RaXPol) radar, this is a great case to test GRF due to ample ground clutter present and the large size of the tornado. This study focuses on the period from 22:34:39 – 22:43:27 UTC.

RaXPol (OU/ARRC)

View of the Morton, TX EF2 from RaXPol's deployment site at 22:32:10 UTC

RaXPol deployed at a range of 5—10 km during this analysis period and used a very slow dish rotation rate to accumulate more pulses per ray and improve radial velocity estimates. During our analysis, the lower elevation angle was approximately 100 m AGL and the higher angle was around 300 m AGL in the tornado. Power lines appear to be the primary ground clutter contaminant as the deployment site is very flat with little vegetation.

Pulse width	0.5 μs (single—tone)
Nyquist velocity	±30.8 m s^{-1}
Dish rotation rate	18° s^{-1}
Azimuthal sampling	0.5°
Elevation angles	1°, 3°

RaXPol scanning parameters during the Morton tornado

Rudimentary clutter mask

- Employed to provide an explainable control for GRF
- Masks out data where both
  - $|V_r| < 3$ m s^{-1}
  - $\sigma_v < 3$ m s^{-1}

How Does GRF Perform?

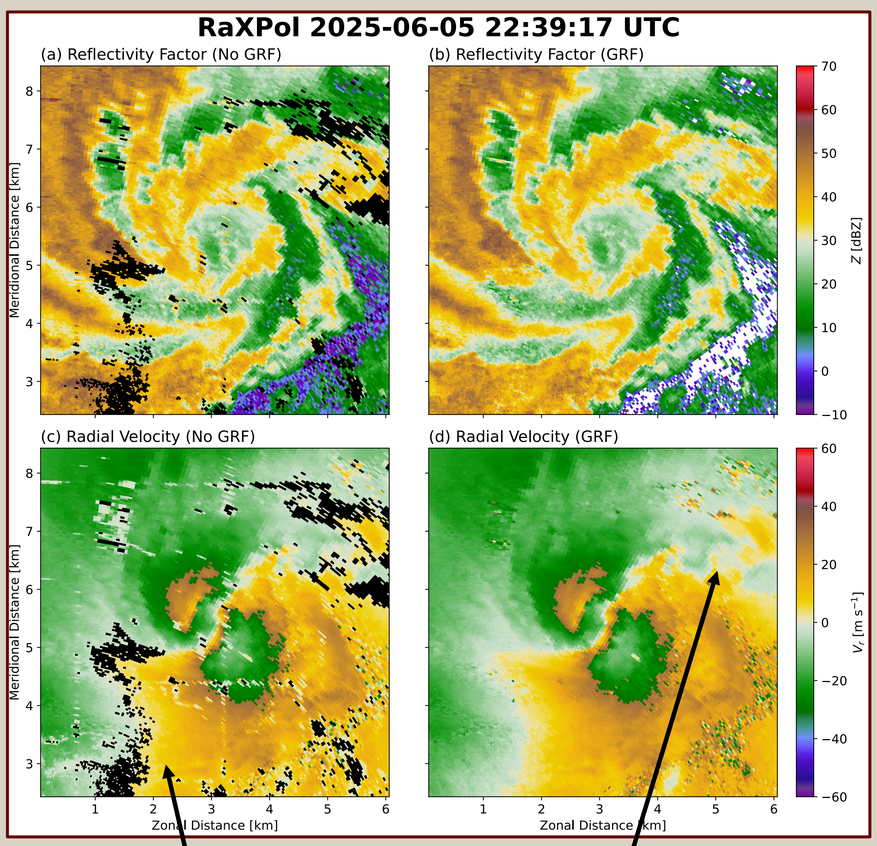


Fig 1: RaXPol 1.0° elevation PPI without GRF (a,c) and with GRF (b,d). The rudimentary clutter mask is shown in black.

Rudimentary clutter mask still misses some clutter

GRF removes clutter while retreiving weather signal

Partially Cluttered Aliased Velocity

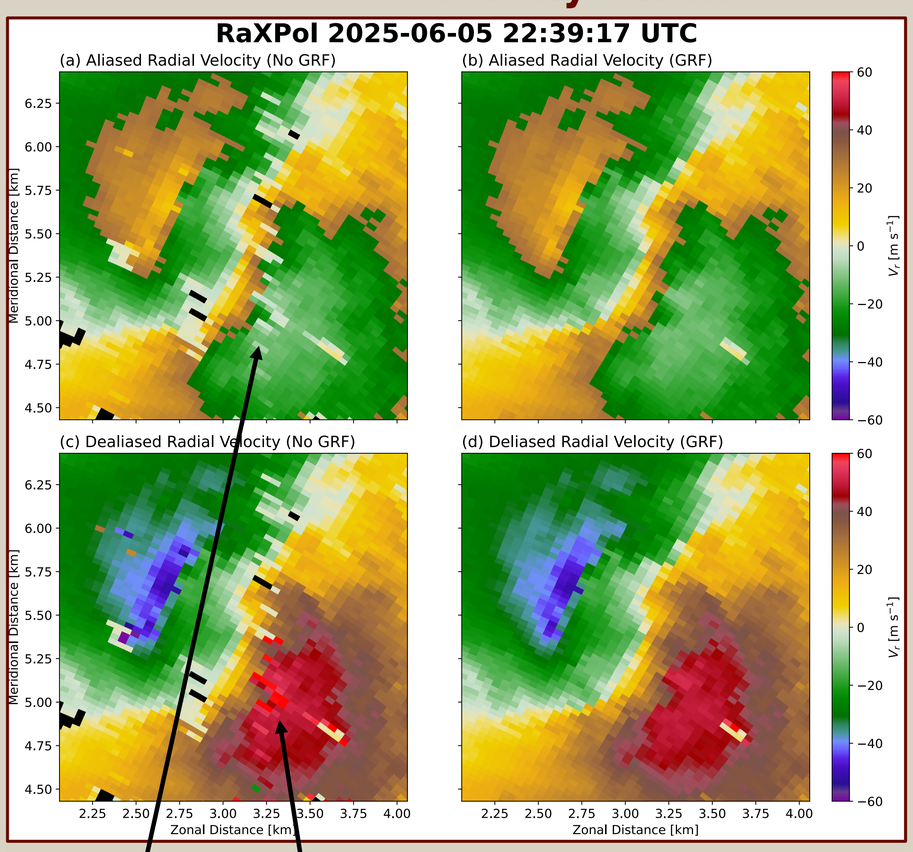


Fig 2: RaXPol aliased (top row) and manually dealiased (bottom row) radial velocity with and without GRF. The rudimentary clutter mask is shown in black.

Aliased gates low biased by clutter become higher when dealiased

GRF removes most low bias from clutter, doesn't overestimate velocities

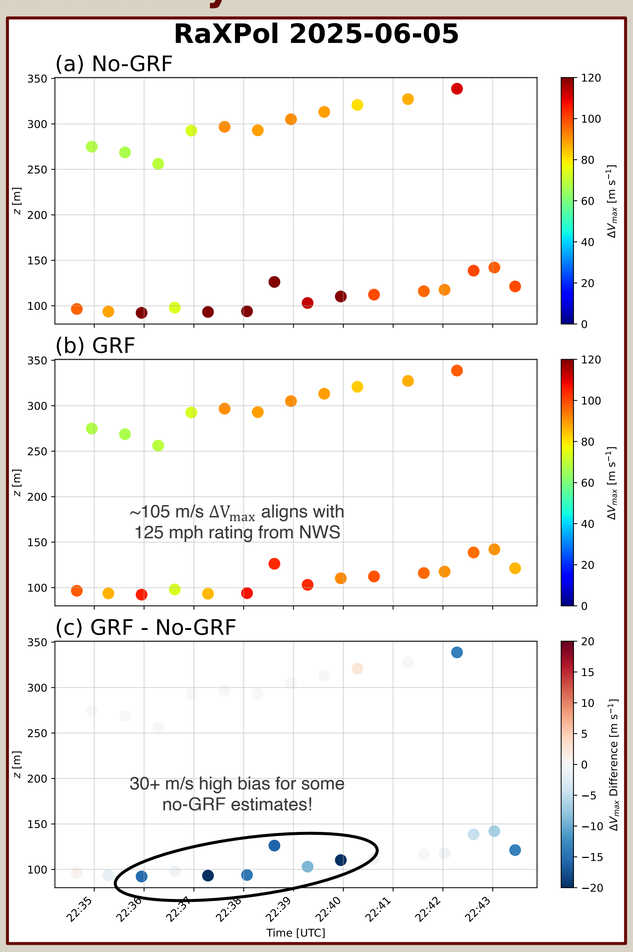


Fig 3: Time-height series of ΔV_{max} for no-GRF (a), GRF (b), and the difference between the two (c). Note that ΔV_{max} is calculated within a 500 m radius of the tornado at each time. The rudimentary clutter mask is used for no-GRF.

Performance of GRF

- GRF appears to do a good job of removing received power from ground clutter contamination while maintaining meteorological signal
- The GRF ΔV_{max} time-height series more closely aligns with the NWS estimate
- GRF performance is sensitive to the polynomial order and azimuthal sampling used

Implications for Tornado Studies

- Echoes only partially contaminated by ground clutter can be missed by rudimentary masks and manual quality assurance
- When partially contaminated gates are folded an odd number of times, they will over-estimate radial velocity when unfolded
- Lyza et al. (2024) states that "radar-based intensity estimates of stronger tornadoes are usually substantially higher than damage-based estimates"
- Though issues with the tornado rating system may contribute to this disparity, our findings herein may provide another reason

Considerations for Future Radar Studies of Tornadoes

- Future field experiments with mobile radars should consider saving I/Q data to perform time series clutter filtering
- Use of mobile Doppler Lidar should be considered as its narrow beam limits the impact of ground clutter contamination and provides high spatial resolution