The Utility of Supplemental Low Elevation Radar Data in Tornado Warning Decision-Making in central NC

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Introduction

Weather radar, including the Weather Surveillance Radar-1988 Doppler (WSR-88D), is the primary tool used by meteorologists to detect tornadoes and their precursor storm-scale signatures. Upon deployment, all WSR-88Ds employed the same scanning configuration and lowest elevation angle of 0.5°. New radar technologies have since emerged and been implemented, including dual polarization, dynamic scanning strategies, and supplemental low elevation angles tailored to individual radar sites. One such supplemental low elevation angle was implemented at the KRAX WSR-88D, located in Clayton, NC and serving Raleigh and surrounding areas in central NC, in late August 2019.

With options that ranged from +0.4° to -0.2°, supplemental low elevation angle of +0.2° was selected for KRAX because it achieved all feasible increase in radar coverage area --a 74.5% increase at 2000 ft ASL-- including improved coverage over the Triad and Charlotte, while avoiding detrimental increase in ground clutter – all with no significant environmental impacts. Both the Supplemental Adaptive Intra-Volume Low-Level Scan (SAILS) and Mid-Volume Rescan of Low-Level Elevations (MRLE) features use the new 0.2° angle.

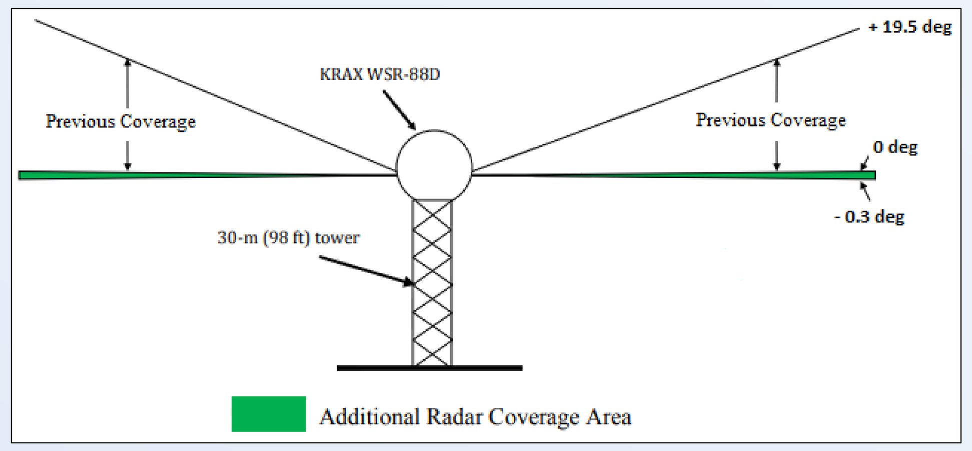

Fig. 1. Schematic adapted from of Manitakos and Tarpinian 2019 indicating the additional radar coverage area and reduction in floor of coverage from 0° to -0.3°

Forecasters at the National Weather Service (NWS) Raleigh Forecast Office utilized 0.2° data in their tornado warning decision-making and warning products within days of implementation, when Hurricane Dorian spawned three tornadoes in central NC in early September 2019. The ability to detect pre-tornadic and tornadic signatures closer to ground level than ever before was both timely and beneficial.

(a) (b) (c)

Fig. 2. Comparison of KRAX WSR-88D Radar Coverage at (a) 2,000 ft, (b) 5,000 ft, and (c) 10,000 ft above Site Level for the previous lowest (0.5°) and new lowest supplemental (0.2°) elevation angles (Manitakos and Tarpinian 2019).

Motivation and Methodology

We wanted to investigate if the anecdotal evidence of improved detection of those features with 0.2° data in real-time was real and applicable to subsequent tornado events. As such, ten tornadoes were identified in NWS Raleigh's area from August 2019 to September 2020, including the three tropical ones referenced above and which will be presented here. Mesocyclone characteristics for each were examined and compared between the new 0.2° data with the previous lowest elevation angle data at 0.5°. How that data relate to established NWS tornado warning guidance for tropical and non-tropical mesocyclones was also explored.

Radar and Tornado Warning Analysis

1. EF-0 Tornado in Smithfield, NC (Johnston Co.) from 2031-2032 UTC 5 Sep 2019

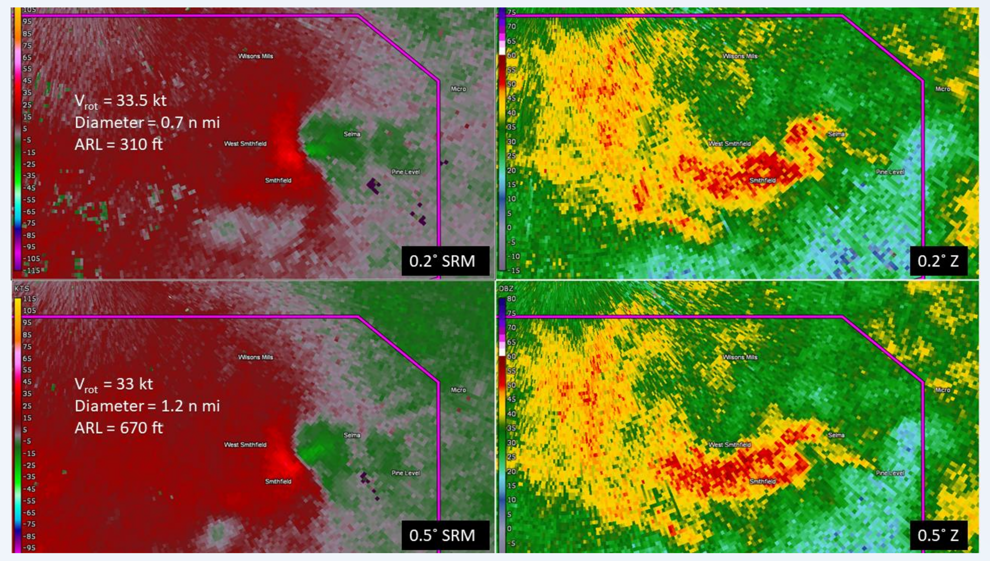

Fig.3. Comparison of 0.2° and 0.5° SRM and Z at 2027-2028 UTC

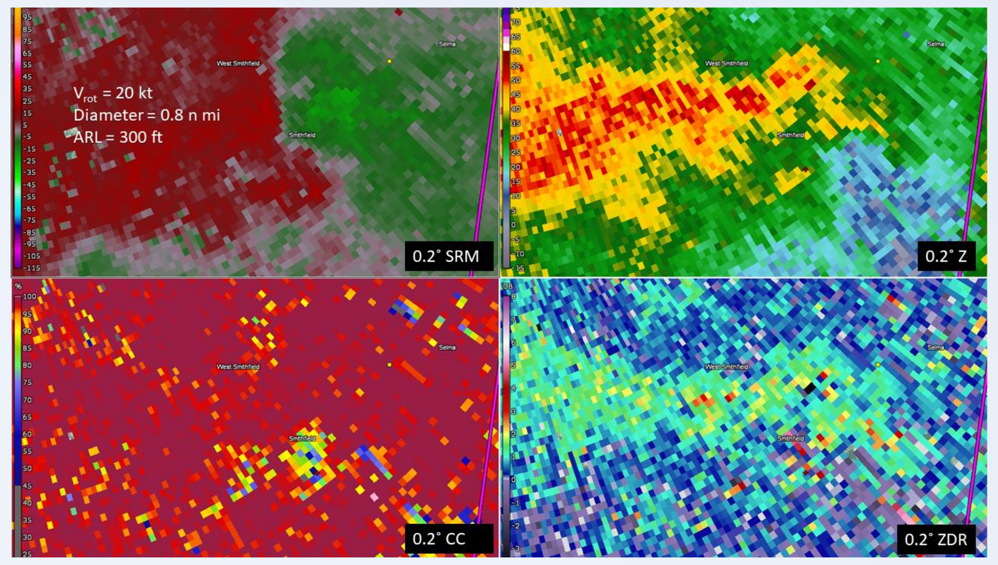

Fig.4. 0.2° SRM, Z, CC, and ZDR data at 2032 UTC

- Mesocyclone rotational velocity (V_{rot}) was similar at 0.2° and 0.5°, but it was wider at 0.5°.
- A hook echo was evident in Z data at both elevation angles, though it was better defined at 0.2°.
- A Tornado Warning was issued at 2022Z, nine minutes prior to weak tornado spin up.

2. EF-1 Tornado 3NW Saratoga, NC (Wilson Co.) from 2007-2008 UTC 5 Sep 2019

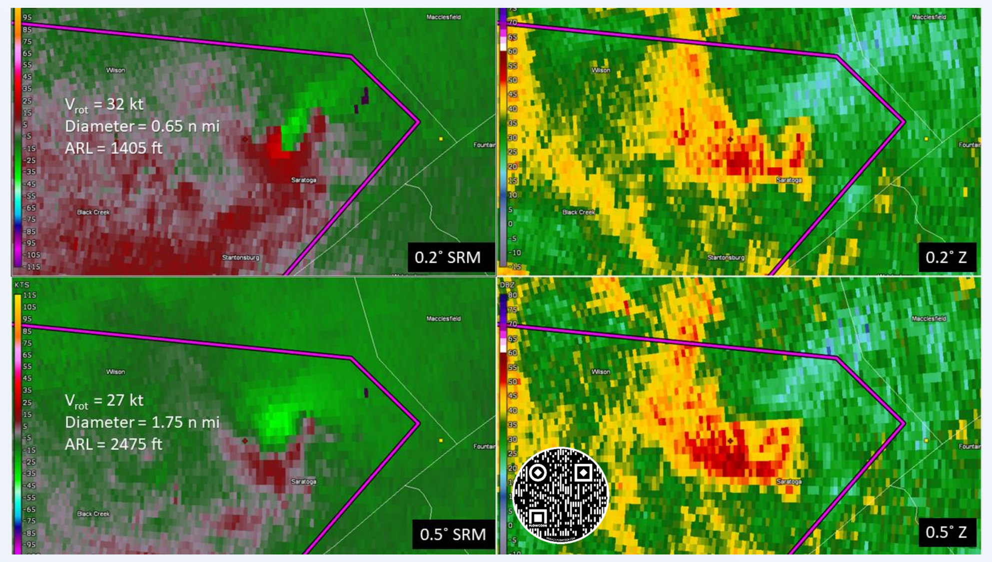

Fig.5. Comparison of 0.2° and 0.5° SRM and Z at 2003-2004 UTC

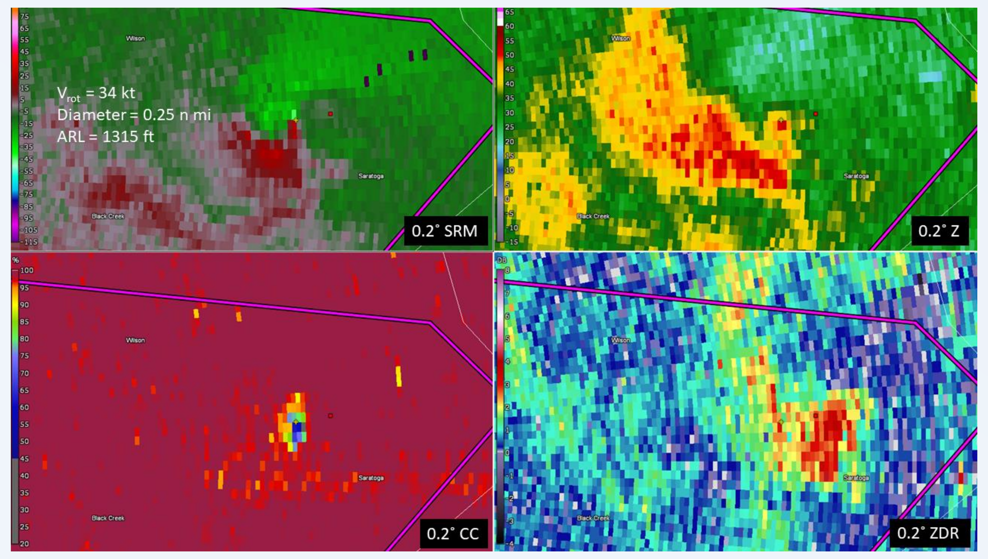

Fig.6. 0.2° SRM, Z, CC, and ZDR data at 2008 UTC

- Mesocyclone rotational velocity (V_{rot}) was stronger and tighter at 0.2° than at 0.5°.
- A hook echo was evident in Z data at both elevation angles, though it better defined at 0.2°.
- TDS detection enabled the warning forecaster to confirm a tornado in an impact-based warning follow-up, available at the QR code in Figure 5.

Scan this QR code for a comparison animation of SRM and CC at 0.2° and 0.5°.

3. EF-0 Tornado in Mar-Mac, NC (Wayne Co.) from 1752-1753 UTC 5 Sep 2019

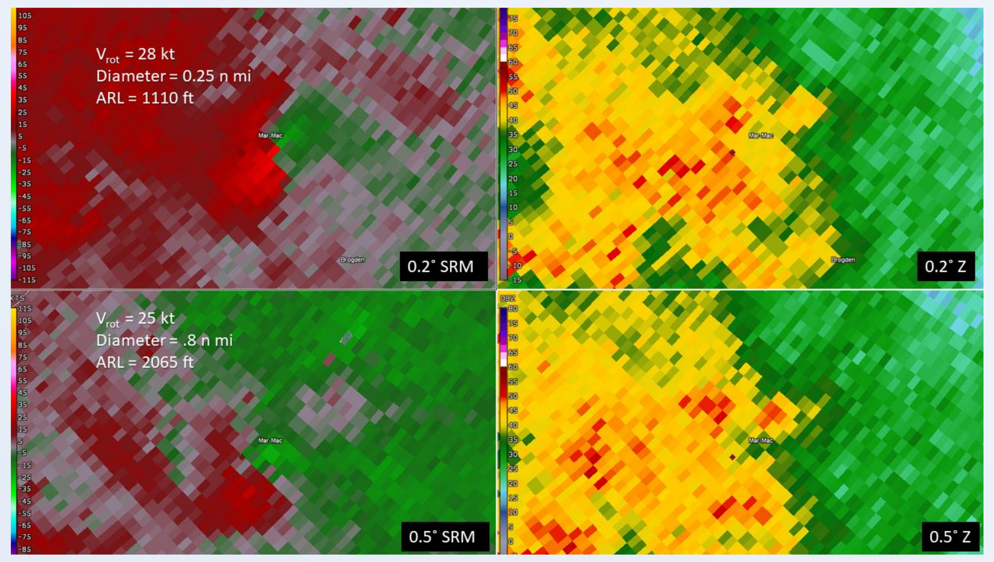

Fig.7. Comparison of 0.2° and 0.5° SRM and Z at 1750-1751 UTC.

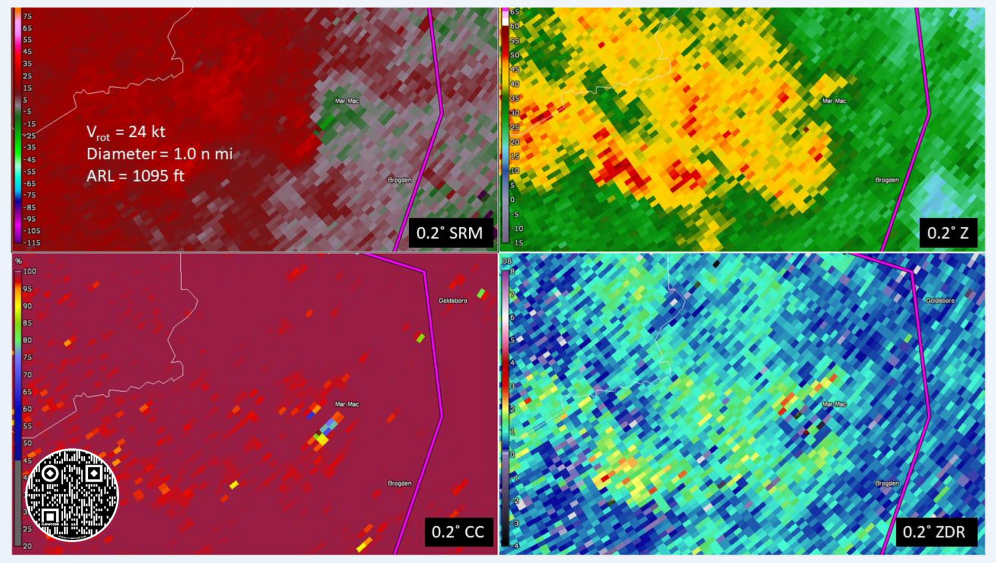

Fig.8. 0.2° SRM, Z, CC, and ZDR data at 1752 UTC

- Mesocyclone rotational velocity (V_{rot}) was stronger and tighter at 0.2° than at 0.5°.
- An inflow notch and weak hook echo was evident in Z data at both angles, though they were relatively better defined at 0.2°.
- A Tornado Warning was issued but with 0 minutes lead time.
- V_{rot} rapidly weakened after the brief tornado spin up, during which time a TDS persisted for 10-15 minutes, evident at the QR code in Fig 8.

Conclusion

The radar coverage area and low elevation radar scanning unquestionably improved over central NC as a result of the recent availability of 0.2° radar data from the KRAX WSR-88D. That data provided an almost immediate positive impact on warning operations at NWS Raleigh upon implementation in late summer 2019, shortly after which time three tropical cyclone-related tornadoes occurred. Warning forecasters were able to leverage the new dataset that day and issue tornado warnings with a probability of detection of 1.00, a false alarm rate of 0.25, and an average lead time of five minutes.

Prior to this study, warning forecasters at NWS Raleigh had anecdotally noted the benefit of the 0.2° data in low level detection of severe storms and tornadoes; and this study confirmed their initial observations. Rotational velocity (V_{rot}) at the 0.5° elevation angle was weaker than at 0.2° in all but one of the ten tornadoes examined in this study. Even in that one case, the EF-0 tornado in Smithfield, NC presented here, V_{rot} was similar between the two elevation angles; and the diameter at 0.2° was almost half of that at 0.5°. Additionally, storm-scale signatures in reflectivity data, including hook echoes, were better defined in 0.2° than 0.5° data in every case. While other severe storm precursors may be better sampled at higher altitudes and radar elevation angles, the cases reviewed here suggest the 0.2° data is superior to 0.5° in terms of low-level mesocyclone and tornado detection.

Seven of the ten tornadoes investigated produced a dual-pol Tornado Debris Signature (TDS), including the three presented here. While TDSs were apparent at both 0.2° and 0.5° in each case, lower sampling afforded by the 0.2° angle should theoretically provide more timely detections, which warning forecasters can relay in Impact-Based Tornado Warnings and Severe Weather Statements.

The availability of this supplemental radar data will make the WSR-88D an even more useful and critical tool in the issuance of timely and accurate NWS warnings, particularly when paired with other information not considered here, such as environmental; numerical weather prediction; and conceptual model data, to name a few.

References

Manitakos, J. and Tarpinian, A. 2019: Environmental Assessment (EA), Lowering the Minimum Scan Angle of the Weather Surveillance Radars – Model 1988 Doppler (WSR-88Ds) serving Greer, SC; Columbia, SC; and Raleigh, NC.

Acknowledgments

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