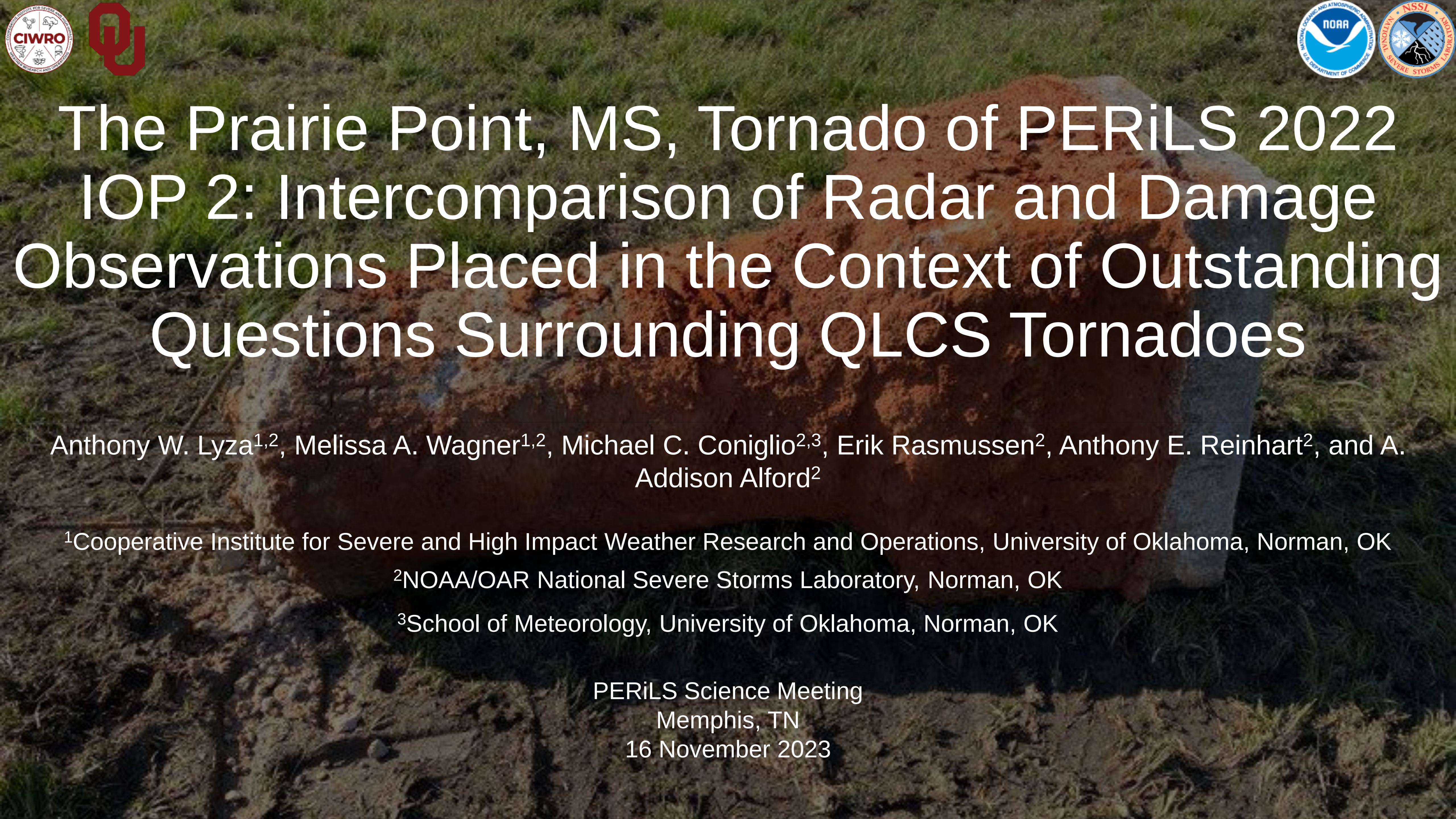

The Prairie Point, MS, Tornado of PERiLS 2022 IOP 2: Intercomparison of Radar and Damage Observations Placed in the Context of Outstanding Questions Surrounding QLCS Tornadoes

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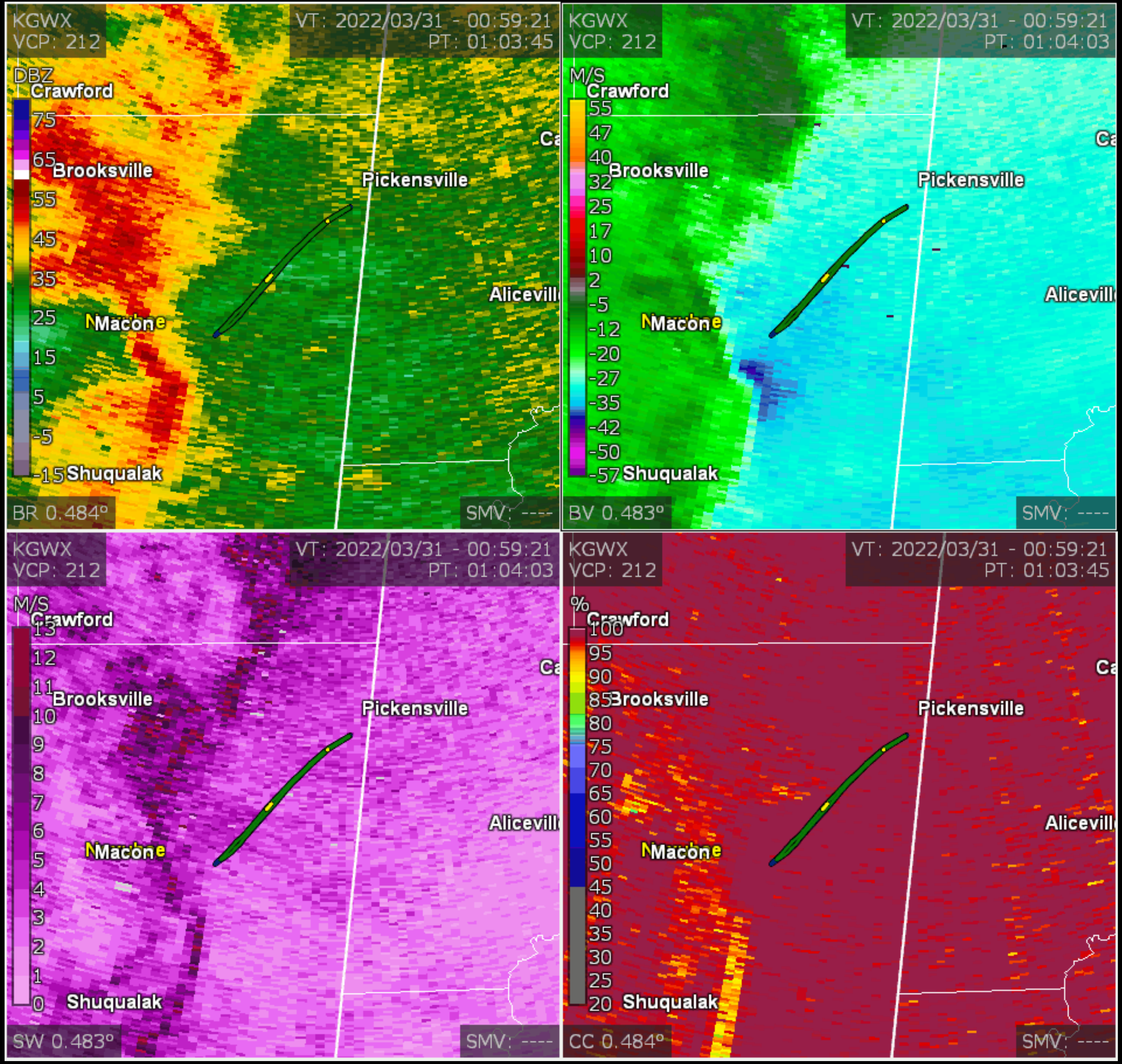
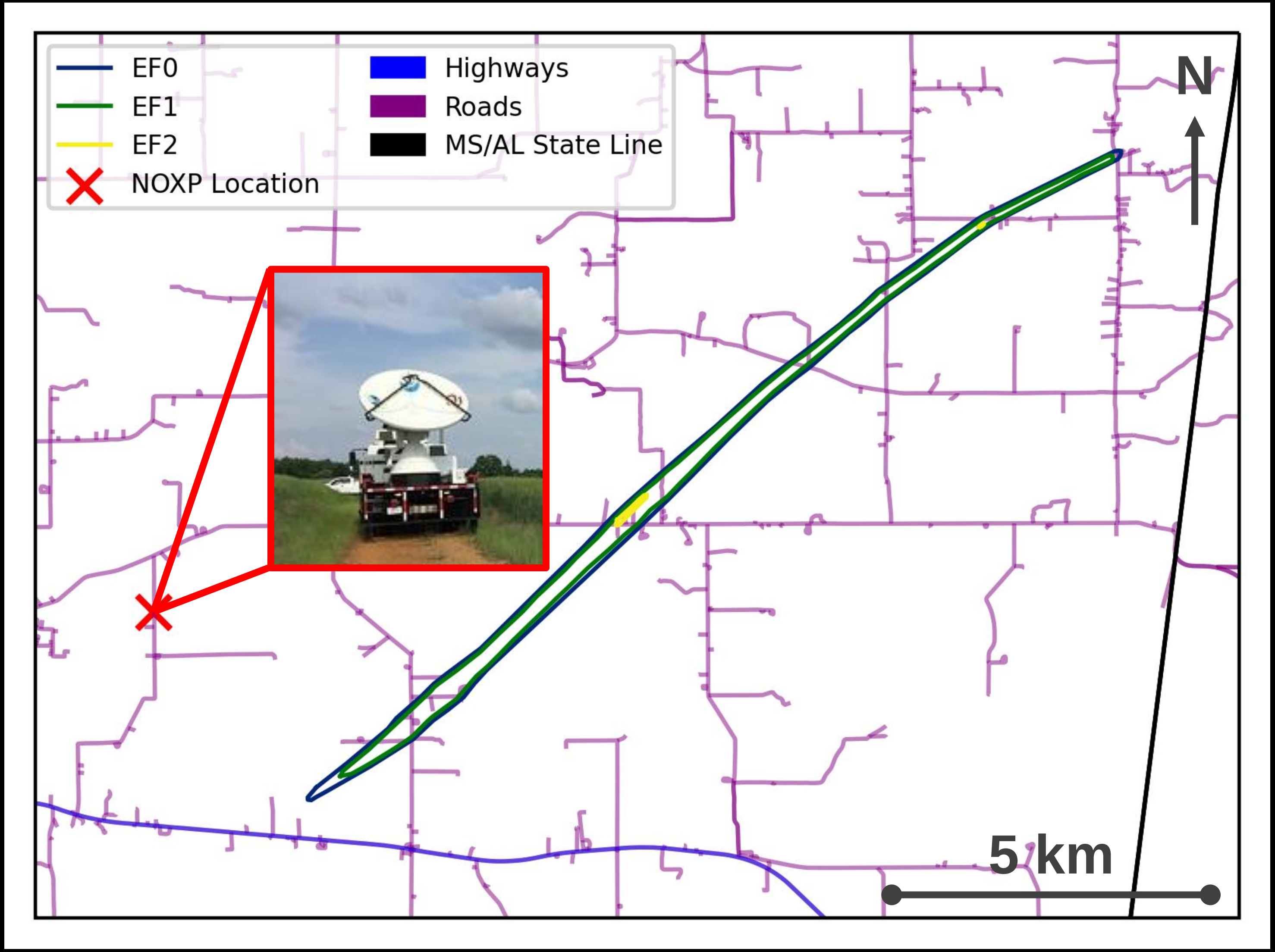
PERiLS Science Meeting
Memphis, TN
16 November 2023

30 March 2022, Prairie Point, MS



- Occurred during IOP 2 of the 2022 PERiLS campaign near the community of Prairie Point in Noxubee County in east-central MS

30 March 2022, Prairie Point, MS

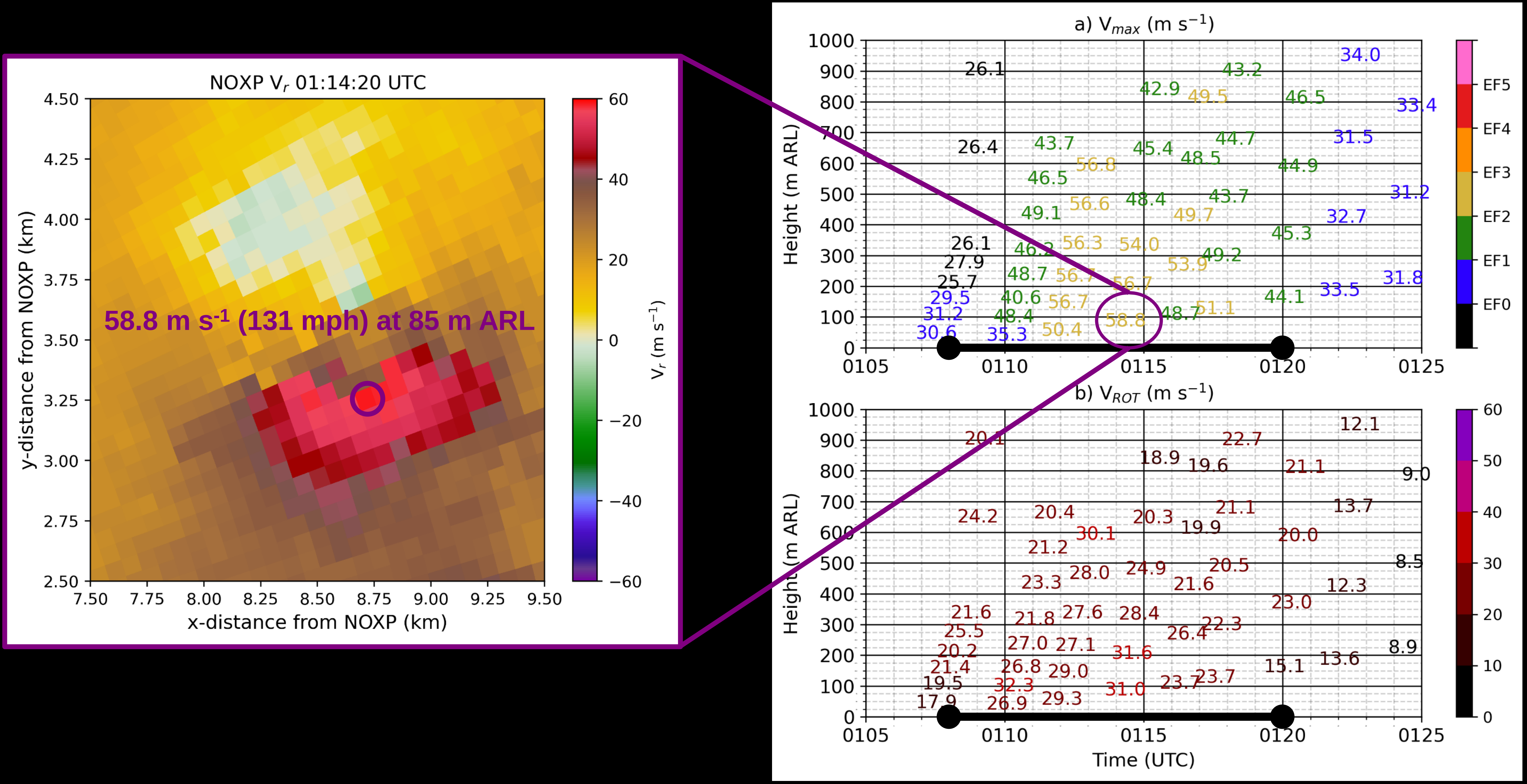


- Occurred during IOP 2 of the 2022 PERiLS campaign near the community of Prairie Point in Noxubee County in east-central MS
- Path length of 17.7 km (11.0 mi), maximum path width of 370 m (400 yd)
- Maximum damage intensity: EF2

30 March 2022, Prairie Point, MS

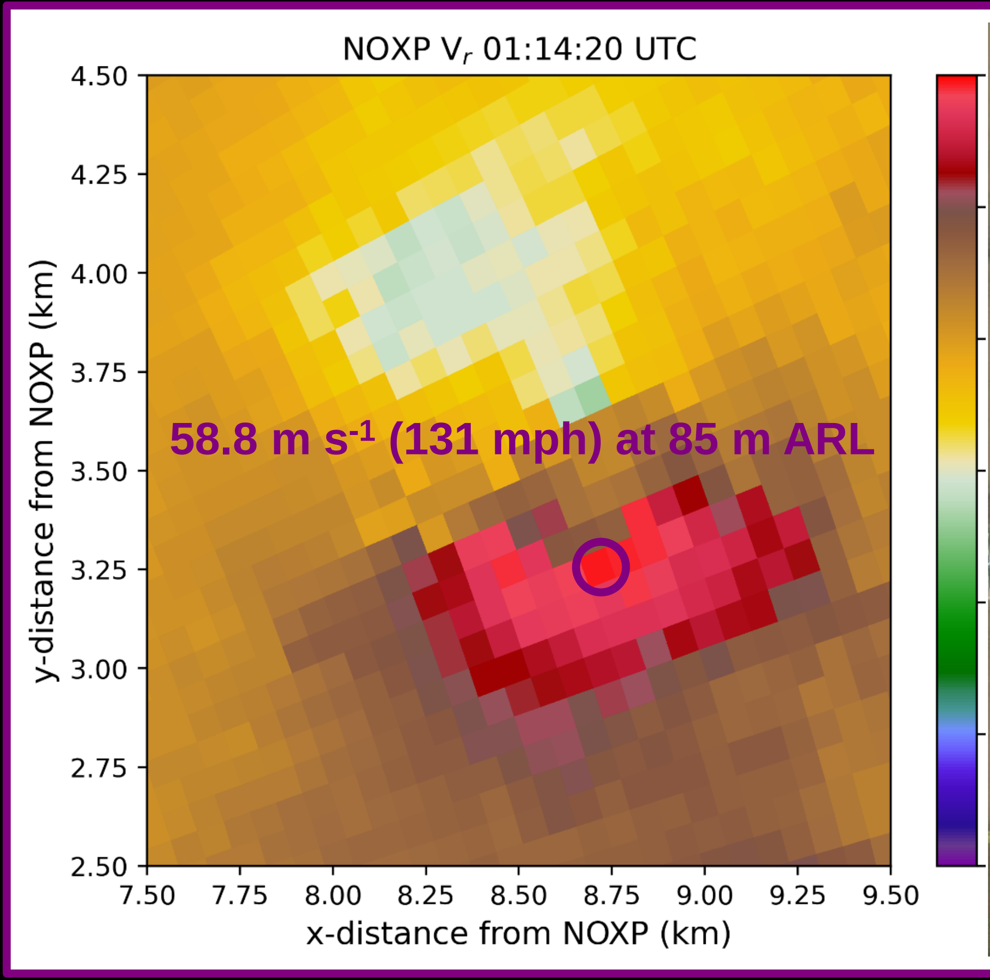
- Occurred during IOP 2 of the 2022 PERiLS campaign near the community of Prairie Point in Noxubee County in east-central MS
- Path length of 17.7 km (11.0 mi), maximum path width of 370 m (400 yd)
- Maximum damage intensity: EF2
- Estimated 3-s wind gust: 60.4 m s^{-1} (135 mph)
- Formed 4.3 km southeast of the NOAA X-Pol (NOXP) radar site

30 March 2022 – NOXP V_r Characteristics

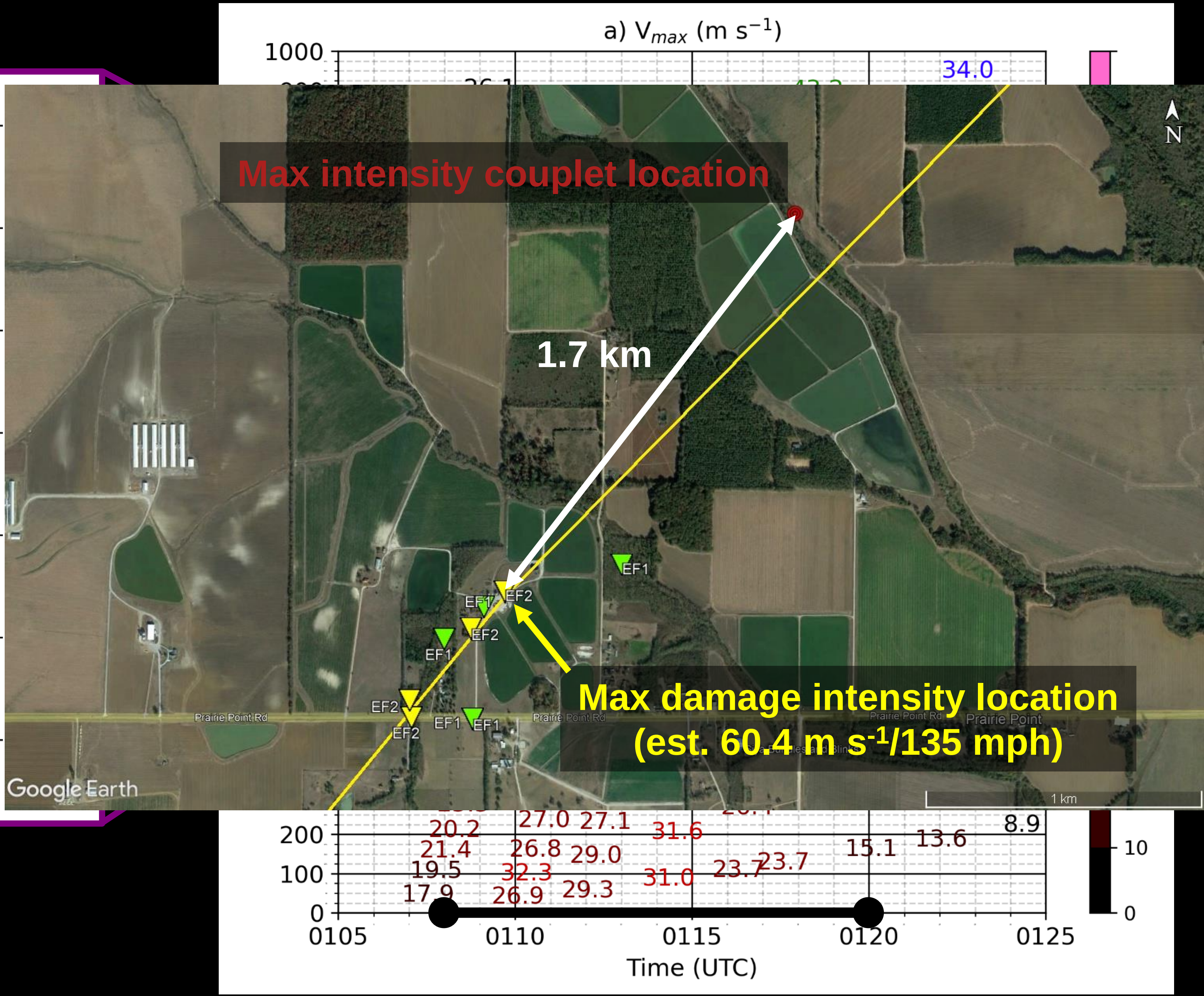


58.8 m s⁻¹ (131 mph) at 85 m ARL

30 March 2022 – NOXP V_r Characteristics



58.8 m s^{-1} (131 mph) at 85 m ARL

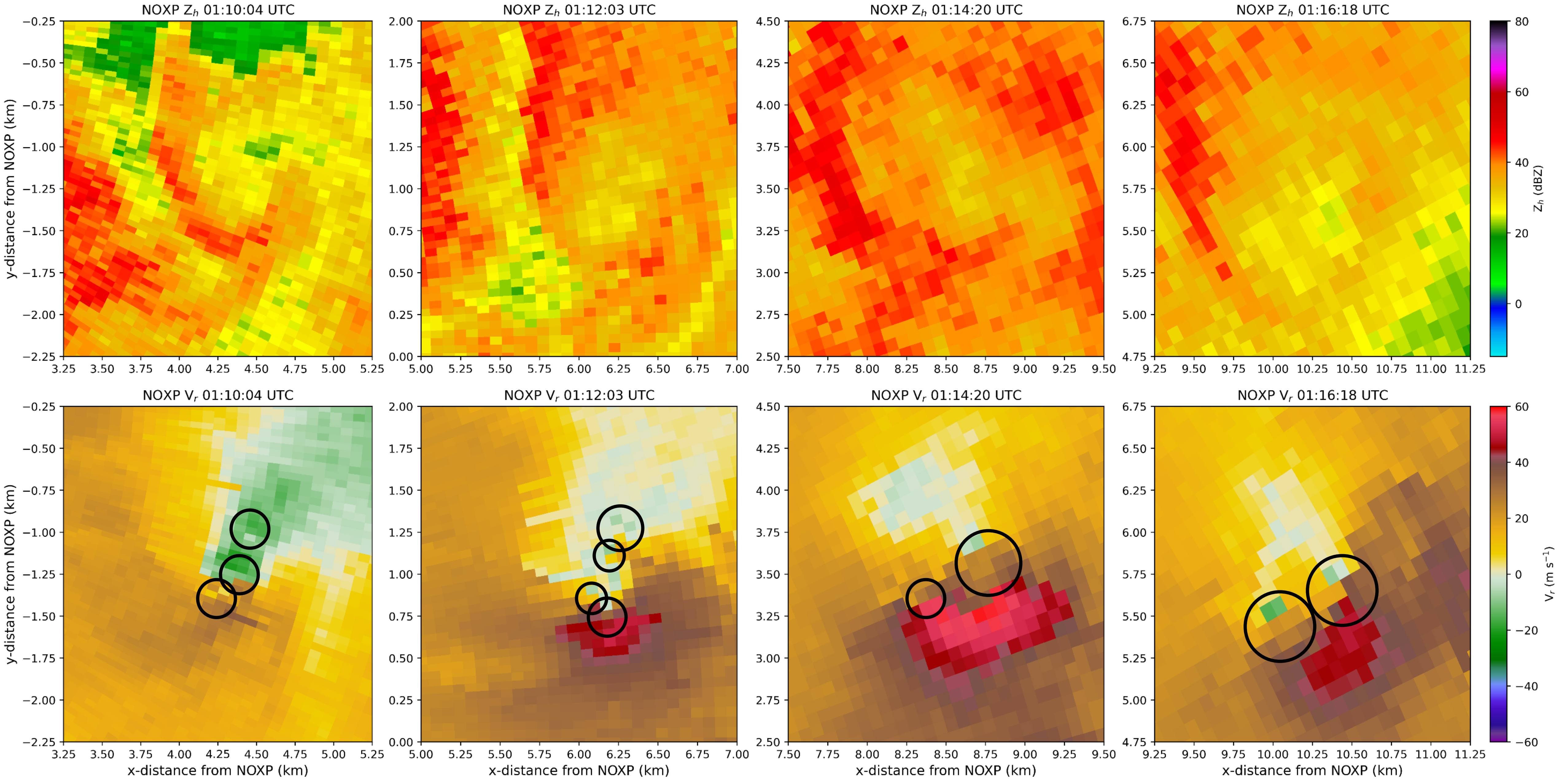


Max intensity couplet location

1.7 km

Max damage intensity location
(est. 60.4 m s^{-1}/135 mph)

30 March 2022 – NOXP 0.5° V_r Characteristics



30 March 2022 – NOXP 0.5° V_r Characteristics

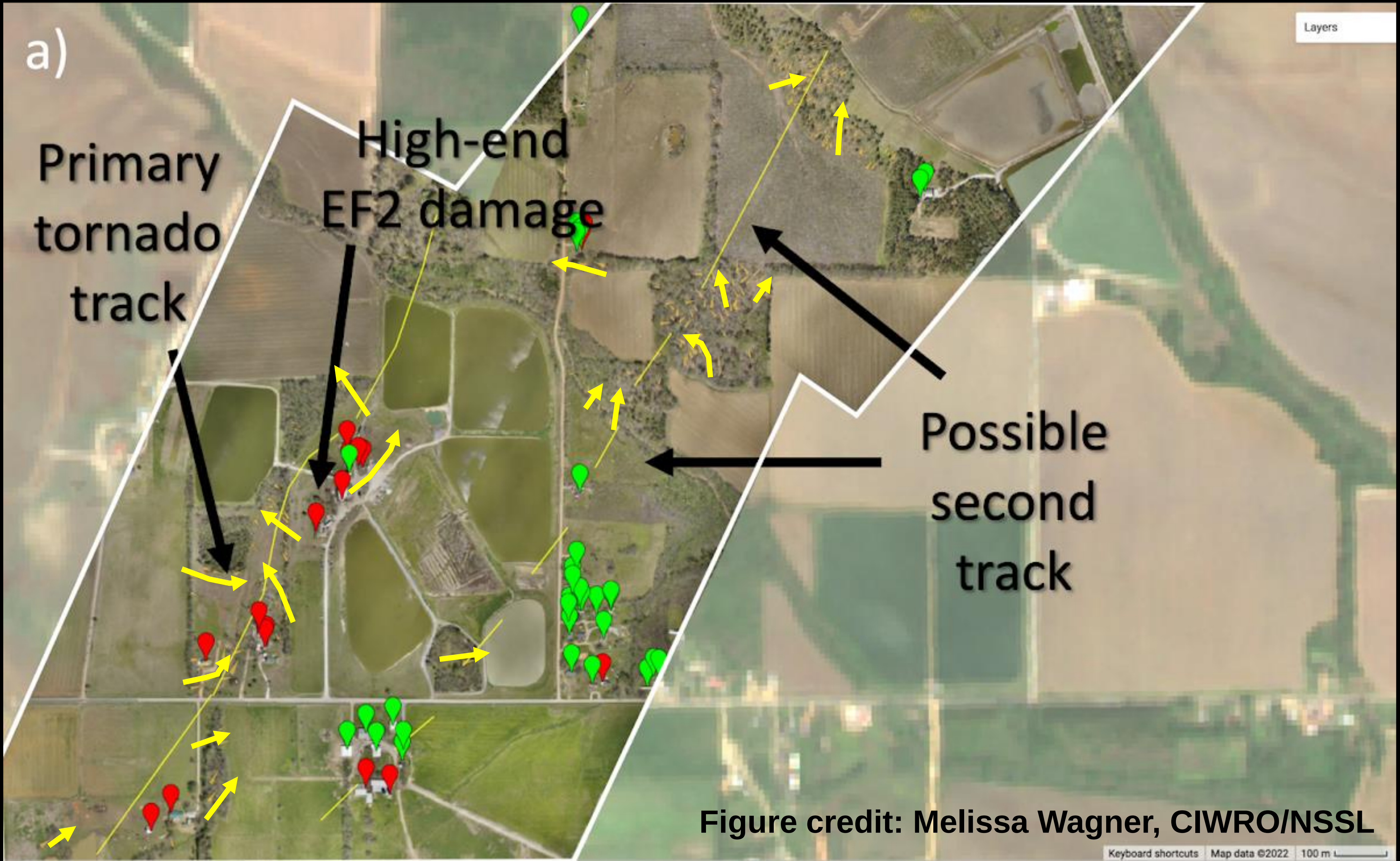


Figure credit: Melissa Wagner, CIWRO/NSSL

30 March 2022 – NOXP 0.5° V_r Characteristics

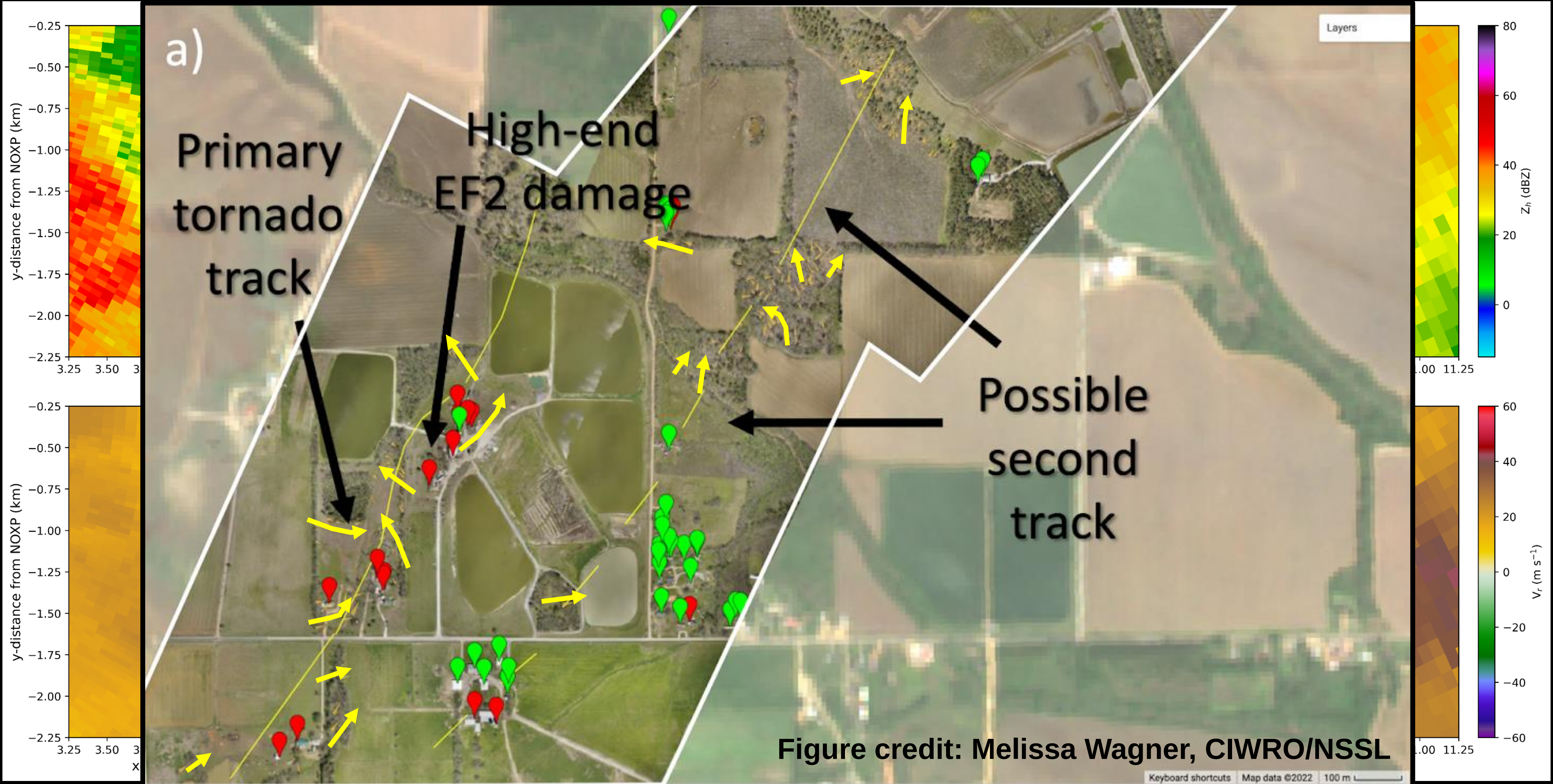
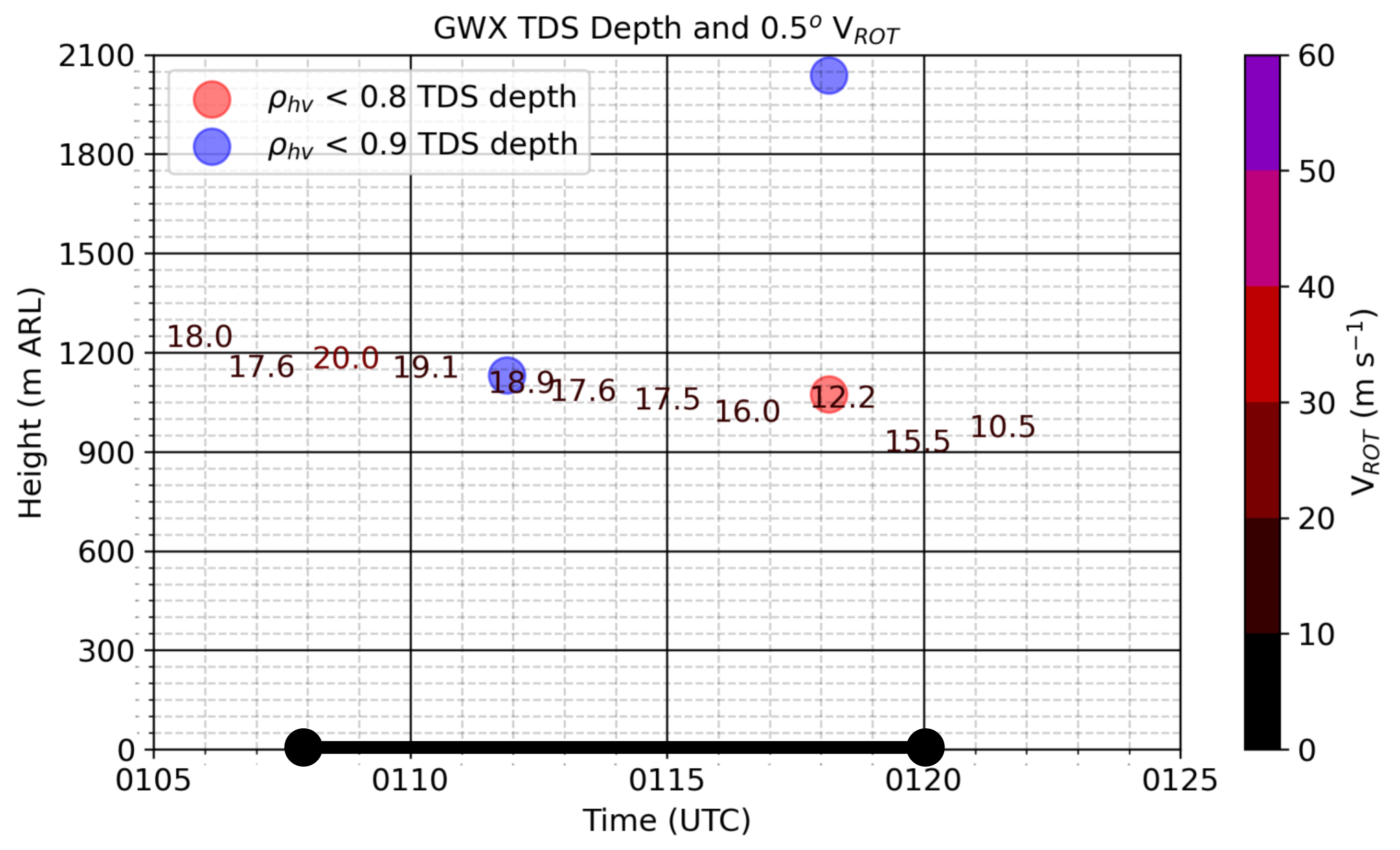


Figure credit: Melissa Wagner, CIWRO/NSSL

30 March 2022 – GWX Radar Observations



30 March 2022 – Comparison to Thompson (2023)

FORECASTERS' FORUM

A Comparison of Right-Moving Supercell and Quasi-Linear Convective System Tornadoes in the Contiguous United States 2003–21

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[a] *NOAA/NWS/NCEP/Storm Prediction Center, Norman, Oklahoma*

(Manuscript received 14 January 2023, in final form 13 May 2023, accepted 16 May 2023)

ABSTRACT: Tornadoes produced by right-moving supercells (RMs) and quasi-linear convective systems (QLCSs) are compared across the contiguous United States for the period 2003–21, based on the maximum F/EF-scale rating per hour on a 40-km horizontal grid. The frequency of QLCS tornadoes has increased dramatically since 2003, while the frequency of RM tornadoes has decreased during that same period. The finding of prior work that the most common damage rating for QLCS tornadoes at night is EF1 persists in this larger, independent sample. A comparison of WSR-88D radar attributes between RM and QLCS tornadoes shows no appreciable differences between EF0 tornadoes produced by either convective mode. Differences become apparent for EF1–2 tornadoes, where rotational velocity is larger and velocity couplet diameter is smaller for RM tornadoes compared to QLCS tornadoes. The frequency of tornadic debris signatures (TDSs) in dual-polarization data is also larger for EF1–2 RM tornadoes when controlling for tornadoes sampled relatively close to the radar sites and in those occurring during daylight versus overnight. The weaker rotational velocities, broader velocity couplet diameters, and lower frequencies of TDSs both close to the radar and at night for QLCS EF1 tornadoes suggest that a combination of inadequate radar sampling and occasional misclassification of wind damage may be responsible for the irregularities in the historical record of QLCS tornado reports.

SIGNIFICANCE STATEMENT: A comparison of radar attributes between tornadoes with right-moving supercells and squall-line mesovortices suggests some irregularities in squall-line tornado records in the contiguous United States. The irregularities appear to be the result of both inadequate radar sampling for the relatively shallow squall-line tornadoes and occasional misclassification of wind damage with the lack of other corroborating evidence, especially overnight.

KEYWORDS: Forecasting techniques; Nowcasting; Operational forecasting; Tornadoes

1. Introduction

The threat to life and property increases dramatically as tornado intensity increases, such that the vast majority of tornado fatalities are the result of significant (F/EF2+ rated damage) tornadoes, which account for less than 15% of all tornado reports (Ashley 2007; Anderson-Frey and Brooks 2019). The majority of these significant tornadoes in the United States are produced by right-moving supercells (RMs) (Smith et al. 2012; Brotzge et al. 2013), and RMs have garnered the majority of the attention of the research, forecasting, and emergency management communities during the past several decades (e.g., Brooks et al. 2019).

Approximately 21% of all tornadoes in the United States are produced by quasi-linear convective systems (QLCSs; Ashley et al. 2019), in general agreement with the previous findings of Trapp et al. (2005) and Smith et al. (2012); however, each of these studies varied in exactly what was considered a QLCS tornado [i.e., Ashley et al. (2019) and Trapp et al. (2005) likely included supercells embedded in a QLCS, whereas Smith et al. (2012) did not]. QLCS tornadoes tend to produce primarily weak (F/EF0–1) damage (Trapp et al. 2005; Gallus et al. 2008; Smith et al. 2012), and QLCS tornado reports have increased over time (Ashley et al. 2019). Examples of RM and QLCS EF1 tornadic storms are shown in Fig. 1.

Trapp and Weisman (2003) and Weisman and Trapp (2003) examined mesovortex formation in QLCSs from a theoretical perspective, focusing on a balance between low-level, vertical wind shear in the ambient environment and vertical circulations generated by the QLCS cold pool. Additional work by Atkins and St. Laurent (2009a,b) identified two potential mechanisms responsible for mesovortex formation in QLCSs:

1) A cyclonic-only mesovortex forms as horizontal baroclinic vorticity (parallel to gust front) is tilted downward to become cyclonic on the equatorward (Northern Hemisphere) side of a downdraft, which combines with streamwise vorticity in the storm inflow to support mesovortex formation.
2) A cyclonic–anticyclonic vortex couplet (cyclonic poleward, anticyclonic equatorward in the Northern Hemisphere) results from a rear-inflow jet/downdraft surge that enhances the low-level updraft on the nose of the surge/bow echo, and this updraft tilts barolinic vorticity generated along the gust front, in addition to streamwise vorticity from storm inflow.

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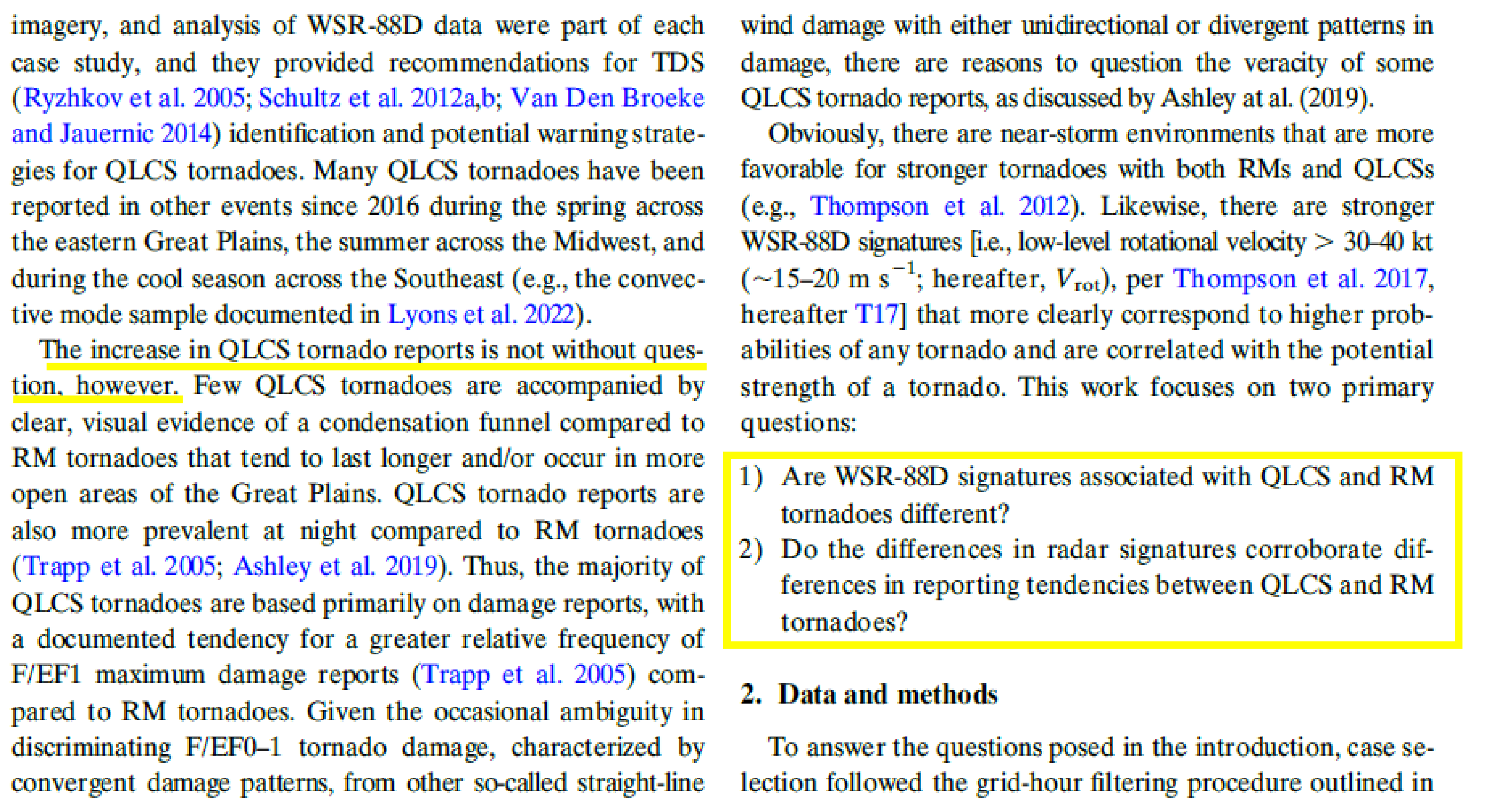
Thompson (2023, *WAF*)



imagery, and analysis of WSR-88D data were part of each case study, and they provided recommendations for TDS (Ryzhkov et al. 2005; Schultz et al. 2012a,b; Van Den Broeke and Jauernic 2014) identification and potential warning strategies for QLCS tornadoes. Many QLCS tornadoes have been reported in other events since 2016 during the spring across the eastern Great Plains, the summer across the Midwest, and during the cool season across the Southeast (e.g., the convective mode sample documented in Lyons et al. 2022).

The increase in QLCS tornado reports is not without question, however. Few QLCS tornadoes are accompanied by clear, visual evidence of a condensation funnel compared to RM tornadoes that tend to last longer and/or occur in more open areas of the Great Plains. QLCS tornado reports are also more prevalent at night compared to RM tornadoes (Trapp et al. 2005; Ashley et al. 2019). Thus, the majority of QLCS tornadoes are based primarily on damage reports, with a documented tendency for a greater relative frequency of F/EF1 maximum damage reports (Trapp et al. 2005) compared to RM tornadoes. Given the occasional ambiguity in discriminating F/EF0–1 tornado damage, characterized by convergent damage patterns, from other so-called straight-line wind damage with either unidirectional or divergent patterns in damage, there are reasons to question the veracity of some QLCS tornado reports, as discussed by Ashley at al. (2019).

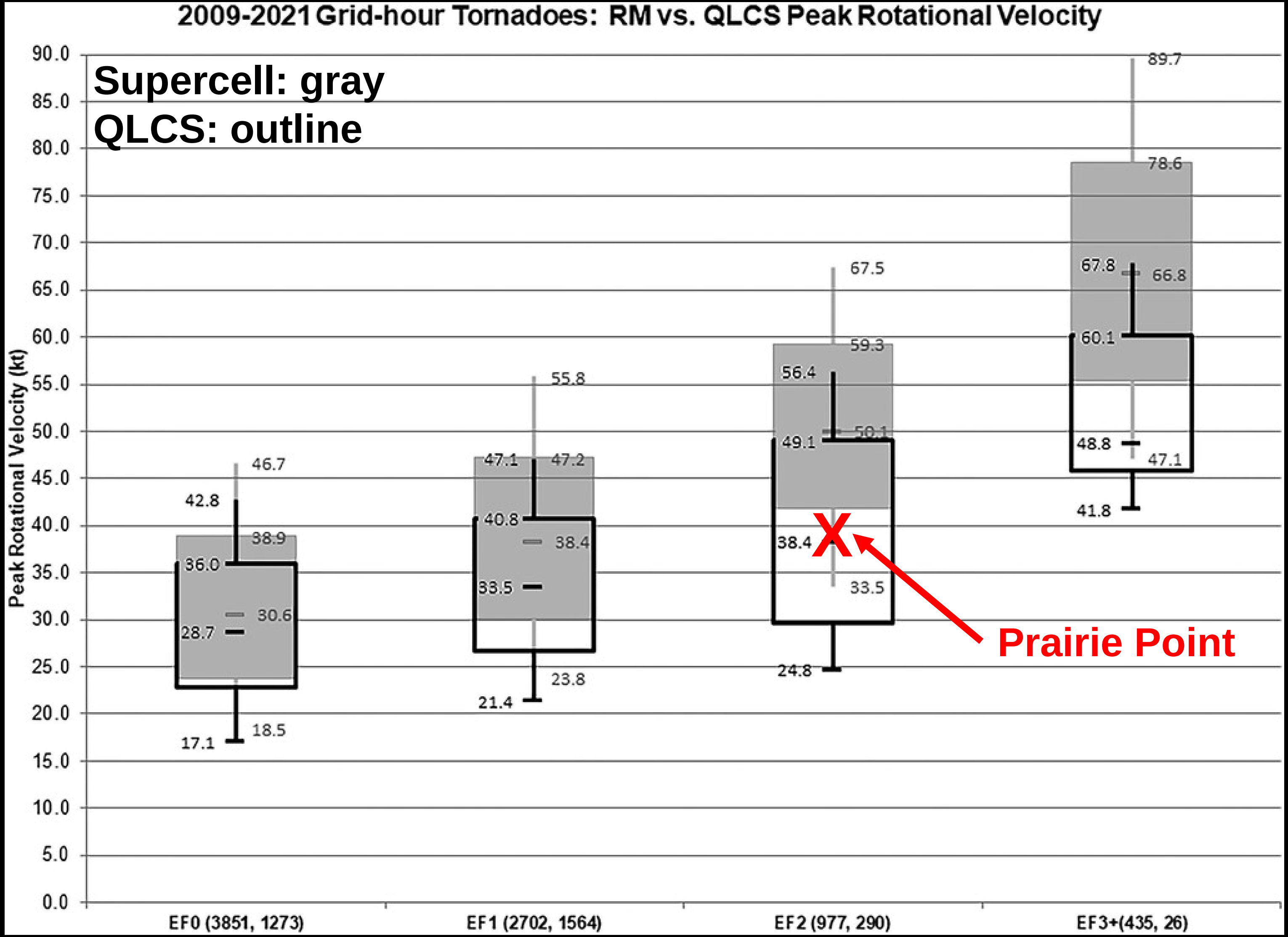
Obviously, there are near-storm environments that are more favorable for stronger tornadoes with both RMs and QLCSs (e.g., Thompson et al. 2012). Likewise, there are stronger WSR-88D signatures [i.e., low-level rotational velocity > 30–40 kt (~15–20 m s^{-1}; hereafter, V_{rot}), per Thompson et al. 2017, hereafter T17] that more clearly correspond to higher probabilities of any tornado and are correlated with the potential strength of a tornado. This work focuses on two primary questions:

1) Are WSR-88D signatures associated with QLCS and RM tornadoes different?
2) Do the differences in radar signatures corroborate differences in reporting tendencies between QLCS and RM tornadoes?

2. Data and methods

To answer the questions posed in the introduction, case selection followed the grid-hour filtering procedure outlined in

30 March 2022 – Comparison to Thompson (2023)



Supercell: gray
QLCS: outline

Prairie Point

Fig. 6 from Thompson (2023)

30 March 2022 – Comparison to Thompson (2023)

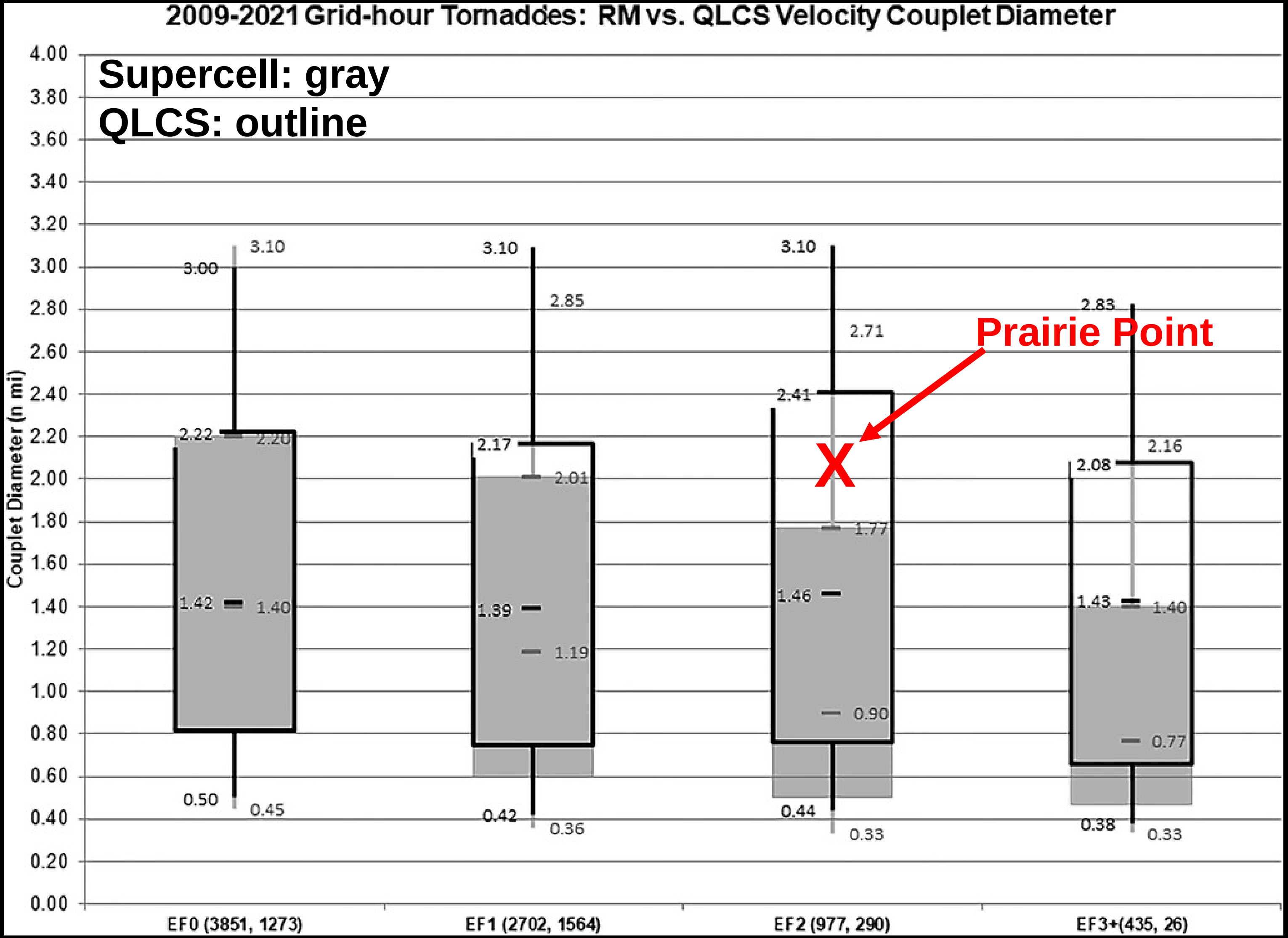
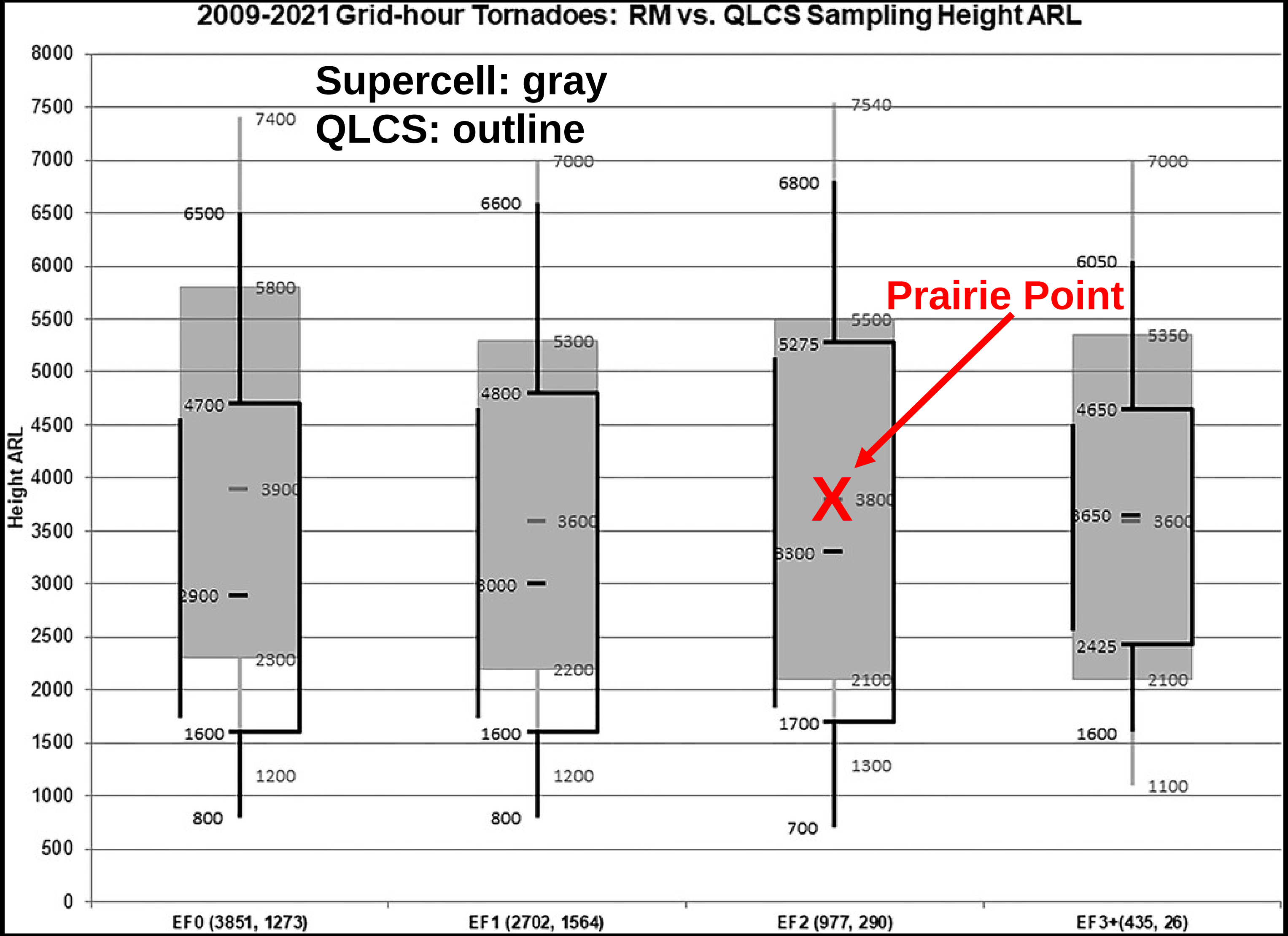


Fig. 7 from Thompson (2023)

30 March 2022 – Comparison to Thompson (2023)



Supercell: gray
QLCS: outline

Prairie Point

Fig. 8 from Thompson (2023)

30 March 2022 – Comparison to Thompson (2023)

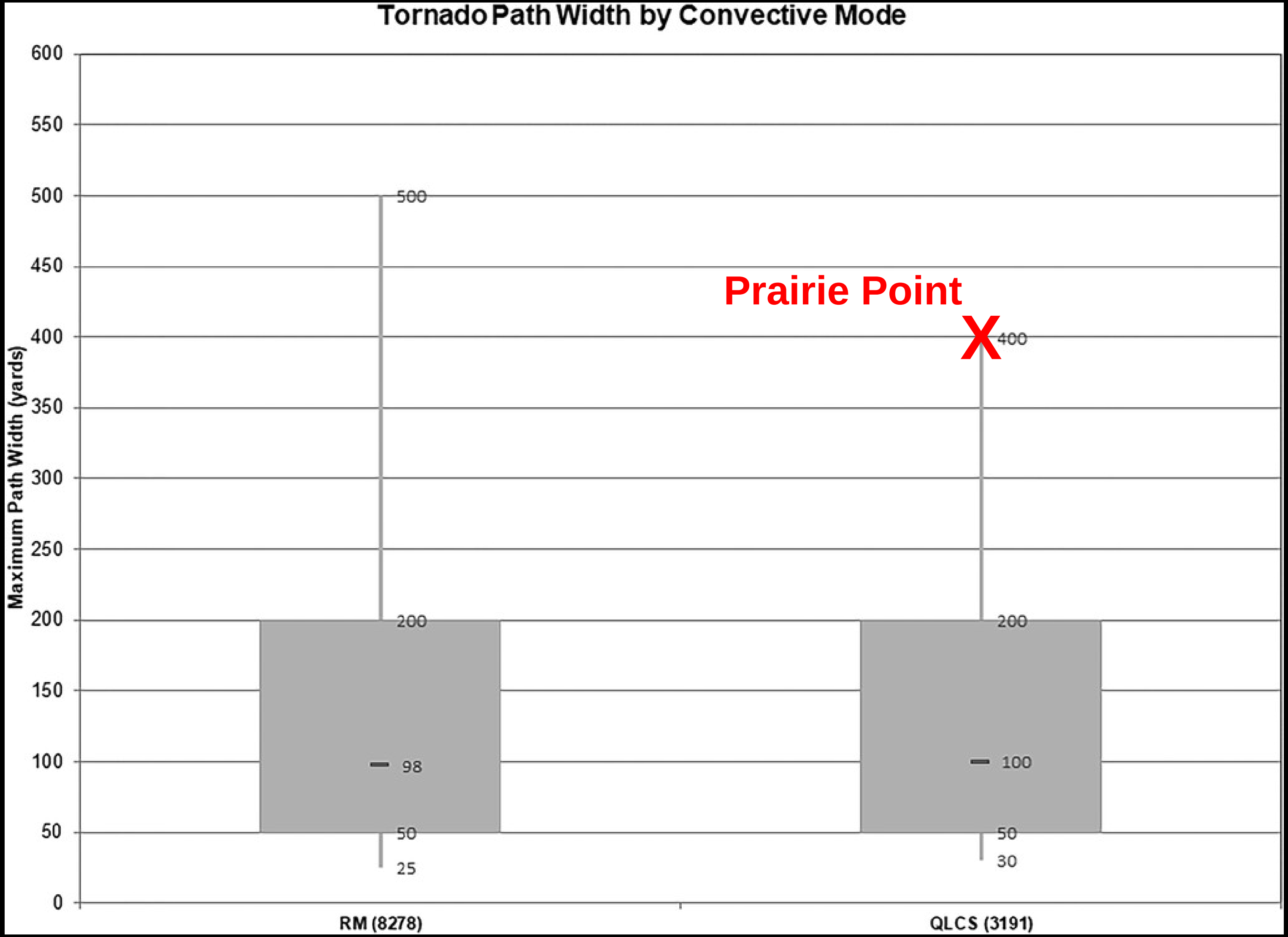
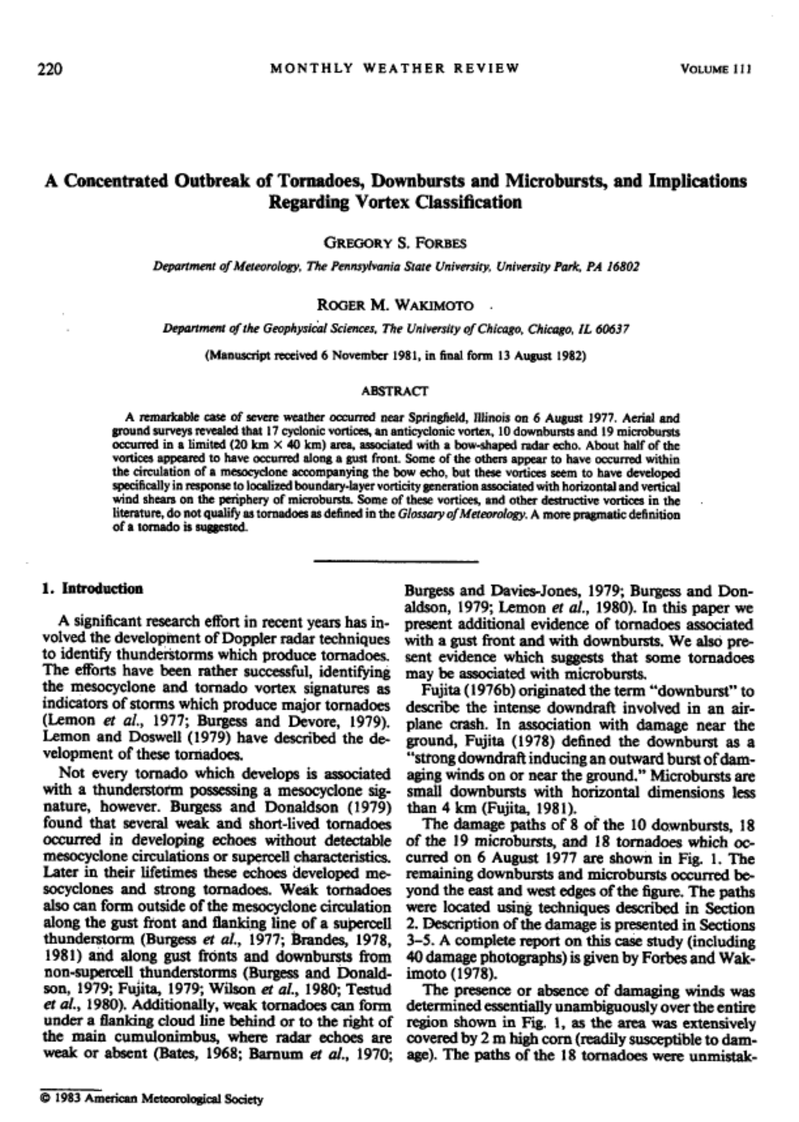


Fig. 5 from Thompson (2023)

30 March 2022 – Comparison to Forbes and Wakimoto (1983)



220 MONTHLY WEATHER REVIEW VOLUME 111

A Concentrated Outbreak of Tornadoes, Downbursts and Microbursts, and Implications Regarding Vortex Classification

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(Manuscript received 6 November 1981, in final form 13 August 1982)

ABSTRACT

A remarkable case of severe weather occurred near Springfield, Illinois on 6 August 1977. Aerial and ground surveys revealed that 17 cyclonic vortices, an anticyclonic vortex, 10 downbursts and 19 microbursts occurred in a limited (20 km × 40 km) area, associated with a bow-shaped radar echo. About half of the vortices appeared to have occurred along a gust front. Some of the others appear to have occurred within the circulation of a mesocyclone accompanying the bow echo, but these vortices seem to have developed specifically in response to localized boundary-layer vorticity generation associated with horizontal and vertical wind shears on the periphery of microbursts. Some of these vortices, and other destructive vortices in the literature, do not qualify as tornadoes as defined in the *Glossary of Meteorology*. A more pragmatic definition of a tornado is suggested.

1. Introduction

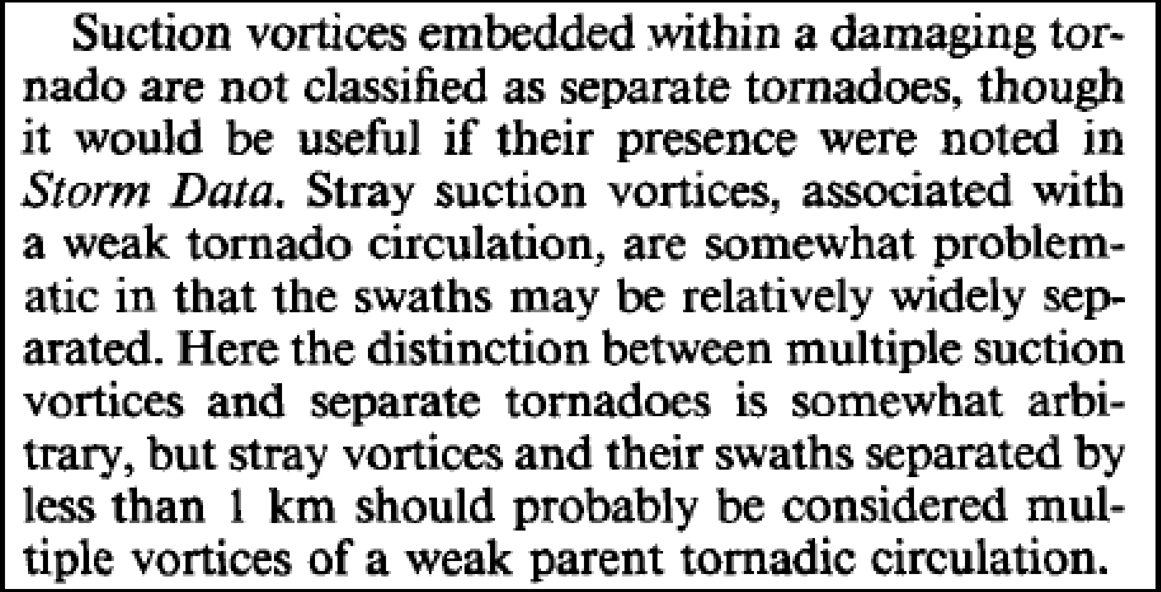
A significant research effort in recent years has involved the development of Doppler radar techniques to identify thunderstorms which produce tornadoes. The efforts have been rather successful, identifying the mesocyclone and tornado vortex signatures as indicators of storms which produce major tornadoes (Lemon *et al.*, 1977; Burgess and Devore, 1979). Lemon and Doswell (1979) have described the development of these tornadoes.

Not every tornado which develops is associated with a thunderstorm possessing a mesocyclone signature, however. Burgess and Donaldson (1979) found that several weak and short-lived tornadoes occurred in developing echoes without detectable mesocyclone circulations or supercell characteristics. Later in their lifetimes these echoes developed mesocyclones and strong tornadoes. Weak tornadoes also can form outside of the mesocyclone circulation along the gust front and flanking line of a supercell thunderstorm (Burgess *et al.*, 1977; Brandes, 1978, 1981) and along gust fronts and downbursts from non-supercell thunderstorms (Burgess and Donaldson, 1979; Fujita, 1979; Wilson *et al.*, 1980; Testud *et al.*, 1980). Additionally, weak tornadoes can form under a flanking cloud line behind or to the right of the main cumulonimbus, where radar echoes are weak or absent (Bates, 1968; Barnum *et al.*, 1970; Burgess and Davies-Jones, 1979; Burgess and Donaldson, 1979; Lemon *et al.*, 1980). In this paper we present additional evidence of tornadoes associated with a gust front and with downbursts. We also present evidence which suggests that some tornadoes may be associated with microbursts.

Fujita (1976b) originated the term "downburst" to describe the intense downdraft involved in an airplane crash. In association with damage near the ground, Fujita (1978) defined the downburst as a "strong downdraft inducing an outward burst of damaging winds on or near the ground." Microbursts are small downbursts with horizontal dimensions less than 4 km (Fujita, 1981).

The damage paths of 8 of the 10 downbursts, 18 of the 19 microbursts, and 18 tornadoes which occurred on 6 August 1977 are shown in Fig. 1. The remaining downbursts and microbursts occurred beyond the east and west edges of the figure. The paths were located using techniques described in Section 2. Description of the damage is presented in Sections 3–5. A complete report on this case study (including 40 damage photographs) is given by Forbes and Wakimoto (1978).

The presence or absence of damaging winds was determined essentially unambiguously over the entire region shown in Fig. 1, as the area was extensively covered by 2 m high corn (readily susceptible to damage). The paths of the 18 tornadoes were unmistak-



Suction vortices embedded within a damaging tornado are not classified as separate tornadoes, though it would be useful if their presence were noted in *Storm Data*. Stray suction vortices, associated with a weak tornado circulation, are somewhat problematic in that the swaths may be relatively widely separated. Here the distinction between multiple suction vortices and separate tornadoes is somewhat arbitrary, but stray vortices and their swaths separated by less than 1 km should probably be considered multiple vortices of a weak parent tornadic circulation.

Summary and Acknowledgments

- Peak in Doppler velocity closest to surface, consistent with Plains tornado observations*
- Radar-observed V_{max} values matched closely to estimated peak wind speeds from damage indicators in surveys for both cases, BUT…unclear how radar observations compare to 3-s, 10-m AGL gust standard for EF scale
- Subvortices coarsely resolved by NOXP in Prairie Point tornado, corroborating complicated damage patterns observed in surveys
  - How common are these multi-vortex structures in QLCSs?
  - Could this multi-vortex structure, and a background commonality of this structure in QLCS cases, explain some of the observed differences between QLCS and supercell tornado radar characteristics?

Acknowledgments

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