Identification of Discrete Updrafts Within QLCSs Using Gridded Radar Data and Potential Implications for Tornadogenesis Prediction

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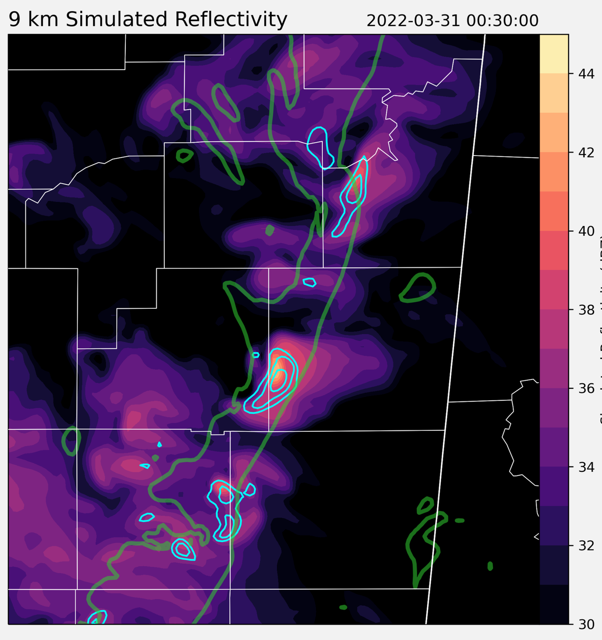
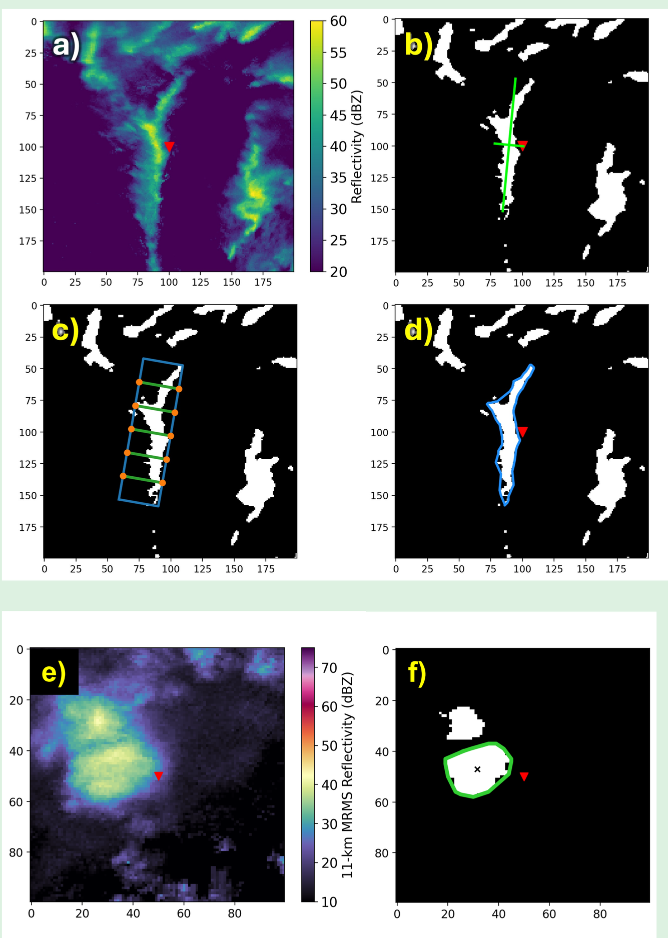
Background

- Quasi-linear convective system (**QLCS**) tornadoes are difficult to predict
  - **Narrower, shallower, shorter-lived** parent mesovortices than supercellular tornadoes
  - Relative size of QLCSs make it difficult for forecasters to know where to focus attention
- Leads to short or negative warning lead times
- **Can discrete updraft cores in a QLCS can signal where tornadogenesis is most likely?**
  - As suggested by Wolff et al. (2025)
- **How does environment affect this relationship?**



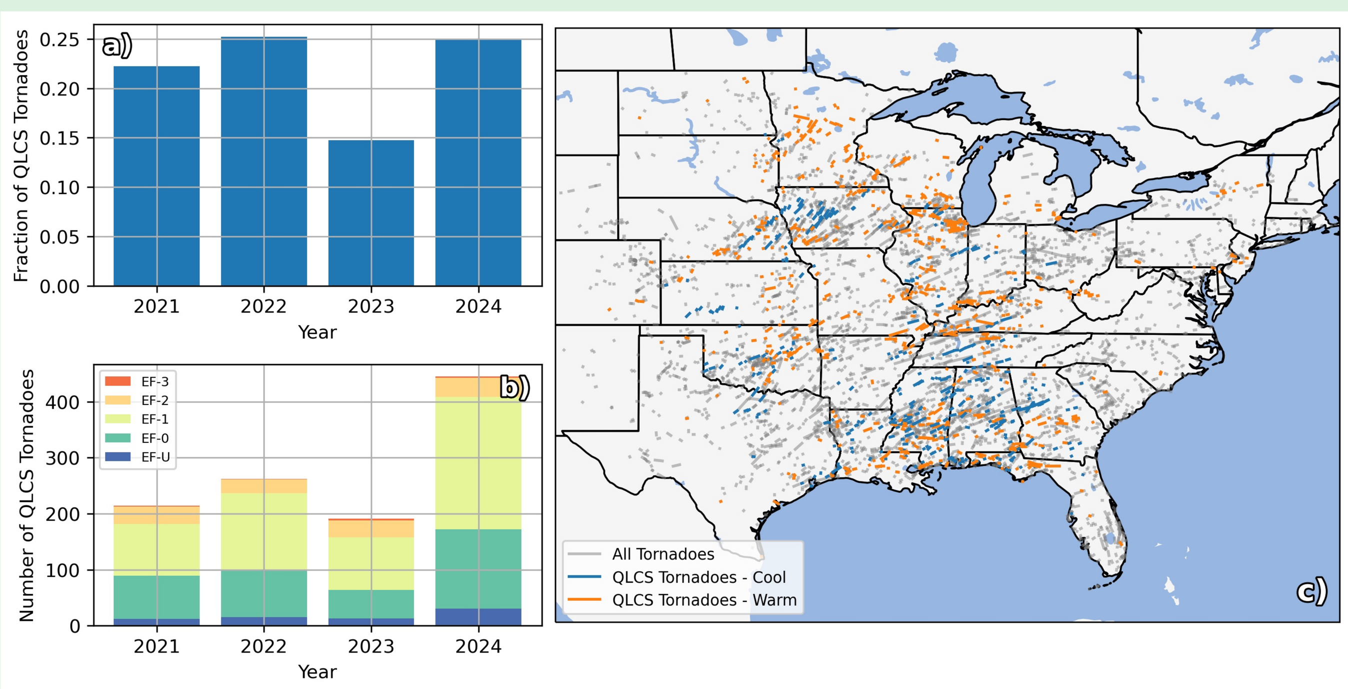
Depiction of relatively deep, discrete updraft cores within a WRF-simulated QLCS (Wolff et al. 2025)

Methodology



Multistep process for identifying QLCSs (a-d) and discrete reflectivity cores (e-f) from gridded 3D radar data

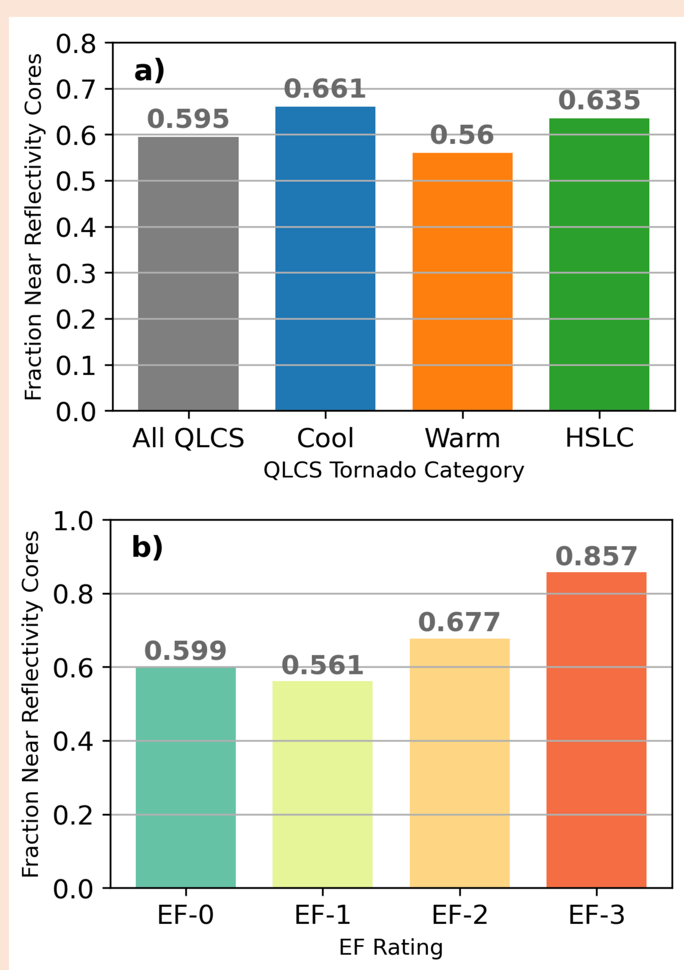
- 3D radar data (MRMS) are used to identify QLCSs and discrete **reflectivity cores** (a proxy for updraft cores several km aloft)
- Every US tornado report (2021-2024) is matched to a **QLCS object**, if one exists (defined by length, length-to-width ratio criteria)
  - **1109** QLCS tornadoes identified
- For tornadoes then labeled as QLCS tornadoes, area-averaged environmental parameters are computed from RAP analysis data (1.5°x1.5° grid centered on the tornado)
- Reflectivity cores are then identified using MRMS data from the level just below the surface-based EL (calculated from RAP)
  - Contoured based on the 95th percentile of all reflectivity within a 1°x1° grid



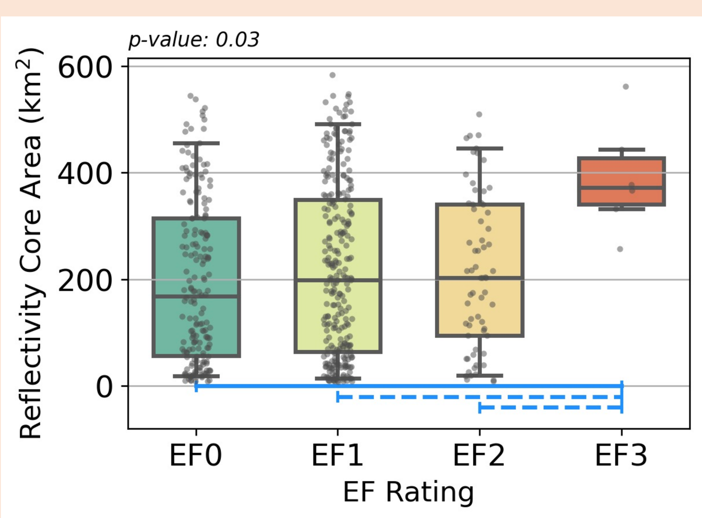
Statistics on all QLCS tornadoes identified from 2021-2024

Results

- Over **59%** of QLCS tornadoes formed within 15 km of a reflectivity core
  - Percentage is higher during the **cool season** and for tornadoes with **higher EF ratings**
  - Wolff et al. (2025) found 85% of tornadoes in a single cool season QLCS formed near reflectivity cores
- Reflectivity cores located near tornadoes with stronger radar-derived rotation tend to be present for a **longer period** prior to tornadogenesis
  - Also true for cores in more highly sheared environments



Fraction of tornadoes with reflectivity cores present, divided by season/environment (top) and EF rating (bottom)

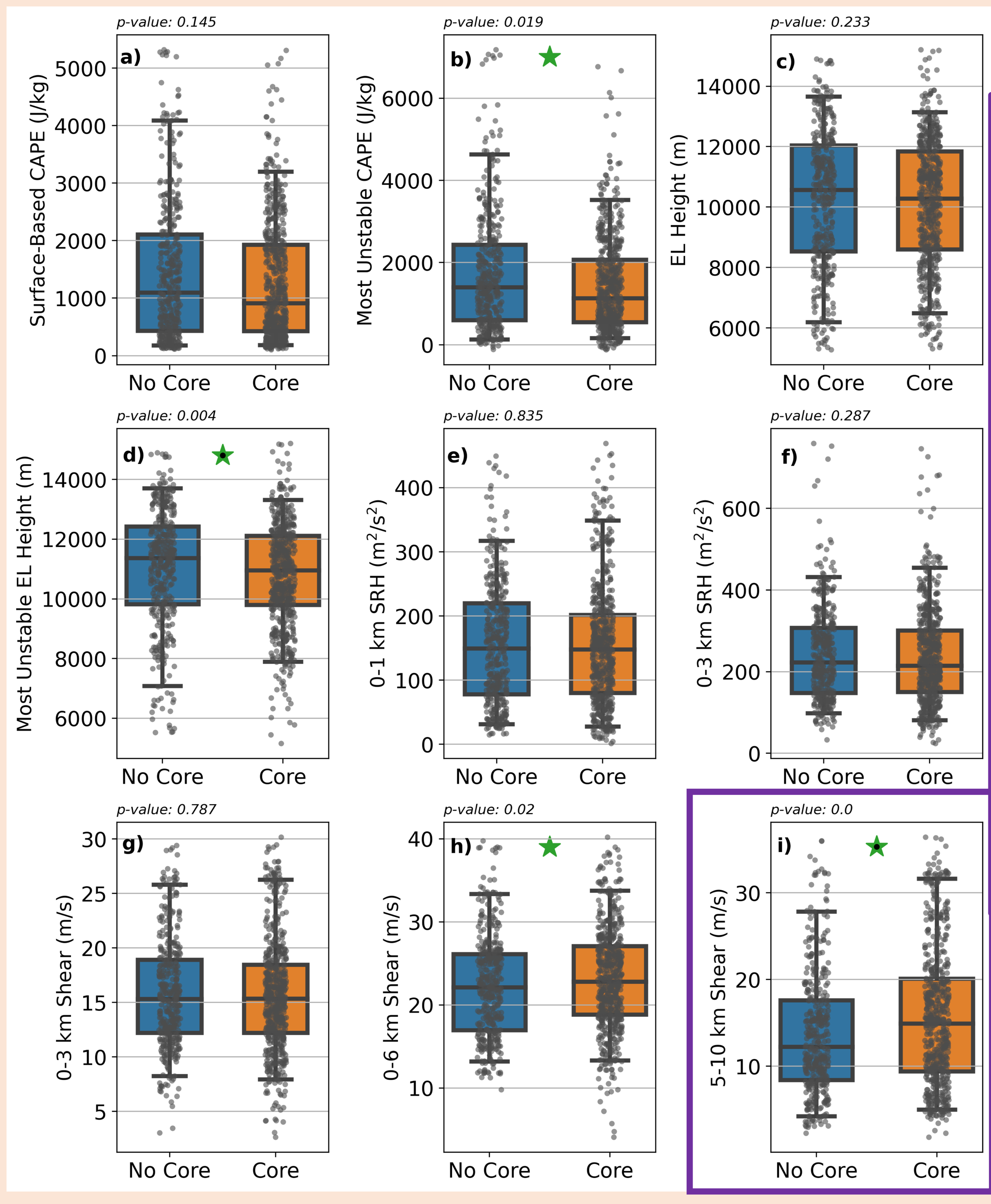


Reflectivity core area separated by EF rating; blue lines denote statistical significance

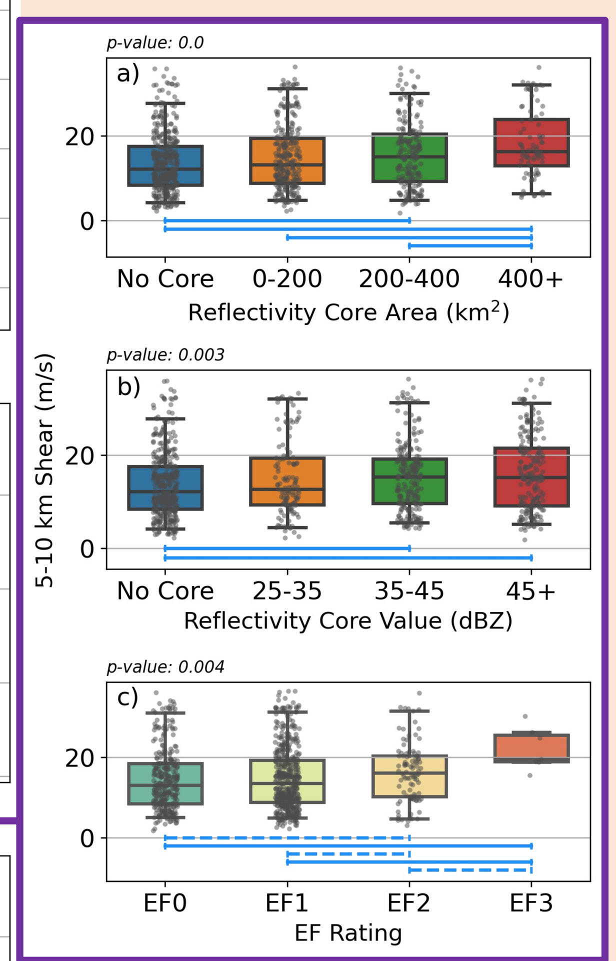
- **Reflectivity core area** at the time of tornadogenesis correlates to the **EF rating** of the associated tornado
- This relationship is weaker for reflectivity core maximum value and for radar-derived rotation at the time of tornadogenesis

Results (cont.)

- Several environmental variables differ between tornadoes with reflectivity cores and those without: **5-10 km shear, 0-6 km shear, MUCAPE,** and **MU EL height**
  - 5-10 km shear has the most statistically significant difference
- **5-10 km shear** also **correlates strongly** to reflectivity core area and maximum value, as well as QLCS tornado EF rating
  - **Negative relationship** seen between **MUCAPE** and these variables, likely due to the prevalence of **high-shear low-CAPE environments** in the sample
- Notably, we do not see relationships between low-level wind profiles (0-3 km shear, 0-1 km and 0-3 km SRH) and reflectivity core occurrence
  - Counter to some idealized modeling studies



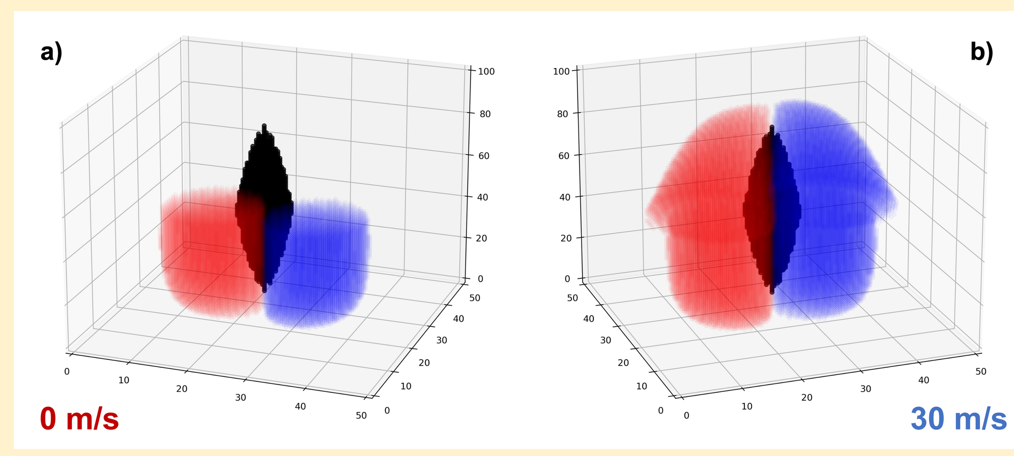
← Environmental parameters separated by tornadoes with and without reflectivity cores; stars denote statistical significance



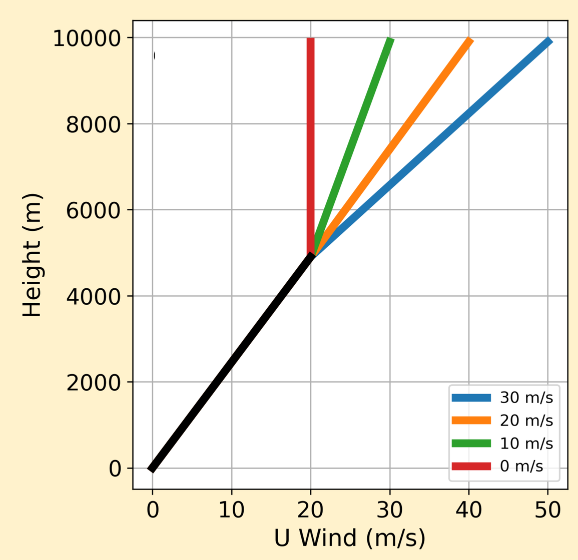
Trends in 5-10 km shear across reflectivity core metrics and EF rating; blue lines denote statistical significance

Dynamical Explanation

- Simple analytic model can demonstrate one effect of mid to upper-level shear
- Increasing 5-10 km shear increases **linear dynamics** contribution to perturbation pressure above 5 km



Linear dynamics contribution to perturbation pressure greater than 10^{-5} Pa in magnitude around an idealized updraft core (black) given a wind profile with 0 m/s or 30 m/s 5-10 km shear



Wind profiles supplied to the analytic model

- Unclear if magnitude of this contribution is nonnegligible
- Also does not explain initial appearance of discrete updraft cores

Conclusions and Future Work

Link to Wolff et al. (2025)

Additional publications

- **Reflectivity cores may highlight regions where QLCS tornadogenesis is most likely**
- Null cases present an issue (many nontornadic reflectivity cores) as do missed cases (~41% of QLCS tornadoes not near cores)
- **5-10 km shear related to core occurrence and properties**
- Questions regarding the exact link between mid to upper-level wind shear and updraft cores
  - How does shear impact discrete core formation?
  - Do these deep updrafts impact near-surface vorticity generation?
- This is the focus of ongoing idealized modeling

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