Specific Differential Phase Signatures within Quasi-Linear Convective System Mesovortices

Caitlyn Scott[1], Charles Kuster[2], Ben Herzog[3], Matthew Van Den Broeke[1]

[1] University of Nebraska - Lincoln, [2] NOAA National Severe Storms Lab, [3] Science and Operations Officer National Weather Service Saint Louis

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Abstract

Issuing convective warnings on quasi-linear convective systems (QLCSs) is a challenge for National Weather Service operations, as they develop quickly and are small-scale phenomena. To guide forecasters, the three ingredients method and QLCS mesovortex warning system were developed. However, this system doesn't yet incorporate dual-polarization radar data other than tornadic debris signatures. Therefore, this study compares mesovortex evolution and strength to the evolution of specific differential phase (K_{DP}) to determine if K_{DP} offers any predictive ability (lead time) to mesovortex development and damage potential. To accomplish this study, we compared low-level K_{DP} core, midlevel K_{DP} core, and K_{DP} drop evolution relative to mesovortex formation. We chose three QLCS events, 20 February 2017 in San Antonio, 10 January 2020 in Memphis, and 19 May 2022 in Saint Louis, and examined the K_{DP} signatures mentioned above for damaging vs non-damaging mesovortices and tornadic vs non-tornadic mesovortices. In general, K_{DP} drops frequently precede mesovortex development and are slightly more frequent for mesovortices that produce damage. Midlevel K_{DP} cores have a higher magnitude for tornadic and damaging mesovortices prior to mesovortex genesis, therefore potentially offering prognostic ability. Furthermore, low-level K_{DP} cores have a higher magnitude for tornadic and damaging mesovortices during mesovortex life, therefore potentially offering diagnostic ability. These findings support the idea that K_{DP} can be used by forecasters to build confidence in whether a given mesovortex might produce damage or not.

Objectives

1. Analyze the evolution of K_{DP} drops to mesovortex development and damage
2. Compare evolution and magnitude of mid and low-level K_{DP} cores for damaging vs non-damaging mesovortices and for tornadic vs non-tornadic mesovortices
3. Compare radar signatures already present within the mesovortex warning system to mesovortex presence, strength, and impacts
4. Tie goals above together to determine possible integration of K_{DP} into the mesovortex warning system as a new confidence builder

Methods

- Record tornado and wind damage reports, noting the location and time
  - All damage reports obtained from NCEI Storm Data Publication
- Locate all Mesovortices
  - Conditions
    - Rotational velocity of at least 10 m/s or 19.4 kts
    - Extend to depth of at least 2.4 km (8000ft)
    - Persist for at least 2 WSR-88D volume scans (8-10 minutes)
    - Occur in location favorable according to Three Ingredients Method
- Connect Mesovortices to damage and classify as tornadic, non-tornadic, damaging, and non-damaging
- Assess confidence builders, K_{DP} cores, and K_{DP} drops for each mesovortex
  - Radar analysis completed using GR2 Analyst
- Compared low-level K_{DP} core, midlevel K_{DP} core, and K_{DP} drop evolution to mesovortex formation, distinguishing between tornadic vs non-tornadic and damaging vs non-damaging mesovortices
  - Analysis and figures created using Matlab

QLCS Events

May 19, 2022 in Saint Louis

11 Mesovortices

- 6 damaging
  - 4 Tornado Reports Alone
  - 1 Wind Reports Alone
  - 2 Tornadic and Wind Reports
- 5 non-damaging

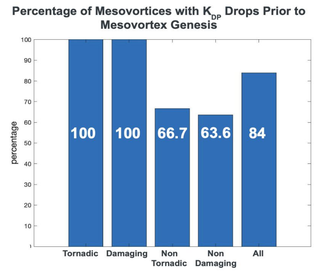
February 20, 2017 in San Antonio

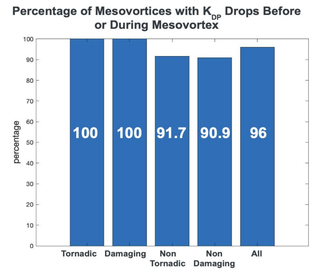
14 Mesovortices

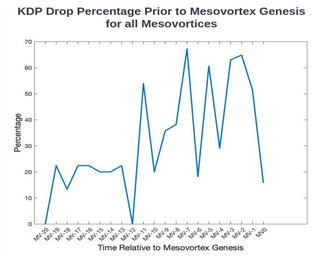
- 7 damaging
  - 7 Tornado Reports Alone
  - 0 Wind Reports Alone
  - 7 Tornadic and Wind Reports
- 7 non-damaging

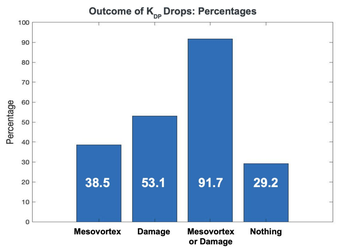
Results

K_{DP} Drops

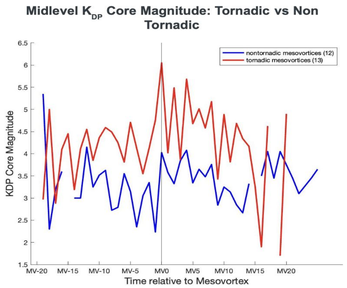


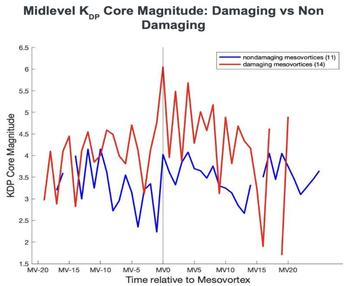




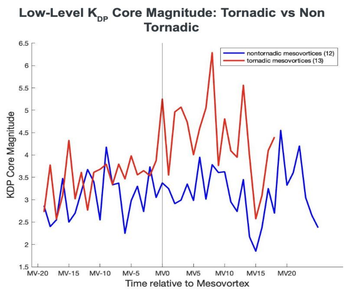


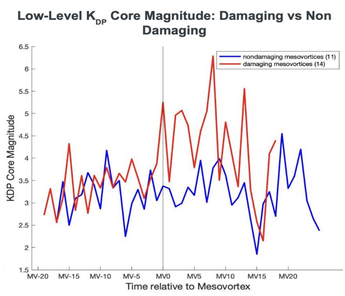
Midlevel K_{DP} Core

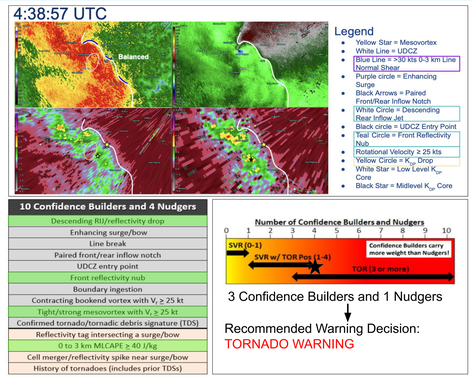


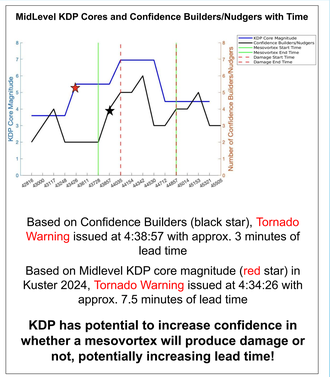


Low-Level K_{DP} Core









Based on Confidence Builders (black star), Tornado Warning issued at 4:38:57 with approx. 3 minutes of lead time

Based on Midlevel KDP core magnitude (red star) in Kuster 2024, Tornado Warning issued at 4:34:26 with approx. 7.5 minutes of lead time

KDP has potential to increase confidence in whether a mesovortex will produce damage or not, potentially increasing lead time!

Conclusions

- K_{DP} drops frequently precede mesovortex development
  - Increase in K_{DP} drop presence 11 minutes prior to mesovortex genesis
- Midlevel K_{DP} cores have higher magnitude for tornadic and damaging mesovortices prior to mesovortex genesis offering prognostic ability
- Low-level K_{DP} cores have higher magnitude for tornadic and damaging mesovortices during mesovortex life offering diagnostic ability

These findings support the idea that K_{DP} can be used by forecasters to build confidence in whether a given mesovortex might produce damage or not.

Future Work

- Adding another QLCS case (10 January 2020 in Memphis) with different environmental characteristics (0-1 km shear and 0-3 km lapse rate)
- Looking at all KDP Drops within the QLCS and their association with a mesovortex or damage
- Compare KDP Drop evolution to confidence builders

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