The Low-level Internal Flow of Tornadoes (LIFT) Experiment: Observations from the 2024 and 2025 Campaigns

Christopher Weiss and Ethan Steward

Texas Tech University

Michael Coniglio
National Severe Storms Laboratory

Erik Rasmussen
Disaster Imaging, Inc.

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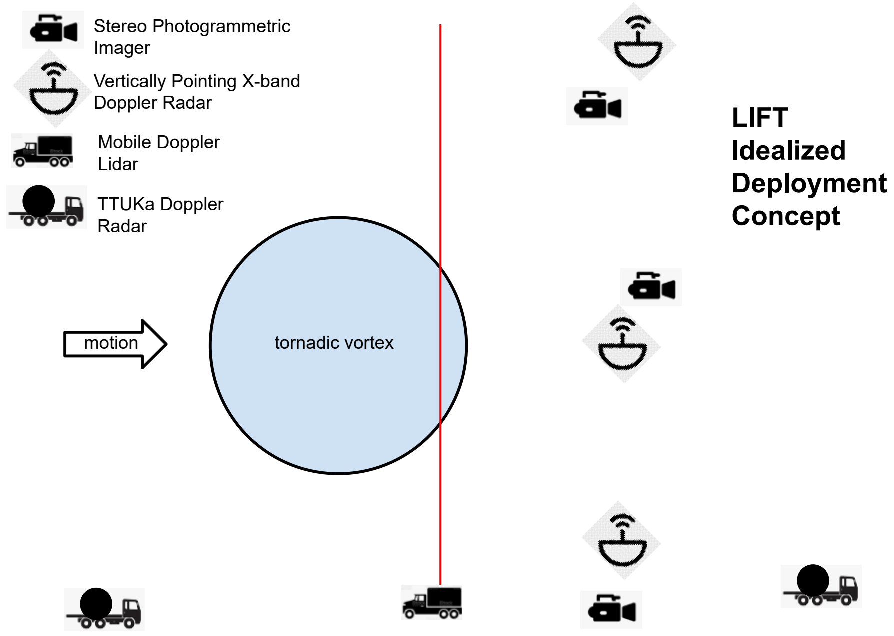
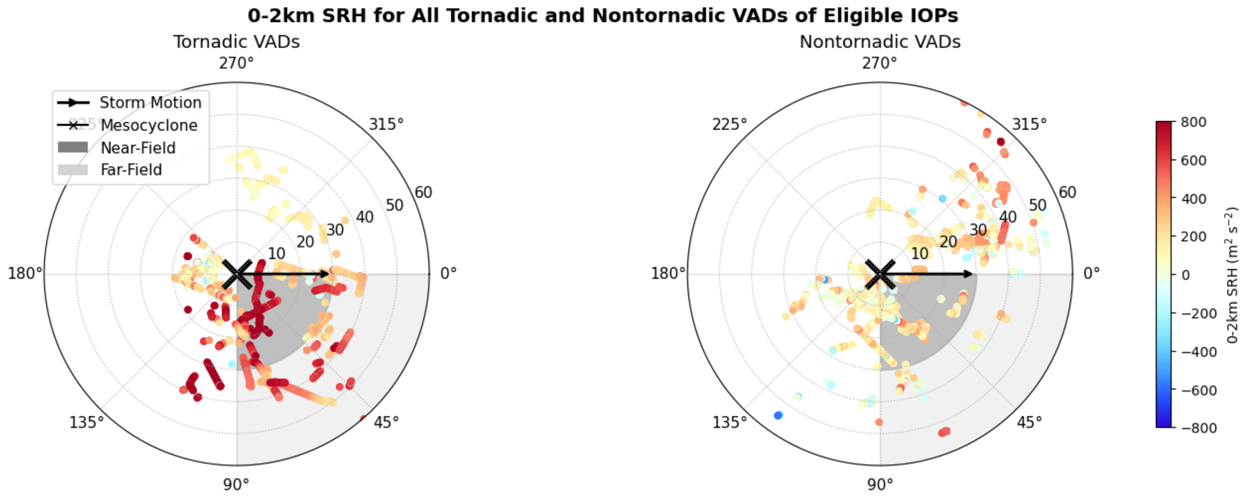
Photo Credit: William Faletti

The Low-Level Internal Flow of Tornadoes Experiment (LIFT)

- First field program aligned with NOAA VORTEX-USA focus on low-level tornado wind fields
- Initial 3-year project dedicated to tornado observations over the Southern/Central U.S. Plains
- Objectives
  - **Low-level tornado structure**
  - Storm-scale influences on vorticity
  - Characterization of inflow



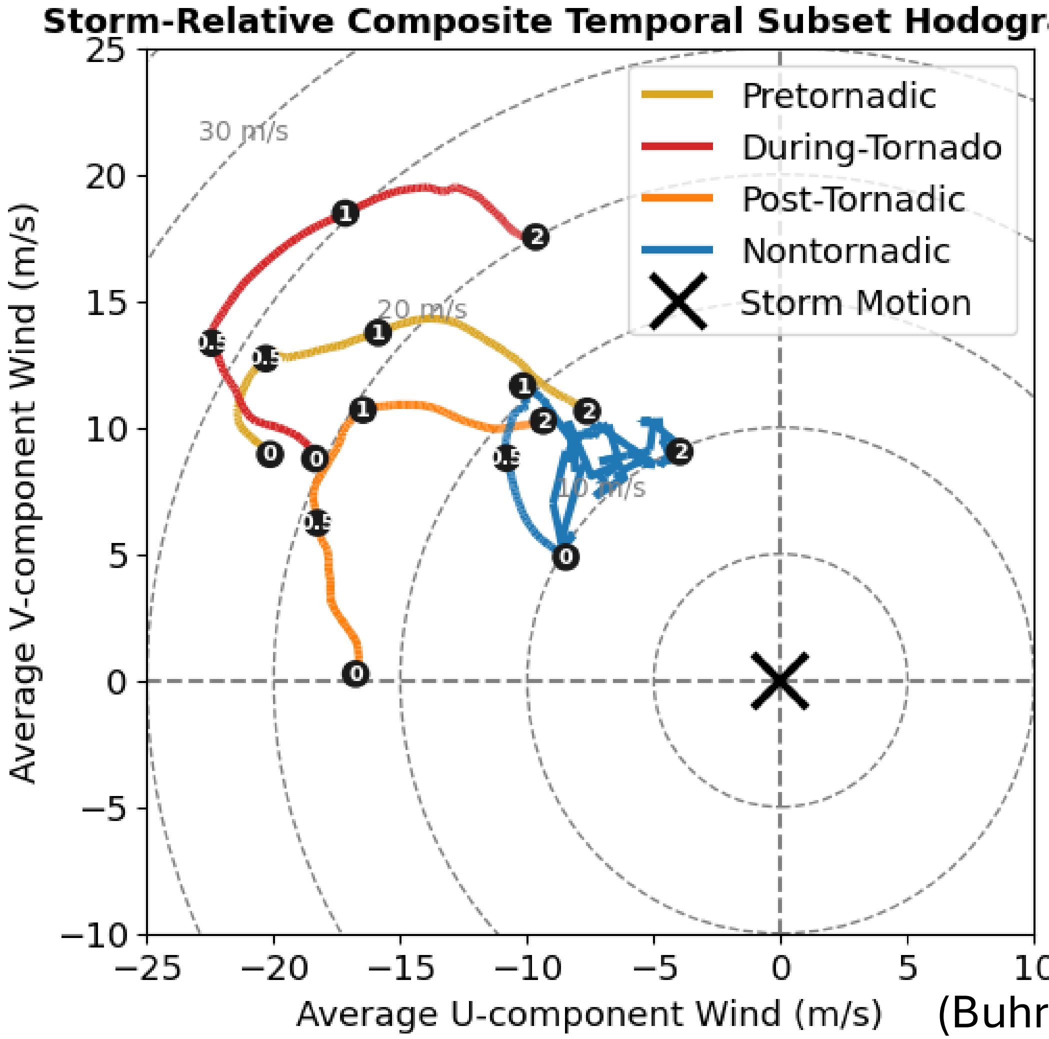
Inflow Characterization



Composite SRH for all tornadic TTUKa VADs

Composite SRH for all nontornadic TTUKa VADs

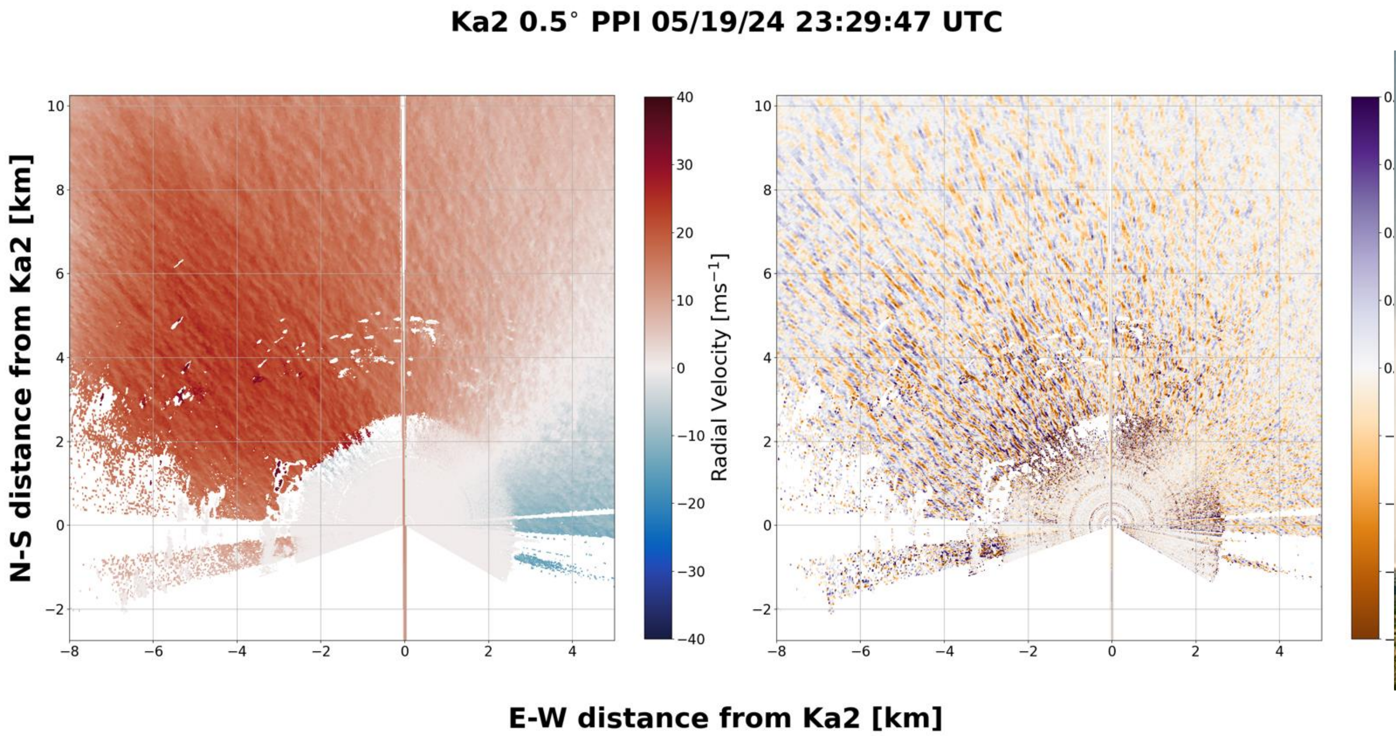
- Composite 0-2 km hodographs delineate differences in storm-relative flow and SRH for:
  - tornadic vs. nontornadic samples
  - periods relative to tornado occurrence



(Buhrman 2025)

Composite hodographs by VAD class

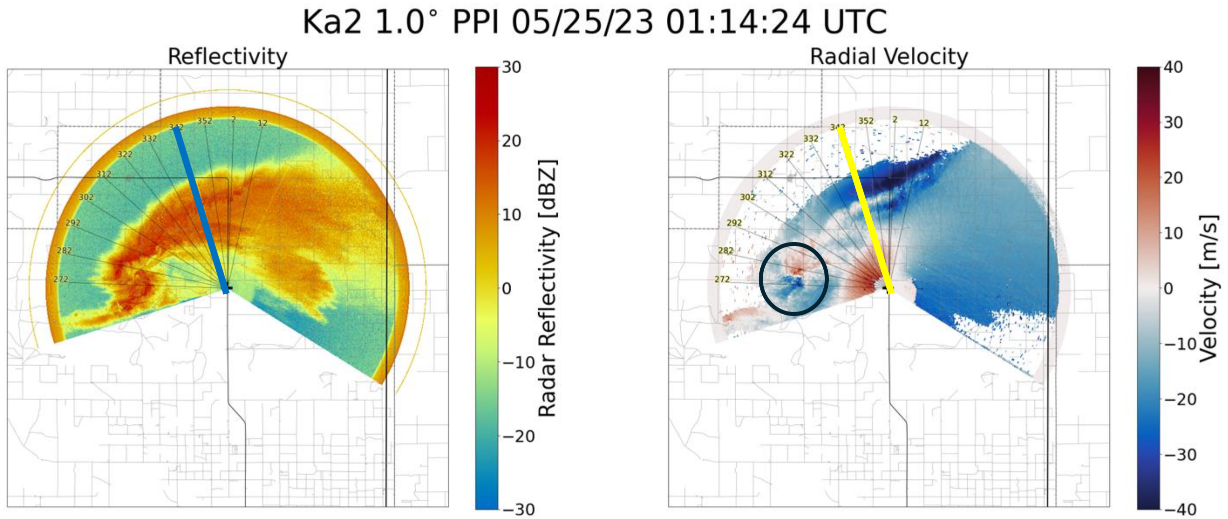
Vorticity Worms



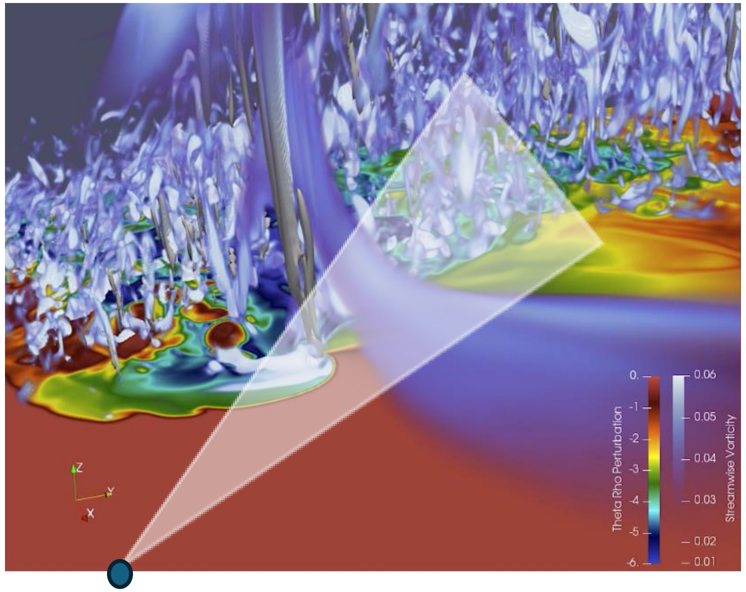
TTUKa radial velocity (m s^{-1}) Inferred vertical vorticity (s^{-1}) Example of worm identification methodology

- Canvasing TTUKa data from LIFT and TORUS to identify examples of inflow vorticity “worms”.
- Wavelengths ~300-400 m for 19 May 2024 (Custer City, OK tornado) case, similar to that simulated by Markowski (2024)
- Assessing favorable environments for worm occurrence and instances of vertical vorticity amplification (e.g., in convergent regions associated with storm-scale boundaries).

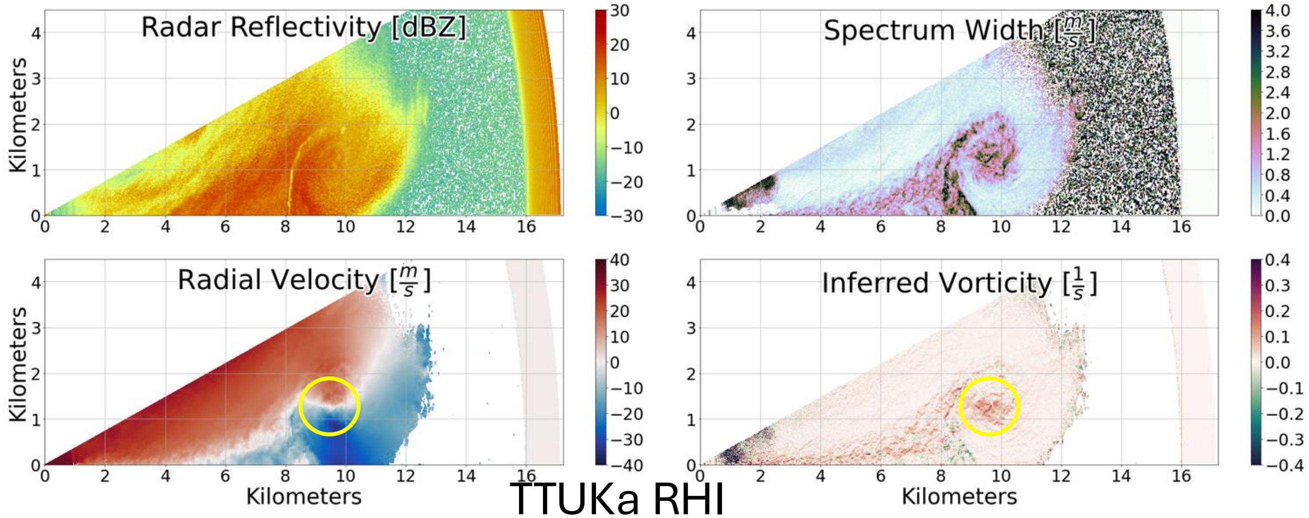
Storm-Scale Influences: Streamwise Vorticity Current



TTUKa 1.0 deg PPI



SVC simulation - Schueth et al. 2021



TTUKa RHI

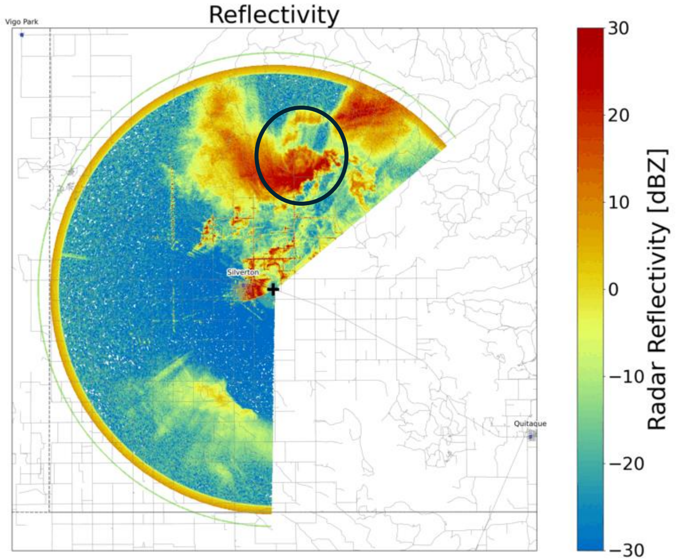
- Diagnosing instances of streamwise vorticity currents from TTUKa intercepts in LIFT and TORUS projects
- Altitude, vorticity magnitude and sources similar to that simulated by Schueth et al. (2021)

Low-Level Tornado Structure

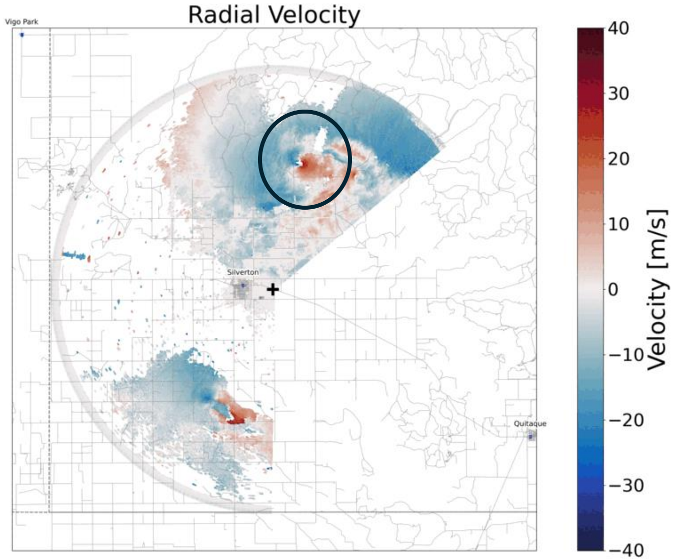
Early evolution of the Eldorado, OK tornado (24 May 2024)

Case #1: 2 June 2024 Silverton, TX (EFU)

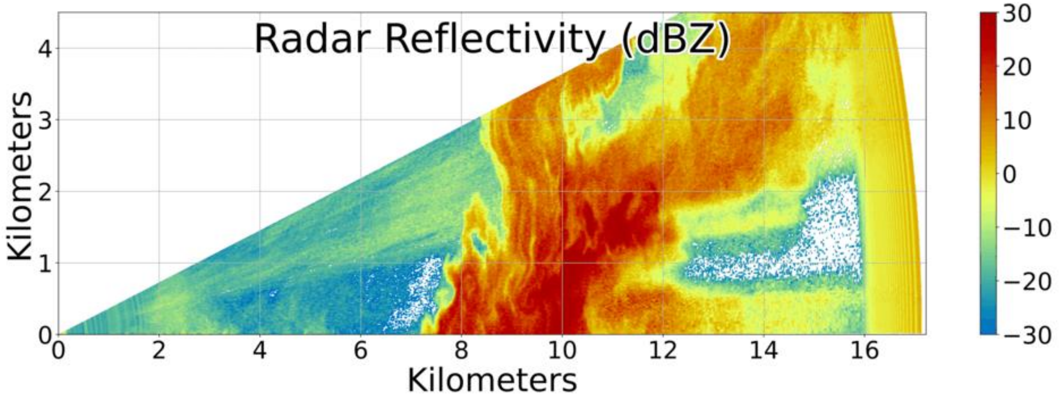
Ka1 0.0° PPI 06/03/24 01:21:40 UTC



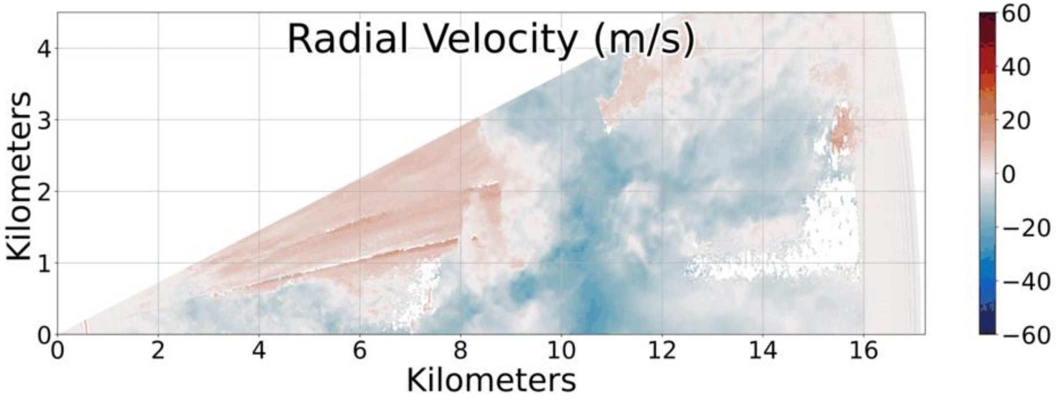
TTUKa PPI 0.0 deg reflectivity (dBZ)



TTUKa PPI 0.0 deg radial velocity (m s^{-1})

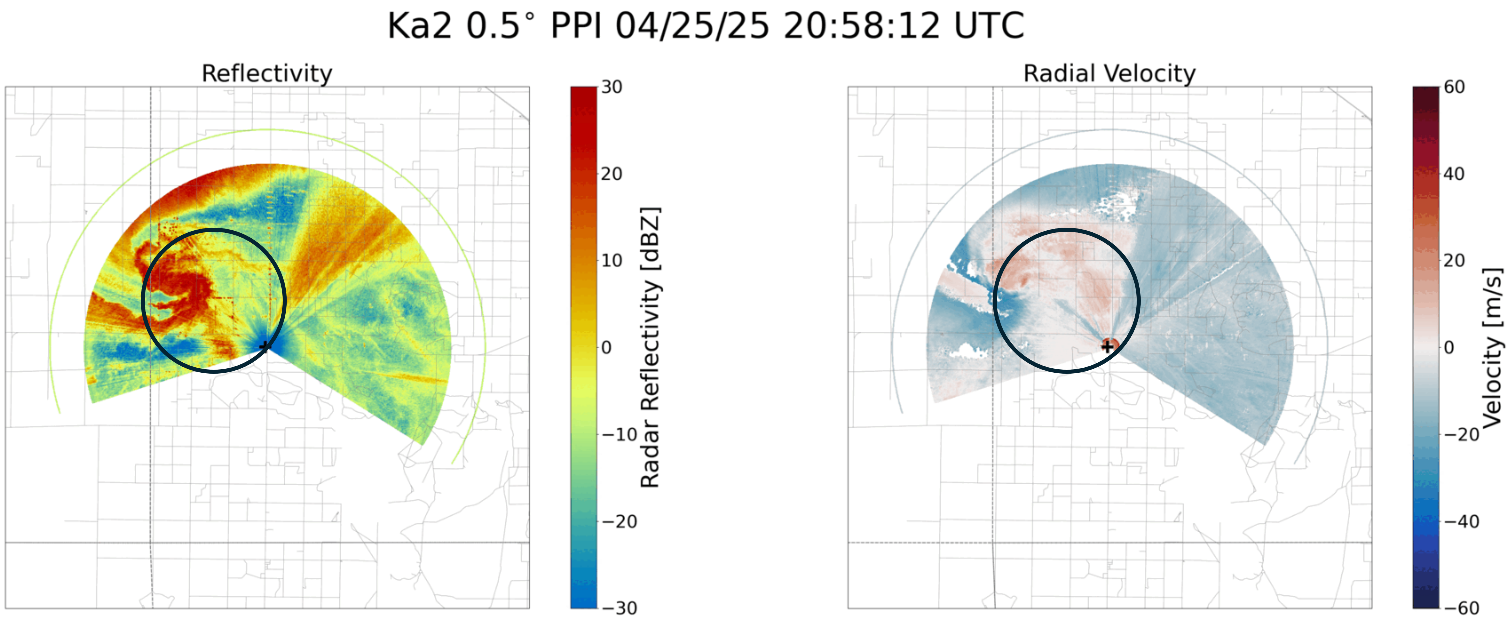


TTUKa RHI reflectivity (dBZ)

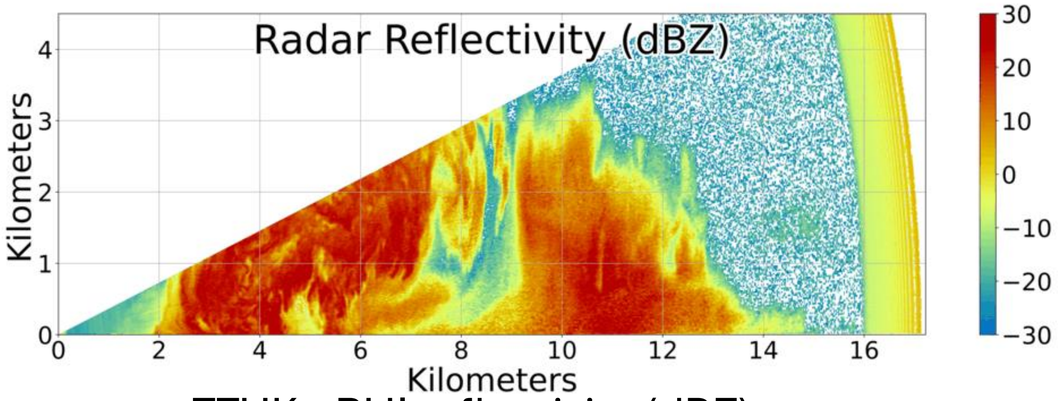


TTUKa RHI radial velocity (m s^{-1})

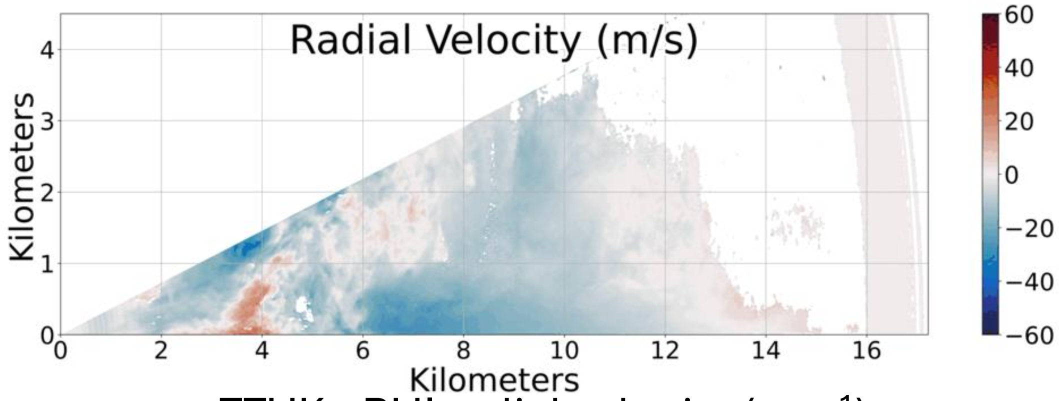
Case #2: 25 April 2025 Sudan, TX (EFU)



TTUKa PPI 0.5 deg reflectivity (dBZ) TTUKa 0.5 deg PPI radial velocity (m s^{-1})



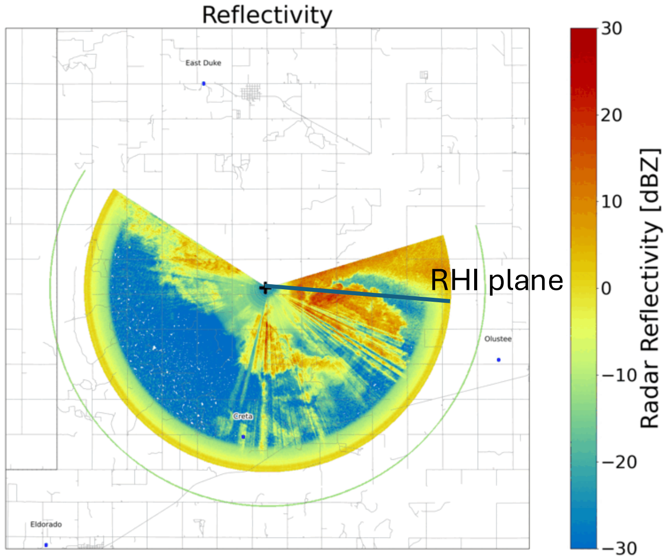
TTUKa RHI reflectivity (dBZ)



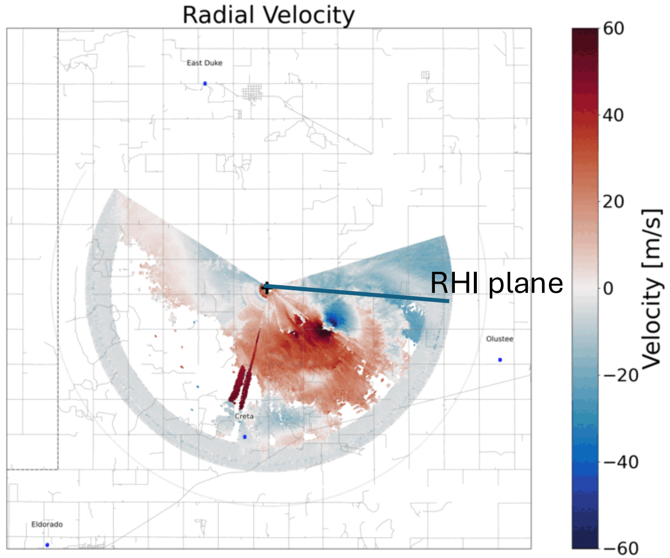
TTUKa RHI radial velocity (m s^{-1})

Case #3: 24 May 2024 Eldorado, OK (EF2)

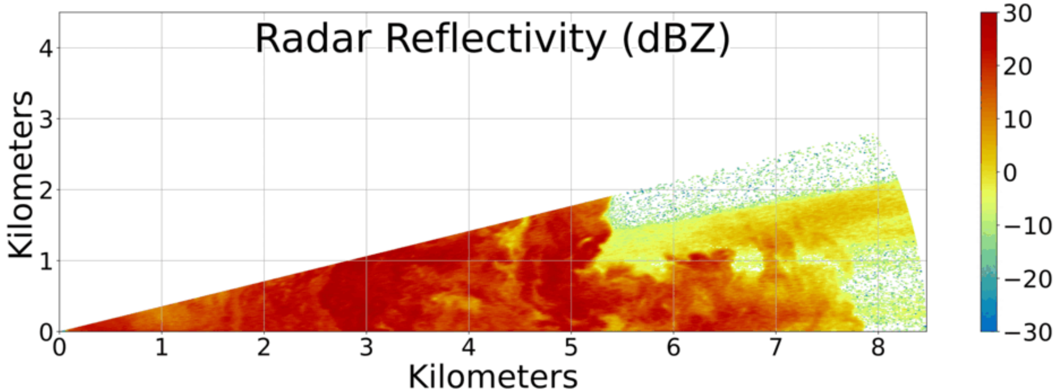
Ka2 0.3° PPI 05/24/24 00:28:39 UTC



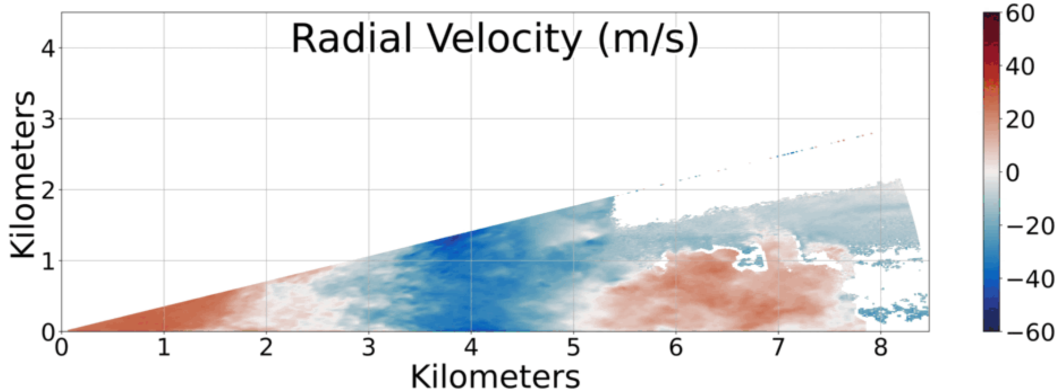
TTUKa PPI 0.5 deg reflectivity (dBZ)



TTUKa 0.5 deg PPI radial velocity (m s^{-1})

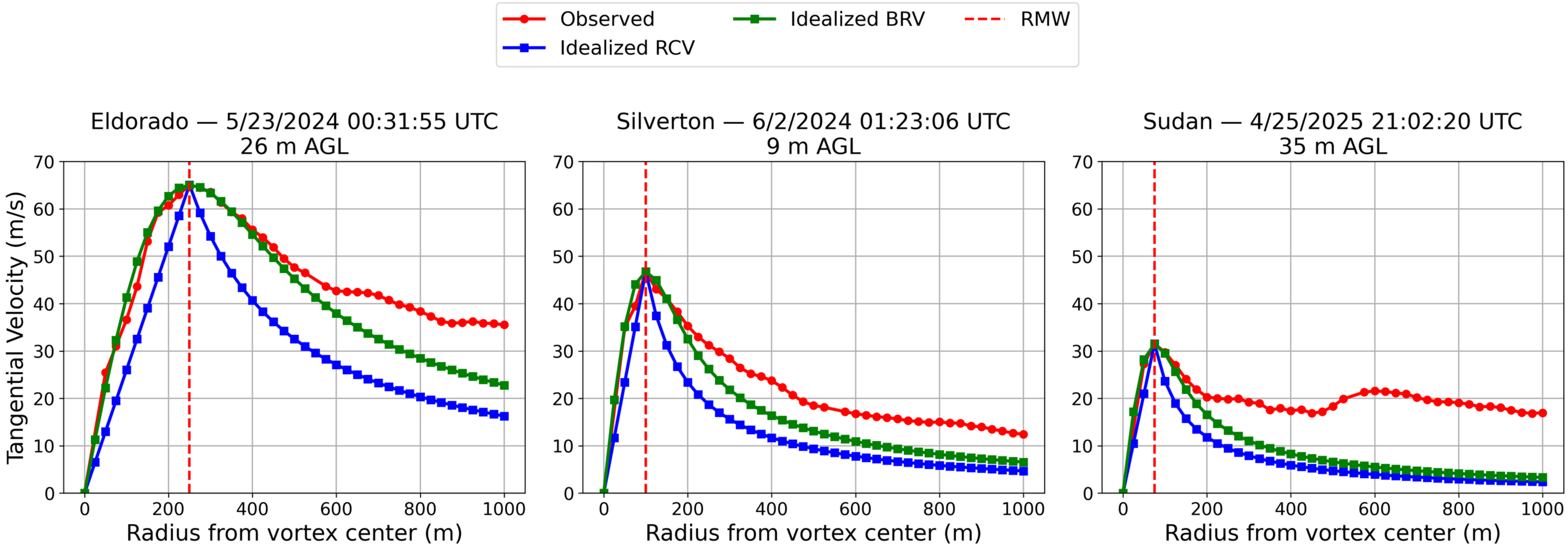


TTUKa RHI reflectivity (dBZ)



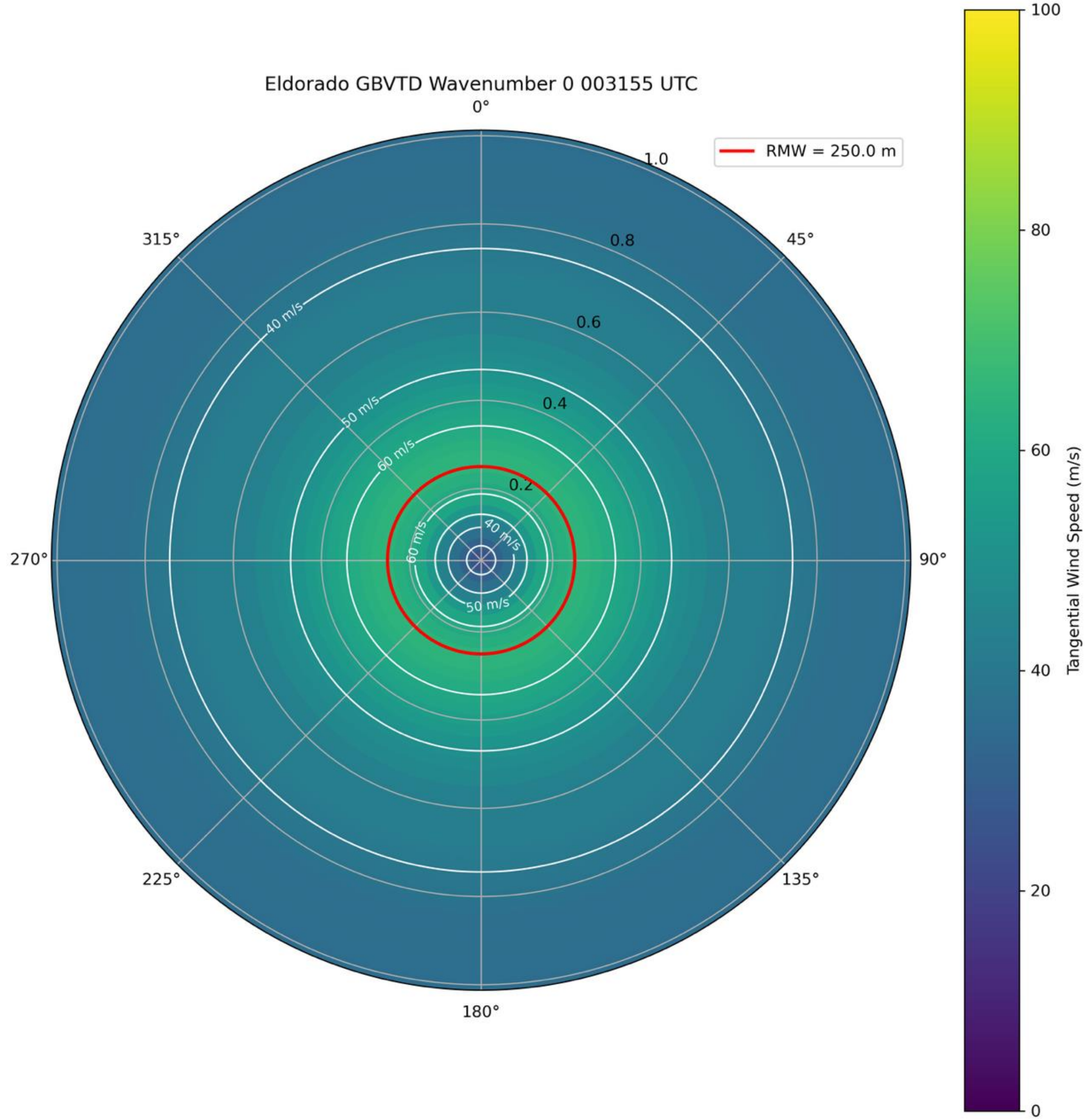
TTUKa RHI radial velocity (m s^{-1})

Idealized Tangential Velocity Profiles

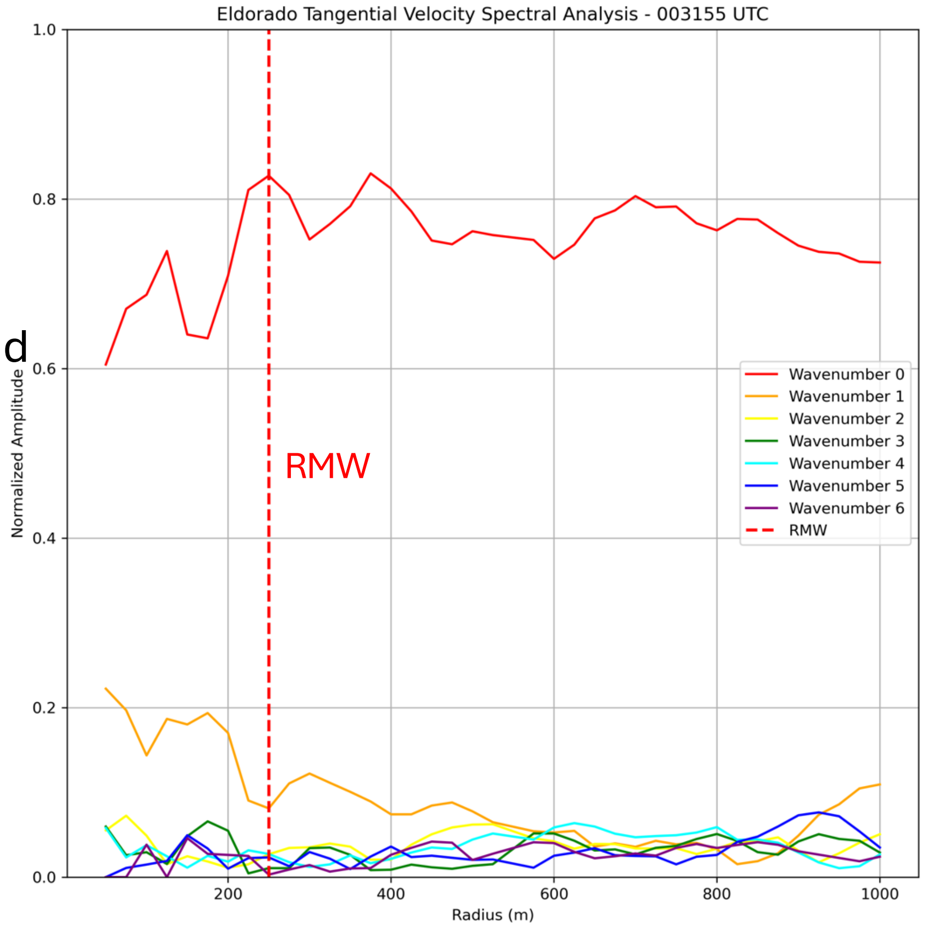


- Ground-based Velocity Track Display (GBVTD; Lee et al. 1999) used to retrieve horizontal profiles of tangential velocity
- Similar to some previous studies, profiles match the analytical Burgers-Rott vortex fairly well through the core flow, but decay is slower in the outer flow.

Spectral Analysis



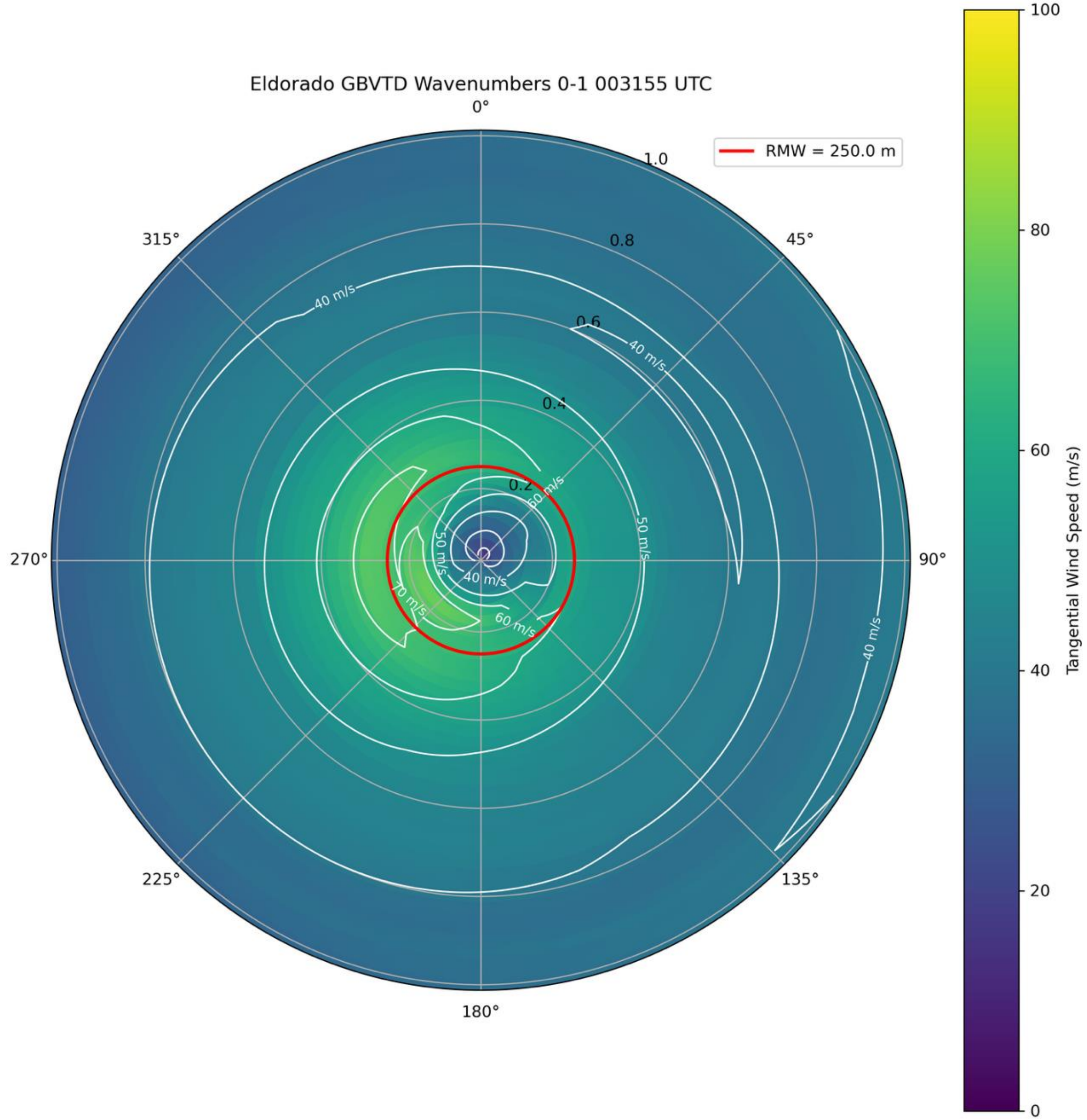
Normalized
Spectral
Power

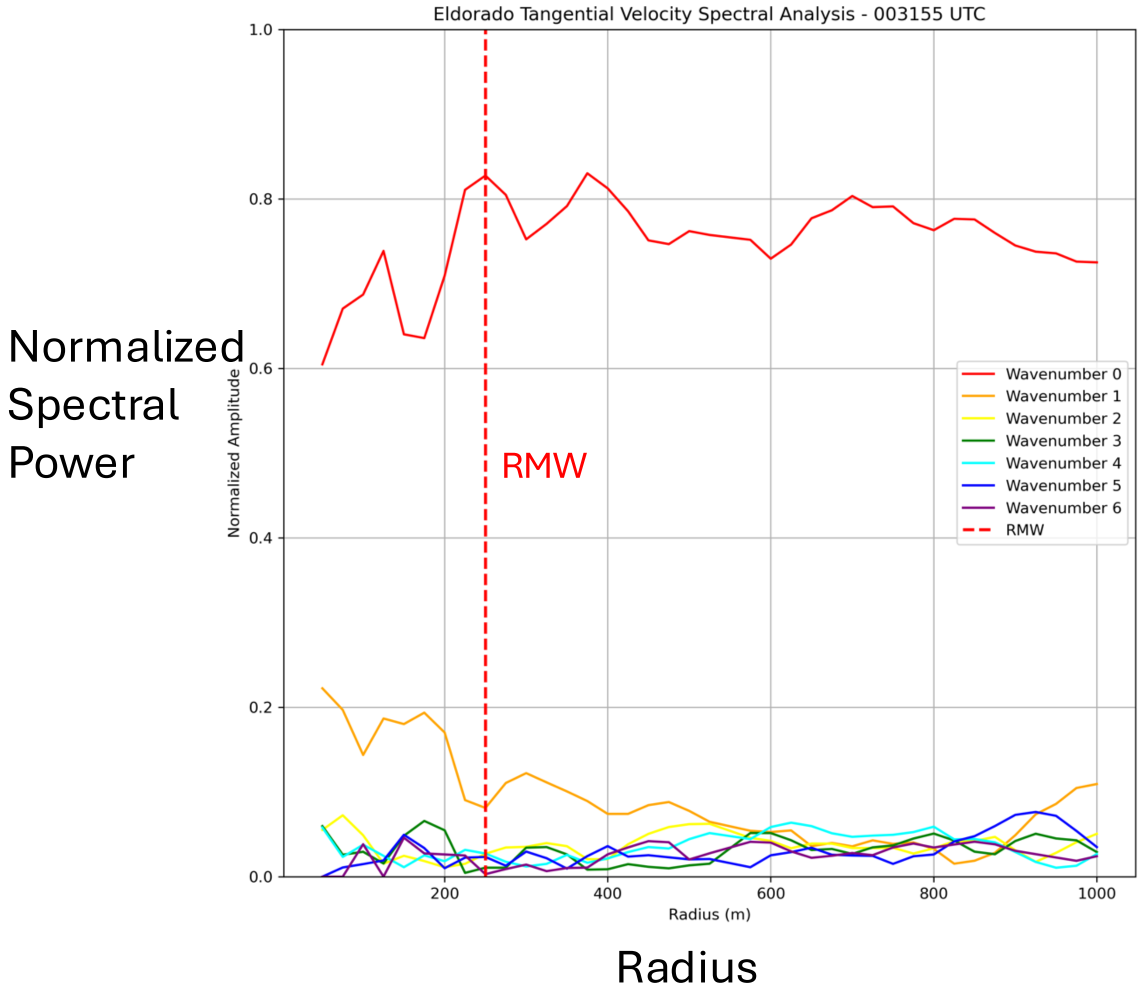


Radius

GBVTD analysis – Eldorado, OK (wavenumber 0)

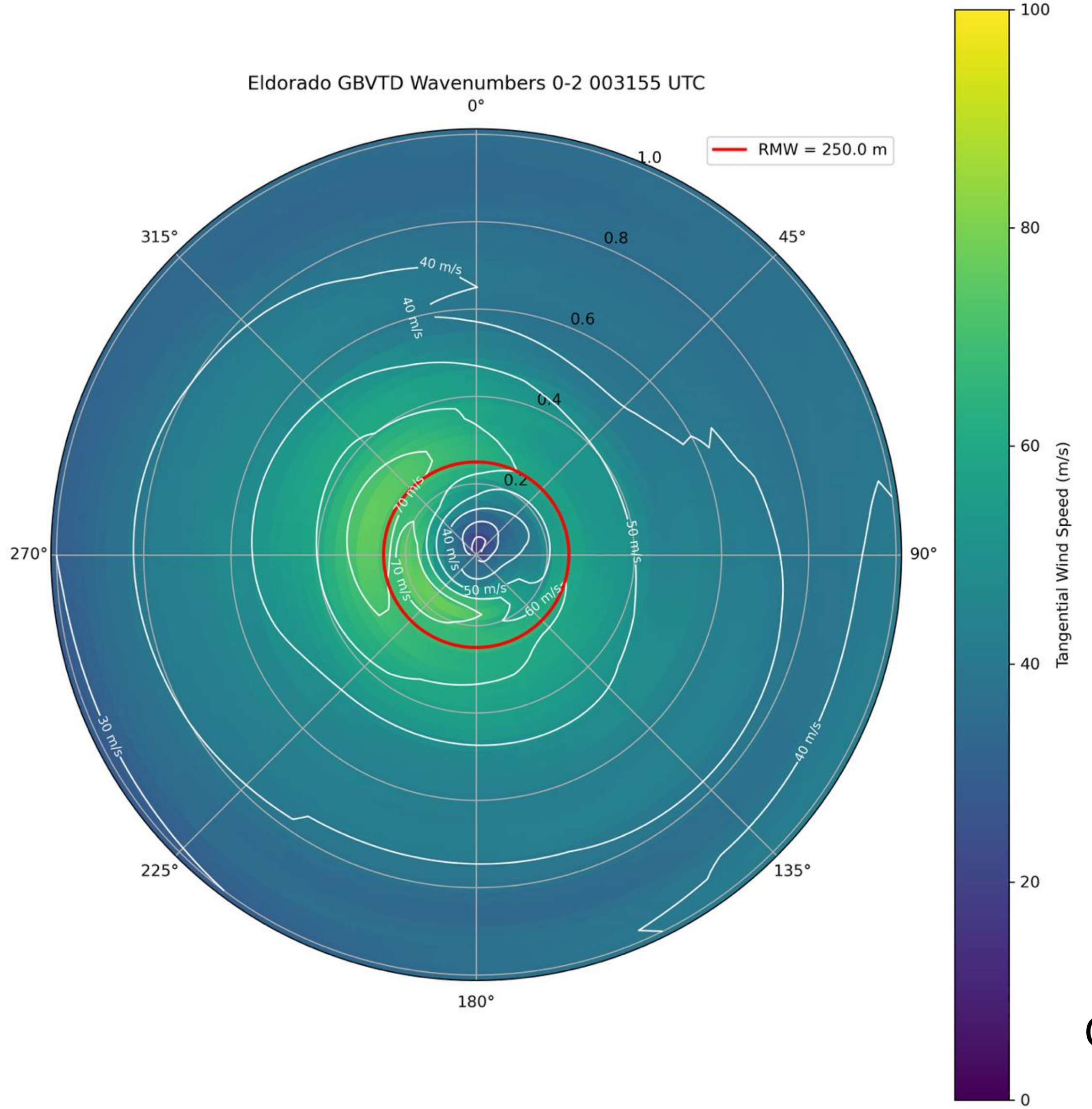
Spectral Analysis



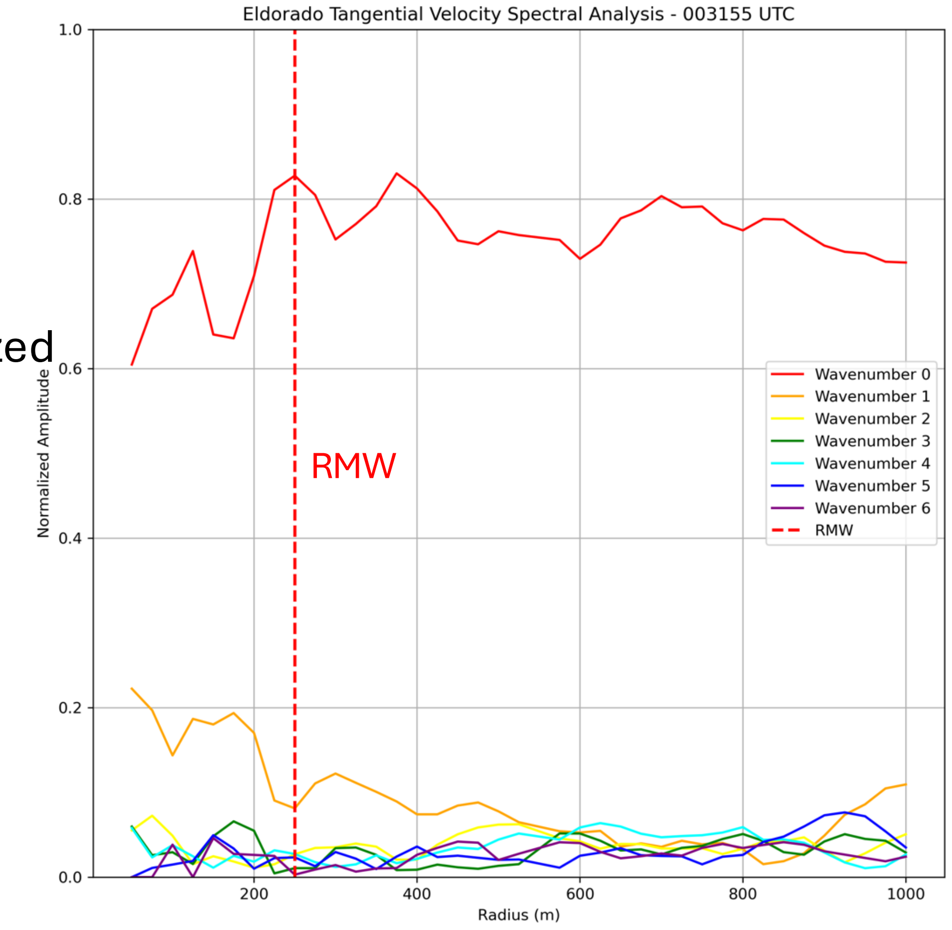


GBVTD analysis – Eldorado, OK (wavenumbers 0-1)

Spectral Analysis



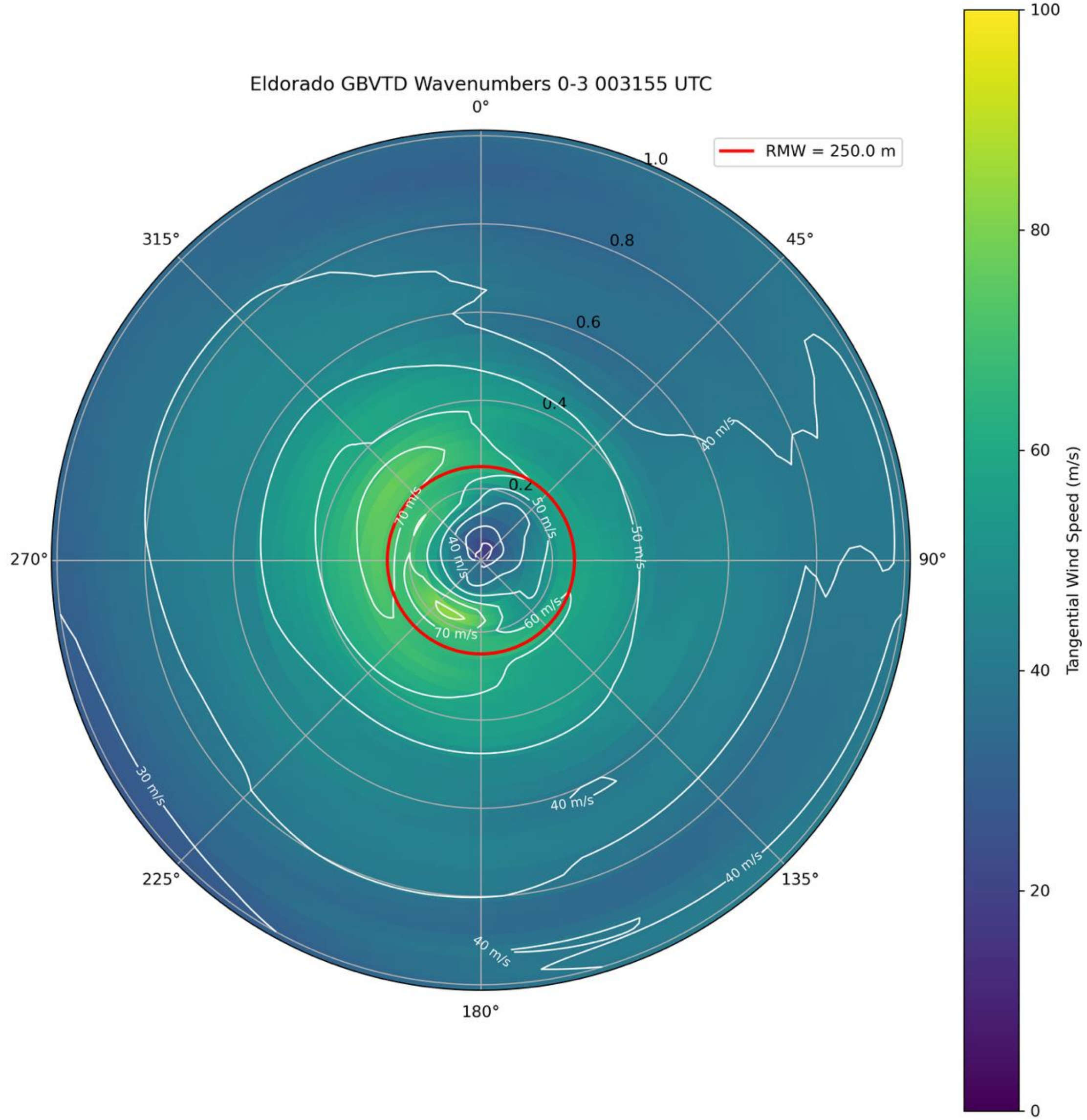
Normalized Spectral Power

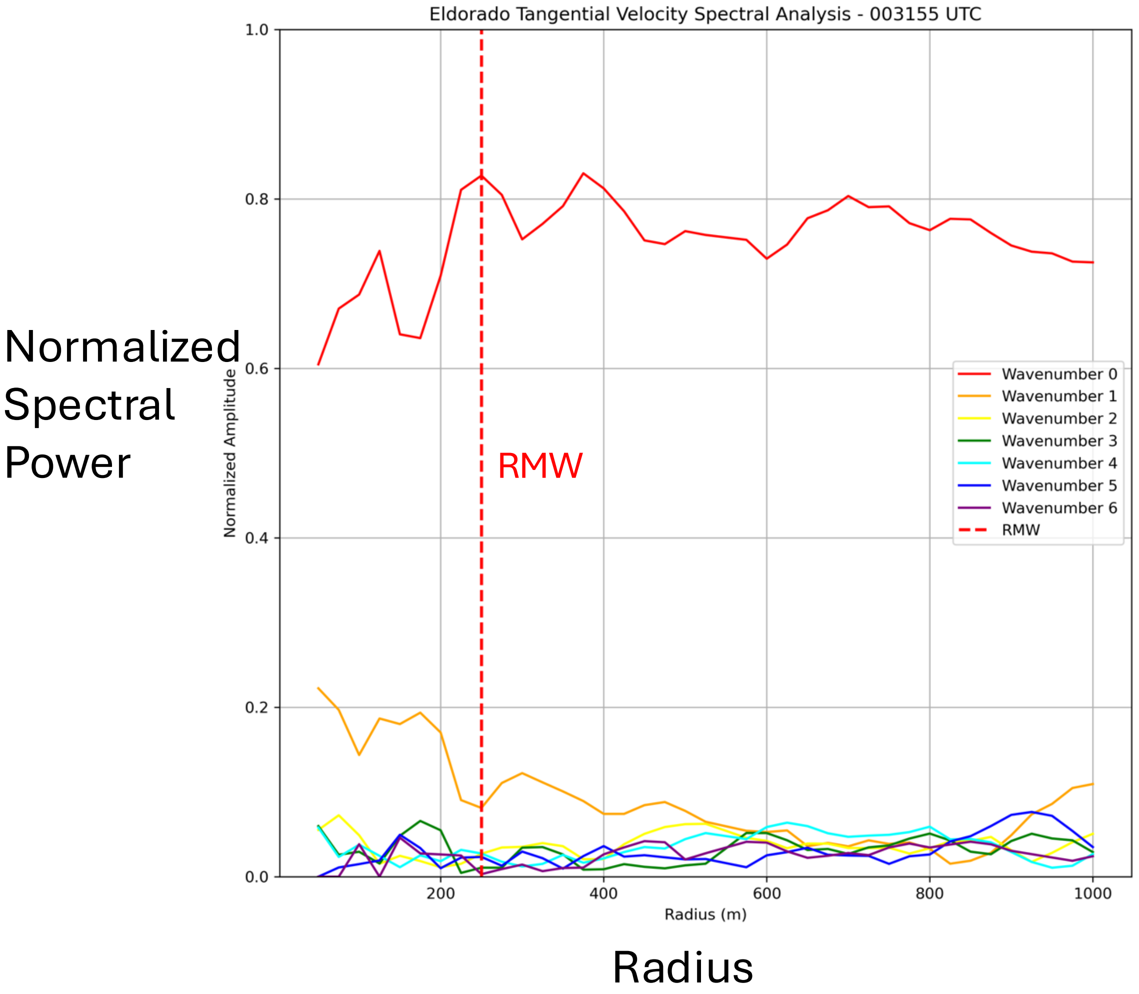


Radius

GBVTD analysis – Eldorado, OK (wavenumbers 0-2)

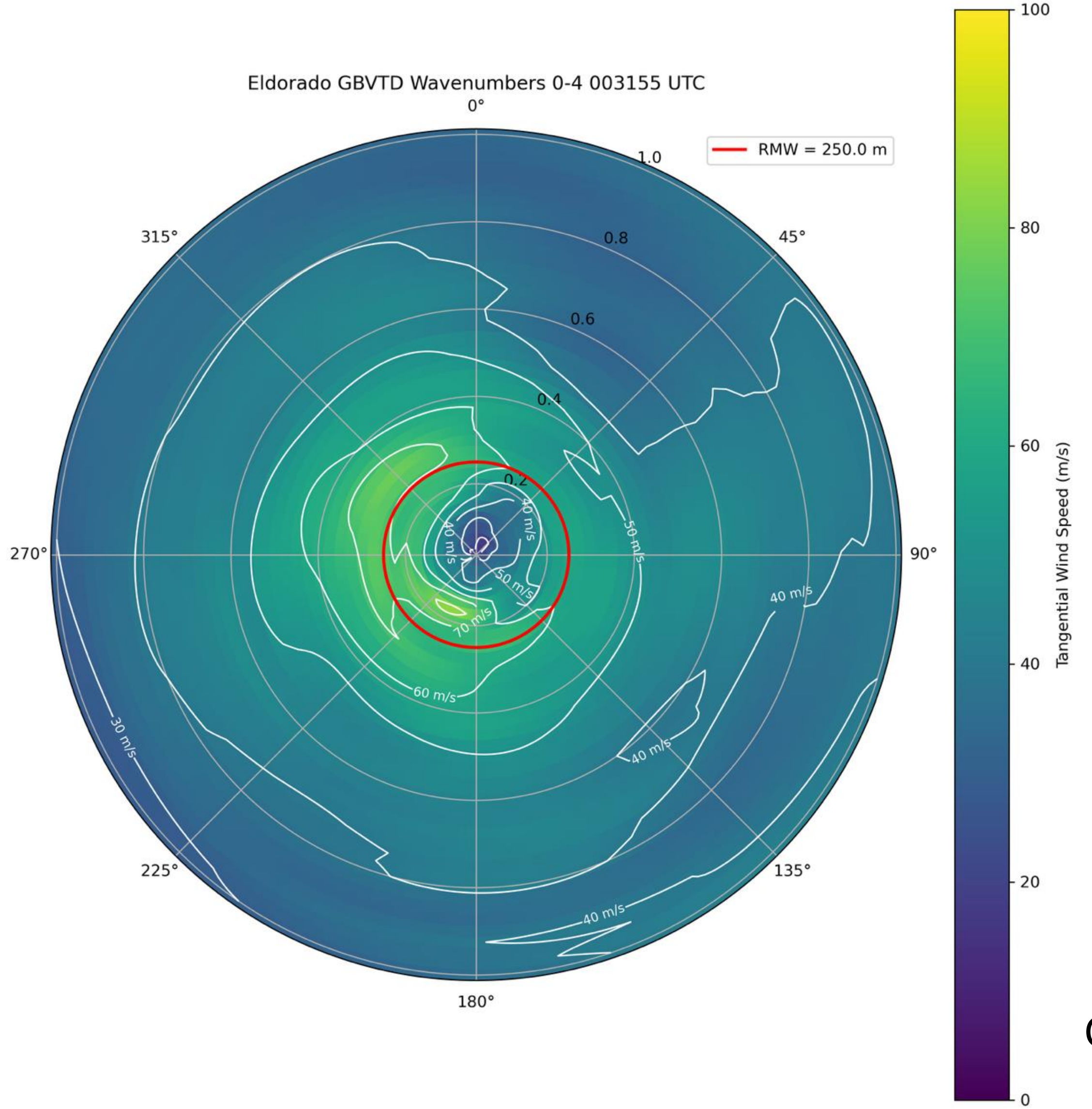
Spectral Analysis



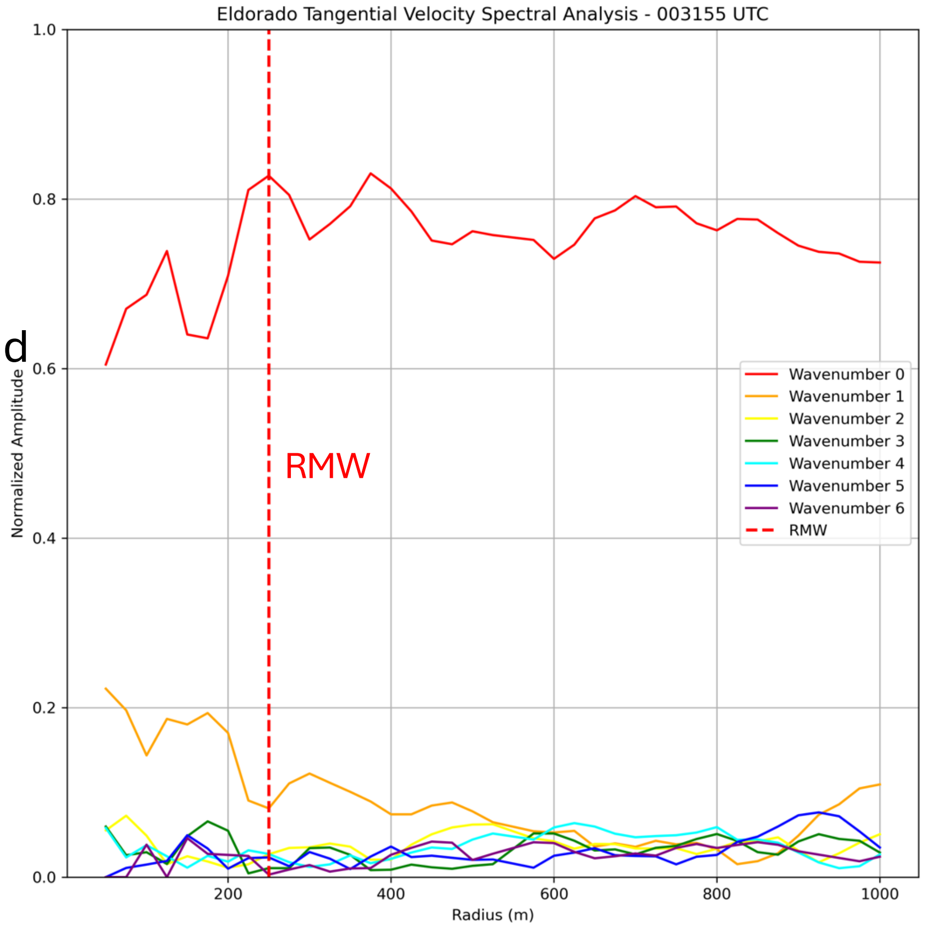


GBVTD analysis – Eldorado, OK (wavenumbers 0-3)

Spectral Analysis



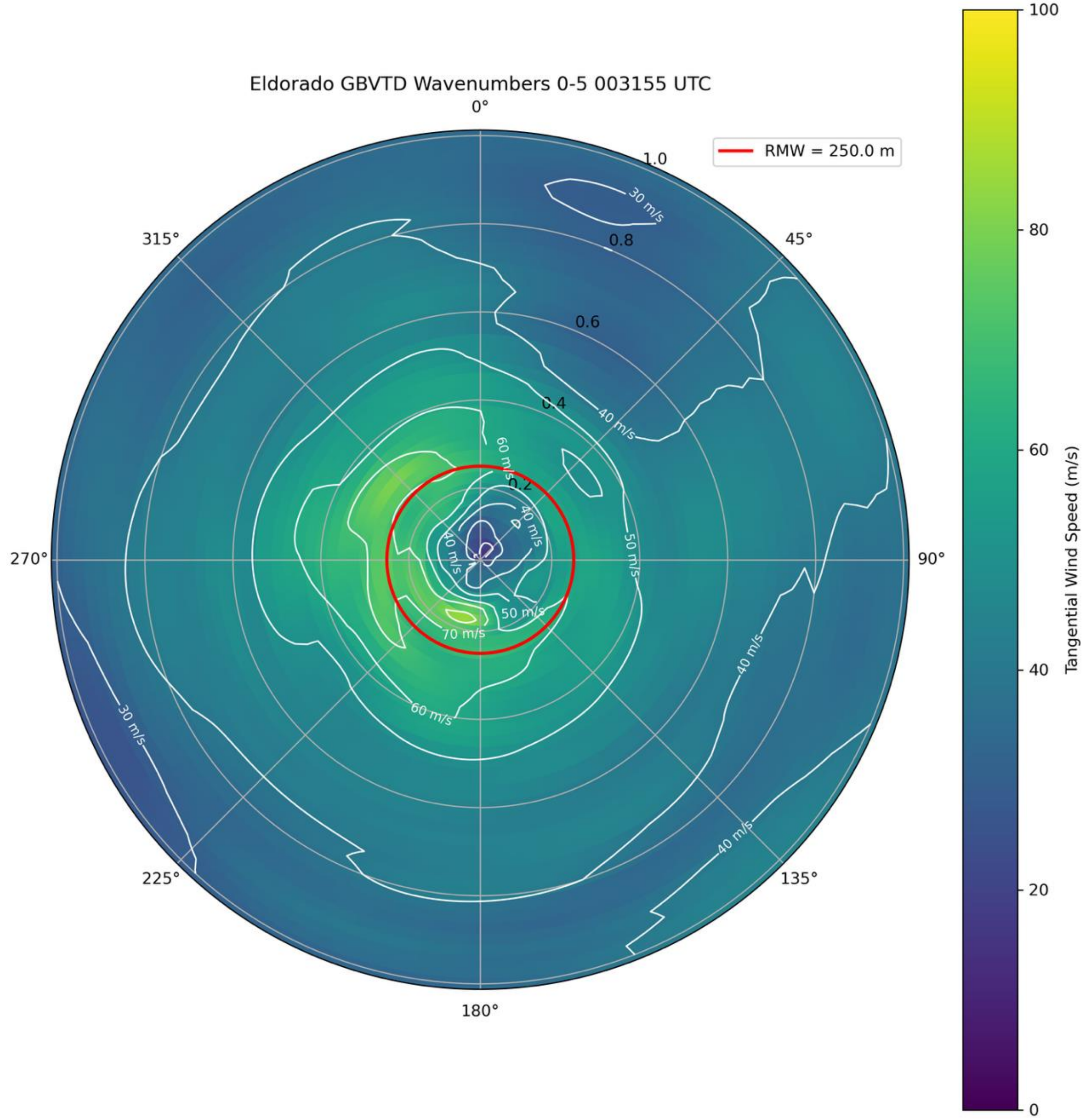
Normalized Spectral Power



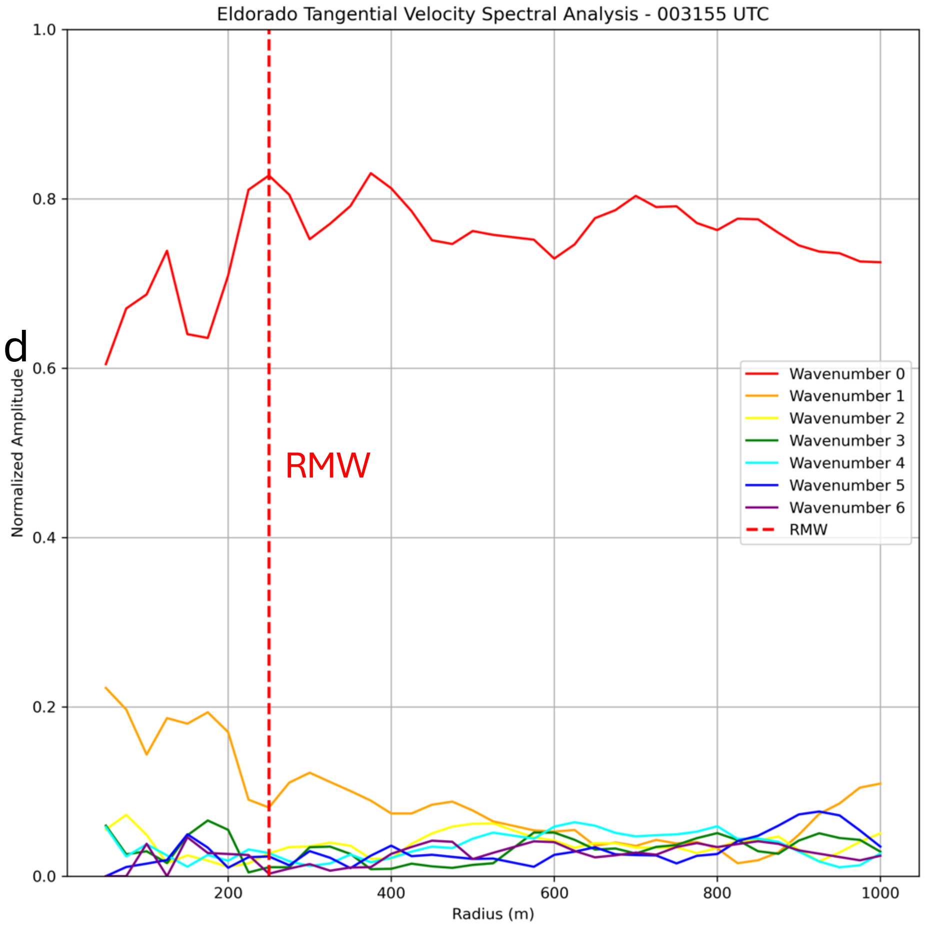
Radius

GBVTD analysis – Eldorado, OK (wavenumbers 0-4)

Spectral Analysis



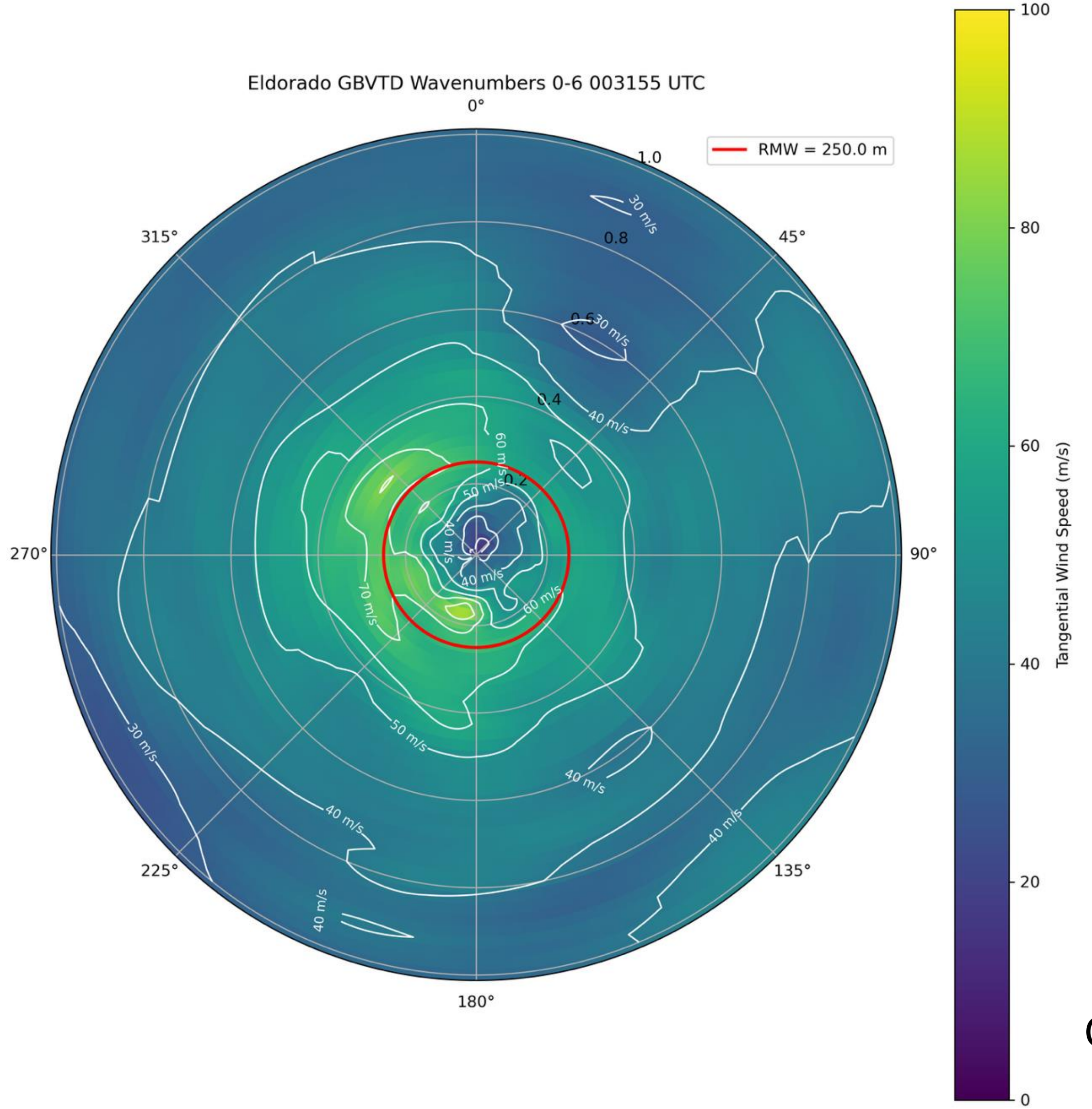
Normalized Spectral Power



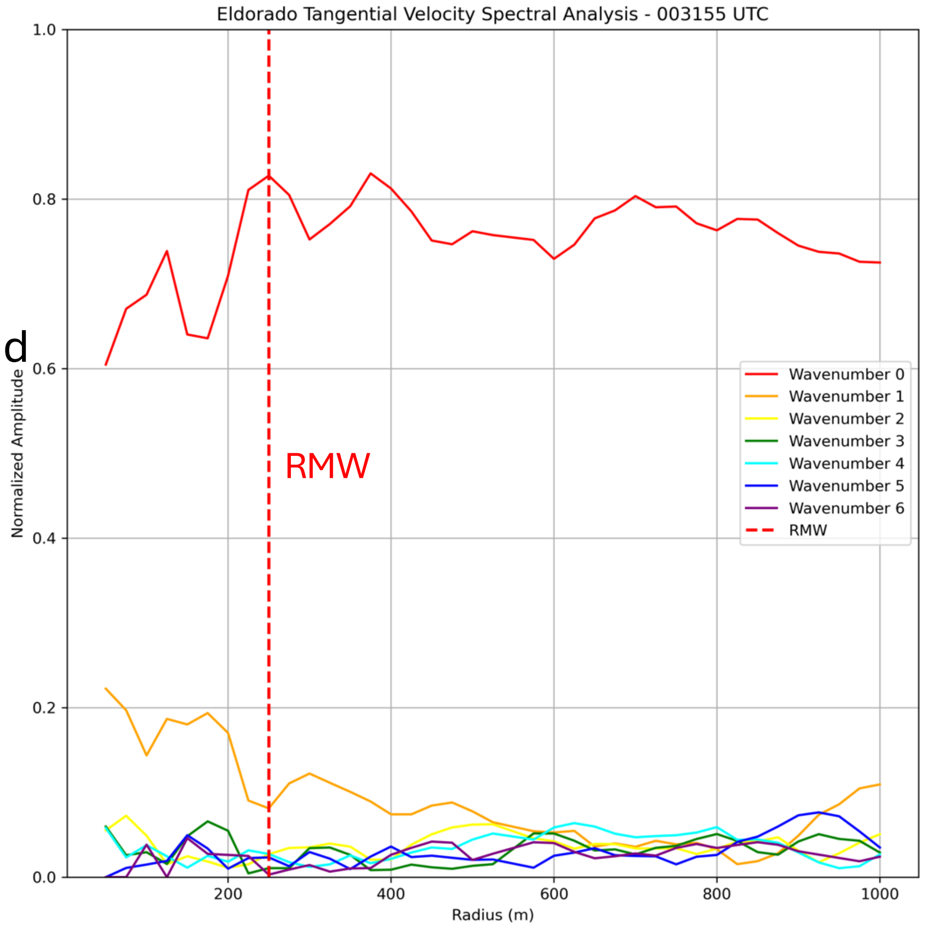
Radius

GBVTD analysis – Eldorado, OK (wavenumbers 0-5)

Spectral Analysis



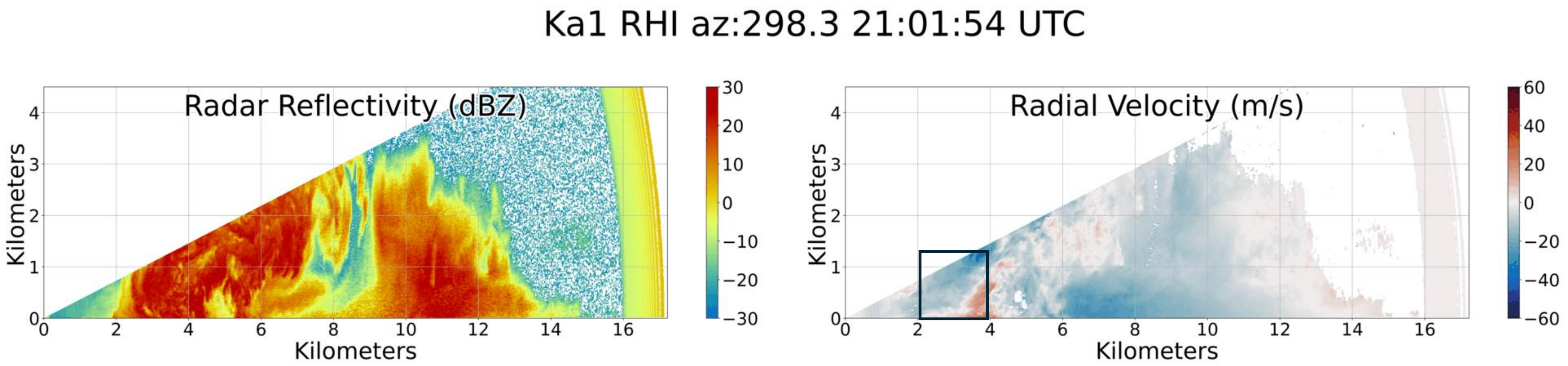
Normalized Spectral Power

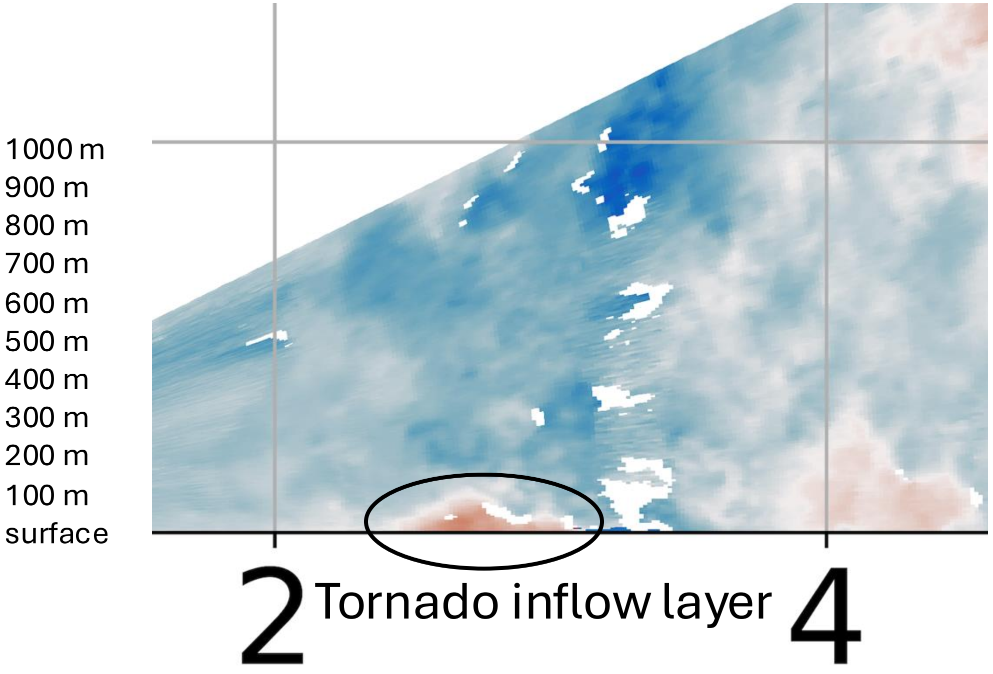


Radius

GBVTD analysis – Eldorado, OK (wavenumbers 0-6)

RHI Analysis





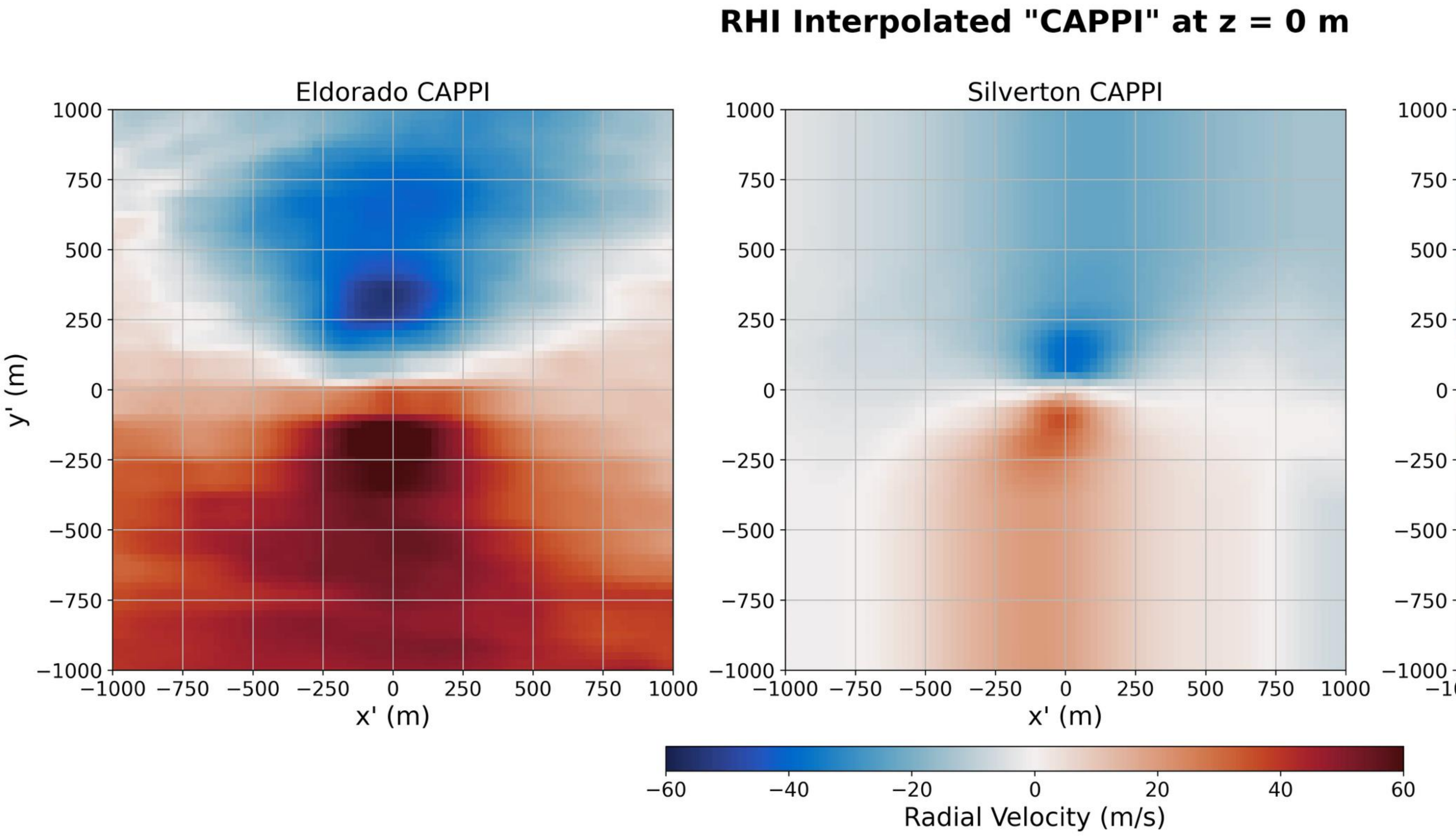
- RHI stare approach allows one to obtain vertical profiles of radial velocity across multiple tornado-relative positions.
- Fortuitous passes through the center of the core allow the diagnosis of radial inflow characteristics.
- In particular, capturing inflow depth (e.g., ~20 m in Sudan, TX example to the left) helps assess the validity of swirl ratio in governing single/multiple-cell structure

$$S = \frac{RV_{\theta,R}}{2hV_{r,R}}$$

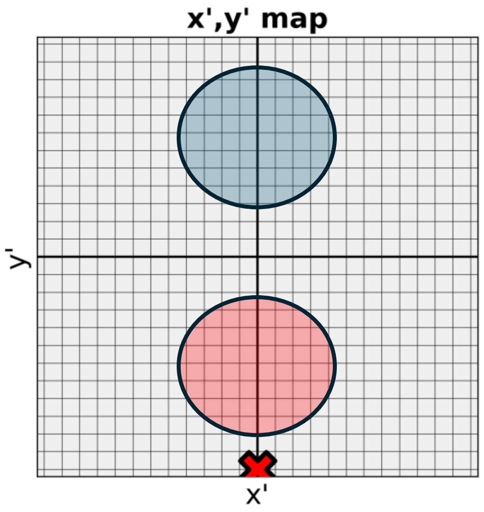
Rotunno 1979

- Can objectively analyze RHI sweeps in tornado-relative frame (accounting for estimate of tilt)

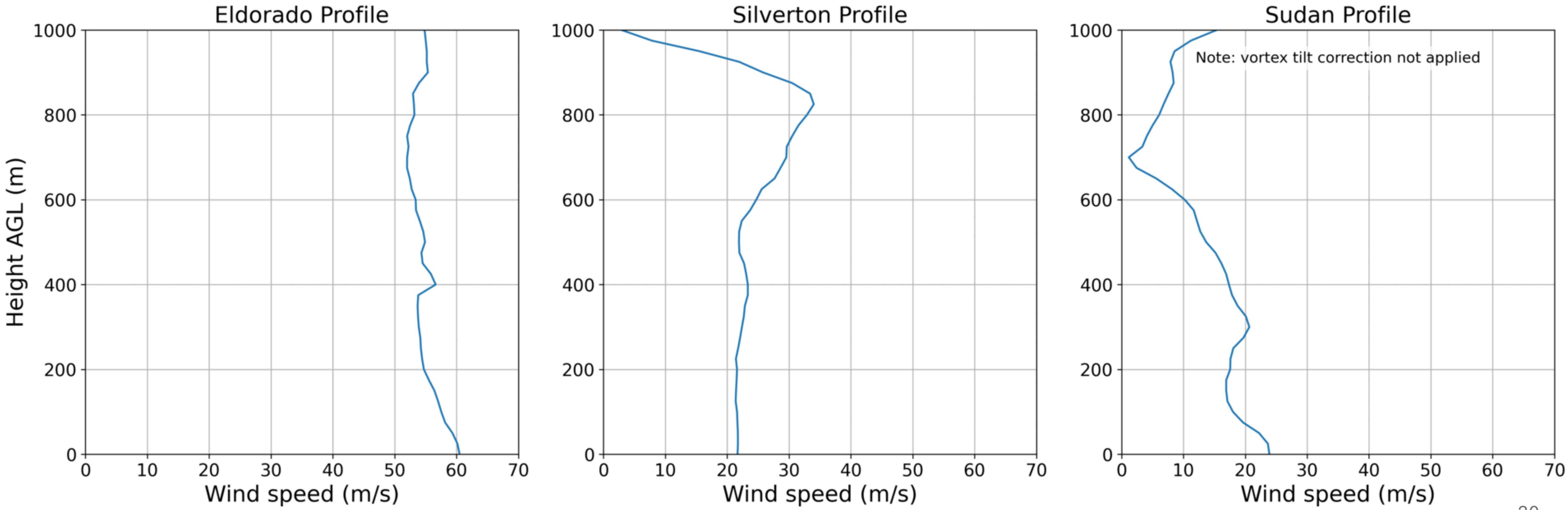
RHI Analysis



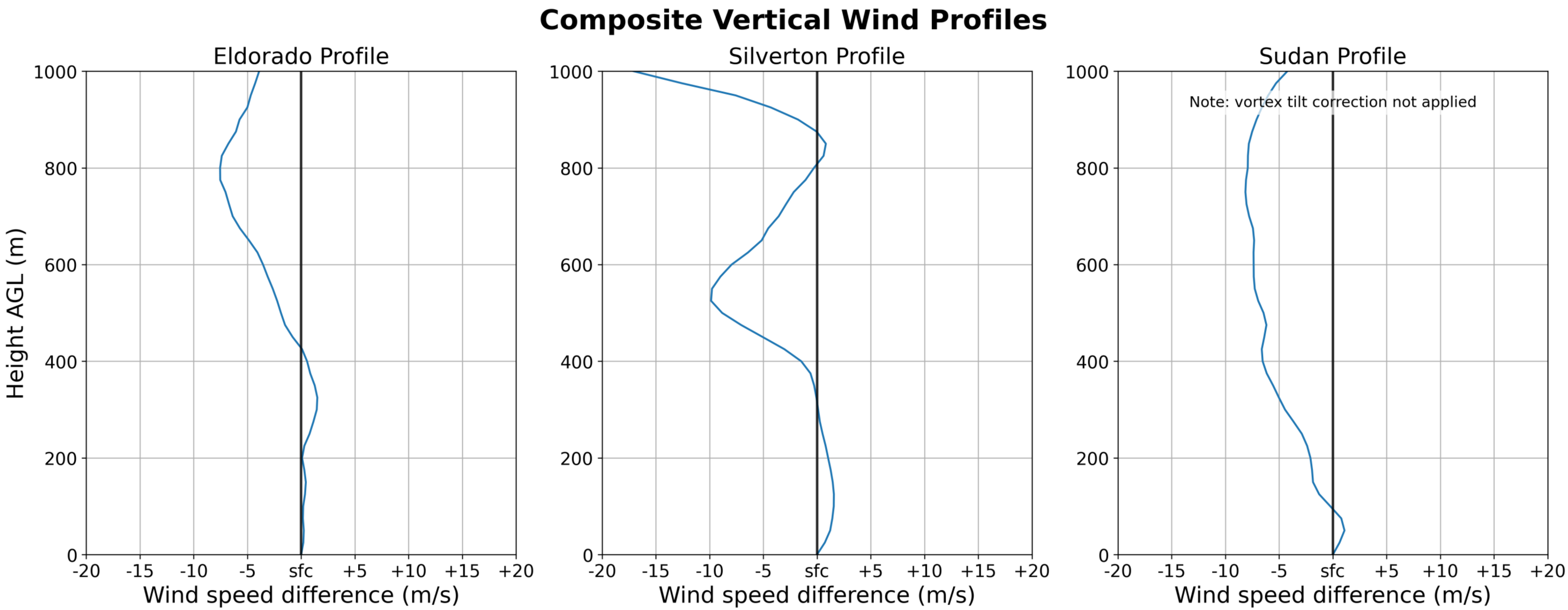
Retrieved Vertical Wind Profiles



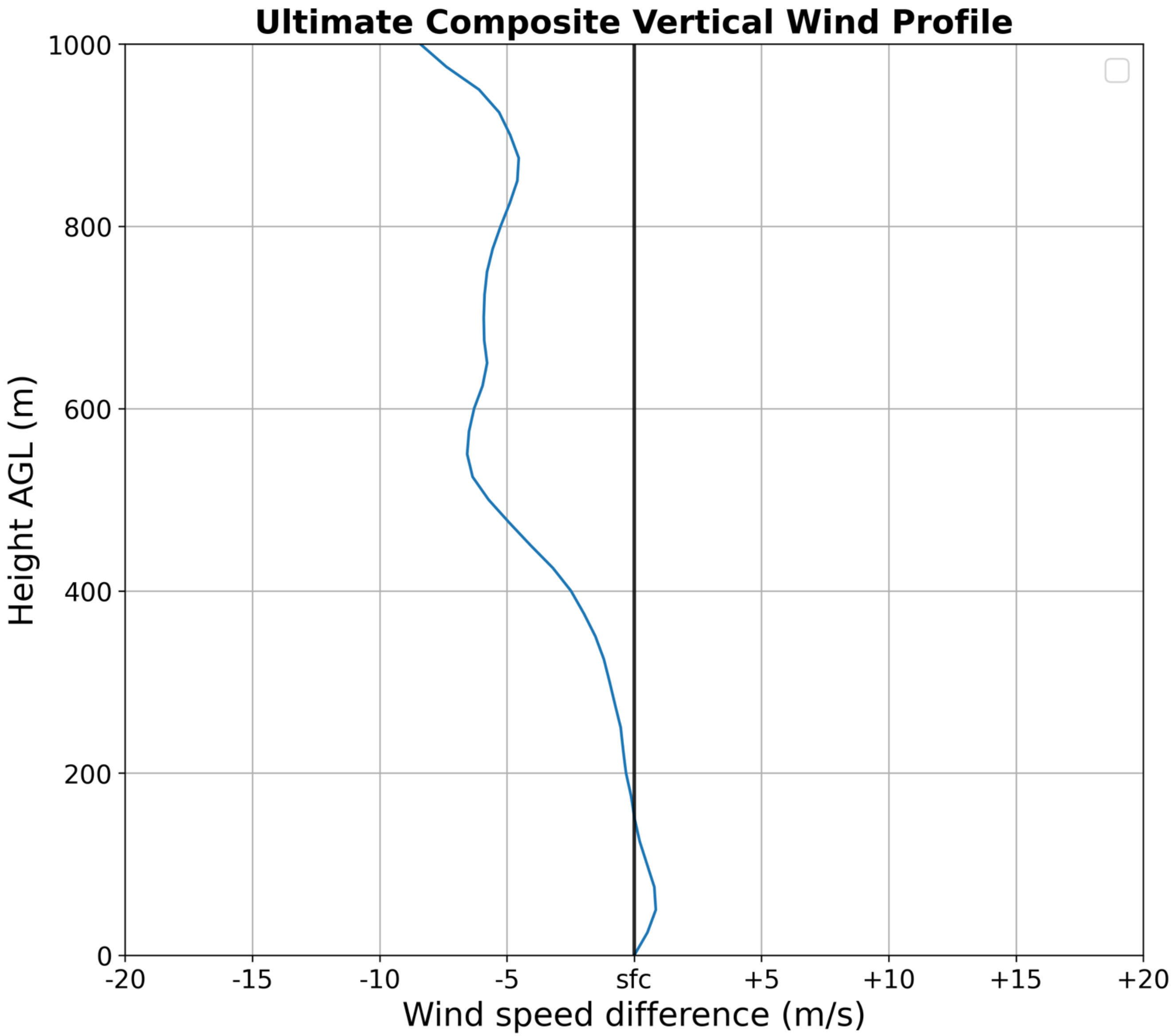
RHI Interpolated Vertical Wind Profiles at y' = -300 m



Composite Profiles



"Ultimate" Composite Profile



Summary and Future Work

- Successful data collection from the first two years of LIFT

  Preliminary data shown on:

  - Low-level tornado wind field: horizontal and vertical structure
  - Storm-scale influences
    - Storm-generated boundaries, particularly the forward-flank convergence boundary and, occasionally, streamwise vorticity currents
    - Near-field inflow characterization and worms

- Continued data collection planned for 2026

Questions?

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NSF grant # AGS-1824713, AGS-2122526, AGS-2312995
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