Vertically-pointing Radar Observations of Convective Updrafts and Downdrafts Associated with Cool-season QLCSs over Northern Alabama

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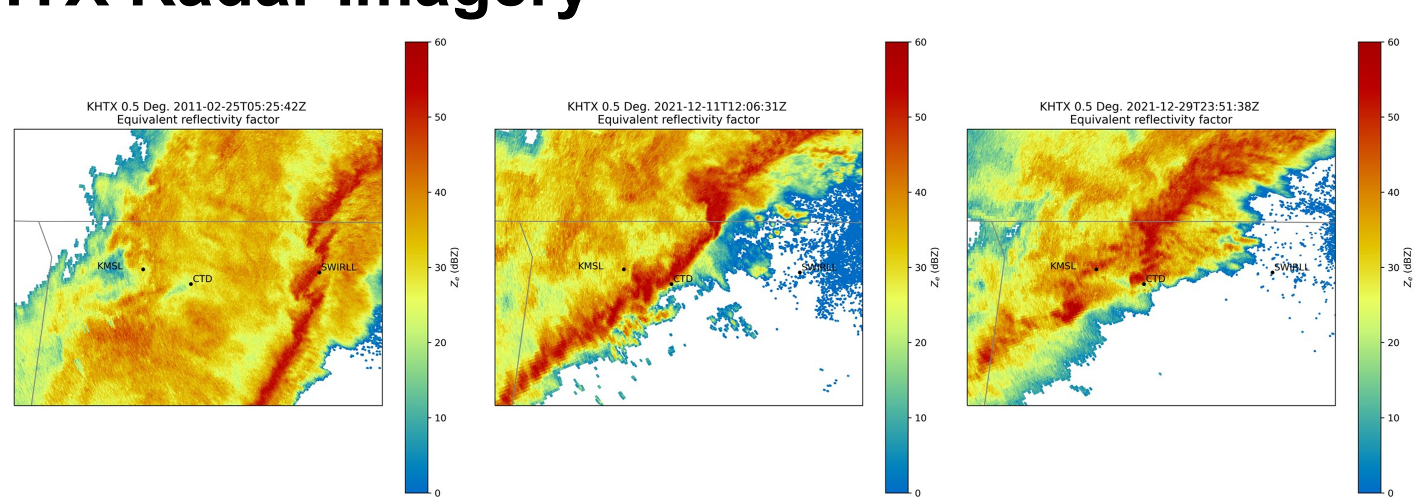
Abstract

Quasi-linear convective systems (QLCSs) are a relatively common occurrence in northern Alabama during the cool-season months. Often these storms develop in high-shear, low-CAPE (HSLC) environments. QLCSs can produce an array of severe weather such as tornadoes, damaging straight-line winds, lightning, and heavy precipitation. The goal of this study is to characterize the kinematic and thermodynamic properties associated with twelve severe QLCS events using an array of meteorological instrumentation. Using the University of Alabama in Huntsville's (UAH) high resolution vertically pointing X-band profiling radar (XPR) and the National Oceanic Atmospheric Administration's (NOAA) S-band precipitation profiler at the Courtland Airport, the reflectivity, signal-to-noise ratio (SNR), depth, width, and magnitude of the updraft and downdrafts are analyzed. Preliminary results show that some of the QLCSs have a maximum updraft on the order of ~18 m s^{-1} confined to the lowest three kilometers of the storm, while the maximum adjacent downdraft corresponds to the high reflectivity (SNR) values at the lower levels due to precipitation offloading. In addition to these vertically pointing radars, a 915 MHz wind profiler, 449 MHz wind profiler, surface observations, balloon and model soundings, the C-band Advanced Radar for Meteorological Operational Research (ARMOR), and lightning data will be used to quantify the characteristics of the QLCSs. Surface observations indicate a reduction in temperature and θ_e and θ_v during the passage of the QLCS. In addition, a pressure increase (up to approximately 5 hPa for some cases) is also observed with the passage of the QLCS. The magnitude of the temperature reduction and pressure increase are utilized to identify the propagation mechanism (e.g., density current vs. bore). Understanding the kinematic and thermodynamic properties of QLCSs will provide vital information on the kinematics of updrafts and downdrafts, along with important insights into the potential differences between nontornadic and tornadic QLCSs.

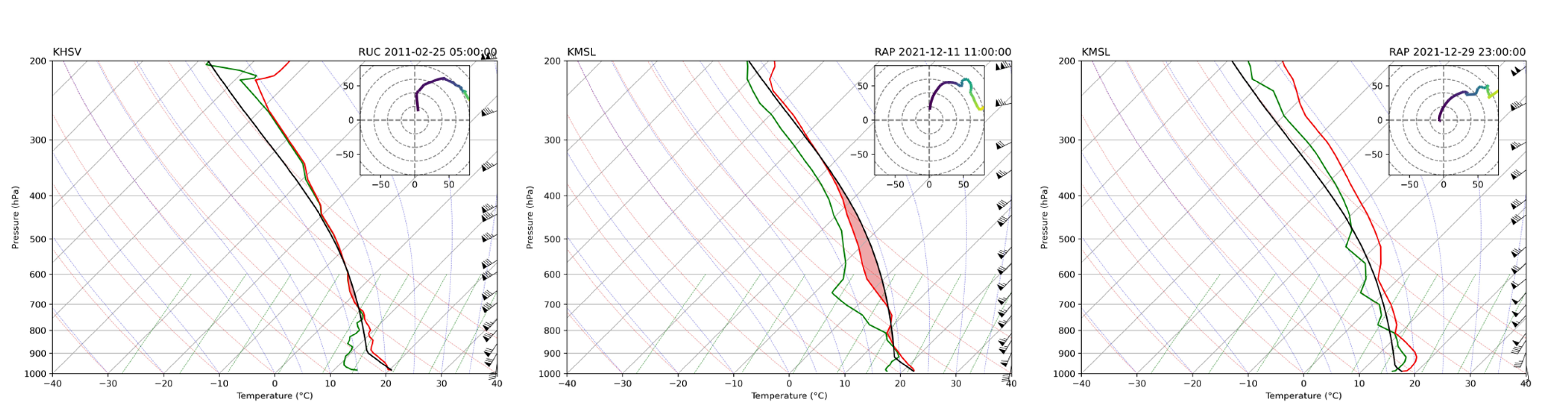
Data/Methodology

- The University of Alabama in Huntsville (UAH) Mobile Atmospheric Profiling Network (MAPNet)
  - X-band Profiling Radar (XPR): ~10 Hz resolution
  - Berm surface measurements and calculated perturbations following Hutson et al. (2019)
  - 915 MHz Wind Profiler
- NOAA Physical Sciences Laboratory Profiler Network Data & Image Library at the Courtland (CTD) Airport in Courtland, Alabama
  - S-band Precipitation Profiler Radar (~1:09 minute temporal resolution)
  - Surface measurements (2 minute temporal resolution)
    - Derived equivalent potential temperature from thermodynamic variables following Bolton (1980)
  - 449 MHz Wind Profiler
- Hourly RUC/RAP soundings obtained from the Iowa State Mtarchive database for KHSV and KMSL (Muscle Shoals, located approximately 27 km northwest of CTD)
  - Obtained surface observations from the Iowa State University IEM database and replaced sounding surface level temperature and dewpoint
  - Calculated vertical profiles of θ_e and θ_v to assess transport of air aloft to the surface and N^2 to assess stability
- Obtained KHTX Level II radar data from NOAA's NEXRAD Data Archive

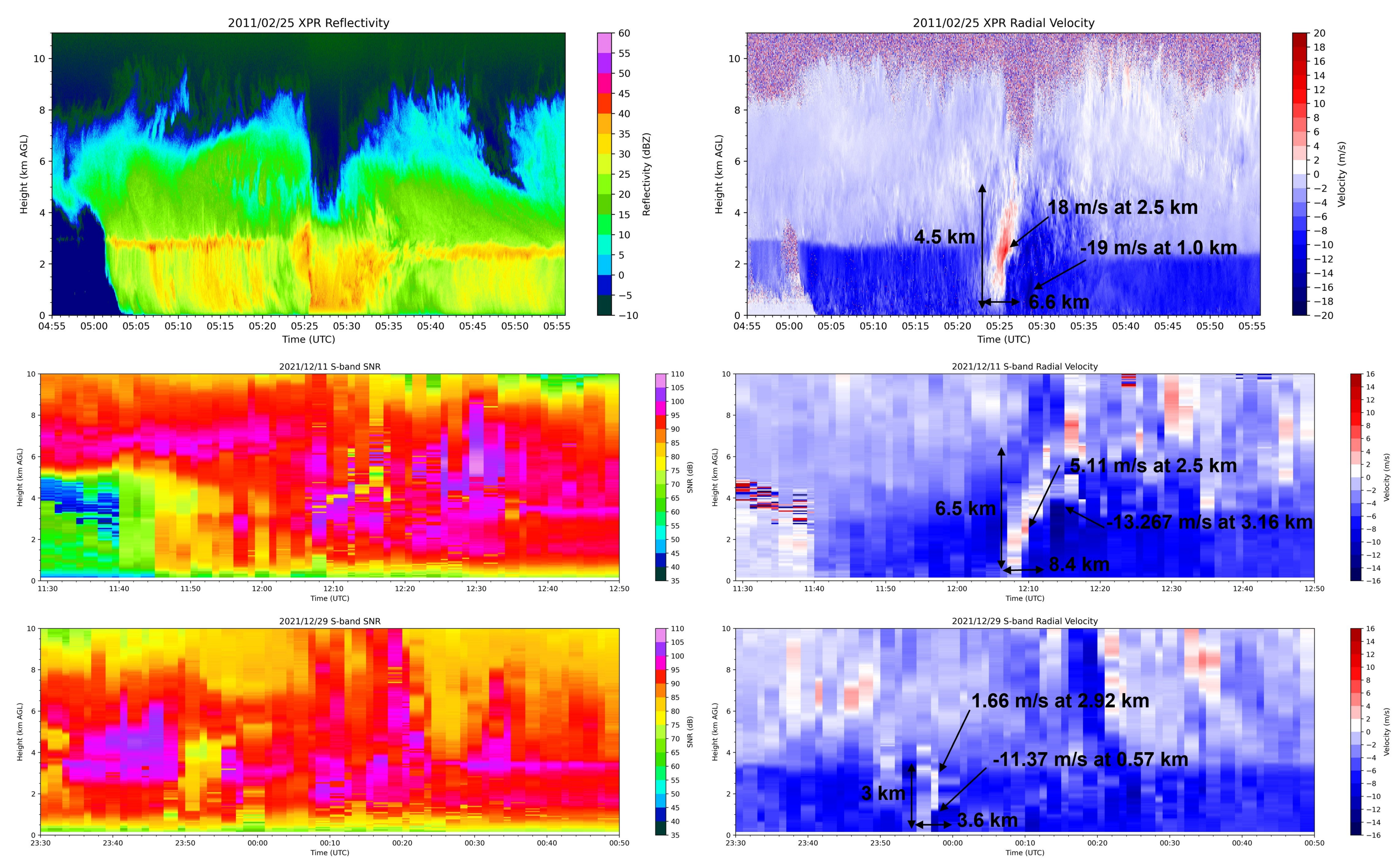
KHTX Radar Imagery



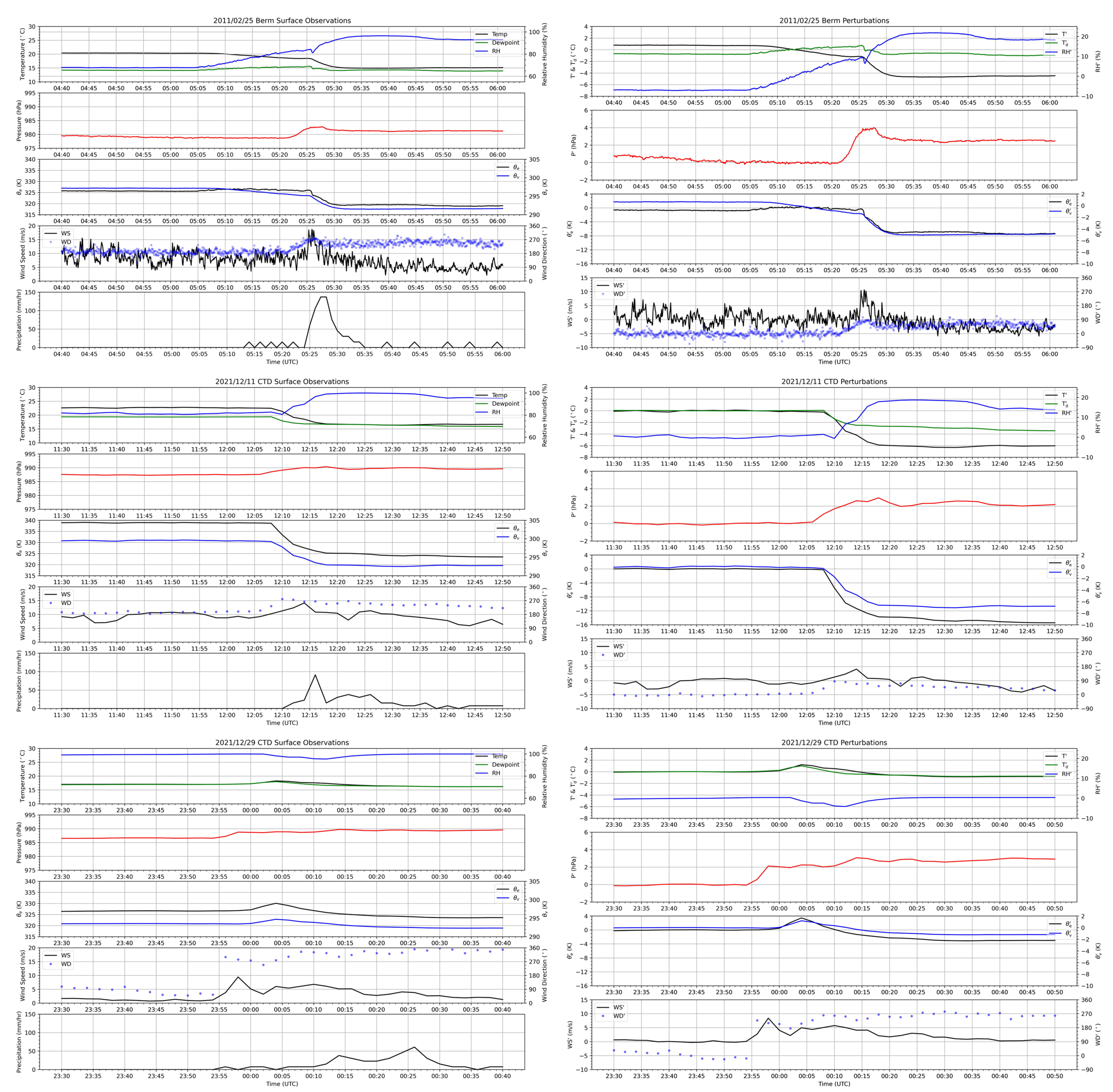
RUC/RAP Upper-Air Analysis



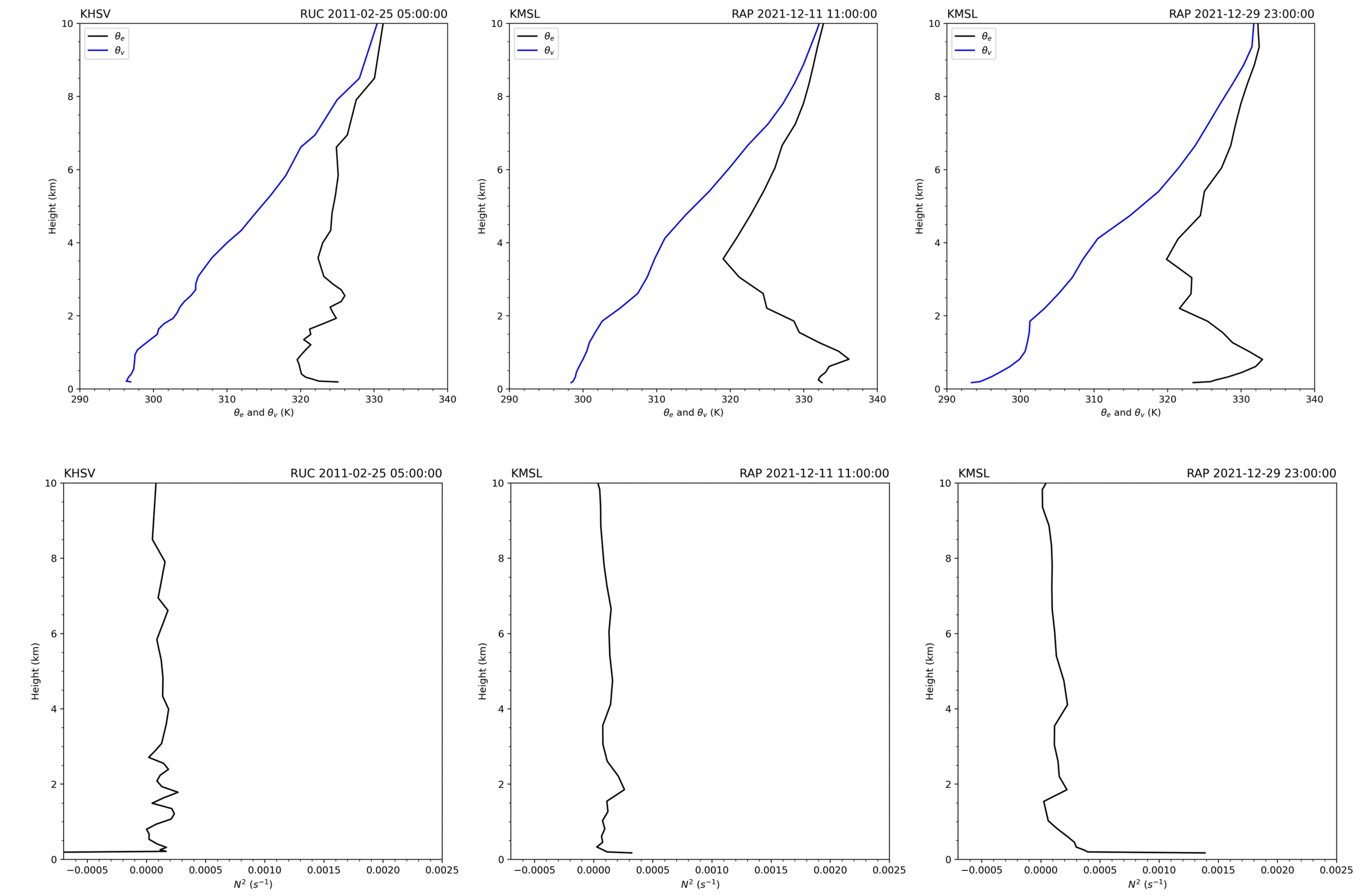
XPR Reflectivity/Velocity & S-band SNR/Velocity



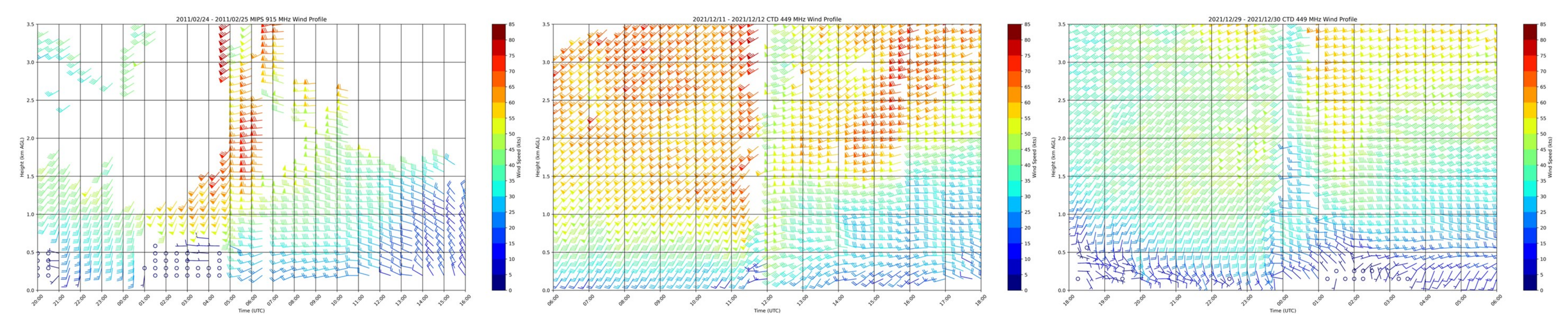
Surface Observations/Perturbations



θ_e and θ_v and Brunt-Väisälä Frequency Vertical Profiles



915 MHz/449 MHz Wind Profiles



Summary/Conclusion

- Maximum updraft associated with QLCS arrival is confined to the lowest 3 km or lower
- Increase in pressure and wind speed and change in wind direction with the arrival of the leading edge of the QLCS
- Decrease in temperature, θ_e, θ_v with the arrival of the QLCS, However, the December 29, 2021 case shows an initial increase in θ_e and θ_v followed by a decrease in θ_e and θ_v. Compared to the other cases, the pre-QLCS sounding showed a prominent inversion near the surface.
  - Initial increase due to warmer air aloft being brought down to the surface with the leading edge of the QLCS
- Different propagation mechanisms observed
  - Bore (increase in pressure, negligible temperature change)
  - Density current (increase in pressure, drop in temperature)
  - Hybrid (density current/bore)

References

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