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

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THE UNIVERSITY OF ALABAMA IN HUNTSVILLE

MAPNet
MIPS MAX RoDAPS MoDLS
Mobile Atmospheric Profiling Network

Background

- Quasi-linear convective systems (QLCSs) are a relatively common occurrence in the southeastern US during the cool-season
- Storms often develop in high shear, low CAPE (HSLC) environments (Sherburn & Parker, 2014)
  - Surface-based CAPE $\leq$ 500 J kg^{-1}
  - MUCAPE $\leq$ 1000 J kg^{-1}
  - 0-6 km shear $\geq$ 18 m s^{-1}
- Can produce an array of severe weather
  - Tornadoes, damaging straight-line winds, lightning, and heavy precipitation

Research Objectives

- Determine thermodynamic and kinematic properties of cool-season QLCSs
    - May provide vital information on the kinematics of updrafts and downdrafts
    - Magnitude, width, height of updraft/downdraft
    - Location of maximum updraft/downdraft
- Potential differences between tornadic and nontornadic QLCSs
- Assess severity of QLCS (wind damage, lightning, tornadoes, hail, etc)
- Identify propagation mechanism (bore, density current, hybrid)
- Identify cold pool intensity and its relation to propagation speed
- Assess environmental and storm parameters

Methodology/Data

Case 1: UAH MAPNet

- X-band profiling radar (XPR; 6 Hz resolution)
- Berm Surface Data (5 second resolution)
  - Surface observations (temperature, dewpoint, pressure, wind speed, wind direction)
  - Derived thermodynamic calculations (potential temperature, equivalent potential temperature, virtual temperature, mixing ratio, etc.)
    - Equivalent potential temperature derived following Bolton (1980)
  - Derived perturbations for surface measurements following similar approach from Hutson et al. (2019) for thermodynamic variables
    - Averaged variable of interest over 15 minutes, at least for 5 minutes before passage of gust front
- 915 MHz Profiler

Methodology/Data (continued)

Case 2: NOAA Physical Sciences Laboratory

- Vertically-pointing S-band Precipitation Profiler Radar (~1:09 resolution)
- Surface Measurements(2 minute resolution)
  - Surface observations (temperature, dewpoint, pressure, wind speed, wind direction)
  - Derived thermodynamic calculations (potential temperature, equivalent potential temperature, virtual temperature, mixing ratio, etc.)
    - Equivalent potential temperature derived following Bolton (1980)
  - Derived perturbations for surface measurements following similar approach from Hutson et al. (2019) for thermodynamic variables
- 449 MHz Profiler
  - Calculated average lapse rate (0-1 km) prior to QLCS passage
- Soundings (available from the Profiler Network Data & Image Library)
  - Radar Wind Profiler, RASS, and Surface Meteorology Sounding

Methodology/Data (continued)

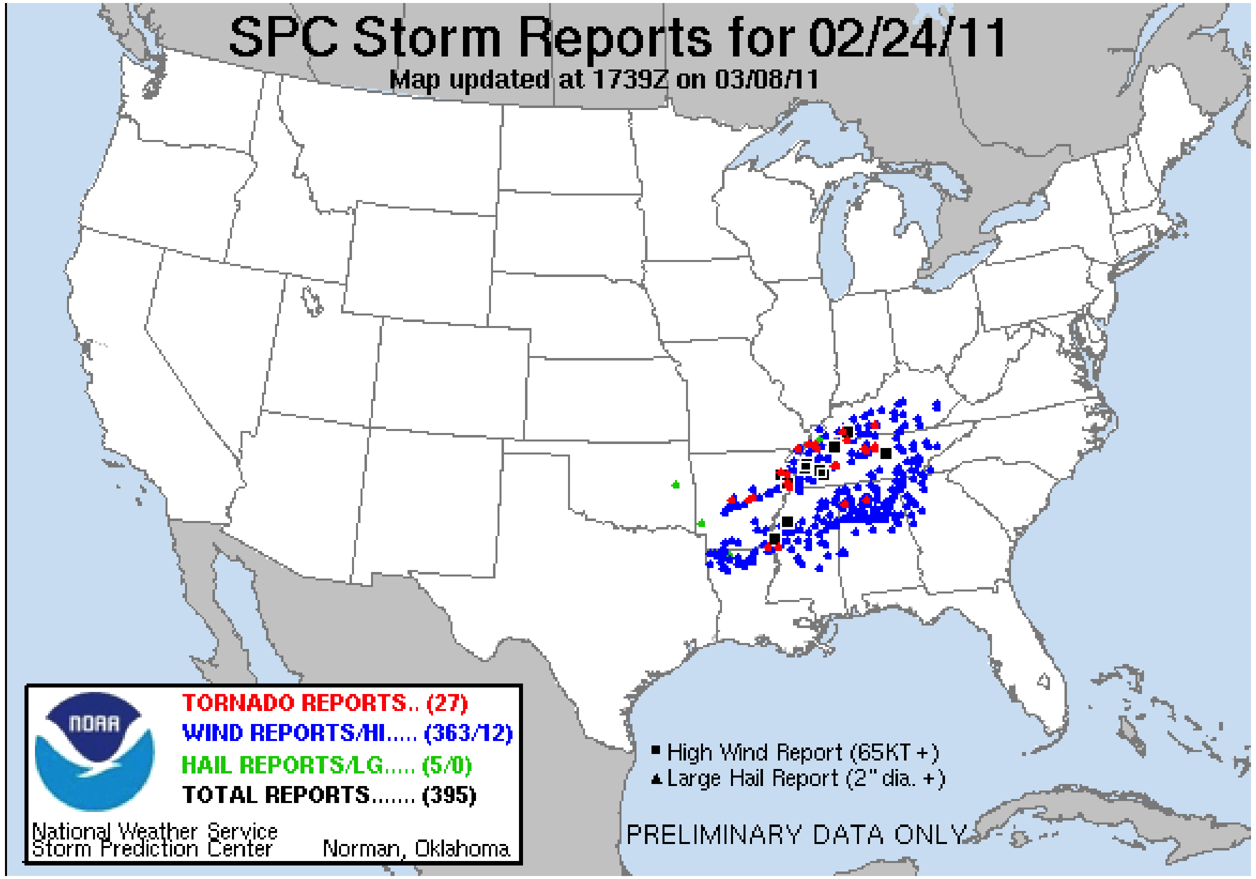
NOAA NEXRAD Data Archive

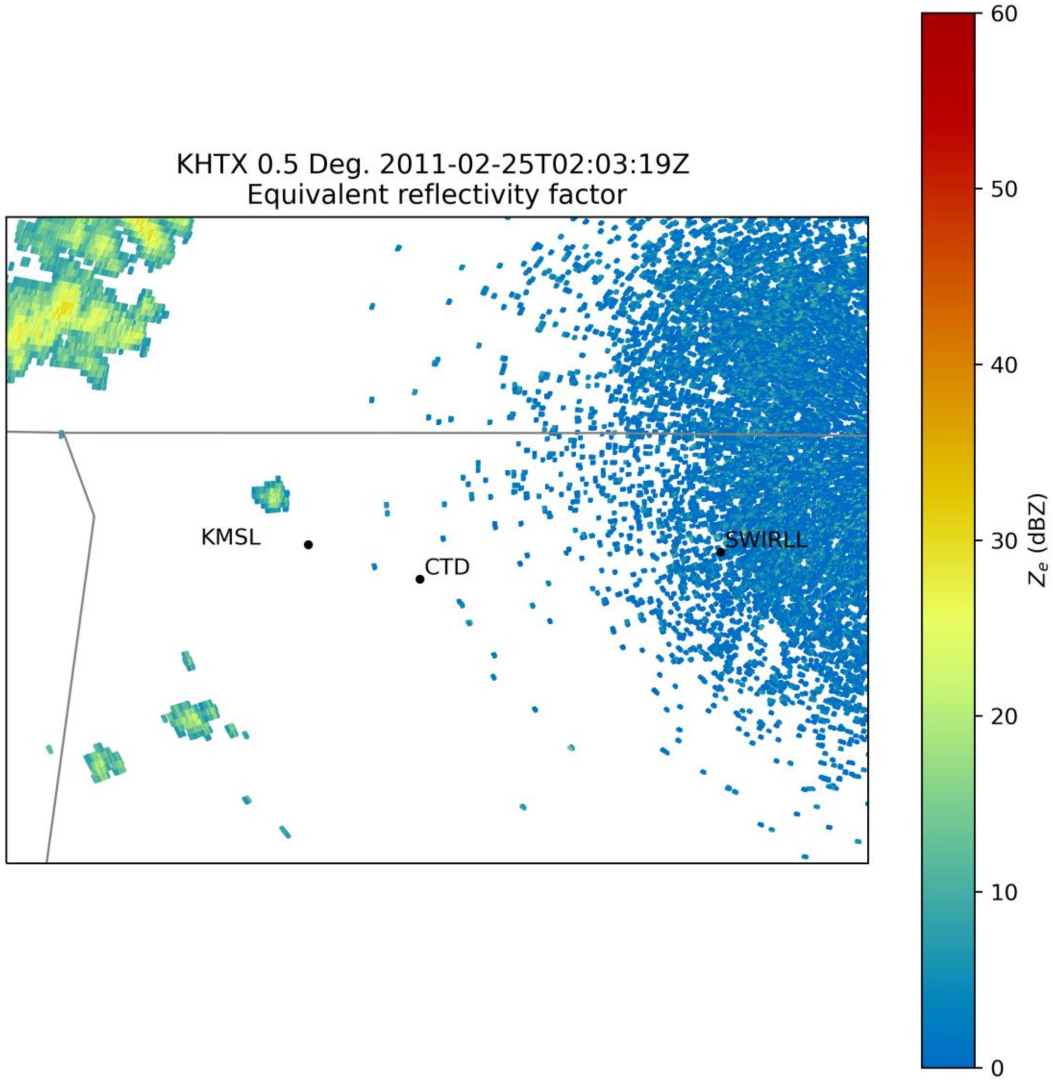
- KHTX NEXRAD Level II Data

Iowa State Mtarchive Database

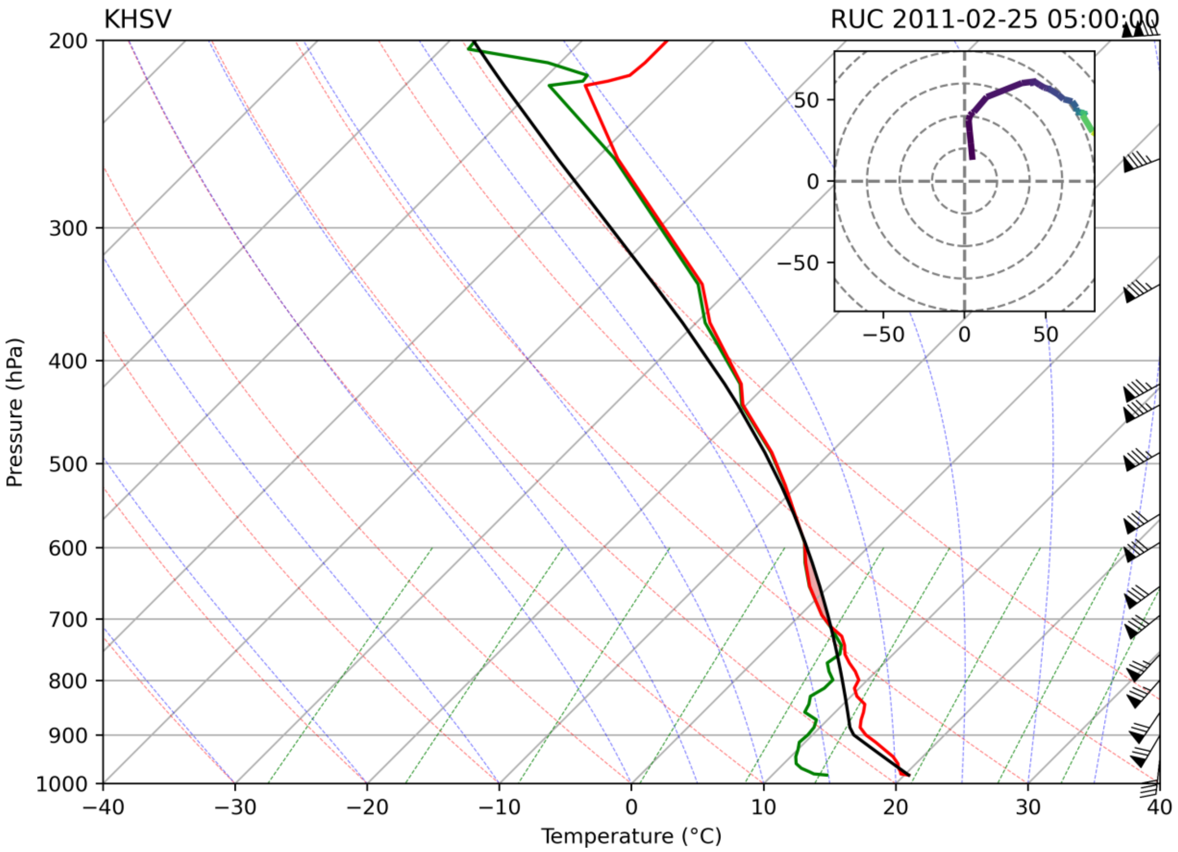
- Hourly RUC/RAP model archived sounding data
  - Obtained surface observations from Iowa State University IEM database and replaced sounding surface level temperature and dewpoint
  - Calculated average lapse rate (0-1 km) prior to gust front passage for Case 1

Case 1 (XPR)
25 February 2011


SPC Storm Reports for 02/24/11
Map updated at 1739Z on 03/08/11
TORNADO REPORTS.. (27)
WIND REPORTS/HI..... (363/12)
HAIL REPORTS/LG..... (5/0)
TOTAL REPORTS....... (395)
National Weather Service
Storm Prediction Center
Norman, Oklahoma
High Wind Report (65KT +)
Large Hail Report (2" dia. +)
PRELIMINARY DATA ONLY

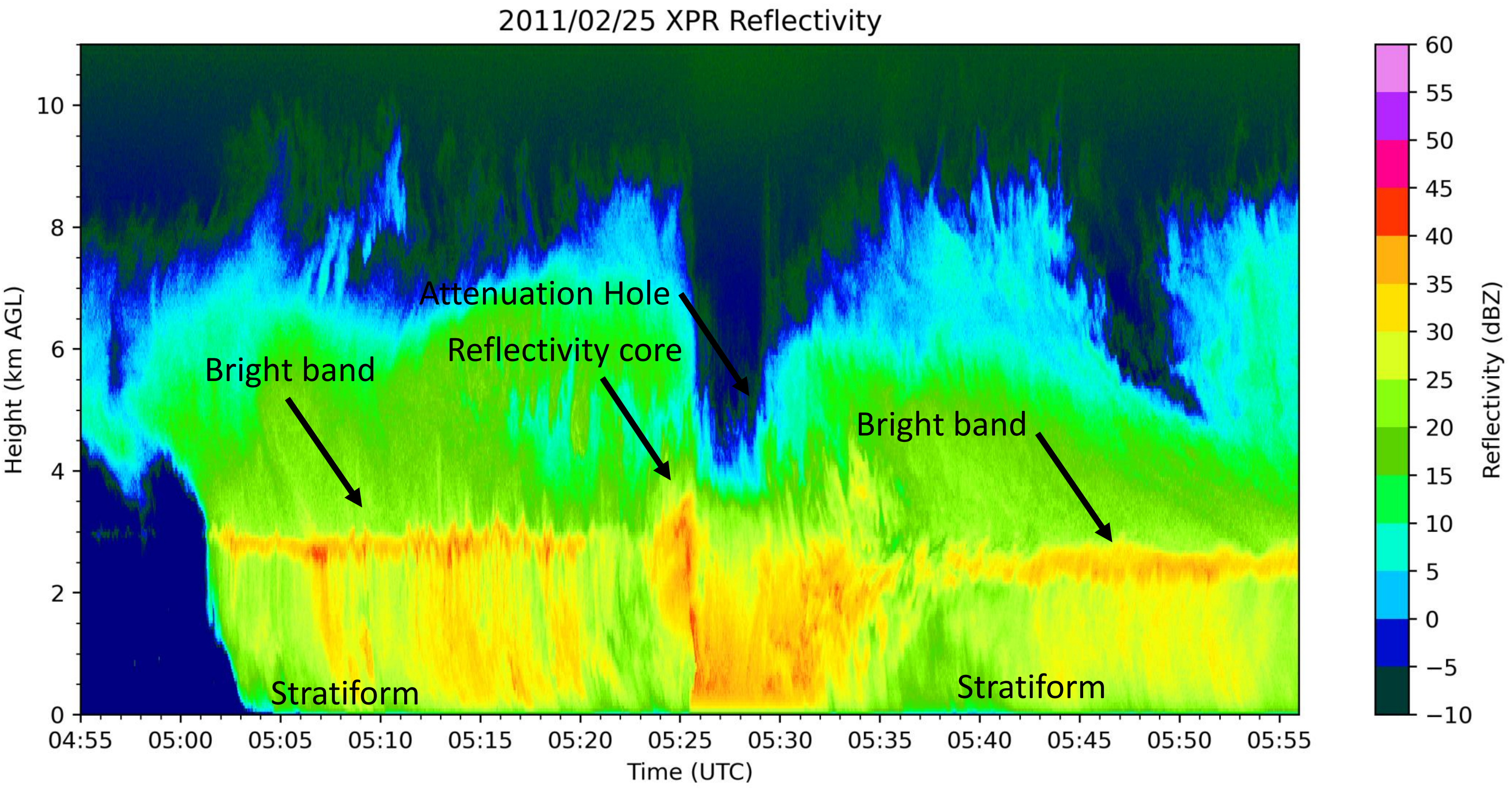

KHTX 0.5 Deg. 2011-02-25T02:03:19Z
Equivalent reflectivity factor
KMSL
CTD
SWIRLL
Z_e (dBZ)
0
10
20
30
40
50
60

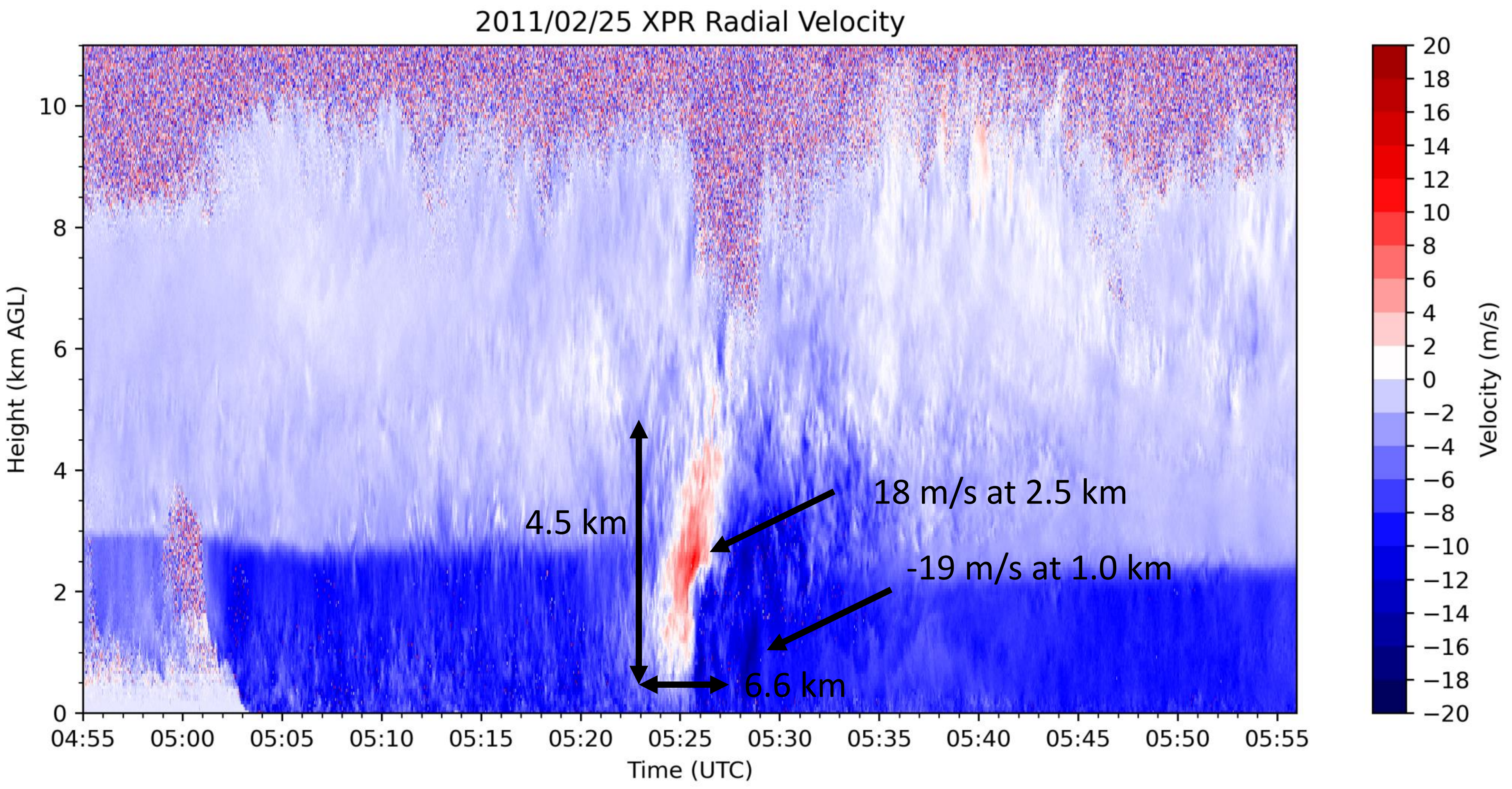
KHSV RUC Model Sounding

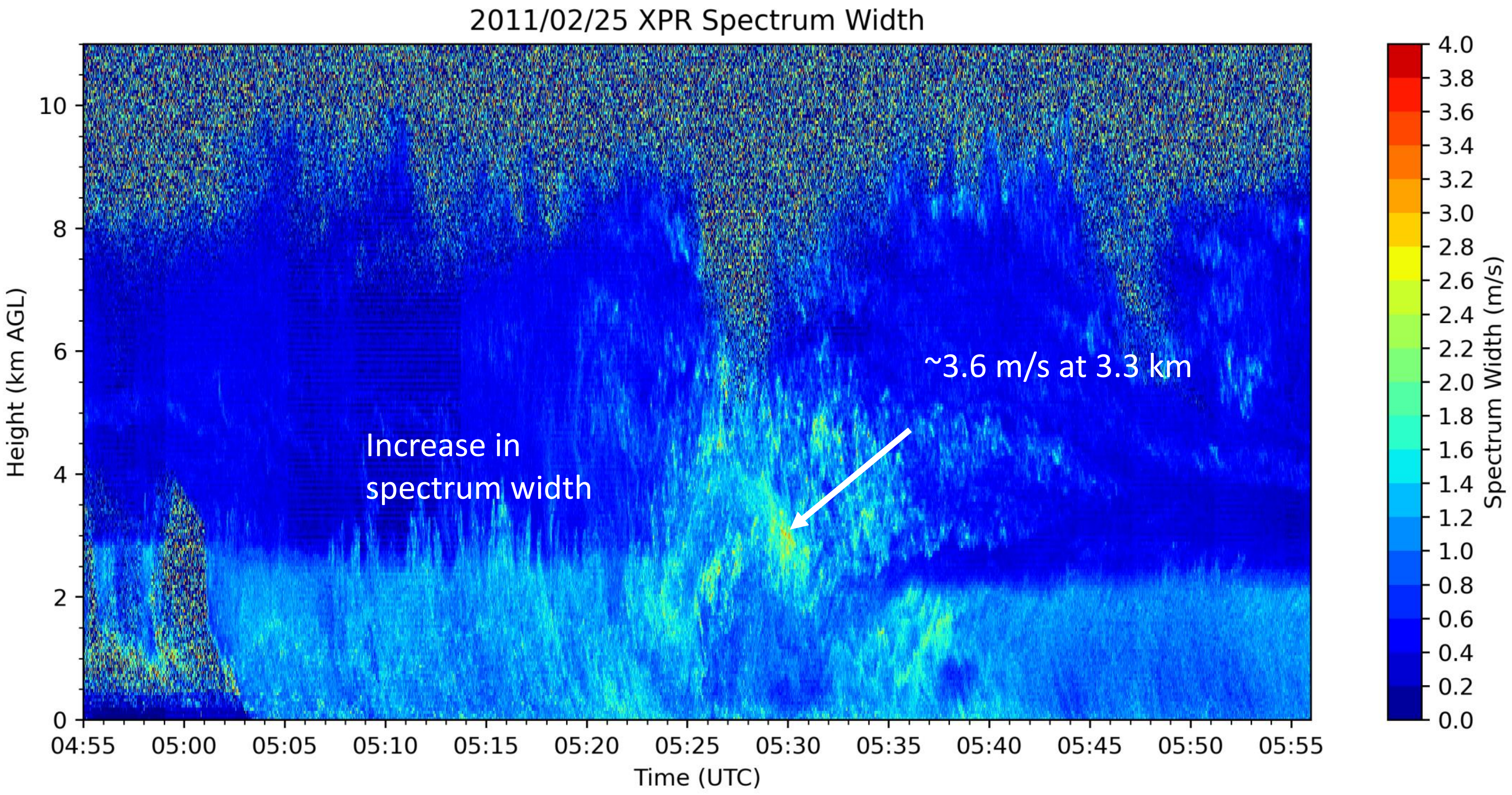


Storm Motion	44 kts (22.64 m/s)
Storm Motion Vector	271°

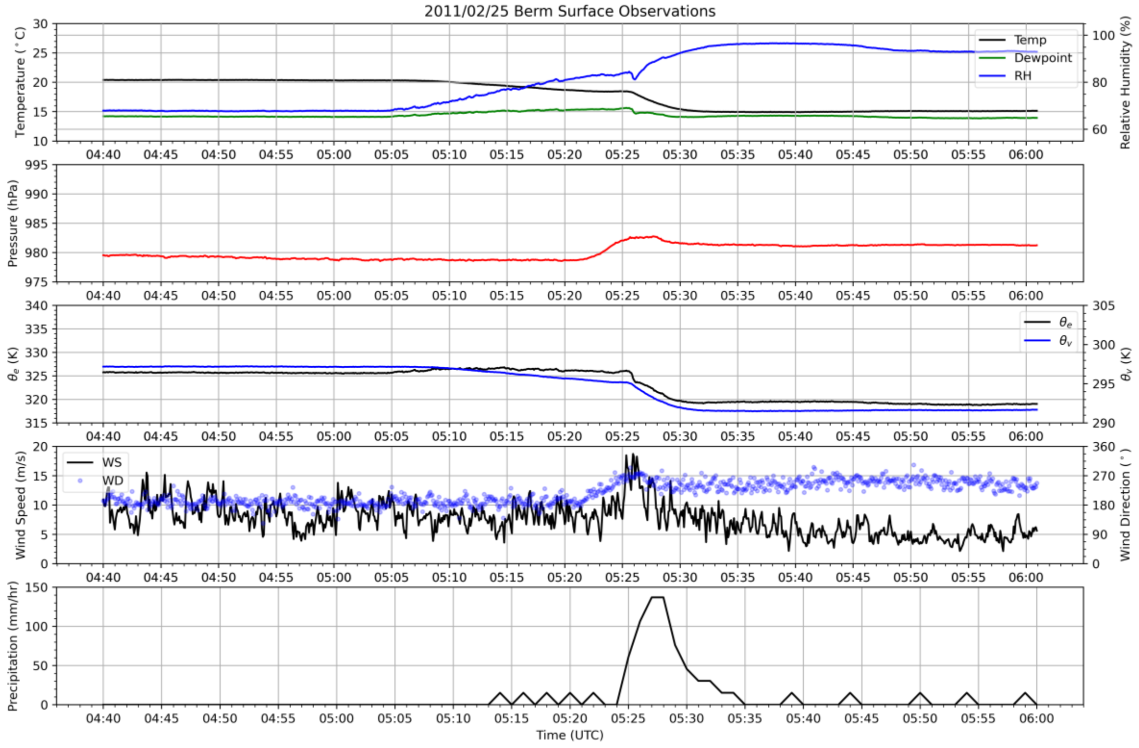
SBCAPE	25.09 J/kg
SBCIN	-72.83 J/kg
MUCAPE	102.15 J/kg
MUCIN	-0.56 J/kg
MLCAPE	0 J/kg
MLCIN	0 J/kg
LCL	895.22 hPa; 12.71°C
LFC	711 hPa; 3.17°C
Shear (0-1 km)	60.34 kts
Shear (0-3 km)	69.17 kts
Shear (0-6 km)	74.69 kts
SRH (0-1 km)	1007.50 m^2/s^2
SRH (0-3 km)	1336.02 m^2/s^2
SRH (0-6 km)	1529.86 m^2/s^2
Lapse Rate (0-1 km; 0200-0500 UTC)	9.24 °C/km

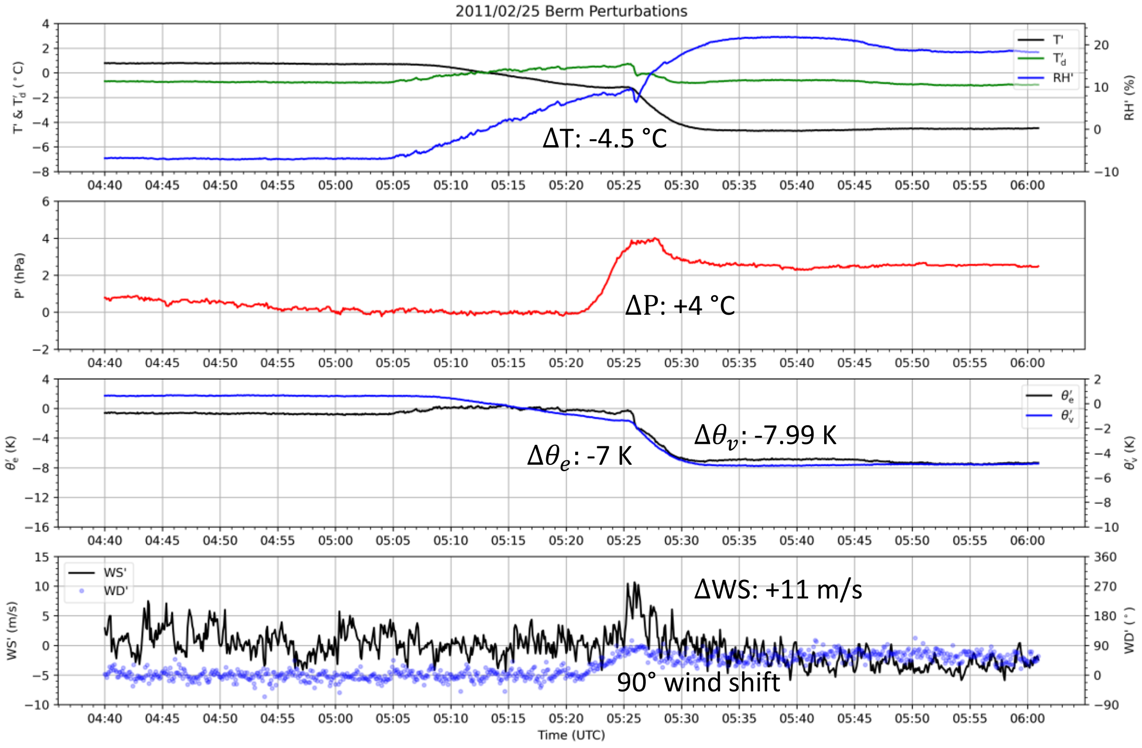

2011/02/25 XPR Reflectivity
Height (km AGL)
Time (UTC)
Reflectivity (dBZ)
Attenuation Hole
Reflectivity core
Bright band
Bright band
Stratiform
Stratiform
04:55
05:00
05:05
05:10
05:15
05:20
05:25
05:30
05:35
05:40
05:45
05:50
05:55
0
2
4
6
8
10
−10
−5
0
5
10
15
20
25
30
35
40
45
50
55
60


2011/02/25 XPR Radial Velocity
Height (km AGL)
Time (UTC)
Velocity (m/s)
0
2
4
6
8
10
04:55
05:00
05:05
05:10
05:15
05:20
05:25
05:30
05:35
05:40
05:45
05:50
05:55
20
18
16
14
12
10
8
6
4
2
0
−2
−4
−6
−8
−10
−12
−14
−16
−18
−20
4.5 km
18 m/s at 2.5 km
-19 m/s at 1.0 km
6.6 km

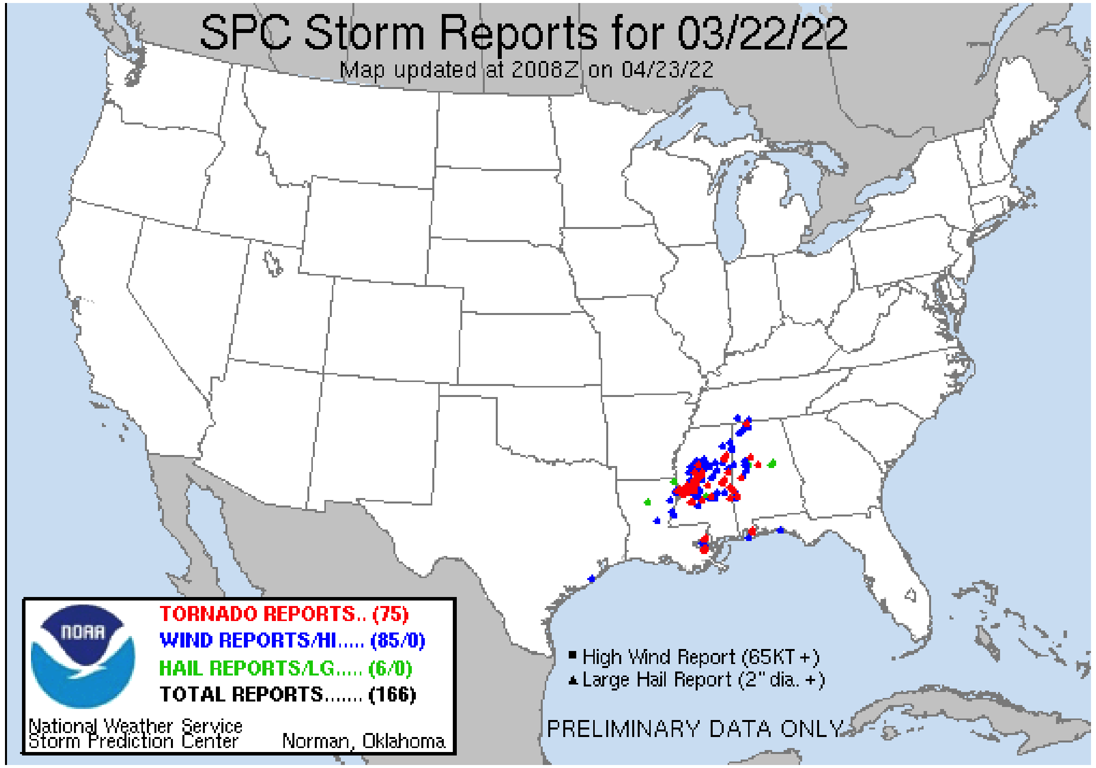

2011/02/25 XPR Spectrum Width
Height (km AGL)
0
2
4
6
8
10
Time (UTC)
04:55
05:00
05:05
05:10
05:15
05:20
05:25
05:30
05:35
05:40
05:45
05:50
05:55
Spectrum Width (m/s)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6
3.8
4.0
Increase in
spectrum width
~3.6 m/s at 3.3 km

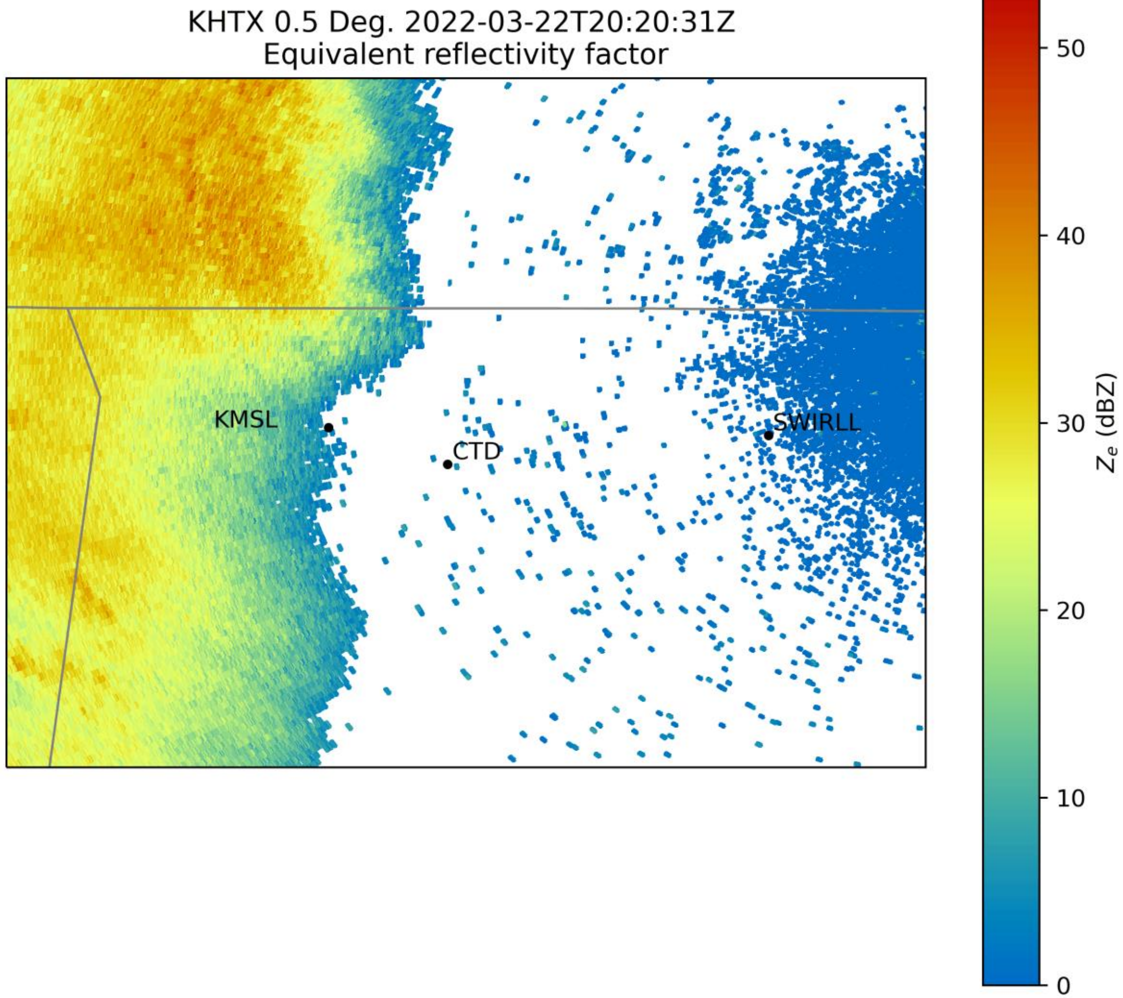
Berm Surface Observations and Perturbations



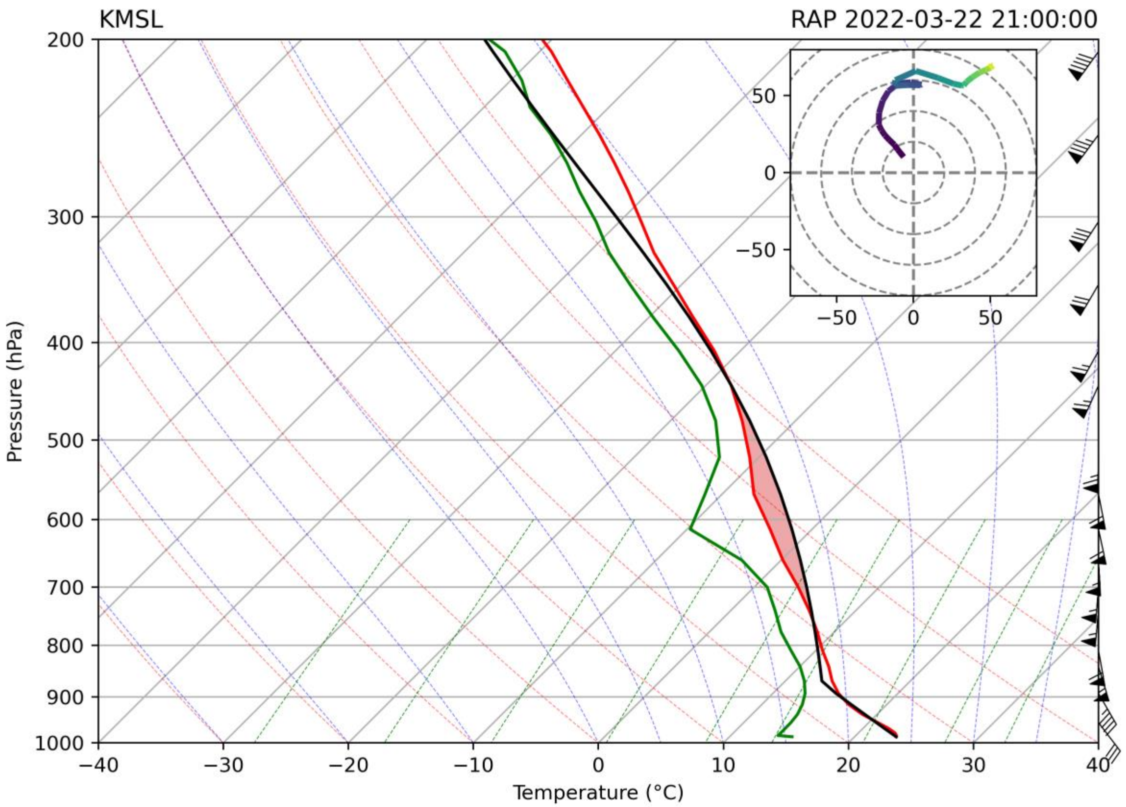


Case 2 (S-band)
22 March 2022


SPC Storm Reports for 03/22/22
Map updated at 2008Z on 04/23/22
TORNADO REPORTS.. (75)
WIND REPORTS/HI..... (85/0)
HAIL REPORTS/LG..... (6/0)
TOTAL REPORTS....... (166)
National Weather Service
Storm Prediction Center
Norman, Oklahoma
High Wind Report (65KT+)
Large Hail Report (2" dia. +)
PRELIMINARY DATA ONLY


KHTX 0.5 Deg. 2022-03-22T20:20:31Z
Equivalent reflectivity factor
KMSL
CTD
SWIRLL
60
50
40
30
20
10
0
Z_e (dBZ)

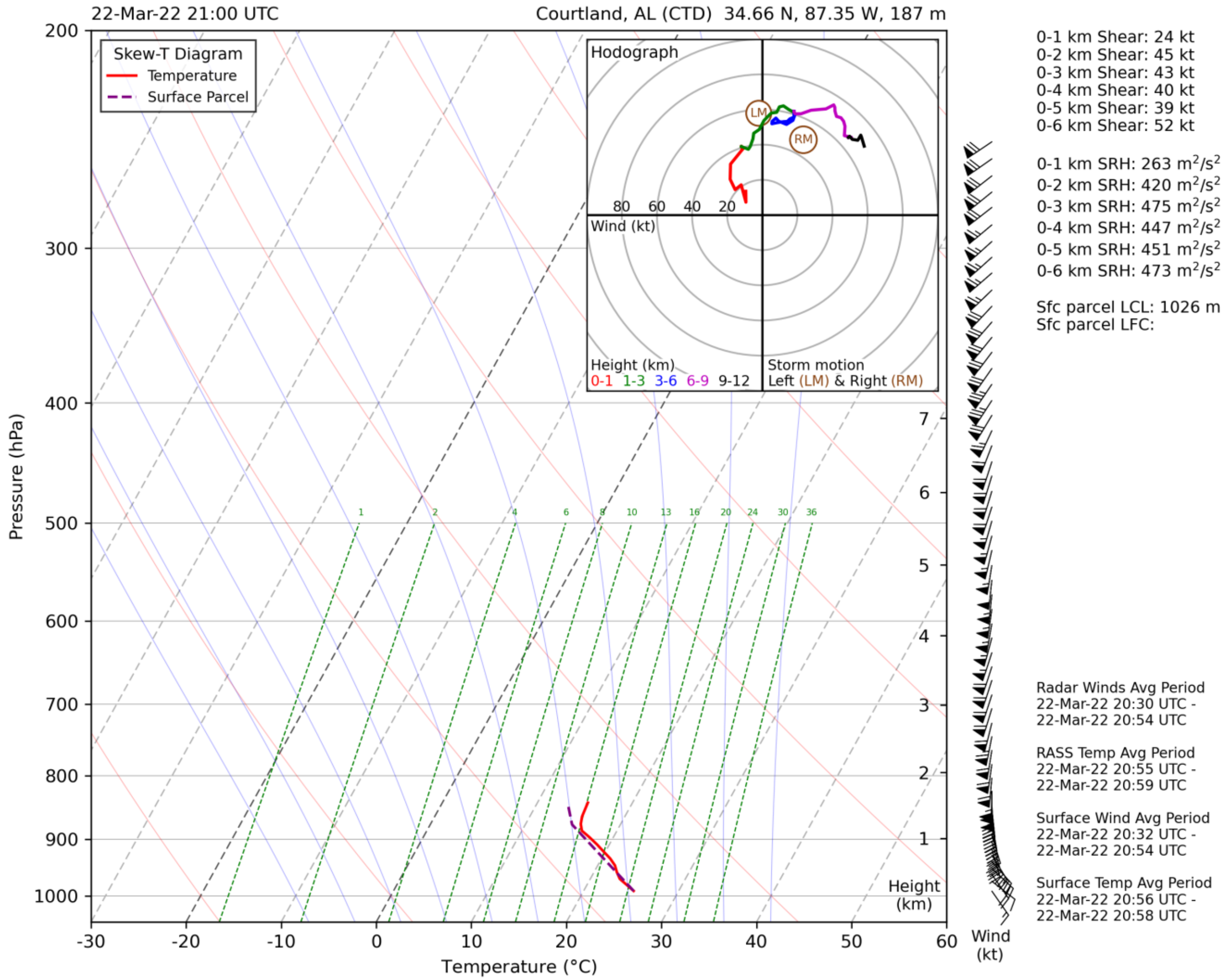
KMSL RAP Model Sounding

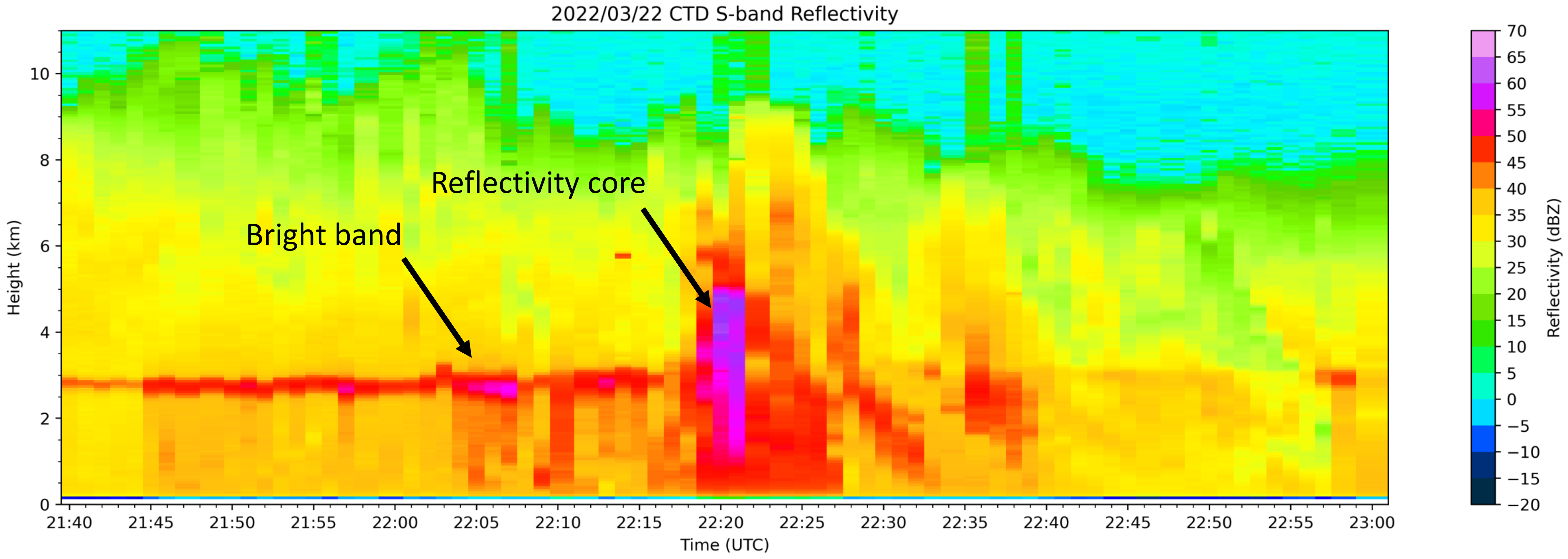


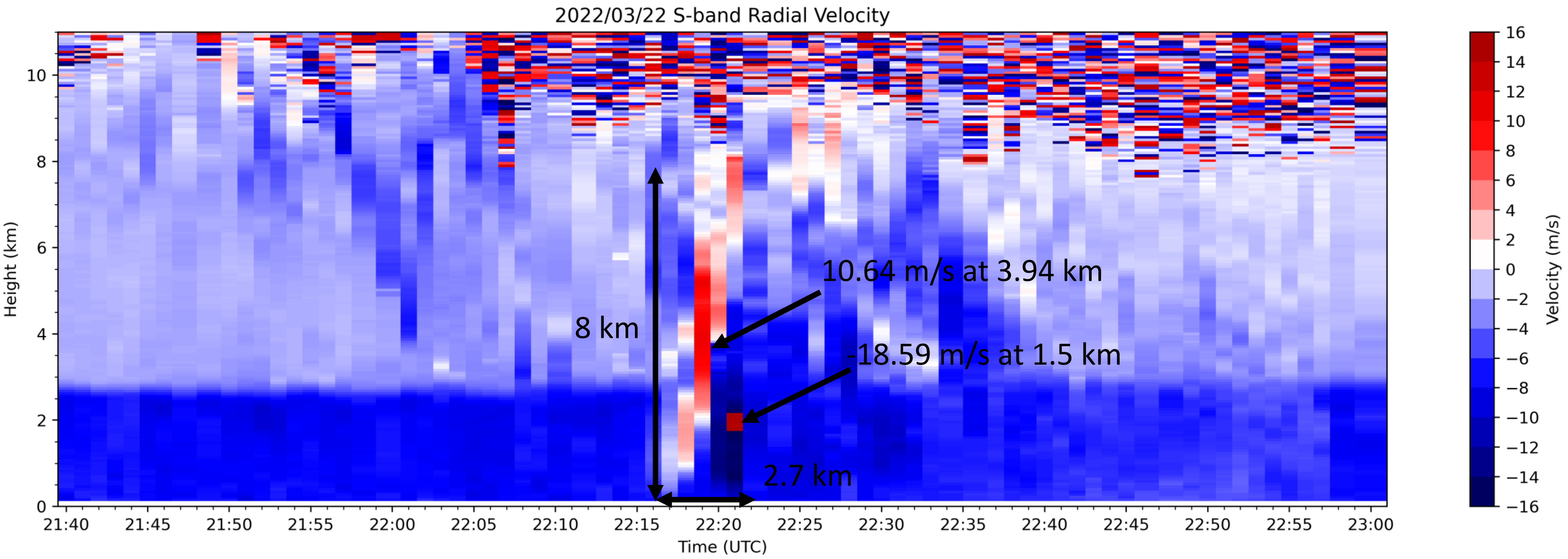
Storm Motion	60 kts (30.86 m/s)
Storm Motion Vector	196°

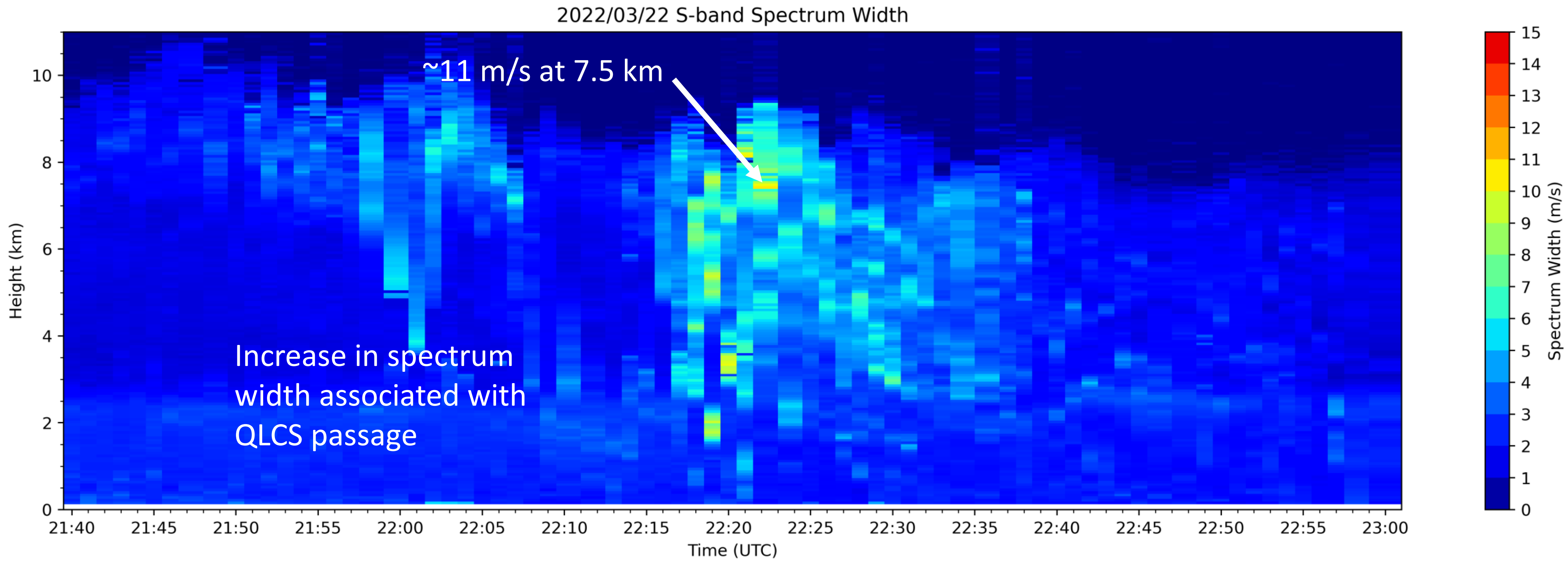
SBCAPE	174.13 J/kg
SBCIN	-22.50 J/kg
MUCAPE	174.13 J/kg
MUCIN	-22.50 J/kg
MLCAPE	88.96 J/kg
MLCIN	-58.61 J/kg
LCL	872.04 hPa; 13.1°C
LFC	756 hPa; 7.41°C
Shear (0-1 km)	31.57 kts
Shear (0-3 km)	47.27 kts
Shear (0-6 km)	56.67 kts
SRH (0-1 km)	456.25 m^2/s^2
SRH (0-3 km)	567.44 m^2/s^2
SRH (0-6 km)	665.67 m^2/s^2
Lapse Rate (0-1 km; 1800-2100 UTC)	8.57 °C/km

CTD Sounding

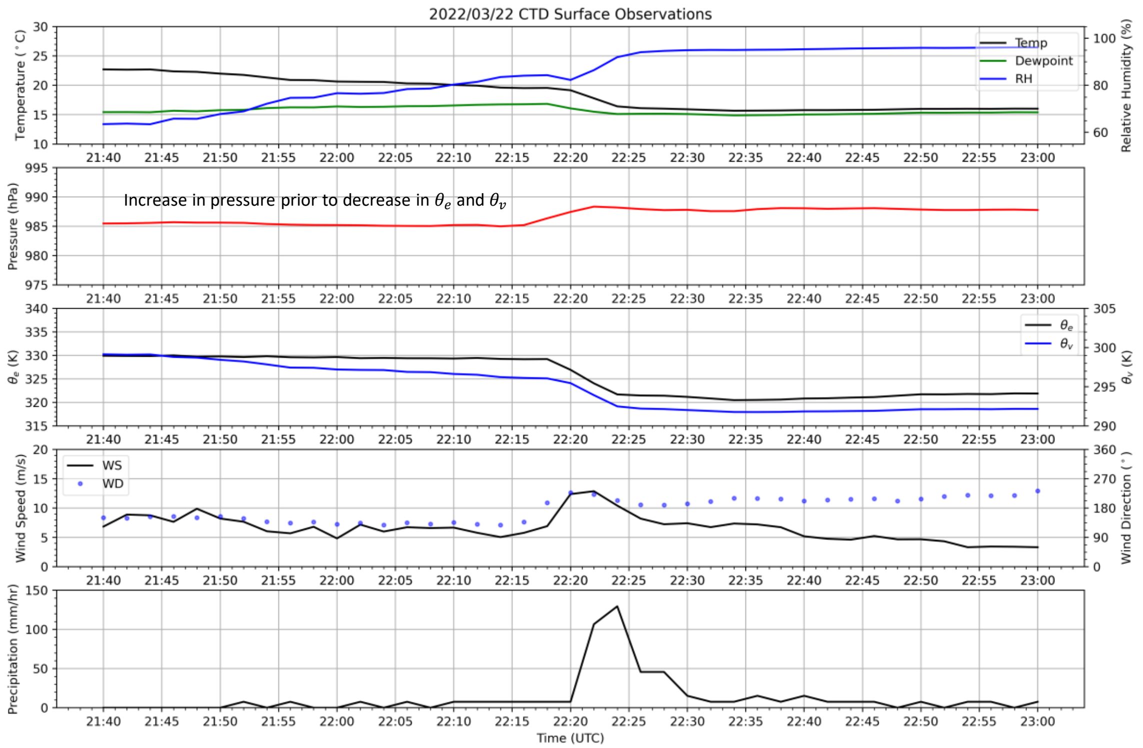


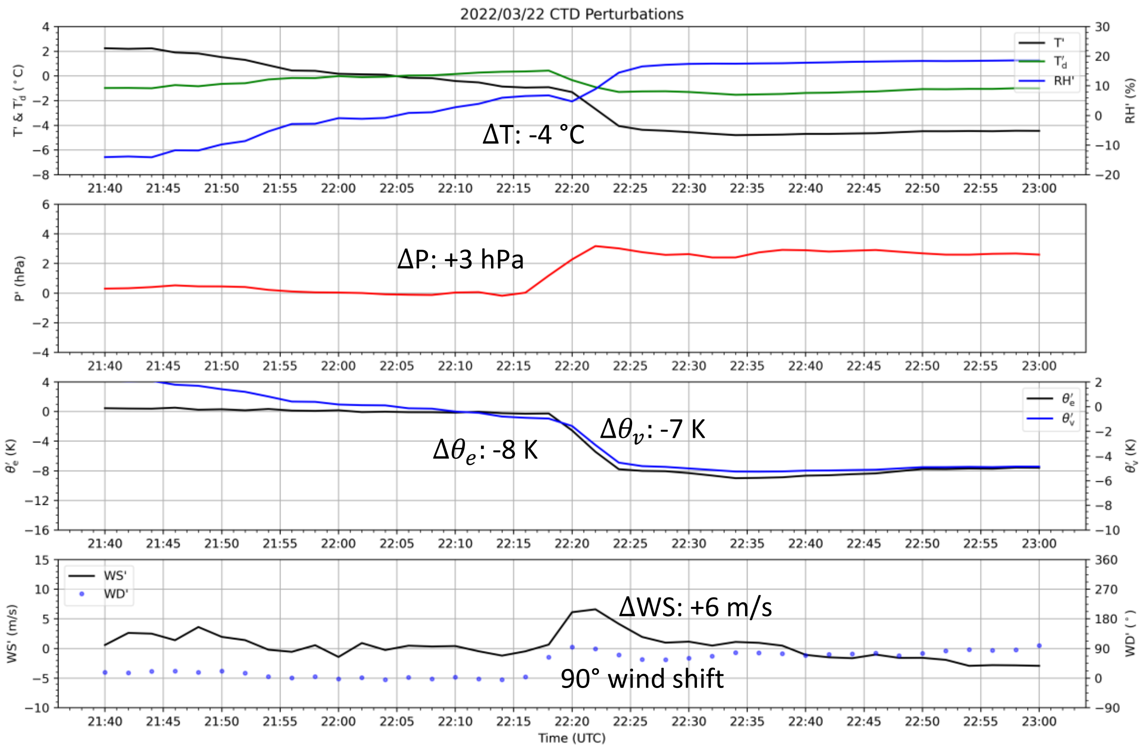

2022/03/22 CTD S-band Reflectivity
Reflectivity core
Bright band
Height (km)
0
2
4
6
8
10
21:40
21:45
21:50
21:55
22:00
22:05
22:10
22:15
22:20
22:25
22:30
22:35
22:40
22:45
22:50
22:55
23:00
Time (UTC)
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
−5
−10
−15
−20
Reflectivity (dBZ)


2022/03/22 S-band Radial Velocity
Height (km)
Time (UTC)
Velocity (m/s)
10.64 m/s at 3.94 km
-18.59 m/s at 1.5 km
8 km
2.7 km
0
2
4
6
8
10
21:40
21:45
21:50
21:55
22:00
22:05
22:10
22:15
22:20
22:25
22:30
22:35
22:40
22:45
22:50
22:55
23:00
16
14
12
10
8
6
4
2
0
−2
−4
−6
−8
−10
−12
−14
−16


2022/03/22 S-band Spectrum Width
~11 m/s at 7.5 km
Increase in spectrum width associated with QLCS passage
Height (km)
0
2
4
6
8
10
21:40
21:45
21:50
21:55
22:00
22:05
22:10
22:15
22:20
22:25
22:30
22:35
22:40
22:45
22:50
22:55
23:00
Time (UTC)
Spectrum Width (m/s)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15

CTD Surface Observations and Perturbations





Summary

- Maximum updraft confined to lowest 4 km
- Maximum downdraft immediately adjacent to updraft due to precipitation offloading
- Increase in spectrum width with QLCS passage
- Gust front observations
  - Temperature decrease and pressure increase observed with passage of gust front
  - Decrease in both θ_e and θ_v observed
    - Pressure increase occurred slightly before θ_e and θ_v decrease
  - Increase in wind speed and change in wind direction (90 degree wind shift)

Acknowledgements

- NOAA Grant NA21OAR4590323
- UAH MAPNet
- NOAA Physical Sciences Laboratory
- Kevin Knupp, Adam Weiner, Joshua Huggins, Matthew Starke, Preston Pangle

References

- Bolton, D., 1980: The Computation of Equivalent Potential Temperature. *Mon. Wea. Rev.,* **108,** 1046-1053, https://doi.org/10.1175/1520-0493(1980)108<1046:TCOEPT>2.0.CO;2
- Hutson, A., C. Weiss, and G. Bryan, 2019: Using the Translation Speed and Vertical Structure of Gust Fronts to Infer Buoyancy Deficits within Thunderstorm Outflow. *Mon. Wea. Rev.*, **147**, 3575-3594, https://doi.org/10.1175/MWR-D-18-0439.1
- Sherburn, K. D., M. D. Parker, 2014: Climatology and Ingredients of Significant Severe Convection in High-Shear, Low-CAPE Environments. *Wea. Forecasting,* **29.** 854-877, https://doi.org/10.1175/WAF-D-13-00041.1