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Title: Near-Continuous Profiling of the Boundary Layer during Bore Passages by Mobile Profiling Systems during PECAN

Conference: NOAA/NESDIS CoRP Symposium

Type of Presentation: Oral

Abstract:

Atmospheric bores are a type of gravity wave that form when a density current interacts with a stable boundary layer. Bores are thought to aid in nocturnal convective initiation by changing boundary layer stability via turbulent mixing and by mechanically lifting air parcels from the stable boundary layer up to the level of free convection. Because of their importance to nocturnal convective initiation, it is important to understand the thermodynamic and dynamic effects that bore passages may have on the stable boundary layer.

The Plains Elevated Convection At Night (PECAN) campaign took place from 1 June to 15 July 2015 in the Central Plains of the United States with the goal of improving the understanding and forecast accuracy of nocturnal convection. Using a network of fixed profiling sites and deploying a network of mobile vehicles, the campaign focused observations on nocturnal convective initiation, boundary layer waves, low-level jets, and mesoscale convective systems. Mobile profiling systems were used to profile the boundary layer for time periods of several hours in locations of interest. The University of Wisconsin Space Science and Engineering Center (SSEC) Portable Atmospheric Research Center (SPARC) and National Severe Storms Laboratory/University of Oklahoma's Collaborative Lower Atmosphere Mobile Profiling System (CLAMPS) were two of the four mobile profiling systems featured during PECAN. Both vehicles retrieve thermodynamic and kinematic profiles of the boundary layer using an Atmospheric Emitted Radiance Interferometer (AERI) and a Doppler Lidar. The Doppler Lidar uses a 1.5 microns laser to measure three-dimensional wind vectors in the boundary layer. AERI measures downwelling infrared radiation from 520 to 3000 $cm^{-1}$ at a spectral resolution of about 1 $cm^{-1}$, from which high-temporal resolution temperature and moisture profiles can be retrieved. In addition to the remote sensing observations, radiosondes were also launched to validate the instruments and offer in situ observations of the boundary layer.

Data collected by CLAMPS and SPARC is used to identify the evolution of the boundary layer during each vehicle's observed bore passages. Characteristic changes of boundary-

layer stability in the pre- and post-bore environment are determined from the vertical observations. This analysis helps characterize changes to the boundary layer induced by bore passages and provide insight into the role of bores in the convective initiation process.

# Near-Continuous Profiling of the Boundary Layer during Bore Passages by Mobile Profiling Systems during PECAN

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# PECAN Overview

- Plains Elevated Convection At Night
- 1 June – 15 July 2015, Central Plains
- Data collection from an assortment of fixed sites and mobile platforms
- Observations from:
  - Aircraft
  - Mobile Doppler radar
  - Mobile mesonets
  - Mobile profiling units

# PECAN Science Objectives

**1.** Initiation and early evolution of elevated convection

**2.** MCS structure and microphysics

**3.** Bores and other mesoscale boundary layer waves

**4.** MCS-scale numerical weather prediction

**Underlying theme:** Determine what observations are needed to observe these phenomena and improve forecasts

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# CLAMPS (OU/NSSL) & SPARC (UW-SSEC) Instrument Suite

- Atmospheric Emitted Radiance Interferometer
- 1.5 μm pulsed Doppler lidar
- Radiosondes and surface meteorology
- High-Spectral Resolution Lidar (SPARC only)

Photo credit: Wayne Feltz, SSEC

Photo credit: David Loveless, AOS

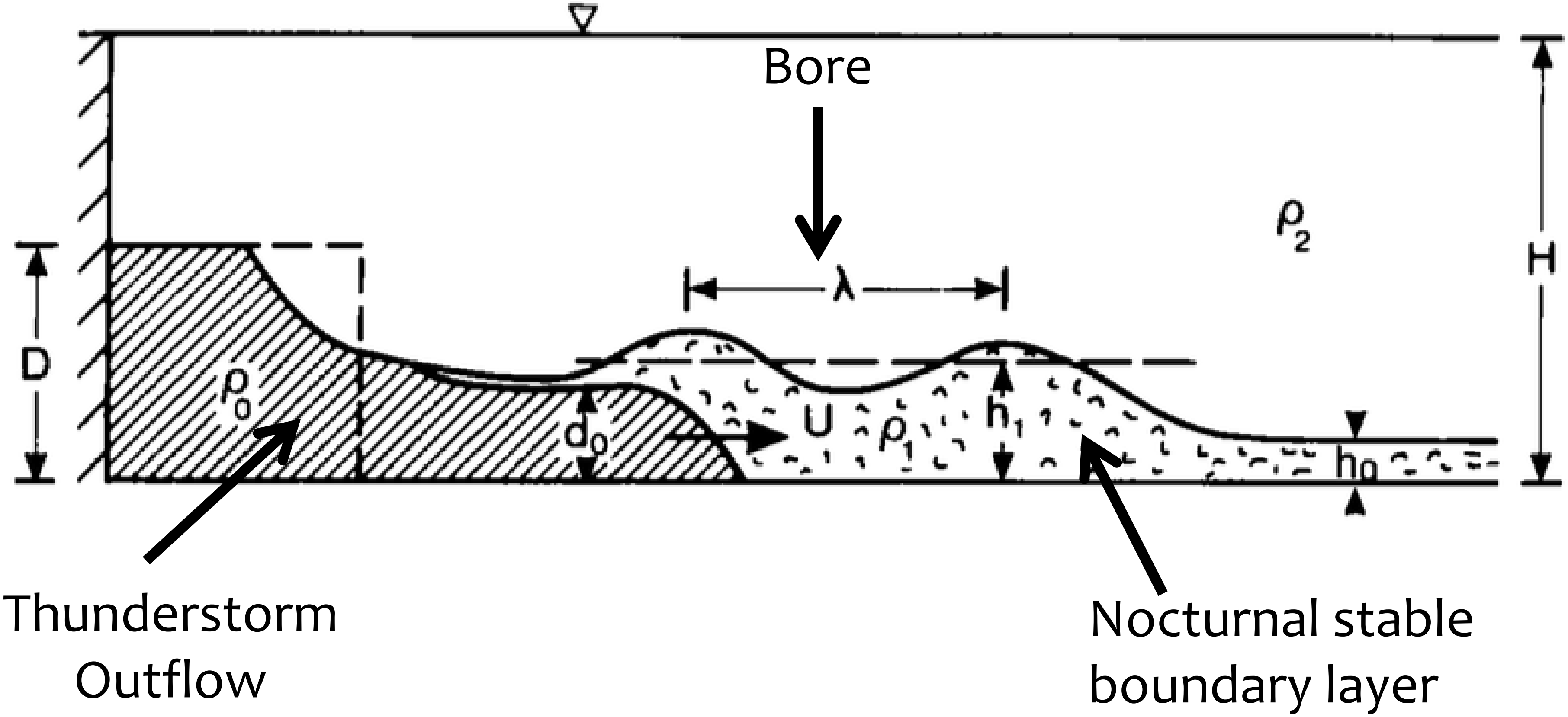
# Atmospheric Emitted Radiance Interferometer (AERI)

- Measures downwelling IR radiation from 3.3 μm to 19.2 μm
- Spectral resolution of 1 $cm^{-1}$
- AERIoe (Turner and Löhnert, *J. Atmos. Oceanic Technol.* 2014)
  - Optimal Estimation retrieval technique
  - First guess: radiosonde climatology (ARM-SGP site)
  - Produce temperature and moisture profiles

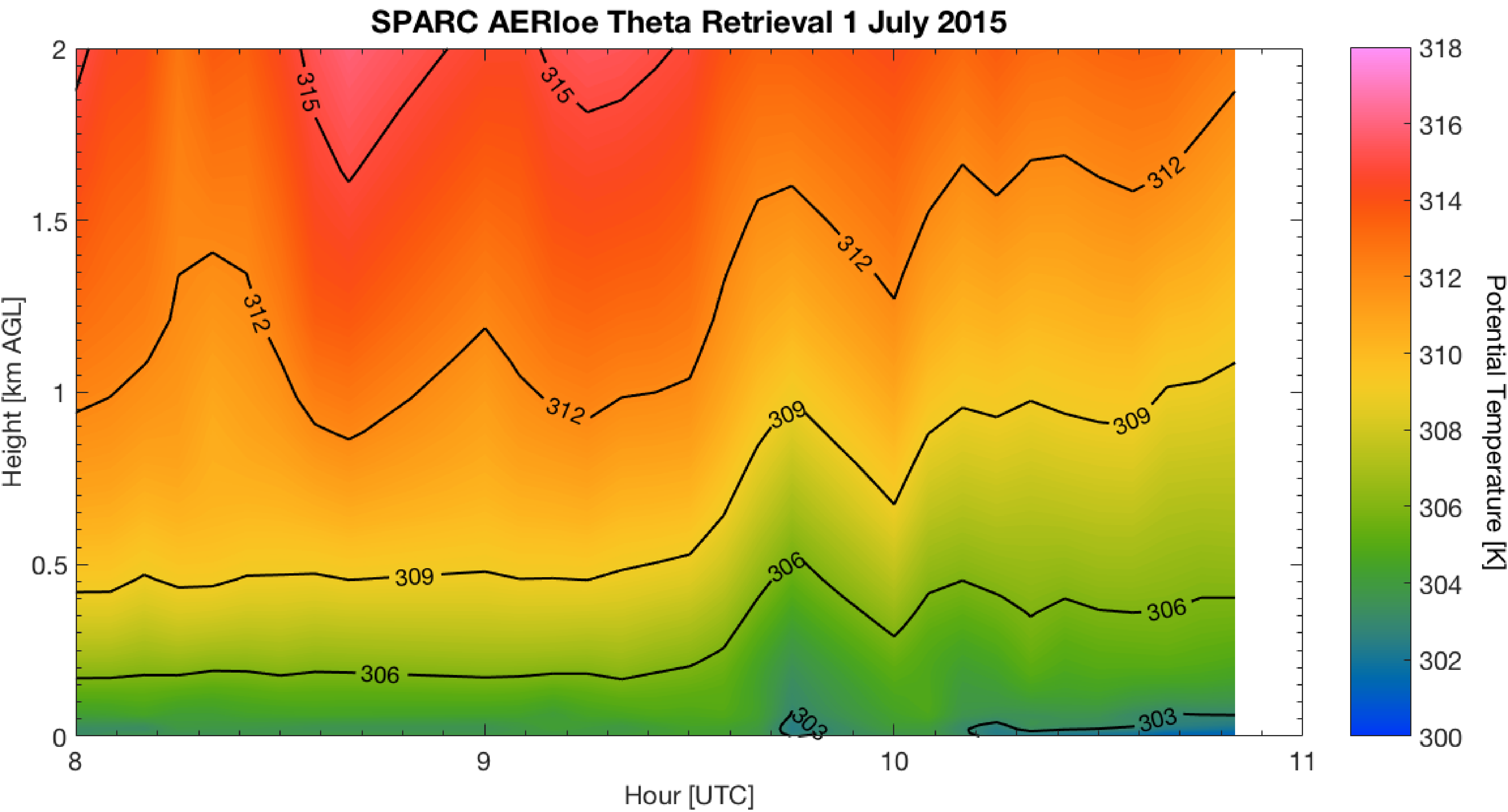
Photo credit: Jon Gero, SSEC

# Pulsed Doppler Lidar

- HALO Photonics (Pearson et al., *J. Atmos. Oceanic Technol.* 2009)
- 1.5 μm laser
- Aerosols and clouds backscatter transmitted pulses
- Horizontal and vertical winds can be analyzed remotely by considering the Doppler shift



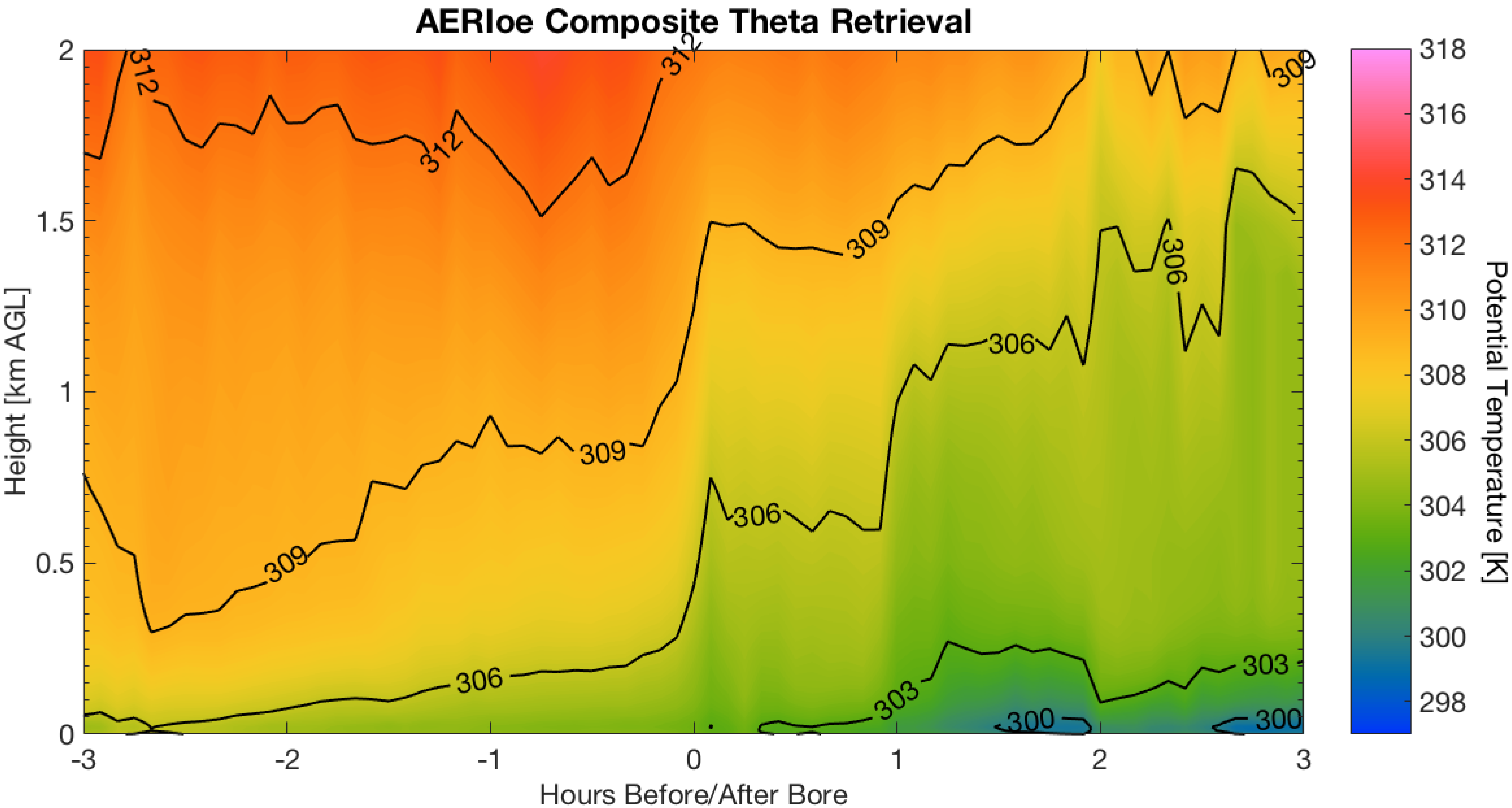

From Rottman and Simpson, 1989, *Q. J. R. Meteorol. Soc.*


SPARC AERIoe Theta Retrieval 1 July 2015
Height [km AGL]
Hour [UTC]
Potential Temperature [K]
315
312
309
306
303
2
1.5
1
0.5
0
8
9
10
11
318
316
314
312
310
308
306
304
302
300

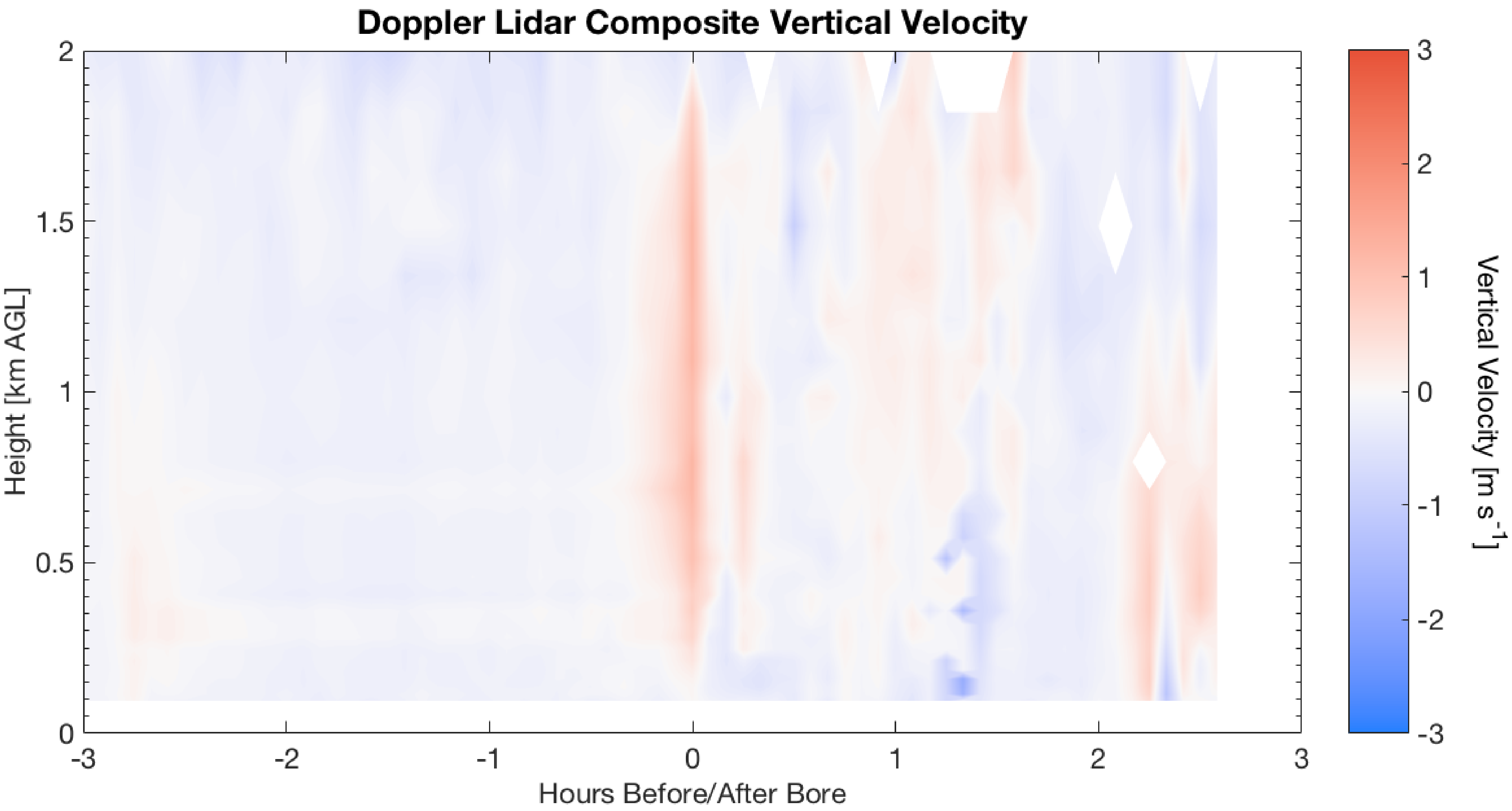
# Composite Analysis

- **Goal: Understand boundary layer evolution during bore passages and implications for convective initiation**
- Identify bore start time as the time of greatest theta change at 0.5 km (subjective criteria)
- Caveat: cases varied with amount of observations available pre- and post-bore

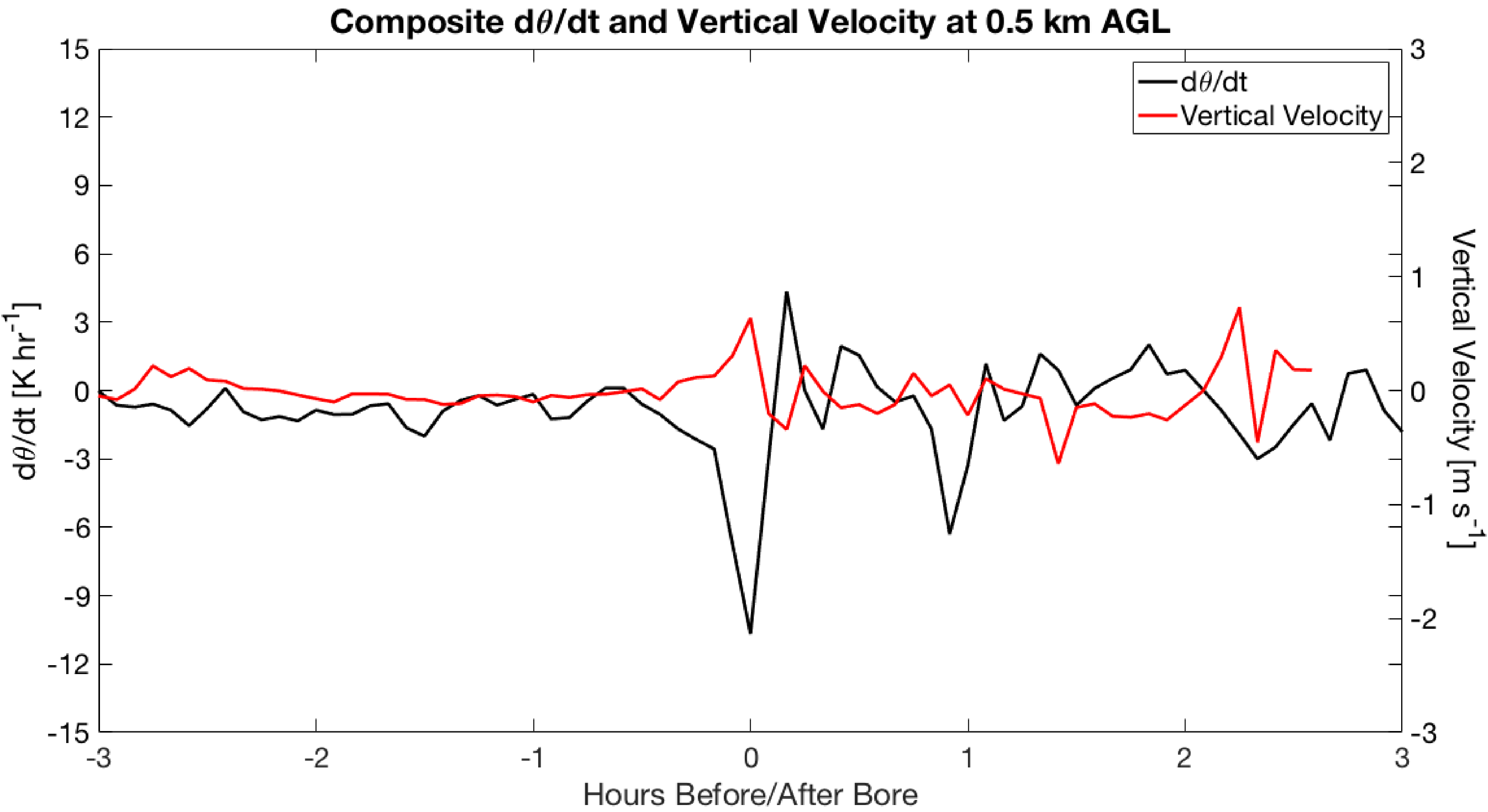
| Date | Platform | PECAN - IOP | Location |
| --- | --- | --- | --- |
| 8 June | SPARC | 6 | Cimarron, KS |
| 8 June | CLAMPS | 6 | St. John, KS |
| 17 June | CLAMPS | 11 | Perry, NE |
| 17 June | SPARC | 11 | Stockville, NE |
| 26 June | CLAMPS | 16 | Madison, KS |
| 26 June | SPARC | 16 | Eureka, KS |
| 1 July | SPARC | 17 | Council Grove, KS |
| 16 July | SPARC | 31 | Chase, KS |



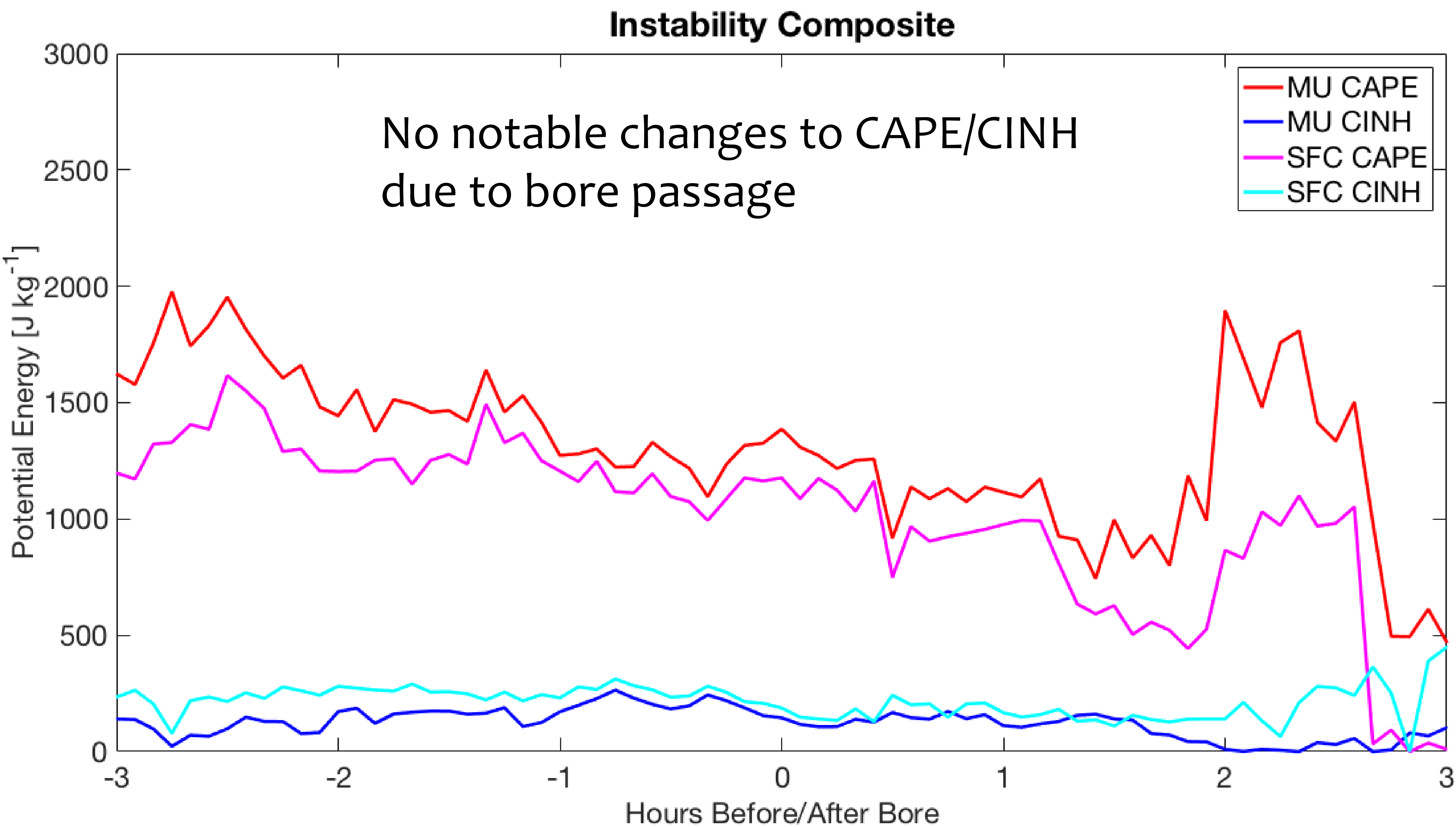
AERIoe Composite Theta Retrieval
Height [km AGL]
Hours Before/After Bore
Potential Temperature [K]
2
1.5
1
0.5
0
-3
-2
-1
0
1
2
3
318
316
314
312
310
308
306
304
302
300
298
312
309
306
303
300

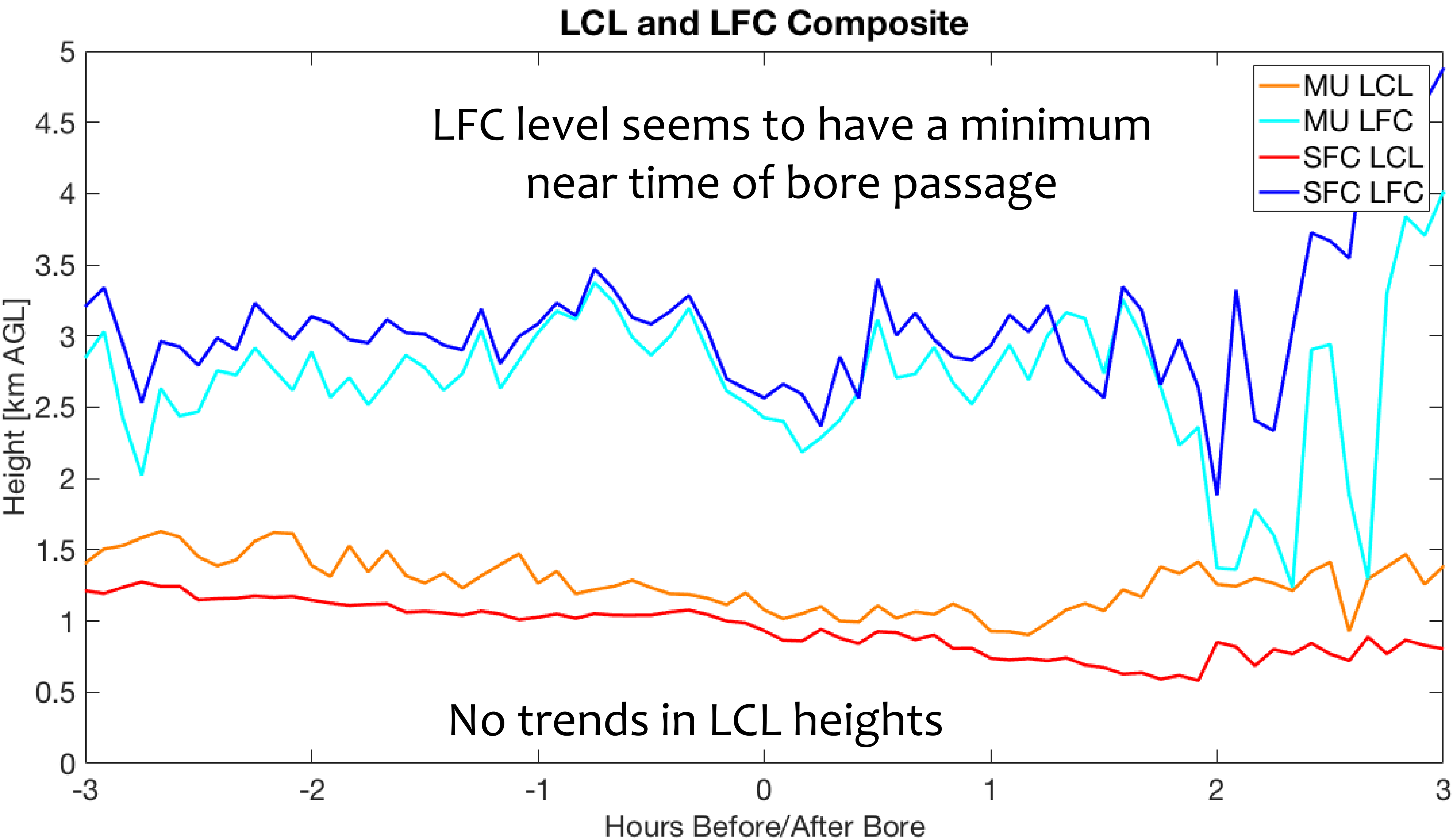


Doppler Lidar Composite Vertical Velocity
Height [km AGL]
Hours Before/After Bore
Vertical Velocity [m s-1]
2
1.5
1
0.5
0
-3
-2
-1
0
1
2
3
3
2
1
0
-1
-2
-3



Composite dθ/dt and Vertical Velocity at 0.5 km AGL
dθ/dt
Vertical Velocity
dθ/dt [K hr-1]
Vertical Velocity [m s-1]
Hours Before/After Bore
15
12
9
6
3
0
-3
-6
-9
-12
-15
3
2
1
0
-1
-2
-3


Instability Composite
No notable changes to CAPE/CINH due to bore passage
MU CAPE
MU CINH
SFC CAPE
SFC CINH
Potential Energy [J kg$^{-1}$]
3000
2500
2000
1500
1000
500
0
-3
-2
-1
0
1
2
3
Hours Before/After Bore



LCL and LFC Composite
LFC level seems to have a minimum near time of bore passage
No trends in LCL heights
MU LCL
MU LFC
SFC LCL
SFC LFC
Height [km AGL]
Hours Before/After Bore
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
-3
-2
-1
0
1
2
3

# Summary

- Composite still displayed the bore structure
- LFC level appears to decrease at the time of the bore passage, would favor convective initiation
- No notable trends in CAPE or CINH
- Future work: Expand analysis to other observing platforms with AERI/Doppler Lidar instrumentation

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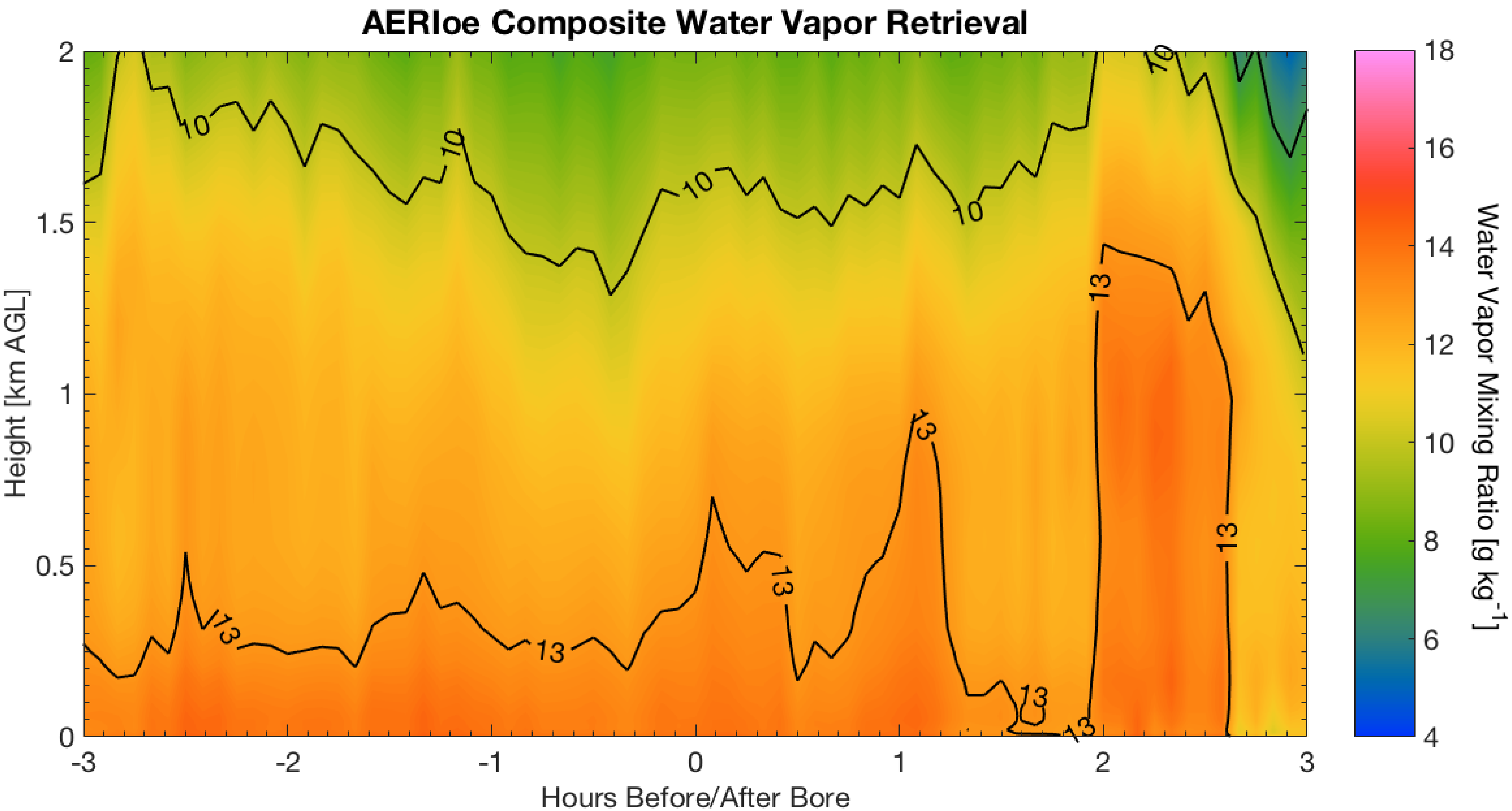
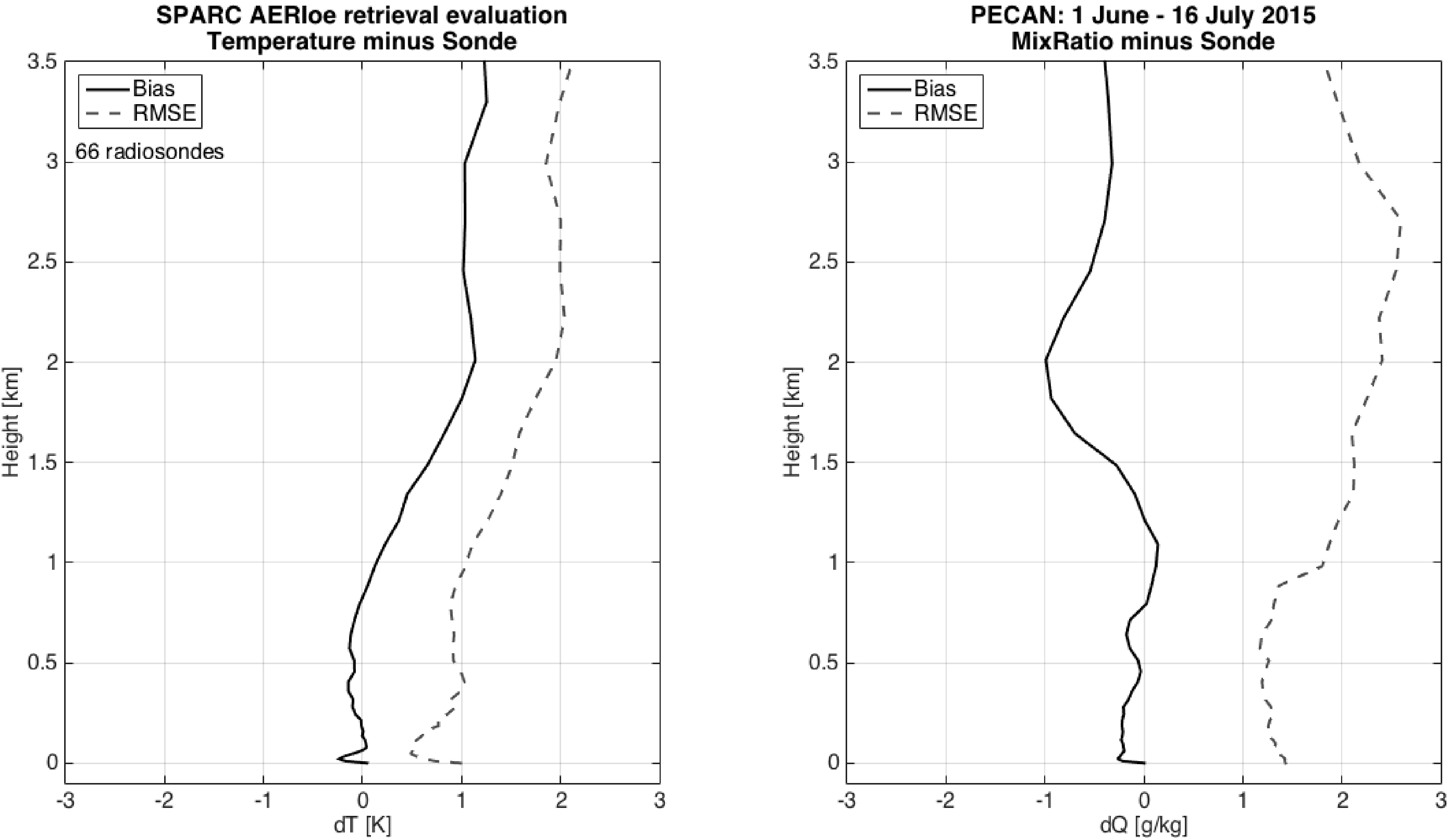
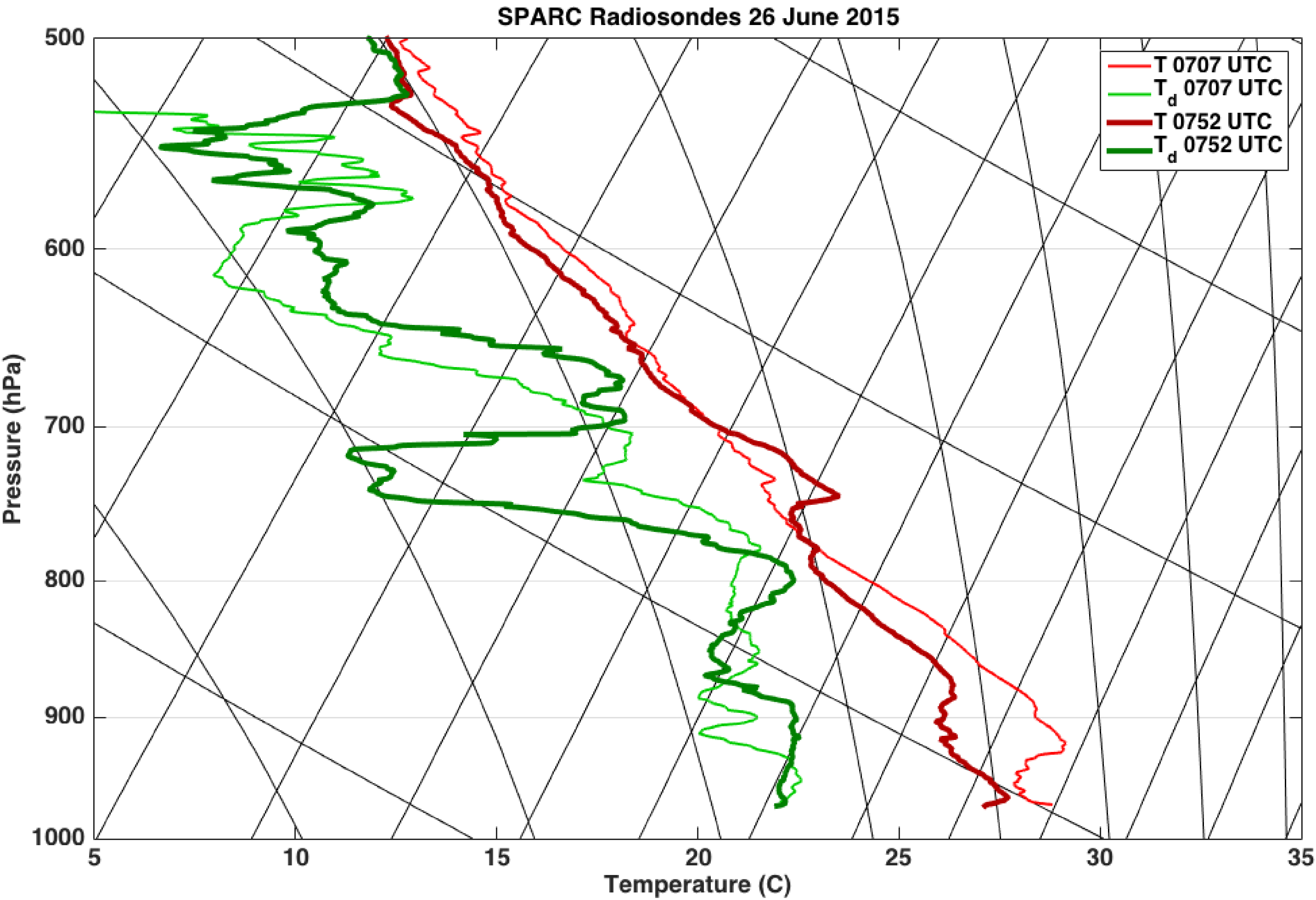


AERIoe Composite Water Vapor Retrieval
Height [km AGL]
Hours Before/After Bore
Water Vapor Mixing Ratio [g kg$^{-1}$]
10
13



SPARC AERIoe retrieval evaluation
Temperature minus Sonde
Bias
RMSE
66 radiosondes
Height [km]
dT [K]
3.5
3
2.5
2
1.5
1
0.5
0
-3
-2
-1
0
1
2
3
PECAN: 1 June - 16 July 2015
MixRatio minus Sonde
Bias
RMSE
Height [km]
dQ [g/kg]



SPARC Radiosondes 26 June 2015
T 0707 UTC
T_d 0707 UTC
T 0752 UTC
T_d 0752 UTC
Pressure (hPa)
500
600
700
800
900
1000
Temperature (C)
5
10
15
20
25
30
35