Water Vapor lidar: The Vaisala Broadband Differential Absorption Lidar (DIAL)

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DOE ASR PI meeting, June 10-14, North Bethesda/Rockville, MD

U.S. DEPARTMENT OF ENERGY

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Background

- There is a need for a national network of (small and cheap) ground-based instruments capable of profiling water vapor and temperature in the atmospheric boundary layer.

- Back in the spring of 2017, Vaisala approached ARM about deploying their new water vapor Differential Absorption Lidar (DIAL) to SGP for evaluation

- Conducted a field campaign at SGP C1 to access performance the Vaisala DIAL
  - 15 May to 12 June 2017
  - Deployed the DIAL next to the Raman lidar
  - Compared water vapor mixing ratio from the DIAL to
    - Raman lidar
    - Radiosonde
    - AERI

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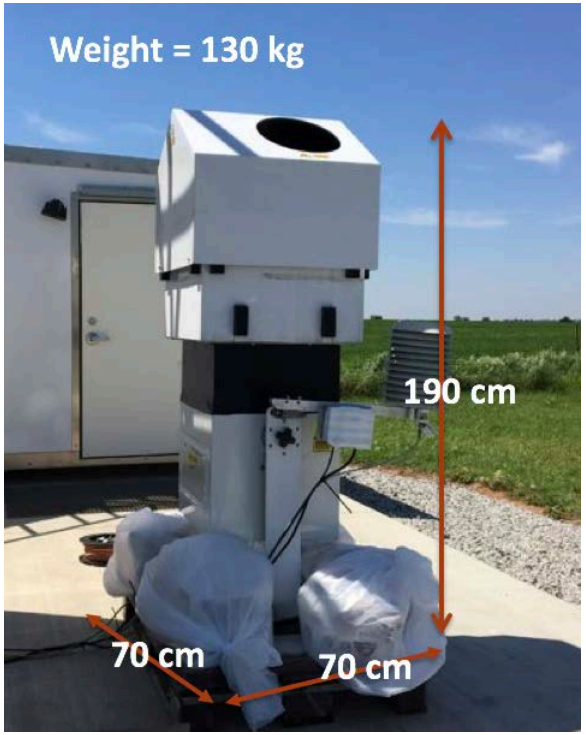
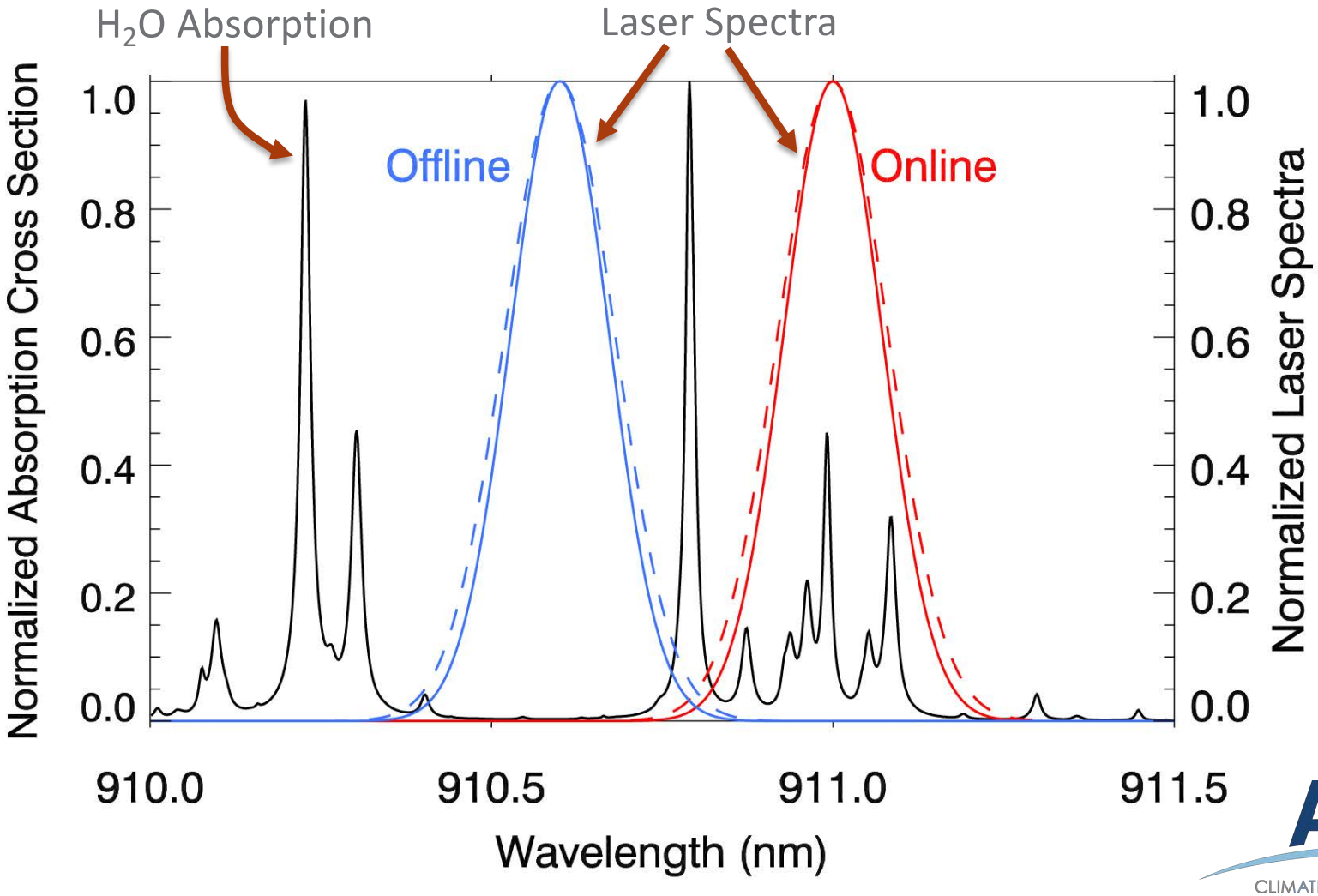


The Vaisala Broadband DIAL

- The Vaisala DIAL is unique in the sense that it uses a broadband approach.



Normalized water vapor absorption cross section at **296K and 1 atm** (black). The normalized laser spectra for **the far-field (solid) and near-field (dashed)** are shown in red for the online laser, and blue for the offline laser spectra.

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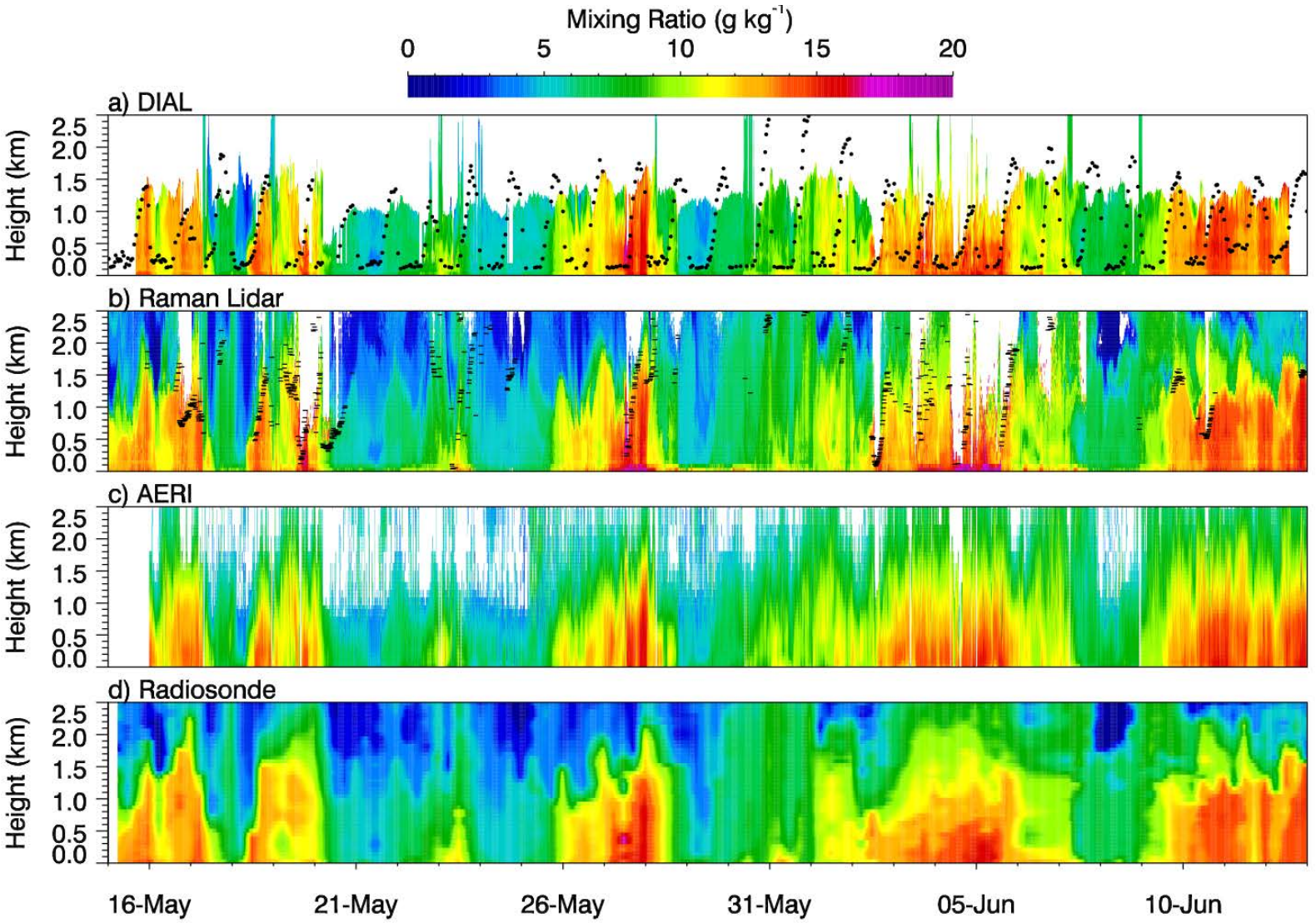
Qualitative Comparisons



DIAL

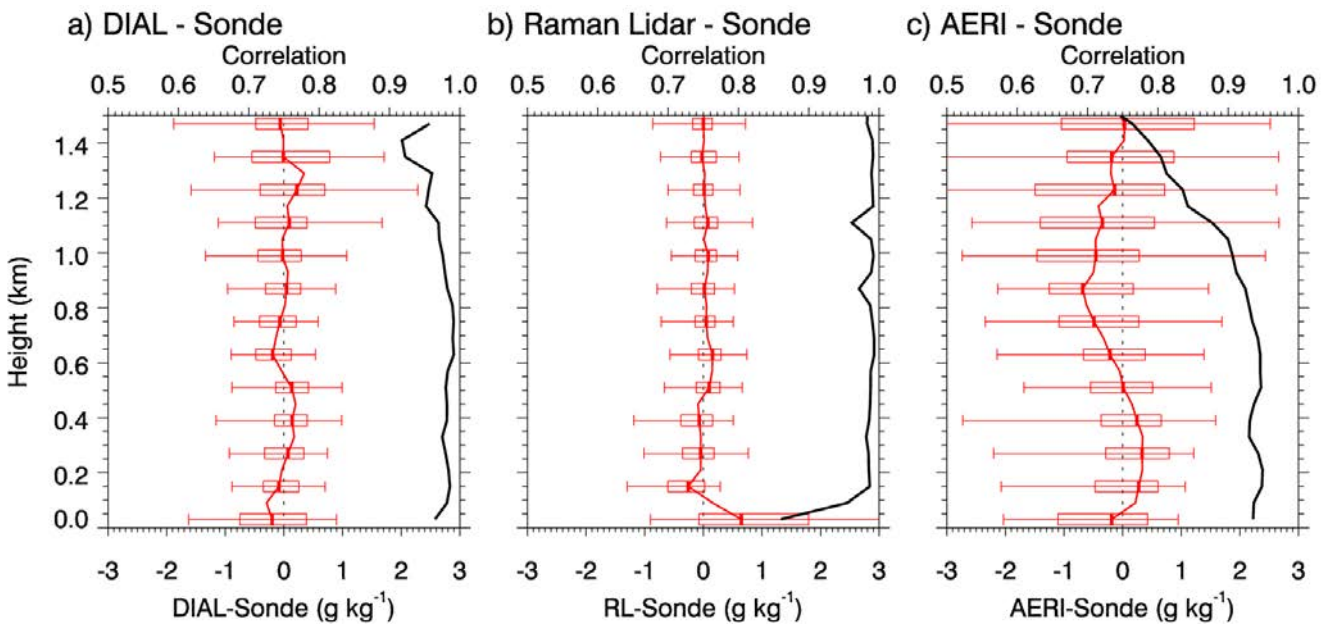
Raman lidar

AERI

Radiosonde (interpolated)

Quantitative comparisons

Profiles

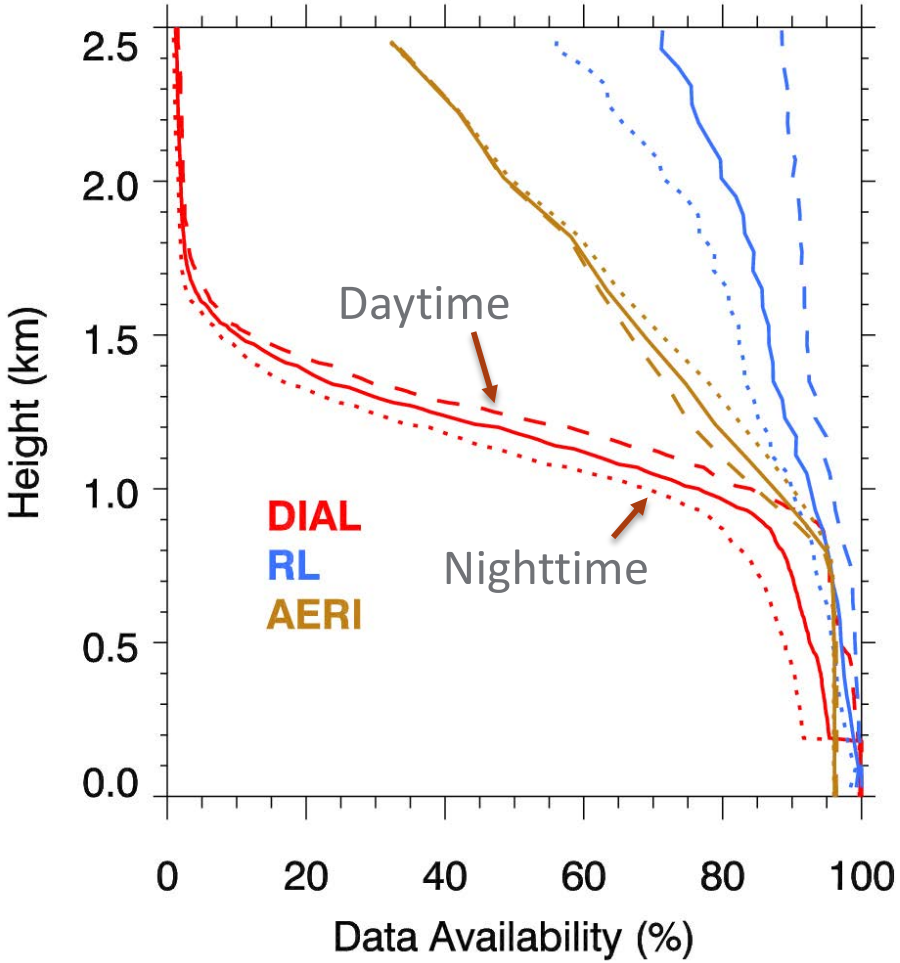


Overall

	DIAL-Sonde	RL-Sonde	AERI-Sonde
Bias (g kg^{-1})	-0.01	0.07	-0.23
StDev (g kg^{-1})	0.65	0.74	1.23
Corr	0.98	0.97	0.92
Mean percent difference (%)	0.42	0.87	-2.0

Data Availability

- Data availability for the DIAL was greater than 90 % below 900 m, but then decreases rapidly with height above this level to less than 10% above 1500 m AGL



Data availability is computed by adding the number of valid samples at a fixed height and dividing by the total number of time samples that were possible.

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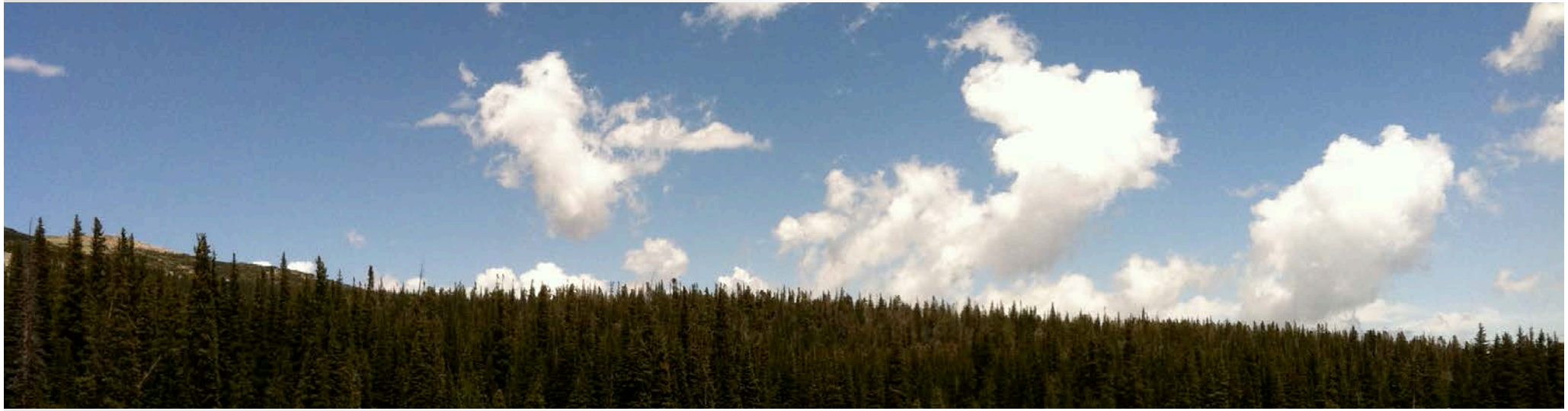
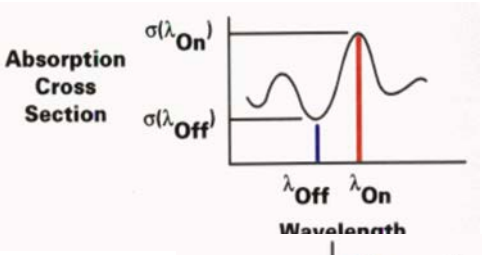
The NCAR / Montana State University Micropulse Water Vapor DIAL

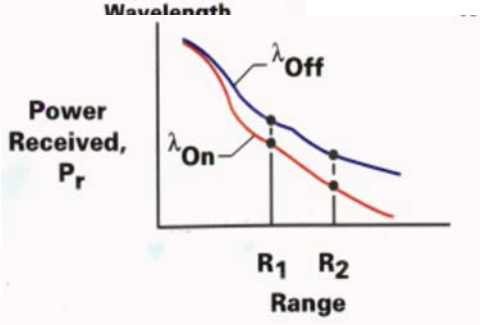
Scott Spuler[1], Tammy Weckwerth[1], Matt Hayman[1],
Robert Stillwell[1], Kevin Repasky[2], Dave Turner[3]
[1]National Center for Atmospheric Research, [2]Montana State University, [3]NOAA / Earth System Research Laboratory

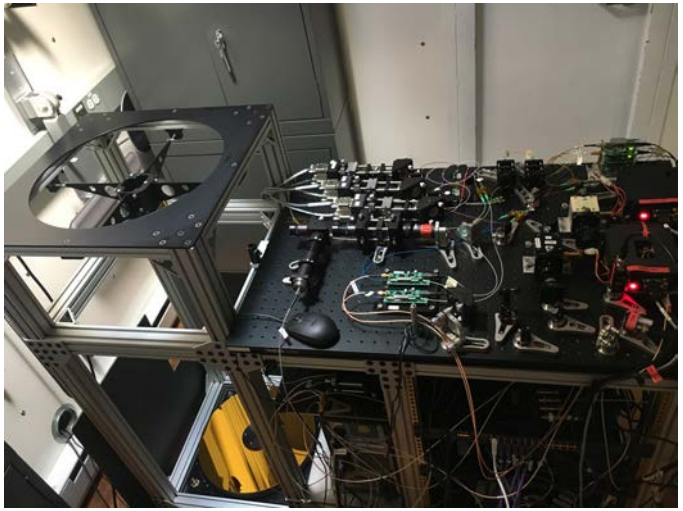


NCAR Water Vapor Differential Absorption Lidar (nDIAL)

- Laser-based active remote sensor
- Developed at NCAR and Montana State University
  - Based upon prototype developed at MSU
- Micropulse system using diode-based lasers
- Automated instrument; self-calibrating (narrowband approach)
- Deployed during FRAPPE, PECAN, Perdigao, and LAFE
- Lowest good data level: ~500 m AGL







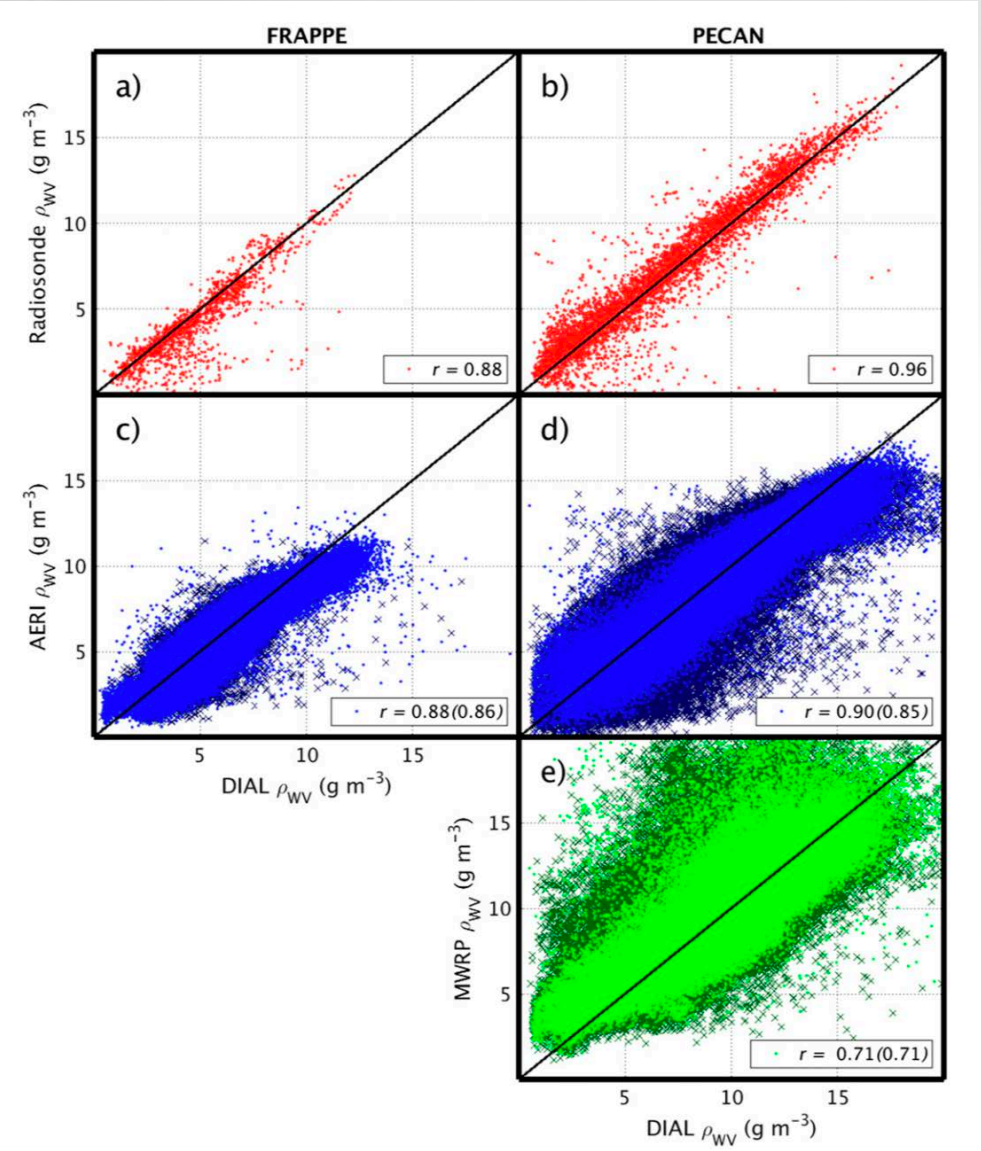
Still research based system
(NCAR now has 5 of these in their instrument pool)

Spuler et al. AMT 2015

Comparisons with Others Sensors

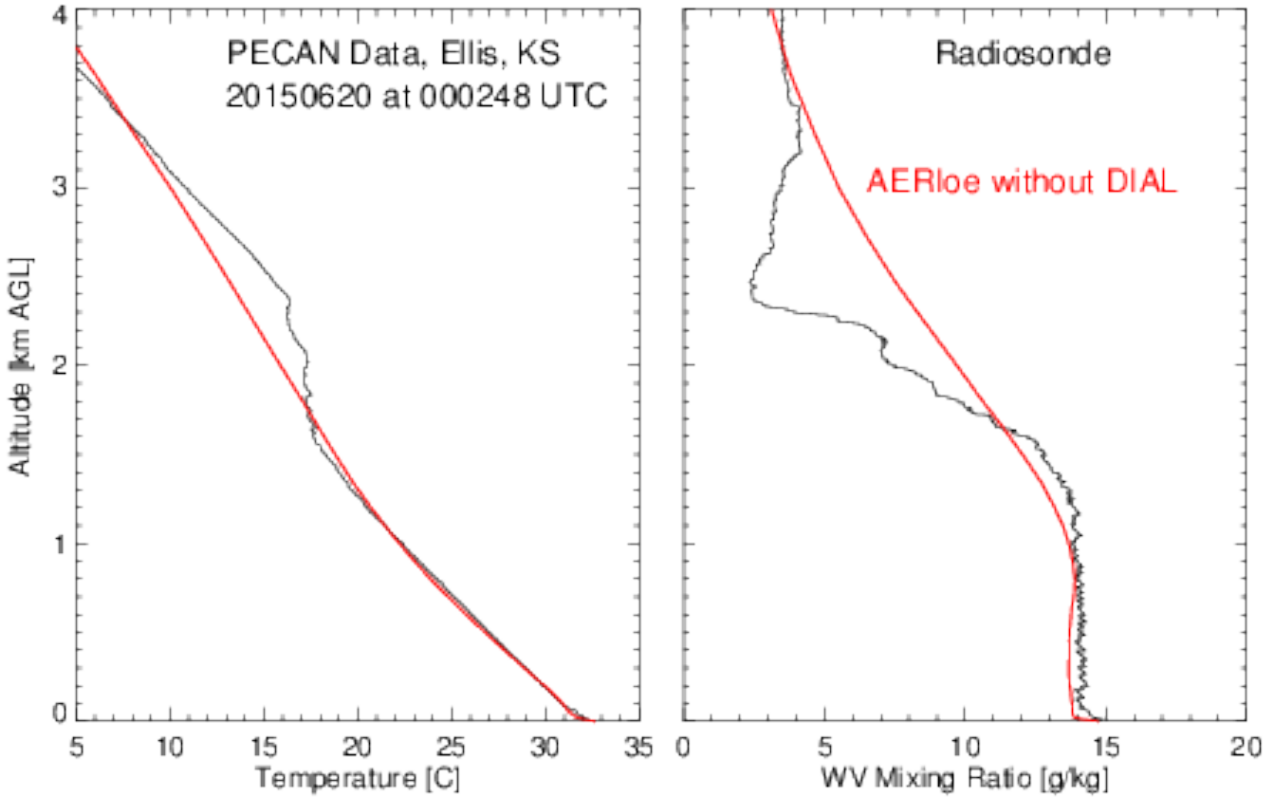
- Two different field campaigns
  - FRAPPE near Boulder CO, 2014
  - PECAN in Hays KS, 2015
- Comparisons of the nDIAL with
  - **Radiosondes**
  - **AERI retrievals**
  - **MWR retrievals**

Weckwerth et al. JTECH 2016



Combining Observations within the Retrieval

PECAN on 20 Jun 2015 at 0248 z



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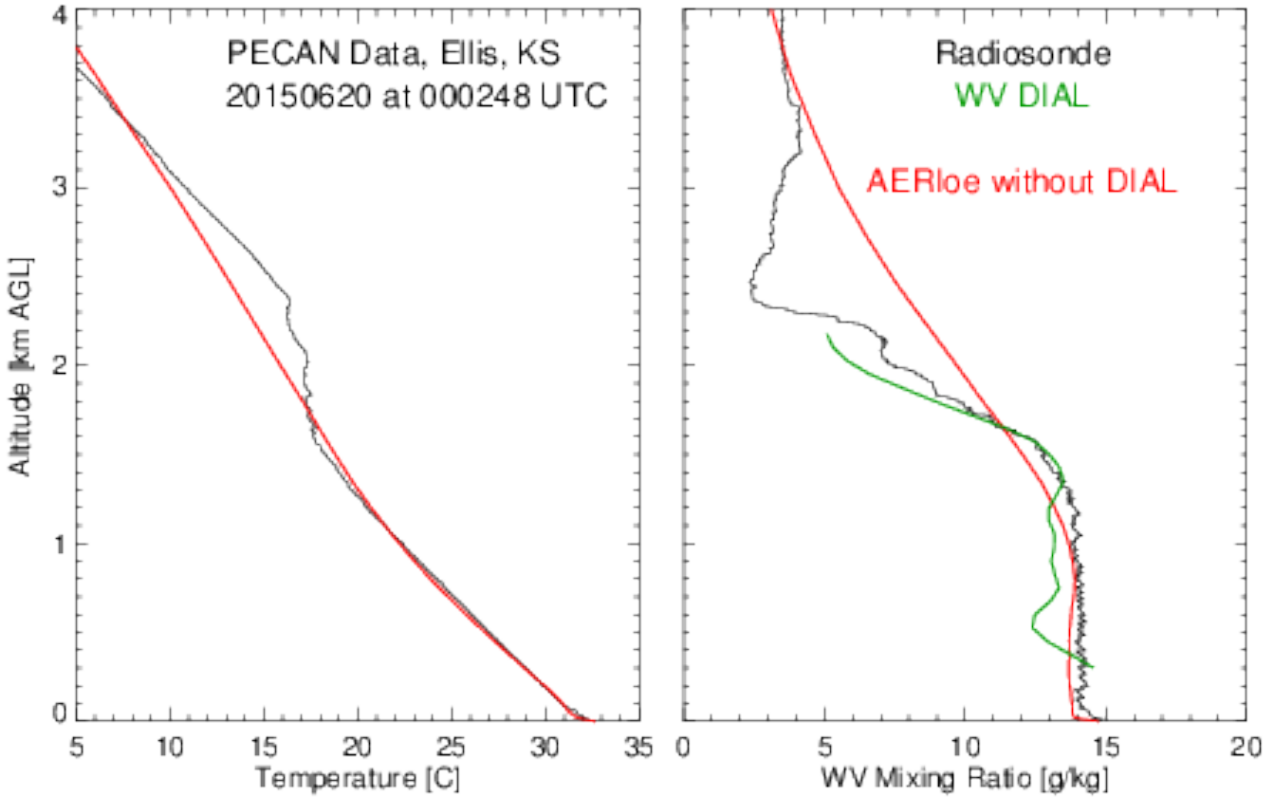

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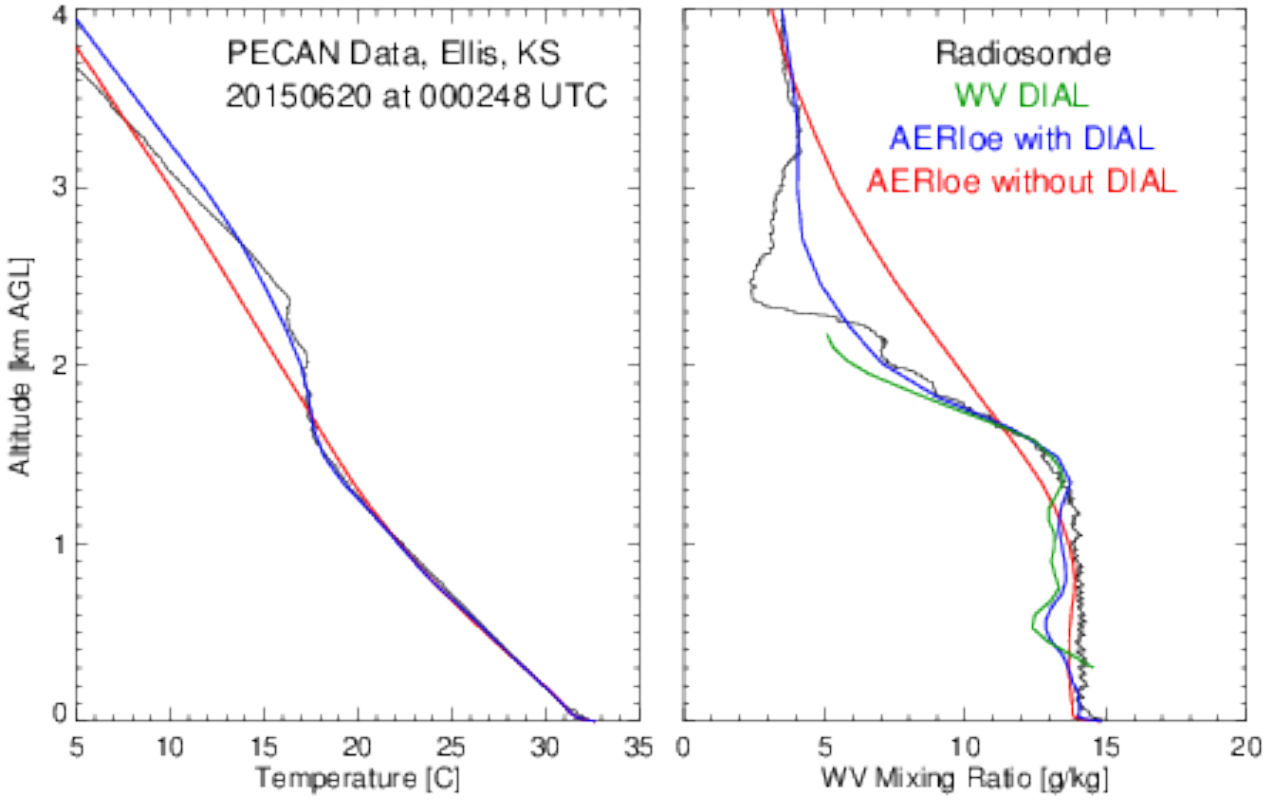
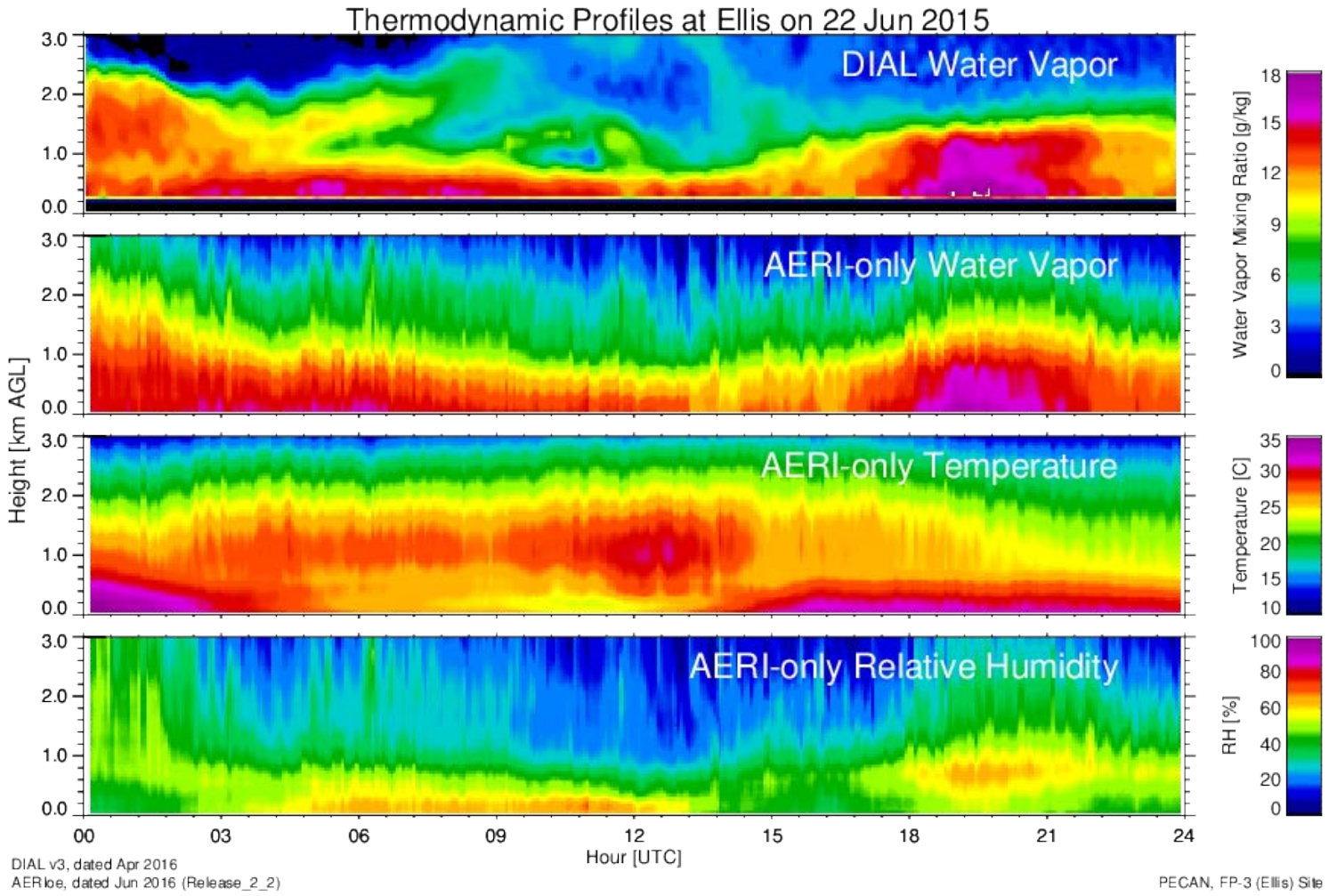
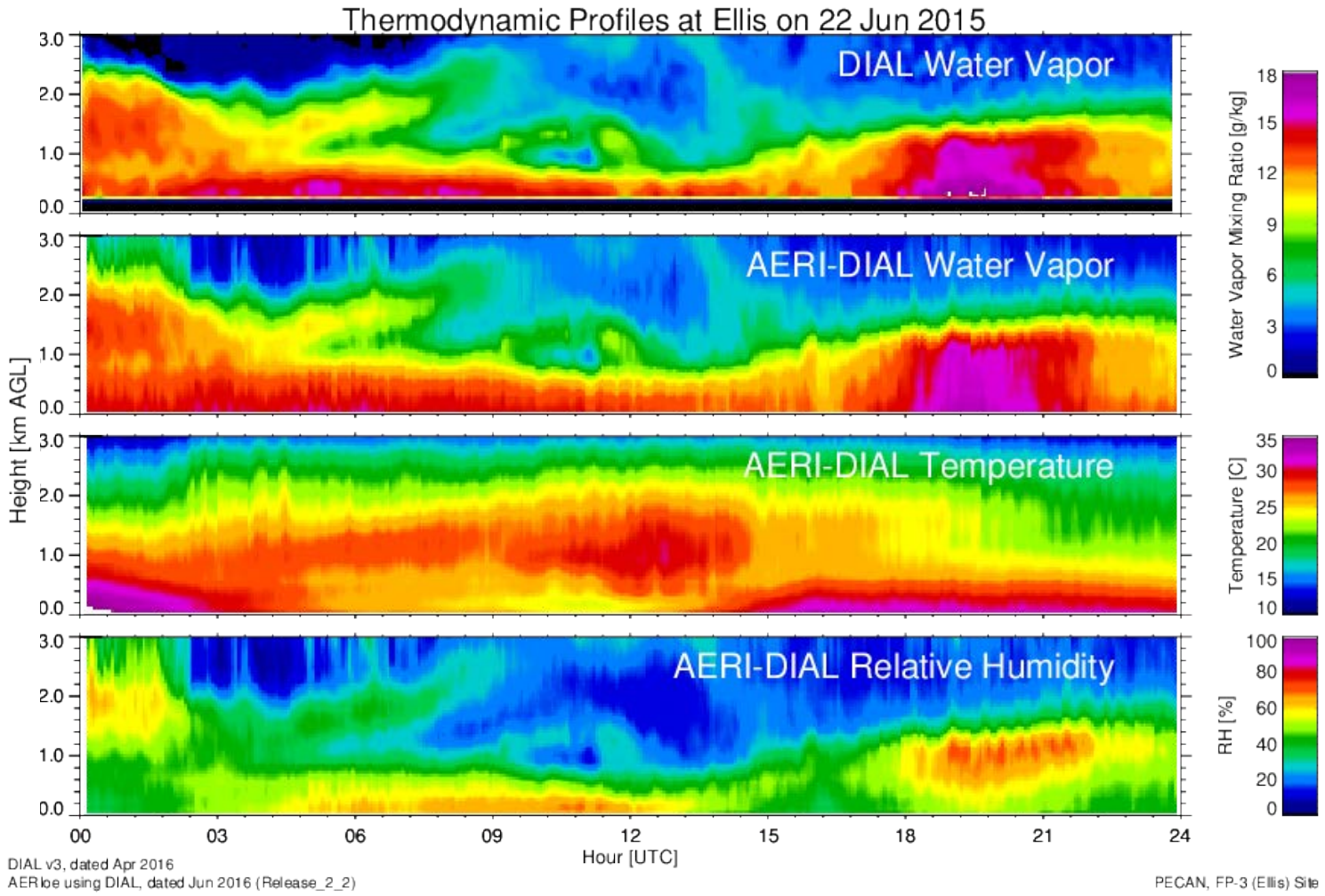


DIAL and AERI-only Retrievals

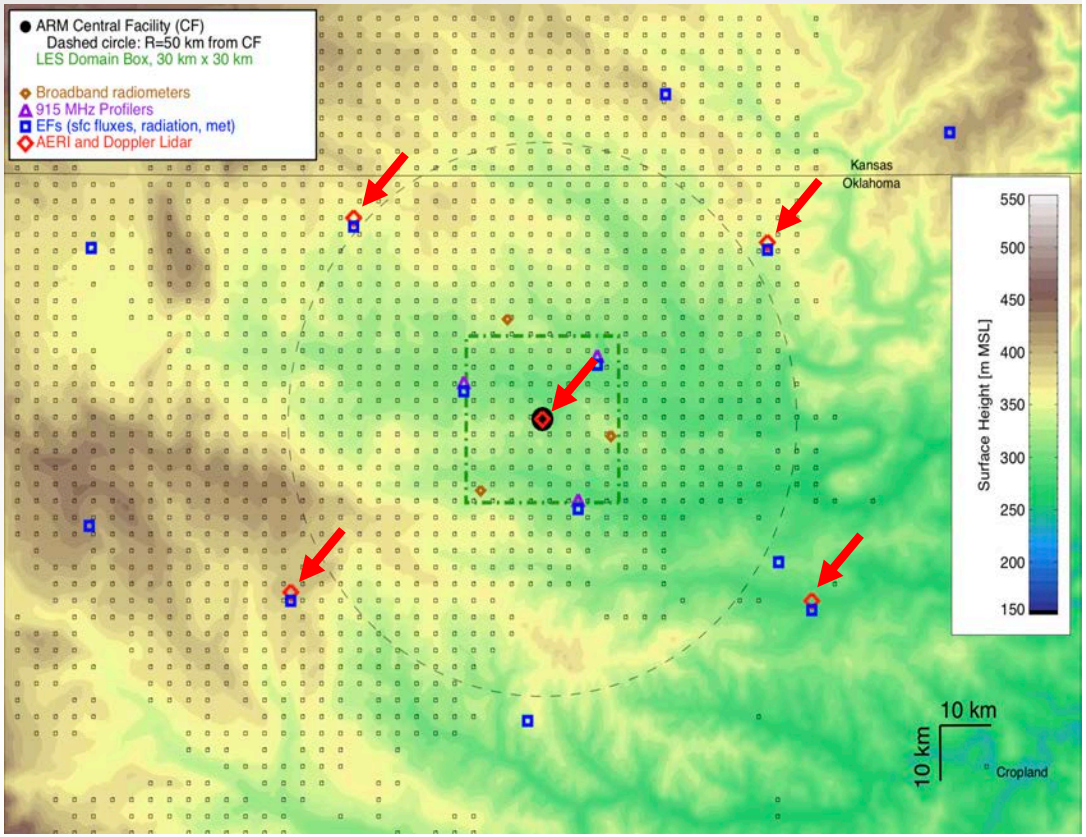


DIAL and AERI+DIAL Retrievals



Testing the Value of the DIALs in a Network

- MPD Network Demonstration IOP
- SGP site, 22 April – 19 July 2019
  - Five systems deployed at C1, E32, E37, E39, and E41
  - Each site has complementary instruments: AERIs, Doppler lidars, SEB
  - Sondes at 8/day from C1
- Objectives:
  - Quantify mesoscale variability in water vapor
  - Improve understanding of convective processes
  - Demonstrate impact of improved NWP and CAM forecasts via data assimilation
- Prototype system at C1 that also has HSRL capability, and is demonstrating O_2 DIAL to profile temperature



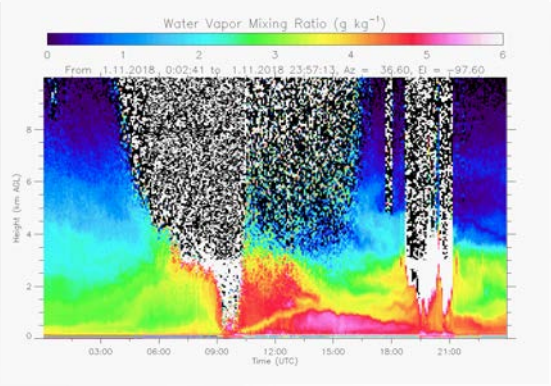
Compact Automatic Rotational Raman Lidar System for Continuous Day- and Nighttime Temperature and Humidity measurements

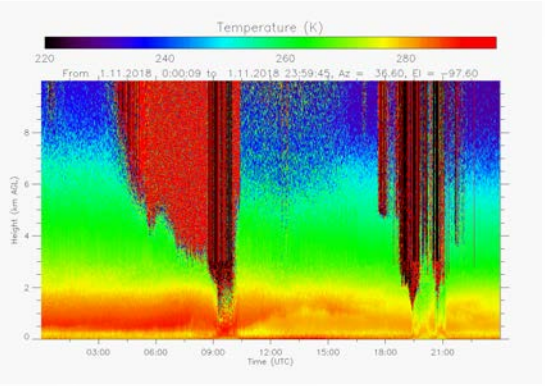
Volker Wulfmeyer, Diego Lange, Andreas Behrendt, Shravan Muppa
Institute of Physics and Meteorology (IPM)
University of Hohenheim (UHOH)
Stuttgart, Germany

MOSES
Modular Observation Solutions for Earth Systems

https://www.ufz.de/moses

Helmholtz Centre for Environmental Research (UFZ)

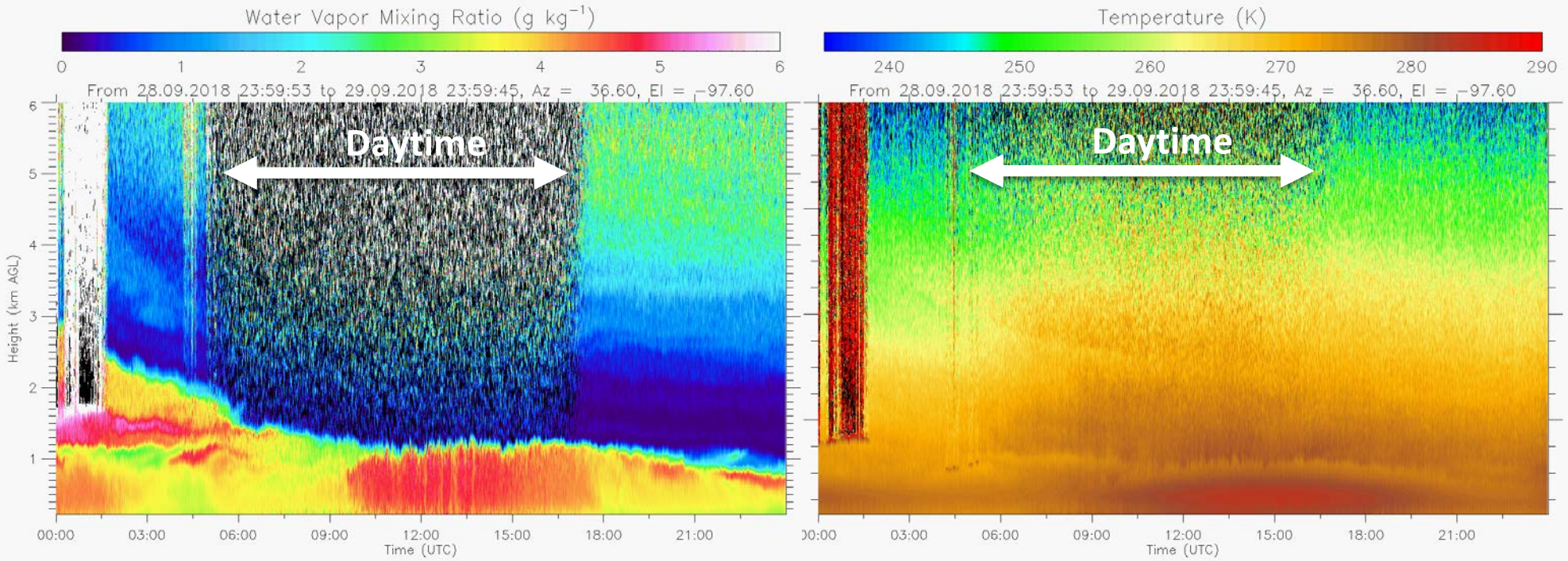




Severe gaps in the observation of thermodynamic profiles must be closed in order to advance our understanding of Earth system processes (*Wulfmeyer et al. Rev. Geophys. 2015*).

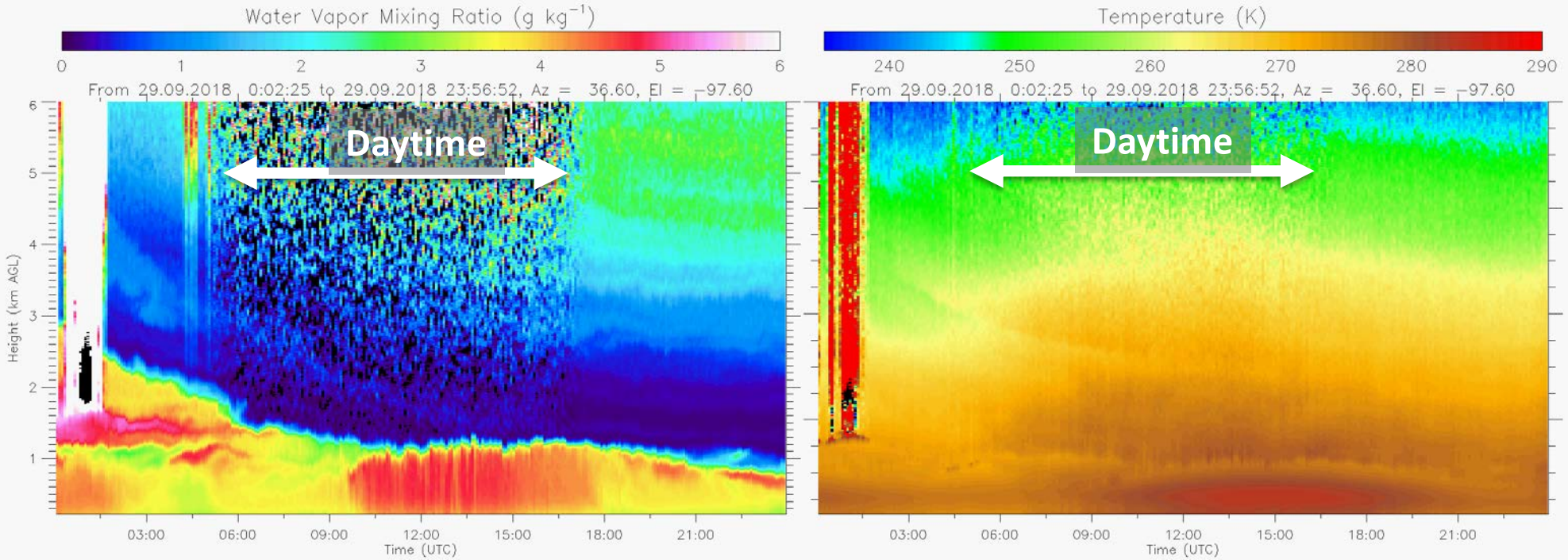
10 s, 100 m

WVTRL Performance



300 s, 100 m

WVTRL Performance



Summary

- Three new water vapor lidars have been developed recently
  - Vaisala system
    - Broadband water vapor DIAL (diode-based lasers)
    - Was evaluated at SGP in May-June 2017 (sondes, Raman lidar, AERI)
    - Being evaluated by Canadian and German weather services (ECCC and DWD)
    - Commercially available ~2021
  - NCAR / Montana State system
    - Narrowband water vapor DIAL (diode-based lasers)
    - Evaluated against sondes, AERI, and MWR during PECAN and FRAPPE
    - Developed 5 of these for the NCAR instrument pool
    - Currently deployed all 5 at the SGP site (April through July)
  - Univ Hohenheim water vapor and temperature Raman lidar
    - Water vapor capability very similar to ARM Raman lidar
    - Temperature capability is exceptional
    - Prototype deployed (in a truck) at SGP during LAFE; now much smaller package
    - Being run autonomously now in field campaign near Munich, come to SGP in 2020?
- Combining with other instruments (e.g., AERI) offers lots of synergy