LOTOS

(LOwer Troposphere Observing System): A proposed instrument suite

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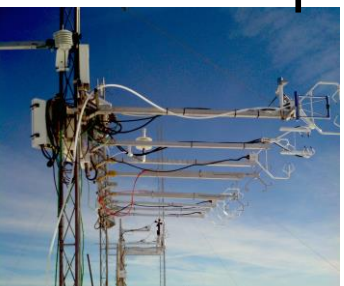
Earth Observing Laboratory
National Center for Atmospheric Research

LOTOS is:

- Proposed as a configurable and scalable integrated suite of automated ground-based in-situ and remote sensors for weather and climate research

LOTOS is designed to:

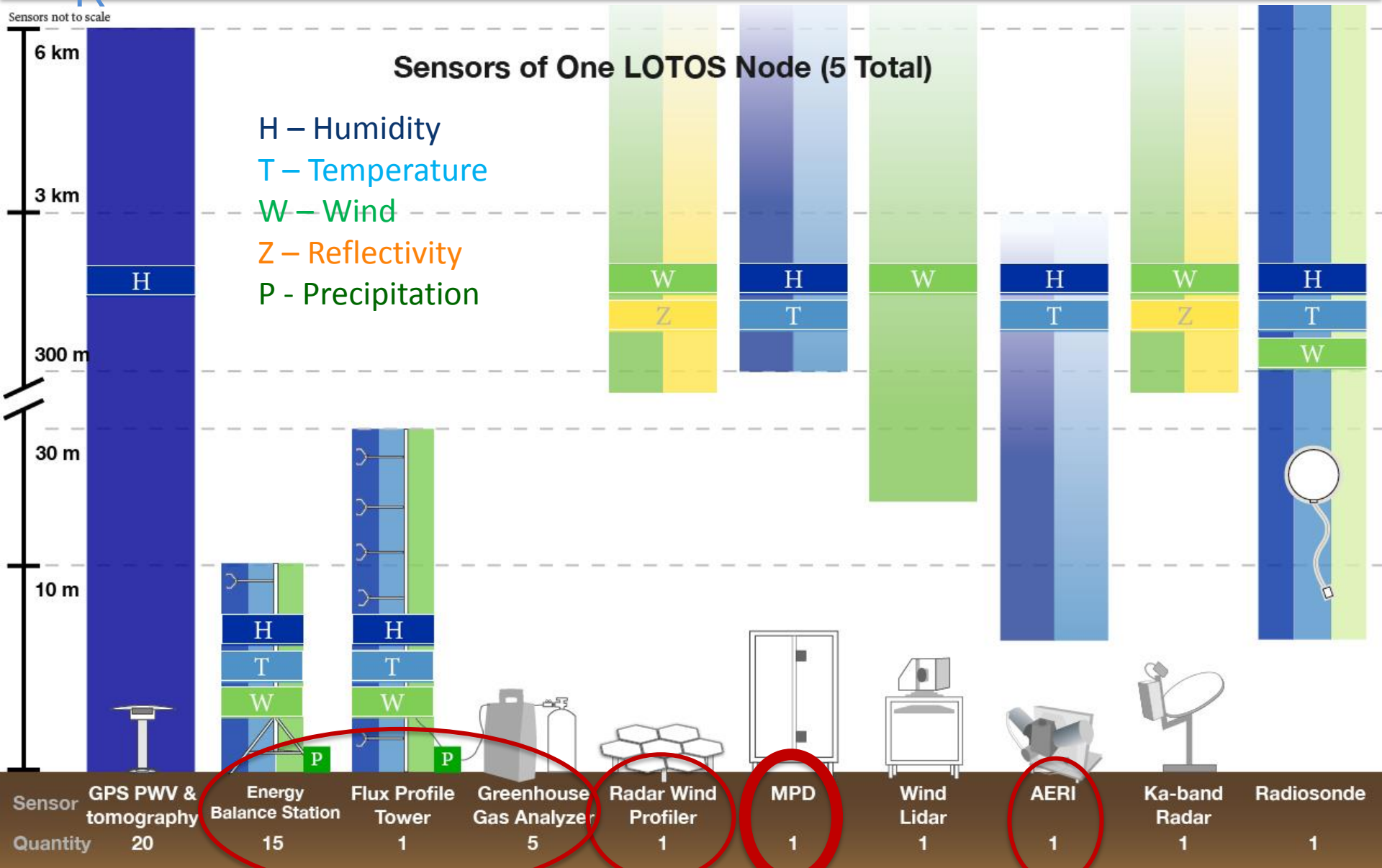
- Provide quasi-3-D sensing of the lower troposphere with horizontal distribution of properties at the Earth's surface
- Provide U, T and WV profiles from five nodes
- Provide multiple observations of exchange processes across the land-surface interface and between BL and the free atmosphere





LOTOS Components

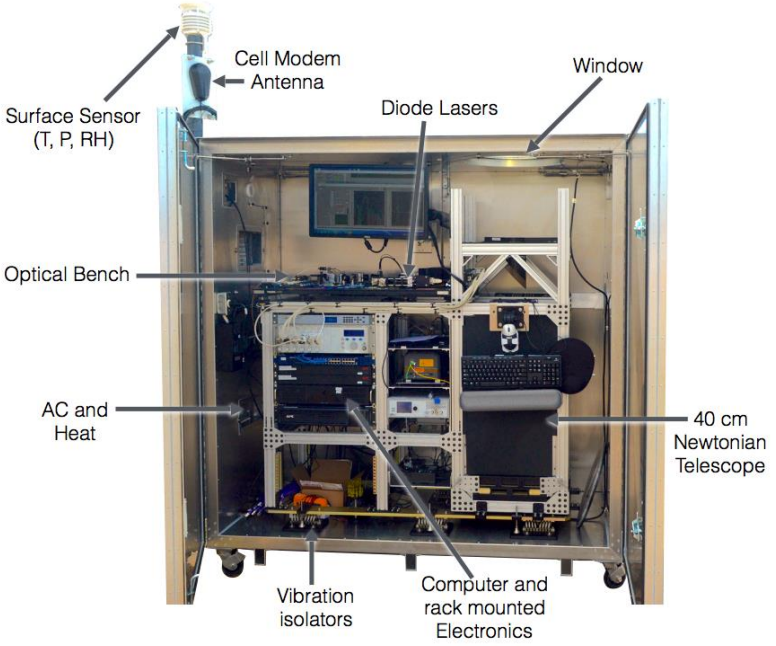
Complementary in-situ and remote sensors



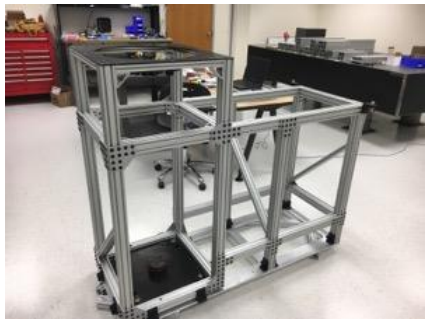
LOTOS Profiling: Water Vapor & Temperature

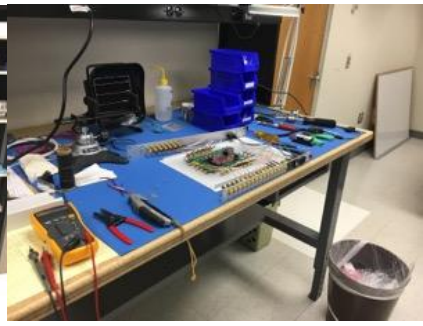
MPD Development

- Two tunable wavelengths (Near IR: 828 nm)
- Water Vapor Micro-Pulse DIAL (MPD) for measuring vertical profiles of water vapor up to 3-5 km AGL
- Network of five MPDs current testing in U.S. Southern Great Plains
- Calibrated aerosol addition via HSRL (780 nm)
- Efforts toward temperature MPD (770 nm)





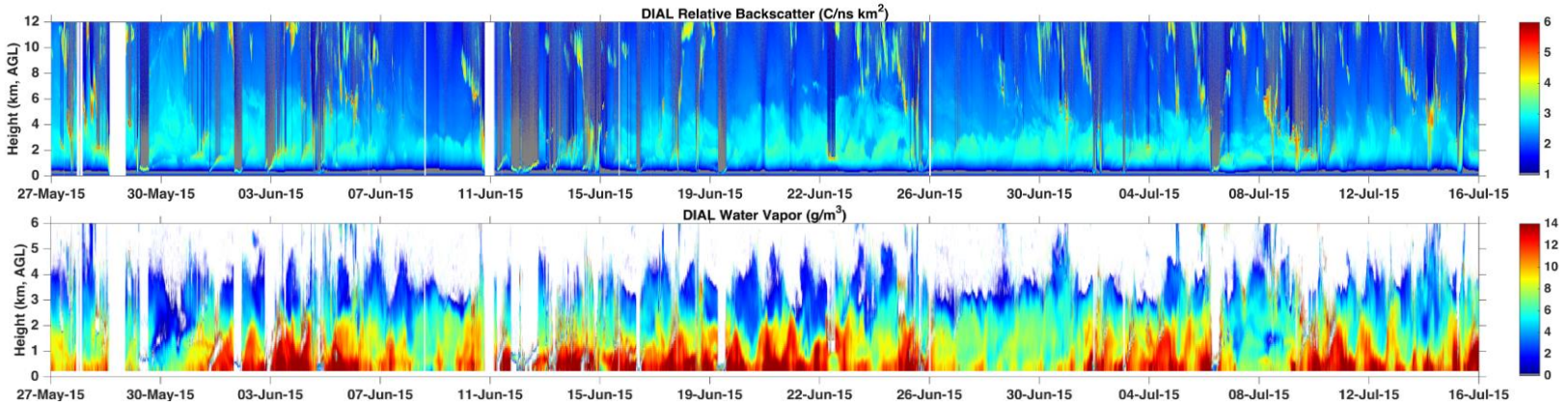




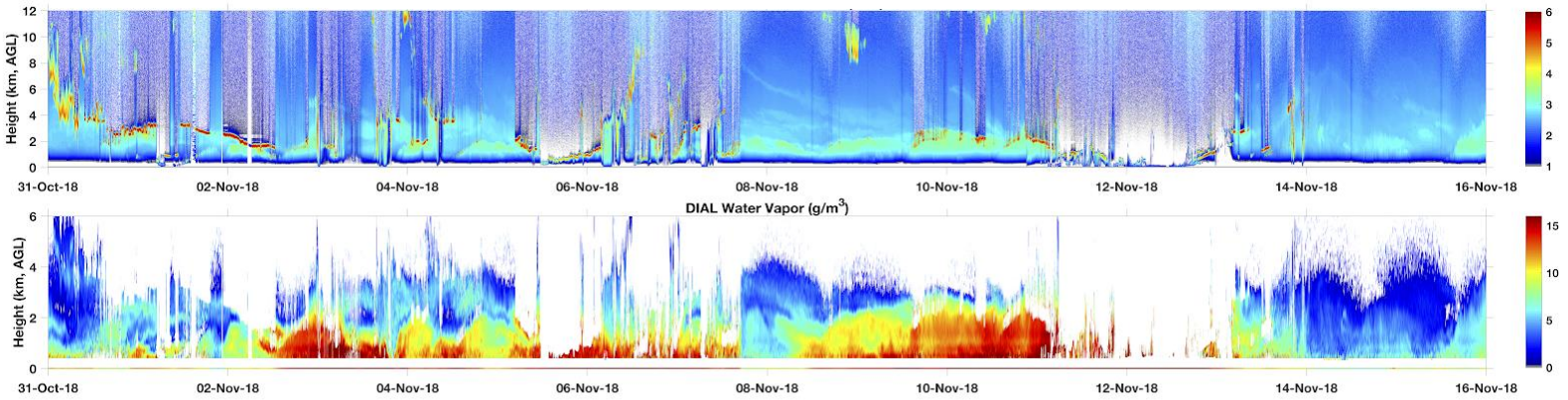
LOTOS Profiling: MPD

MPD Water Vapor and Aerosol Backscatter Profiles

- Water vapor concentration at 150 m vertical and 5 min temporal resolution
- From 300 m to 3-5 km (or cloud base) in day, night and cloudy conditions



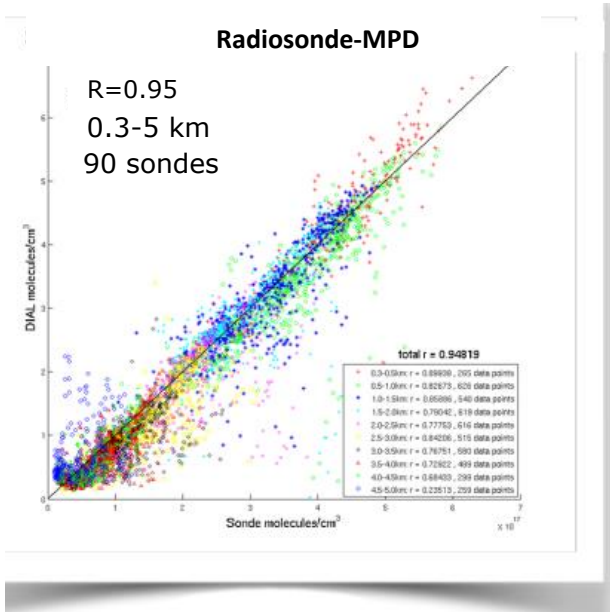
50 days from PECAN, 2015 in Kansas, USA

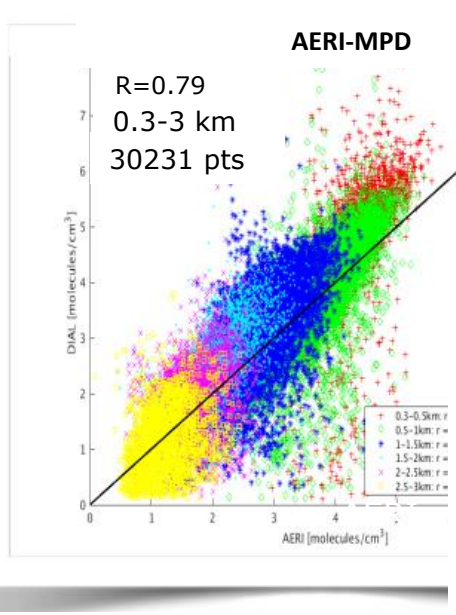


14 days from RELAMPAGO, 2018 in Pilar, Argentina

LOTOS Profiling: MPD

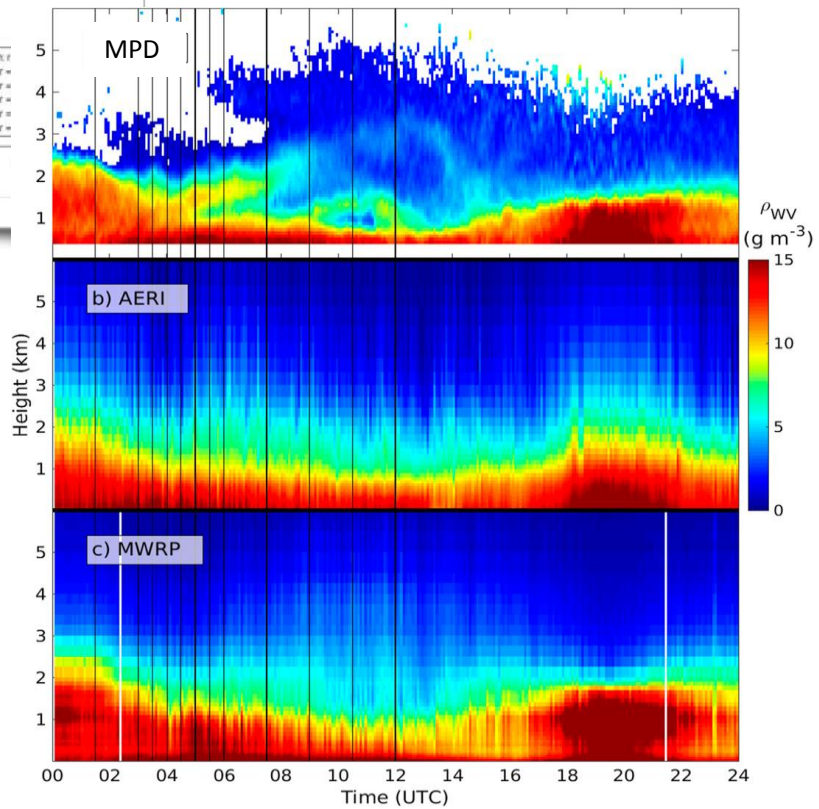
MPD Validation





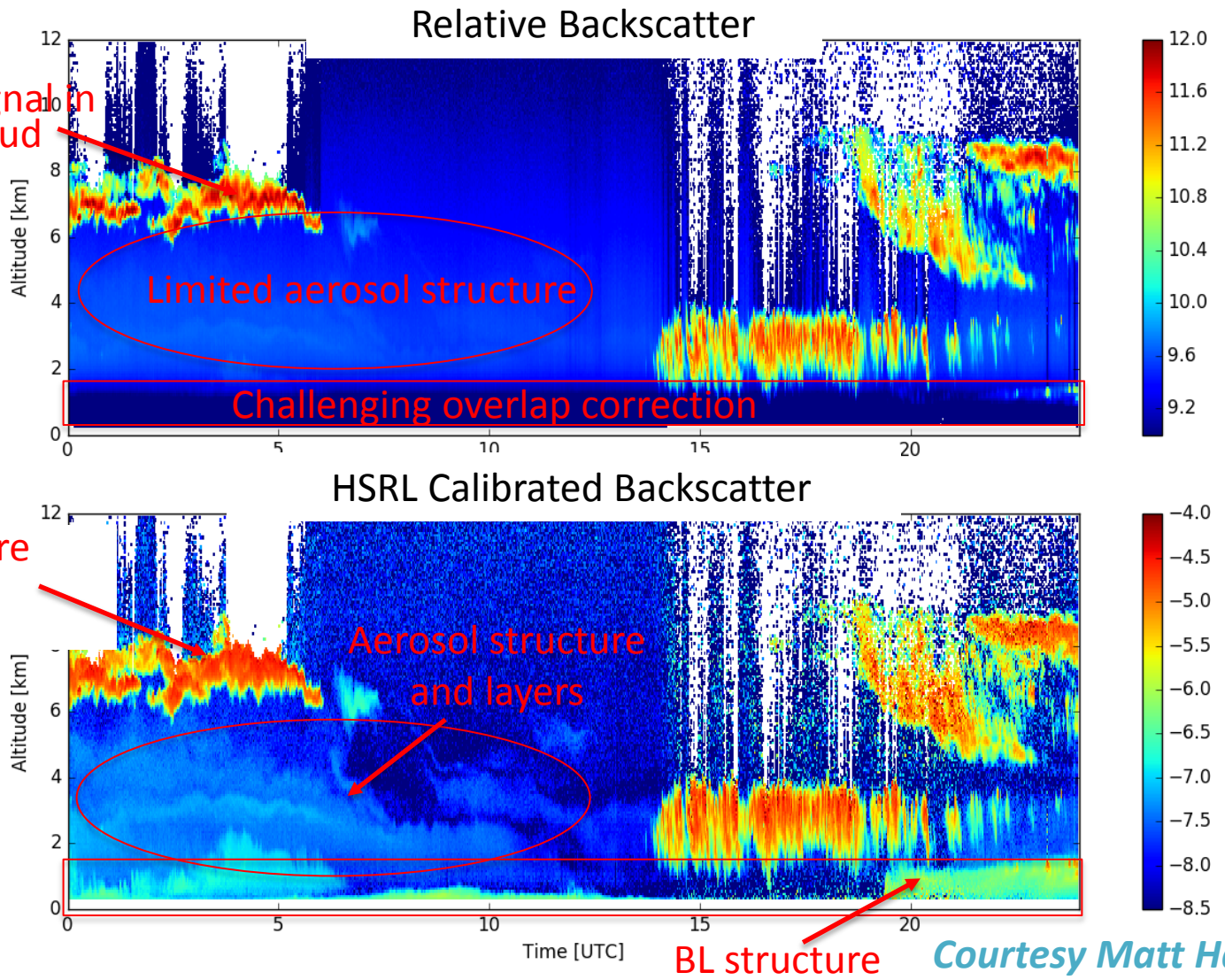
Weckwerth, Weber, Turner and Spuler, 2016,
J. Atmos. Oceanic Technol.

- Excellent comparisons with radiosondes, MWRP, AERI and GPS receivers providing PWV
- Elevated layers of moisture observed by MPD but not by passive remote sensing systems
- MPD + AERI are complementary



LOTOS Profiling: MPD

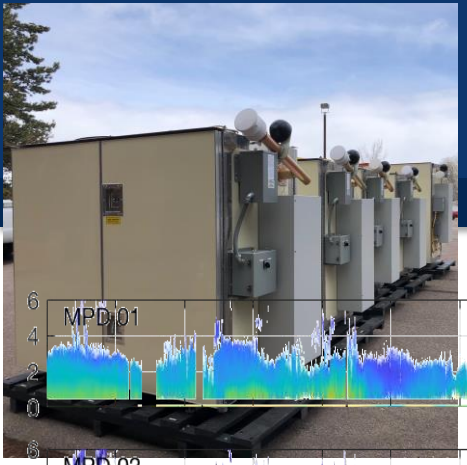
Calibrated backscatter via HSRL

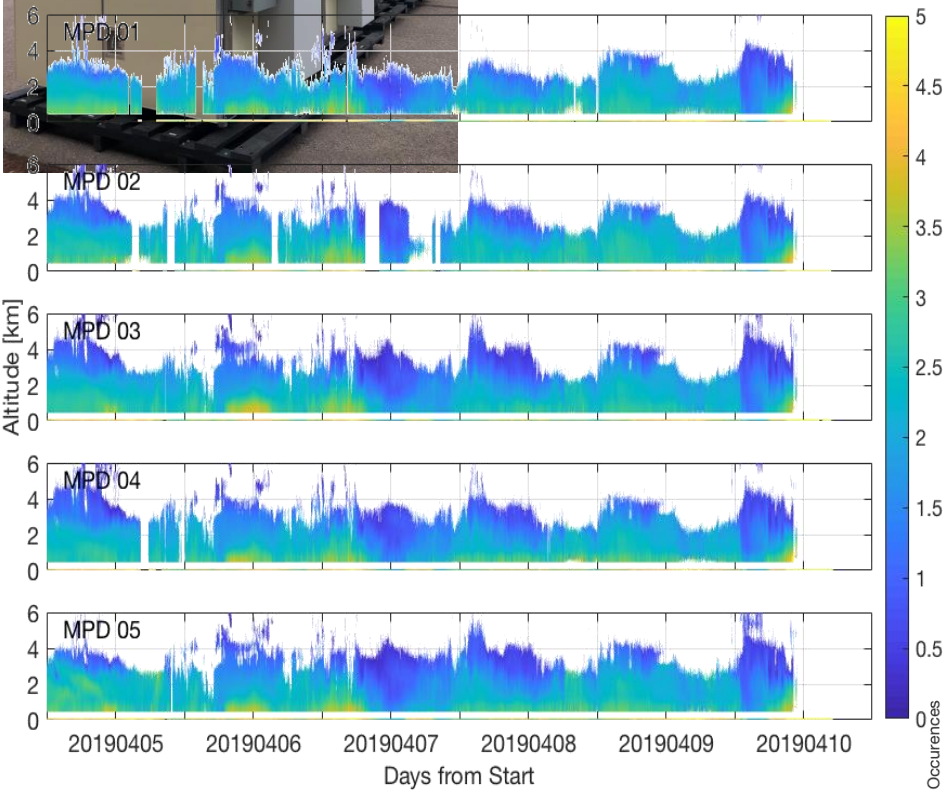


Courtesy Matt Hayman (EOL)

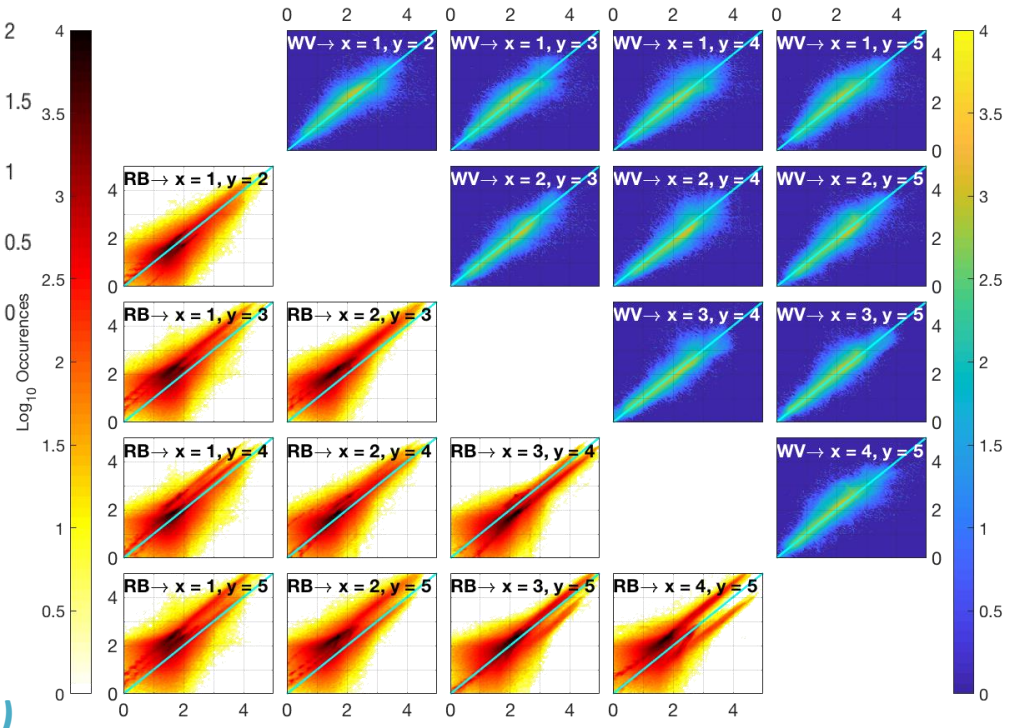
LOTOS Profiling: MPD

Network of five MPDs





- 6-10 April 2019
- All: WV
- MPD 02: WV, HSRL
- MPD 05: WV, HSRL, Temp (prototype)

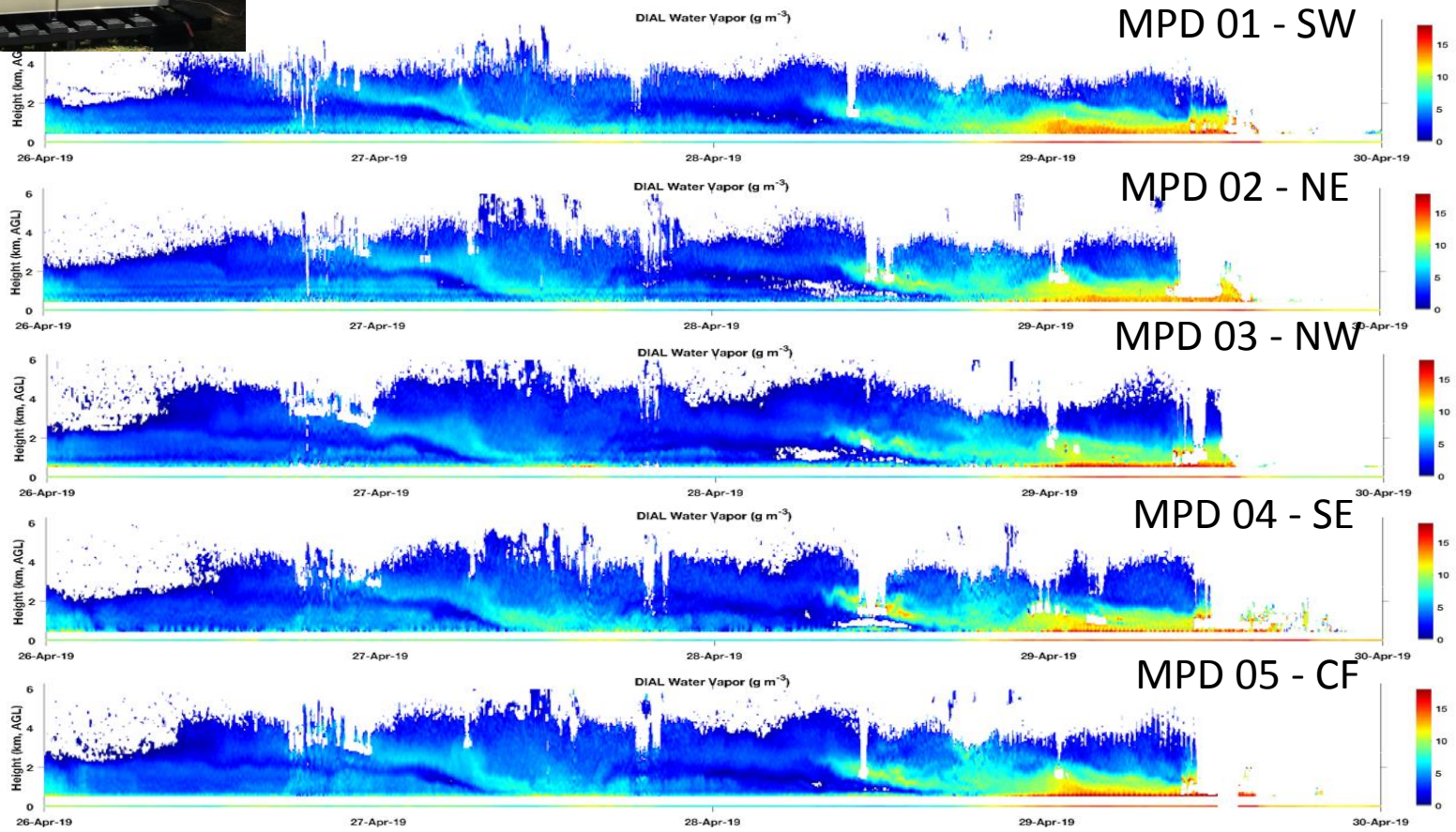


- Relative backscatter varies due to different Tx and Rx efficiencies
- WV is consistent!

Courtesy Robert Stillwell (EOL)

LOTOS Profiling: MPD

Network of five MPDs at DOE/ARM/SGP



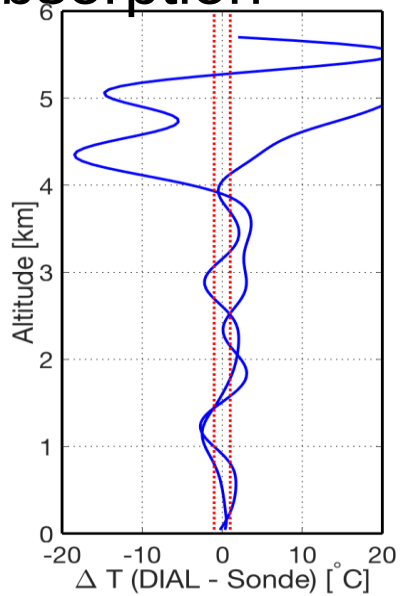
Courtesy Scott Spuler (EOL)

- 26-30 April 2019
- Consistent WV pattern
- Descending moist layer
- Development of CBL

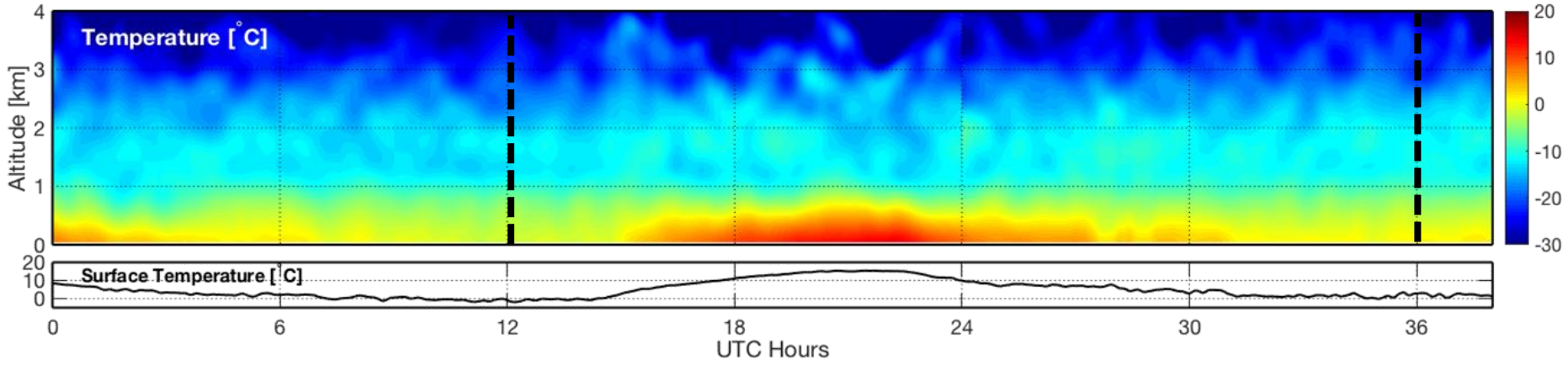
Adding Temperature Profiling

Bunn, Repasky, Hayman, Stillwell and Spuler, 2018, *Applied Optics*

- Use DIAL technique to measure oxygen A-band absorption
- Number density of O_2 profile estimated from surface temperature and pressure
- Must correct for water vapor (available from water vapor MPD)
- Must correct for Rayleigh-Doppler broadening (available from HSRL MPD)
- Solve for temperature profiles!



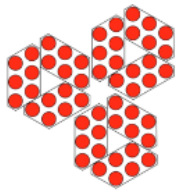
Courtesy Robert Stillwell (EOL)



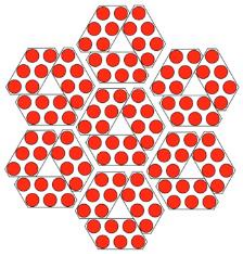
LOTOS Vertical Profiling: Wind

Modular Wind Profiler

- NCAR/EOL developed radar wind profiler
- Operates at 449 MHz (other frequency options are also proposed)
- Spaced antenna for rapid wind measurement
- Modular design enables scalability and flexibility
- *Please see Bill Brown's talk today – final talk of the conference at 1145*

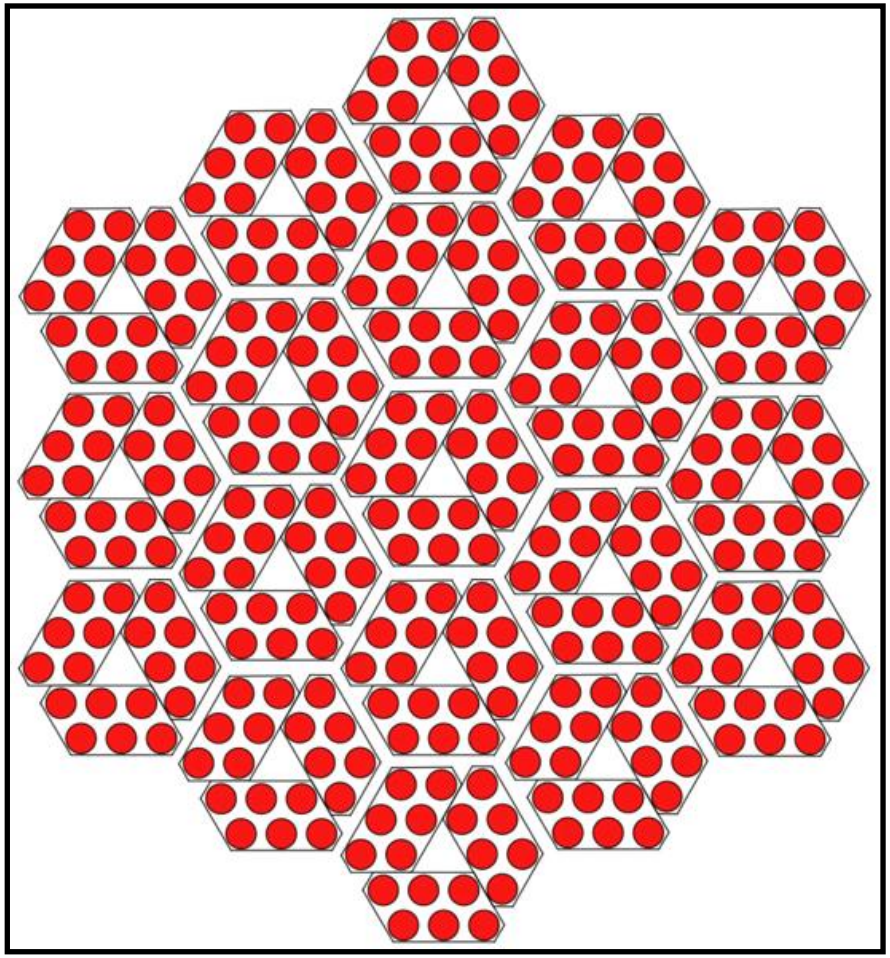


Boundary Layer Configuration
3 antenna modules
Range: 150 m – 4 km
Resolution: 30 - 100 m



Mid Troposphere Configuration
7 antenna modules
Range: 200 m – 7 km
Resolution: 50 - 200 m

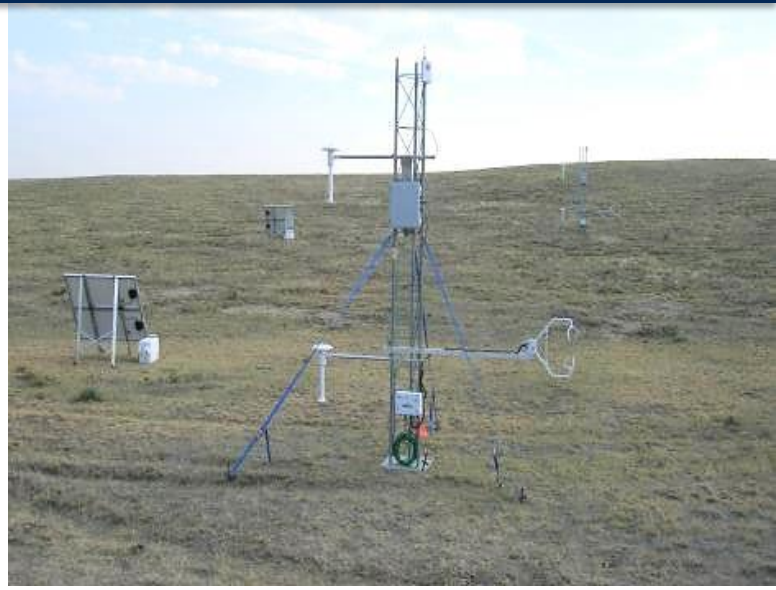
19-module version for full troposphere

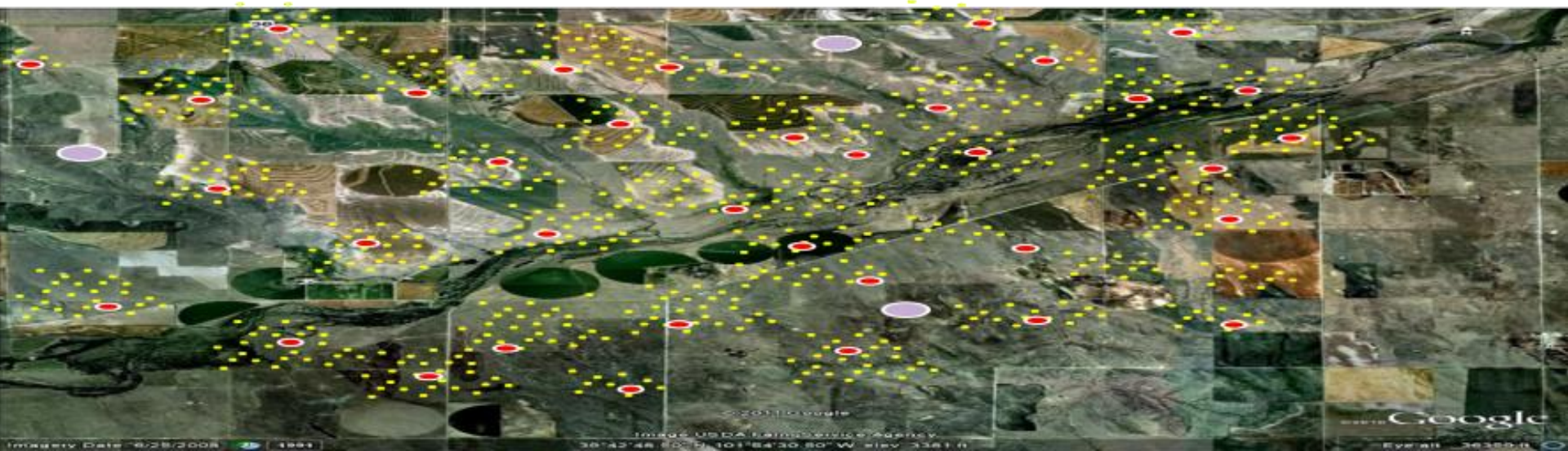


LOTOS Surface Characterization

Next Generation Surface Flux System

- Up to 80 surface flux stations
- Extending observations to complex land surfaces
- Information on the surface and subsurface mean state and surface exchange processes of U, T, WV, and CO_2 and CH_4
- All digital sensors and wireless data transfer

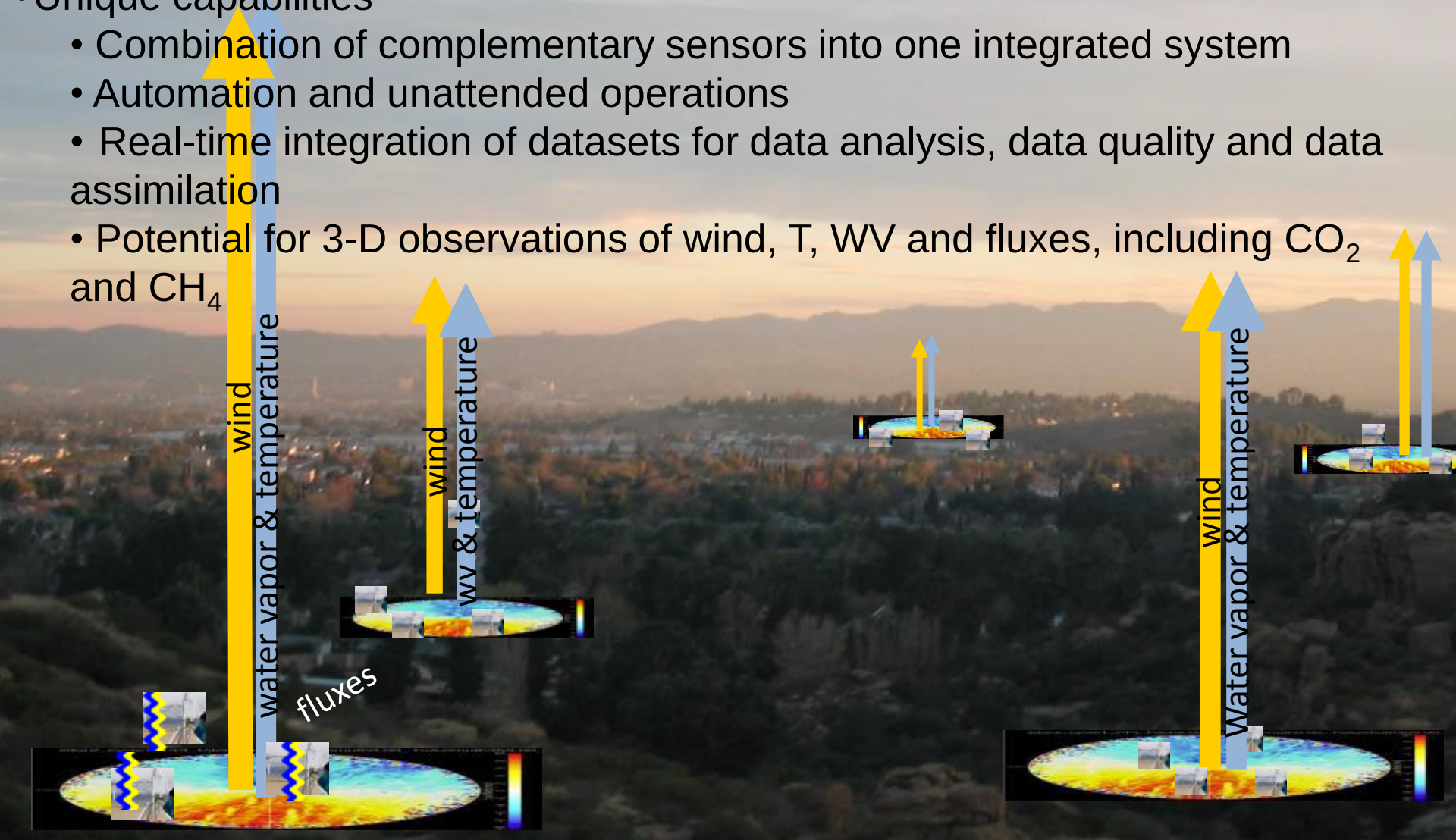




EARTH OBSERVING LABORATORY

Lower Troposphere Observing System (LOTOS)

- EOL has some components, some to be developed, some to be purchased
- Unique capabilities
  - Combination of complementary sensors into one integrated system
  - Automation and unattended operations
  - Real-time integration of datasets for data analysis, data quality and data assimilation
  - Potential for 3-D observations of wind, T, WV and fluxes, including CO_2 and CH_4



How would you use LOTOS?

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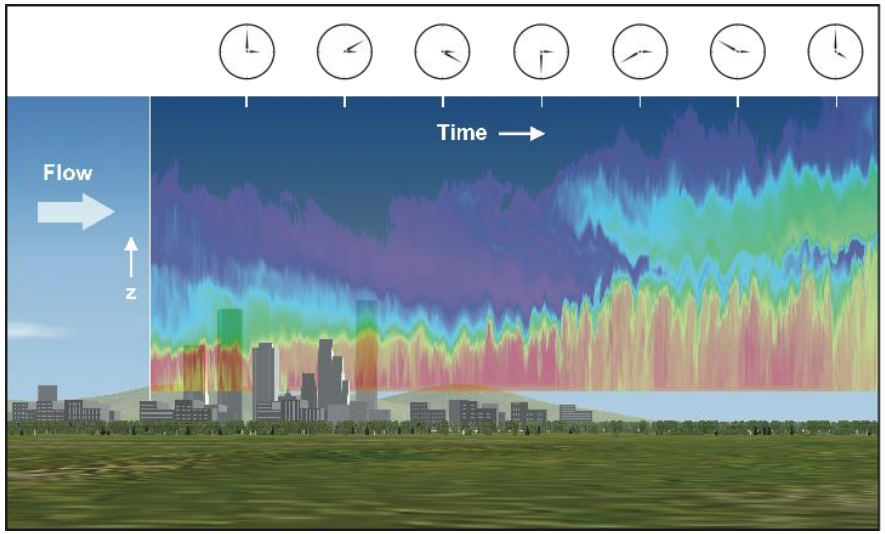
Extra slides

LOTOS Profiling: Water Vapor & Temperature

MicroPulse DIAL (MPD)

Developing low-cost laser remote sensing to provide unattended, continuous, high vertical resolution profiles of water vapor and temperature (future)
MPD technology developed by laser remote sensing groups at NCAR and MSU

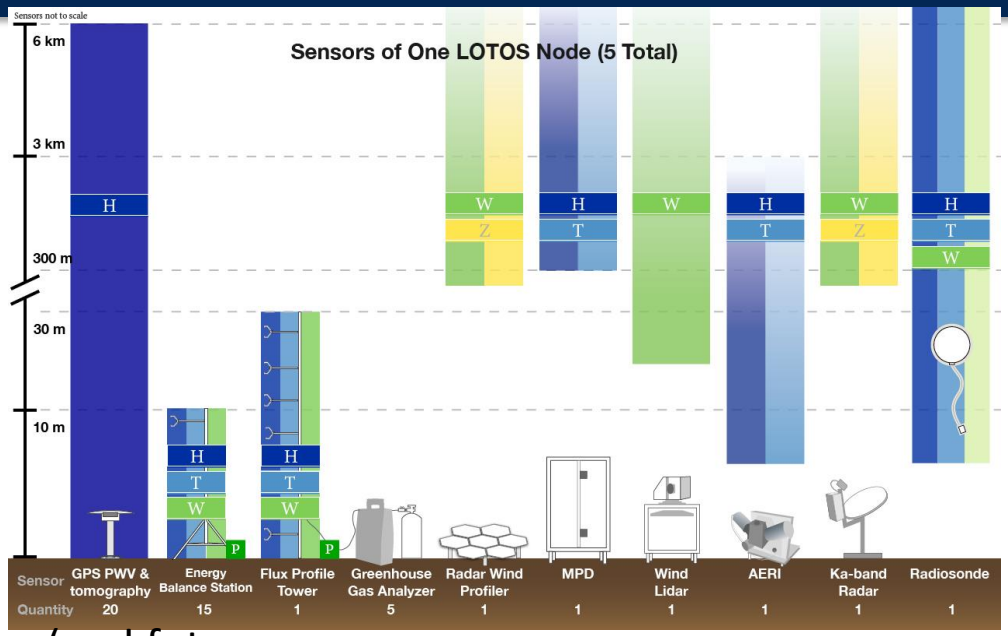


- MP (MicroPulse) - class of laser remote sensors that use low-energy "micro" pulses of light at high repetition rates and photon counting receivers
- D (DIAL: Differential Absorption Lidar) - class of laser remote sensors that measure the difference in absorption from two nearby frequencies

LOTOS

- A novel concept for quantifying spatial structure and temporal evolution of the lower troposphere – needed to advance Earth System science
- To be developed, and be evolved, as a tightly integrated observing system
- Integration of sensors for vertical profiling of the lower troposphere with sensors for surface and subsurface characterization and quantification of exchange processes at the lower boundary
- MPD and modular wind profiler will provide the backbone of LOTOS profiling 5 nodes and CentNet of its surface network (up to 100 towers)
- Currently writing MSI proposal to NSF

LOTOS Components

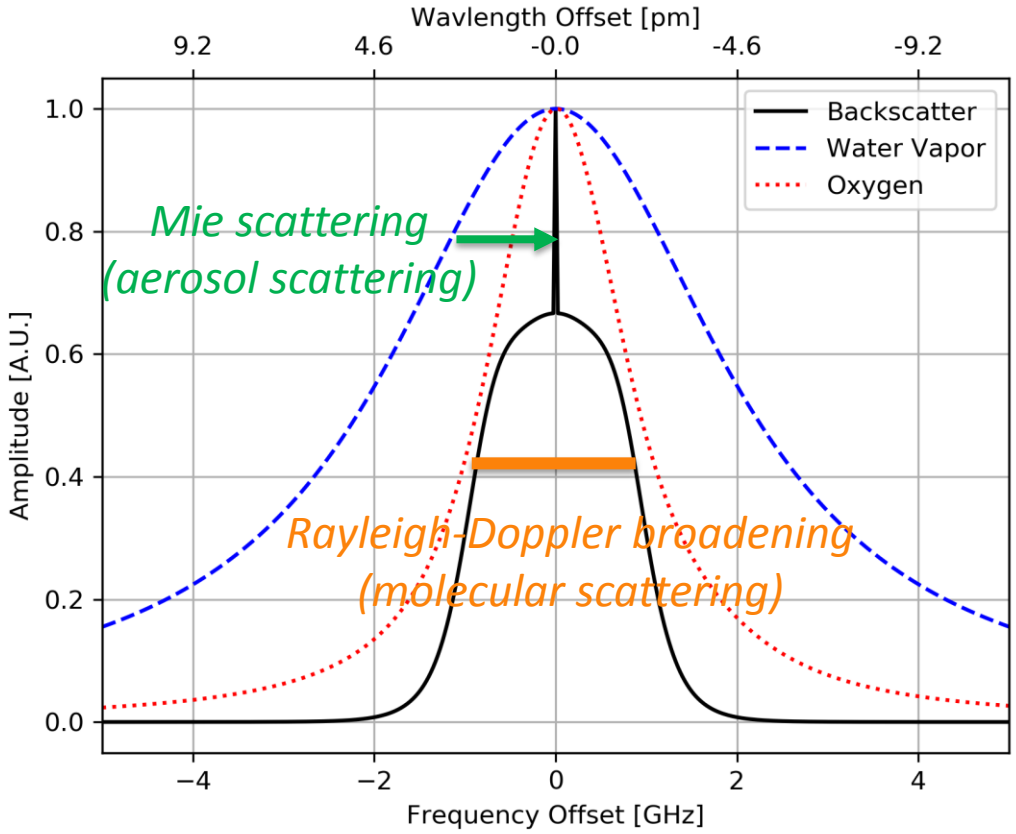


H – Humidity
T – Temperature
W – Wind
Z – Reflectivity
P - Precipitation

- 5 MPDs for water vapor (and future temperature) profiles
- 5 commercial wind lidars with vertical profiling and scanning capabilities
- 5 radar wind profilers for 3D wind profiles
- 5 AERIs for passive water vapor and temperature profiles
- 5 Ka-band radars for vertical wind profiles and cloud detection

- 5 commercial automated radiosondes for full tropospheric T, H and W profiles
- 5 flux profiling towers for fluxes at heights up to 30 m
- 75 surface flux stations
- 25 greenhouse gas analyzers for flux profiles of CO_2, CH_4 and H_20
- 100 GPS receivers for PWV and 3-D tomographic retrievals of water vapor

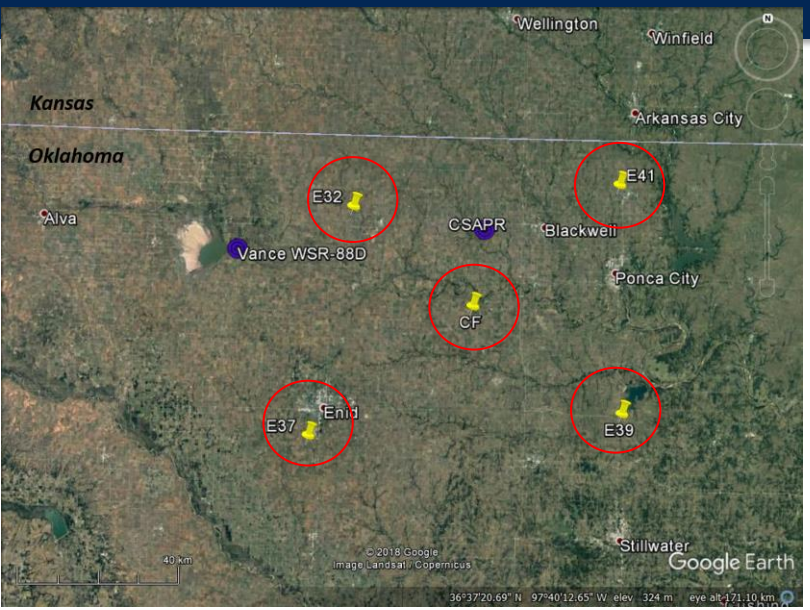
Quantitative Aerosol via HSRL



Hayman and Spuler, 2017, *Optics Express*

- Use Potassium D_1 line for offline wavelength
- Distinguishes molecular vs. aerosol backscatter and provides direct retrieval of backscatter optical properties
- Calibrated aerosol backscatter for quantitative comparisons between instruments
- Necessary for model intercomparisons since quantities can be computed (e.g., aerosol size distribution)

MPD Network Demonstration



- MPD Network demonstration at DOE/ARM/SGP sites
- 22 April – 19 July 2019
- Collaboration with Dave Turner (NOAA)

- 8 radiosondes/day from CF
- Raman lidar (WV and temp) at CF
- Collocated with AERIs, MWRPs and Doppler lidars
- Collocated with three GPS receivers