ON MULTI-SCALE INTERACTIONS IN COMPLEX TERRAIN AND EXPERIMENTAL DESIGN

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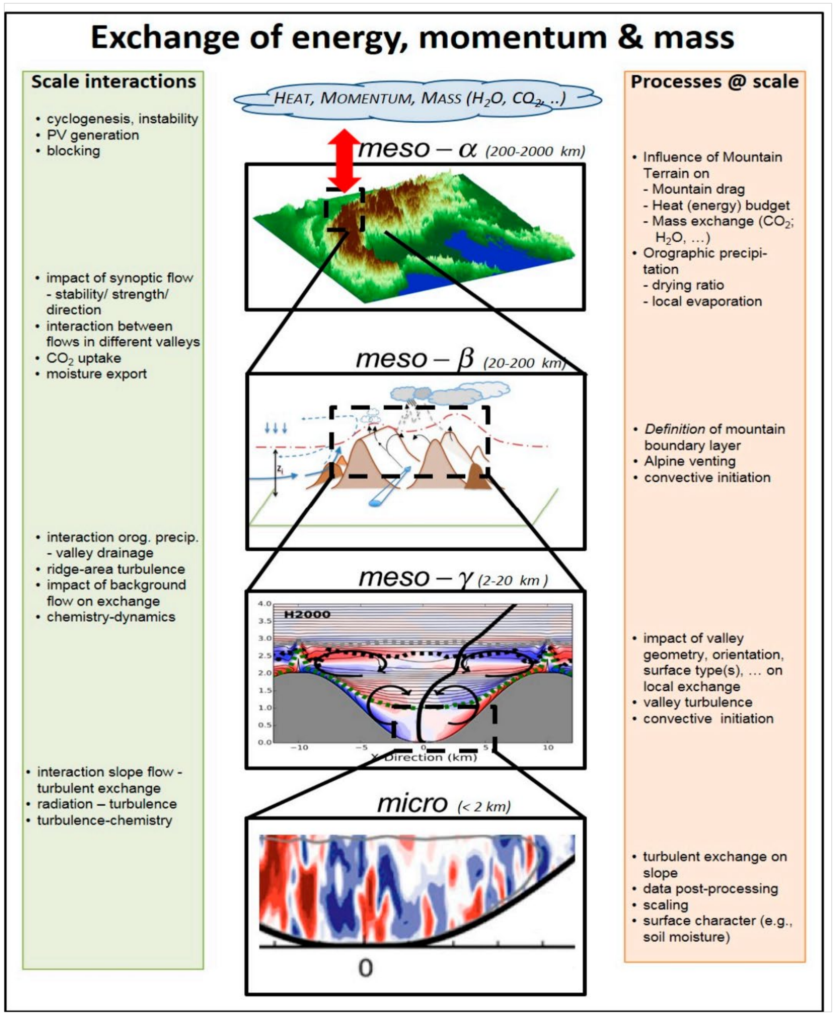
Multi-scale Interactions in Orographic Flows

- Orographically-induced circulations (breezes, foehn, cold-air pooling etc.) span a wide range of temporal and spatial scales,
- Spatial scales from micro- to meso-α,
- Processes and their interactions are complex and often strongly non-linear: Small differences in initial or BC may cause a very different response.

TEAMx

Multi-scale **T**ransport and **E**xchange processes in the **A**tmosphere over **M**ountains – programme and e**x**periment

www.teamx-programme.org



Lehner and Rotach (2018)

PBL Structure

Wagner et al (2015)

What we know:

- The vertical structure of the mountain boundary layer (MBL) is more complex than that of the simple convective BL (CBL) over flat terrain (evidence from both *observations* and numerical modelling),
- Different ways of estimating z_i yield varying results over complex terrain,
- Horizontal exchange over complex terrain is important.

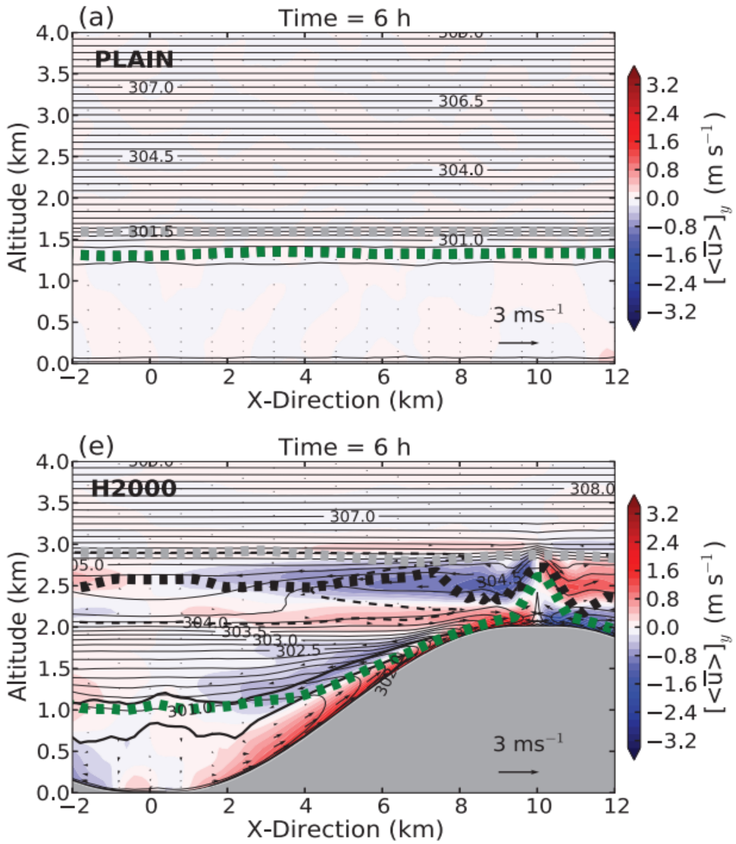


Figure 4. (a)–(e) Cross-sections of potential temperature (thin contour lines), cross-valley (colour shading) and along-valley wind speed (thick contour lines, negative values dashed, interval 1.0 m s^{-1}, the zero line is not shown) averaged between $y = 5$ and $y = 15$ km after 6 h of simulation. Boundary-layer heights PBL1, PBL2 and PBL3 are plotted with thick dashed green, black and grey lines, respectively.

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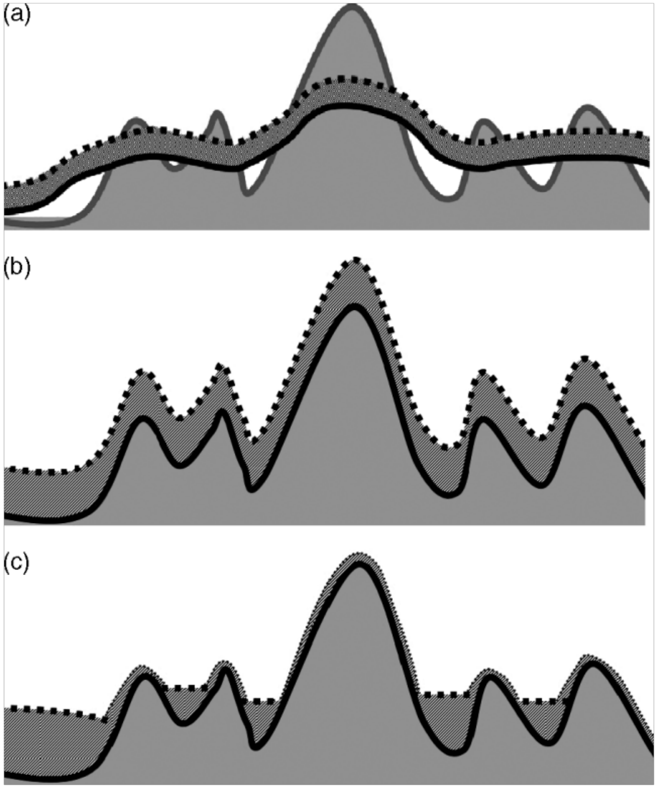
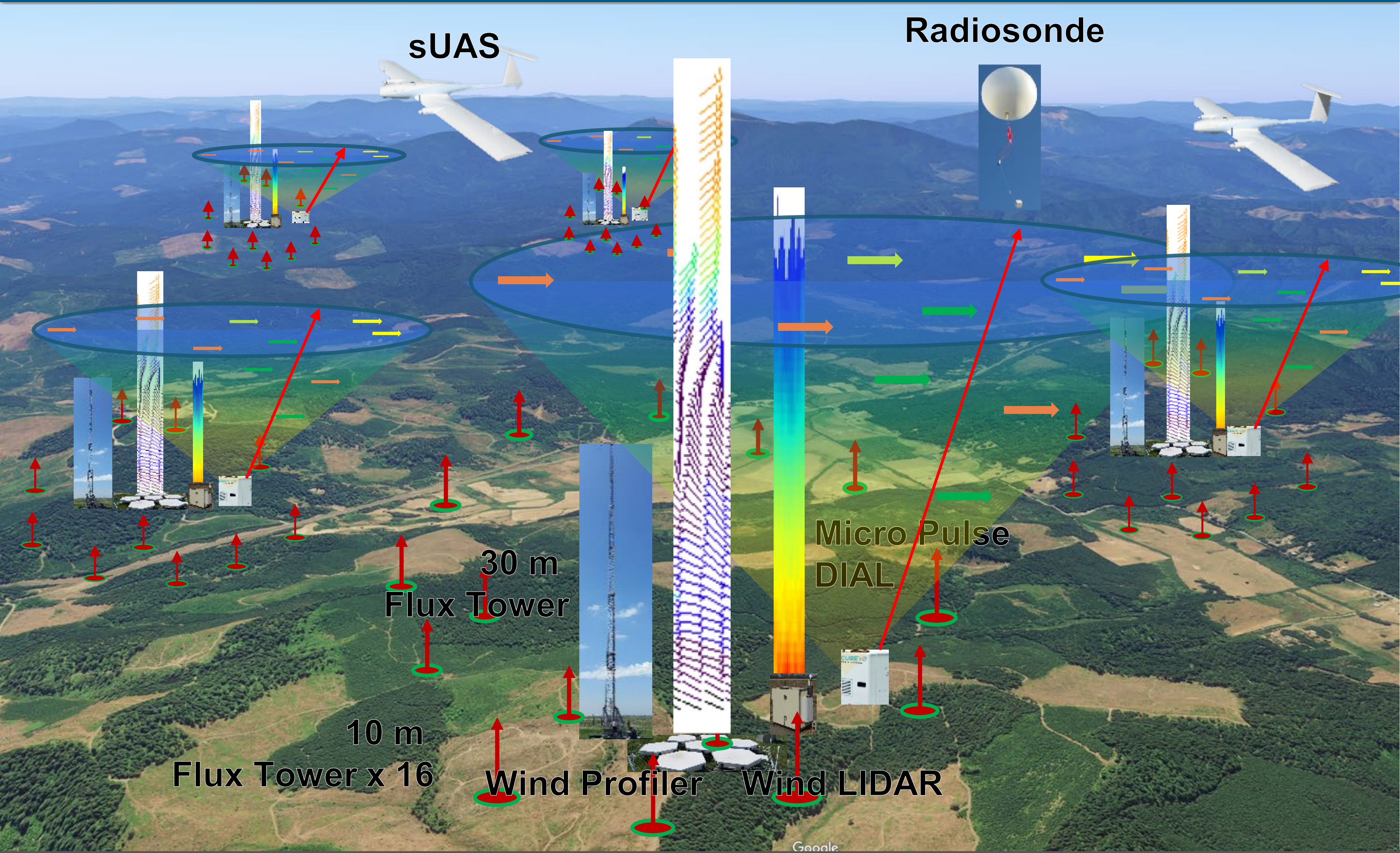


Figure 5. Schematic representation of the boundary layer in (a) a low-resolution numerical model, (b) a high-resolution operational numerical model, and (c) the turbulent boundary layer as found from different MAP boundary-layer studies.

LOTOS: Integrated Boundary Layer Observations



What is LOTOS?

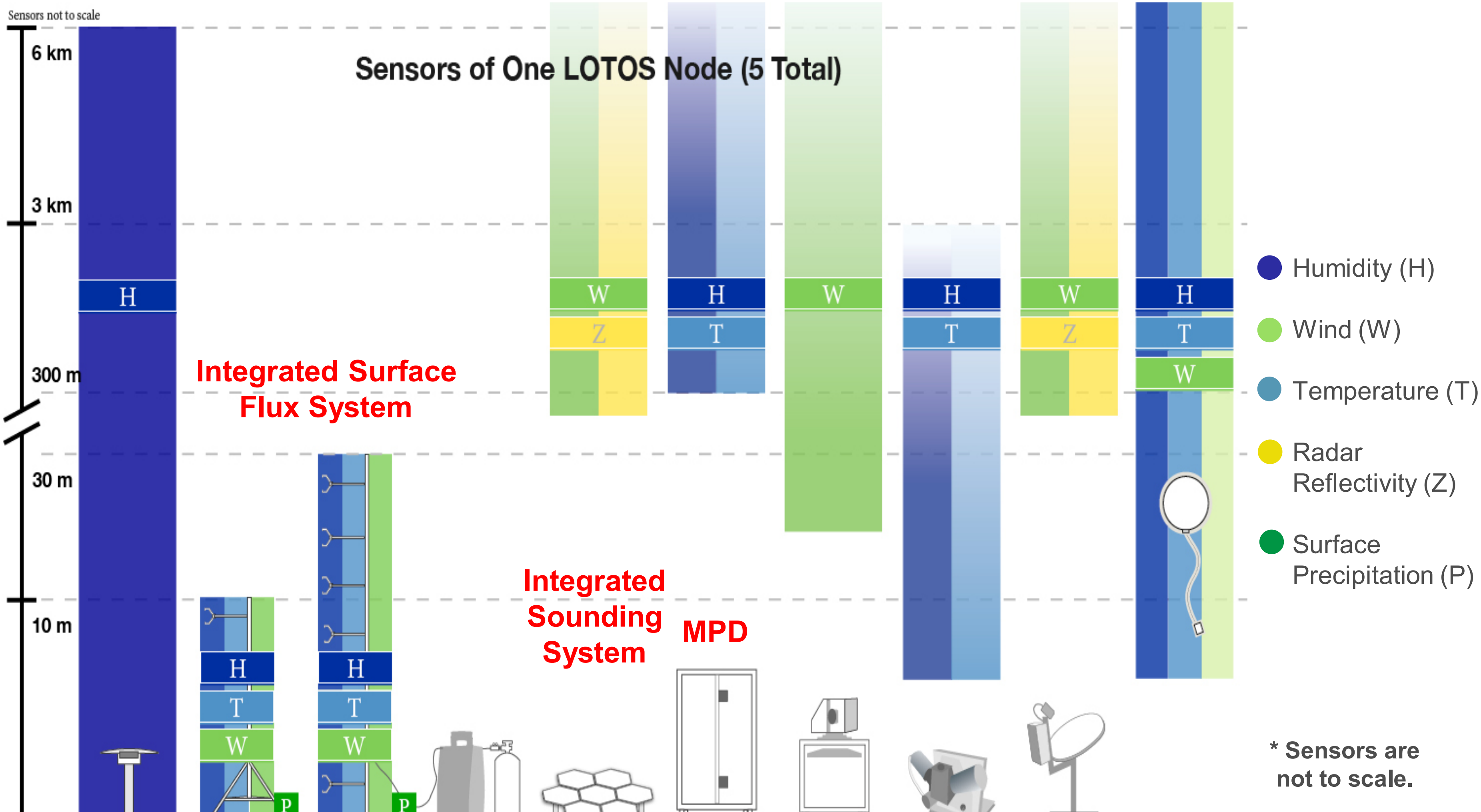
LOTOS is proposed as a configurable and scalable integrated suite of automated and unattended ground-based in-situ and remote sensors for weather and climate research

LOTOS is designed to provide:

- Quasi-3D sensing of the lower troposphere plus mapping of spatial distribution of properties at the Earth's surface
- Full kinematic and thermodynamic profiling at five nodes
- Multiple observations of exchange processes across the land-surface interface and between BL and the free atmosphere

LOTOS Node Components

Complementary In-situ and Remote Sensors

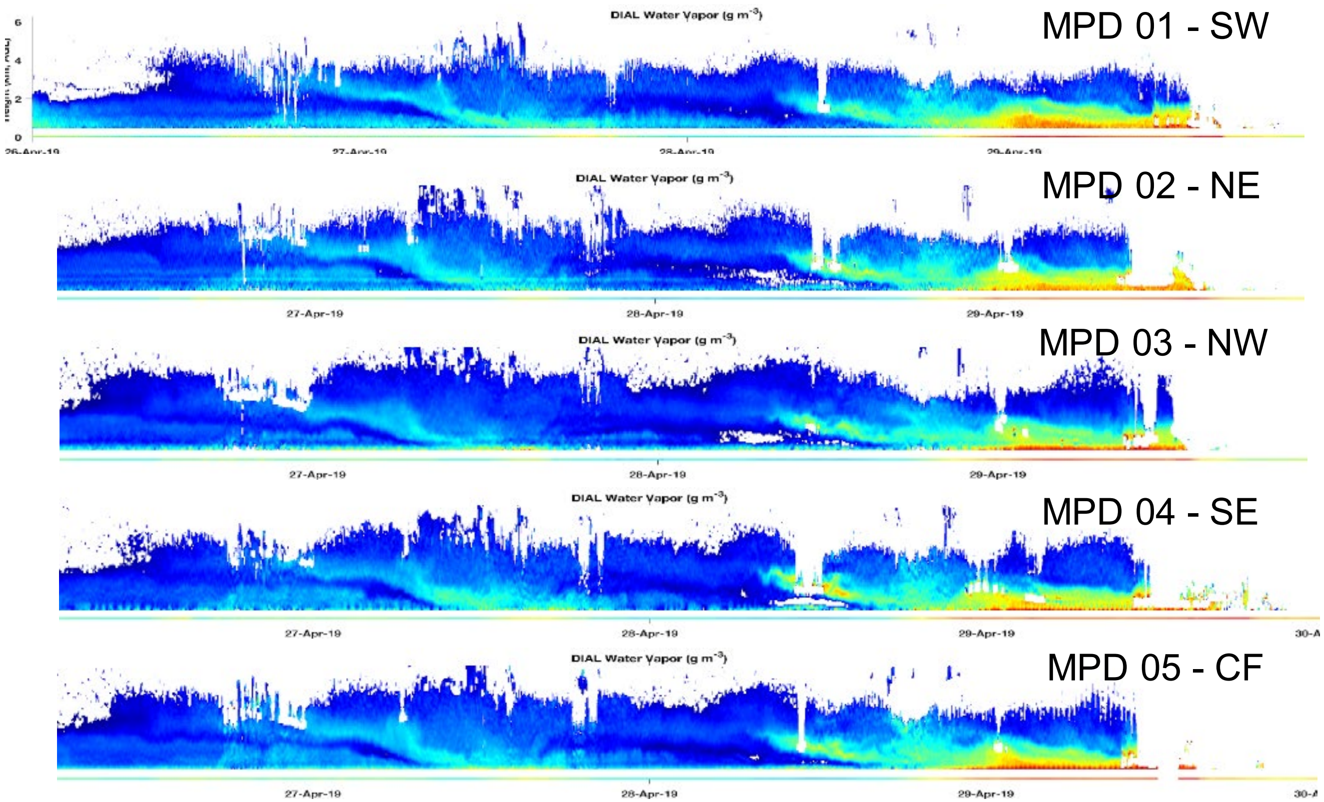


Sensor	GPS PWV & tomography	Energy Balance Station	Flux Profile Tower	Greenhouse Gas Analyzer	Radar Wind Profiler	MPD	Wind Lidar	AERI	Ka-band Radar	Radiosonde
Quantity	20	15	1	5	1	1	1	1	1	1

Vertical measurement range of the LOTOS sensors at a single node.

LOTOS Profiling: Micro-Pulse DIAL (MPD)

- Aerosol backscatter and 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



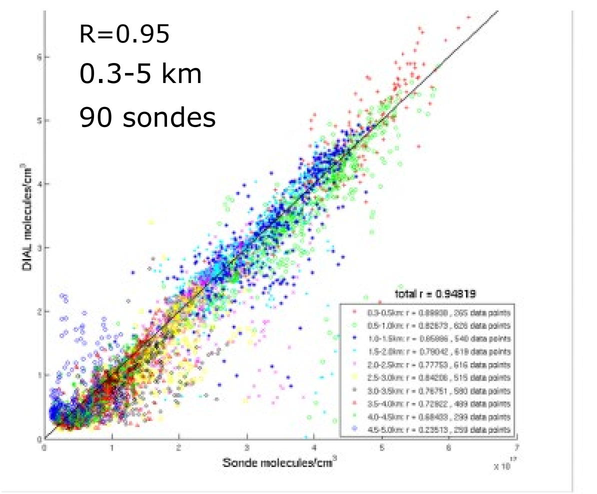
26-30 April 2019

- MPD Network Demonstration at DOE/ARM/SGP sites
- 22 April – 19 July 2019

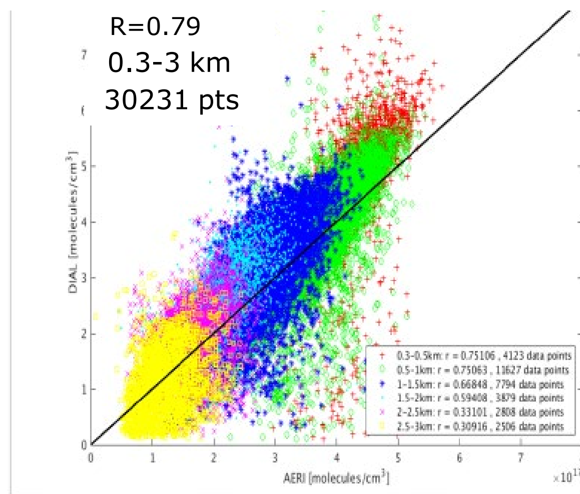
Courtesy Scott Spuler (EOL)

LOTOS Profiling: Micro-Pulse DIAL (MPD)

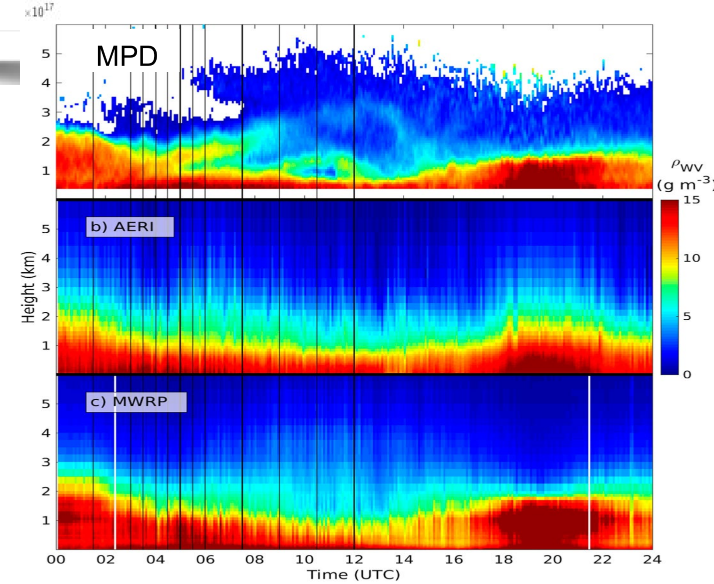
Radiosonde-MPD



AERI-MPD



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.

IS A LARGE AIRCRAFT NEEDED?

Documenting conditions, both upwind- and downwind of target valleys, is important!

Beyond a large chemistry payload, a large (long-endurance) aircraft indispensable for:

i) Sampling thermodynamic and kinematic structure (and chemistry) upwind of a target valley for determining a background state,
ii) Sampling downwind for estimating how venting from valleys impacts regional air quality.

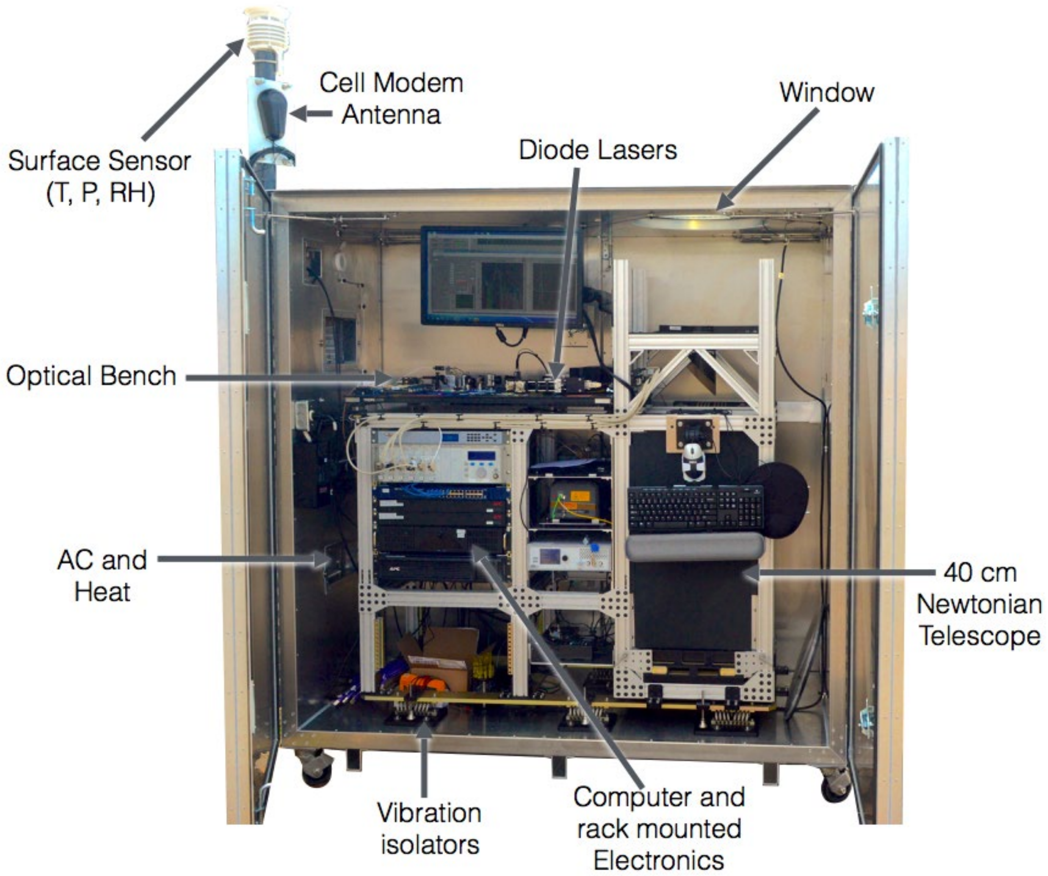
Some Thoughts about Experimental Design

1) Coordinated airborne and ground-based measurements, both in situ and remote sensing – multitude of temporal and spatial scales and processes, both meteorological and chemical,
2) Airborne platforms (manned aircraft, large and small, UAS?): chemistry in situ, remote sensing (clouds & aerosols) – high-frequency measurements needed for fluxes,
3) Ground-based: surface characterization + BL profiling, chemistry measurements, both stationary and mobile platforms – high-frequency measurements needed for fluxes,
4) Use of tracers (WV and C isotopes, chemical tracers, etc.),
5) Target area: Many arguments for the SLCV and SJ Valleys (previous studies, existing observing networks, long measurements records, etc.) but a complementary compact, small to mid-size valley might prove beneficial for coupled meteorological-chemical process studies and modeling.

Questions?

LOTOS Profiling: Water Vapor & Temperature

MPD Development

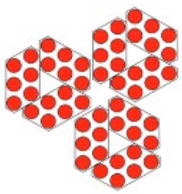


- Two tunable wavelengths (Near IR: 828 nm)
- Water Vapor Micro-Pulse DIAL (MPD) for measuring vertical profiles of water vapor up to 3-5 km AGL
- Network of five MPDs current testing at U.S. Southern Great Plains
- Calibrated aerosol addition via HSRL (780 nm)
- Efforts toward temperature MPD (770 nm)

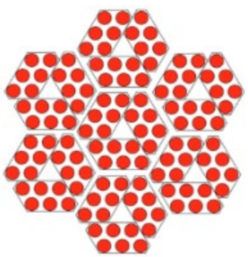
LOTOS Vertical Profiling: Wind

449 Modular Wind Profiler

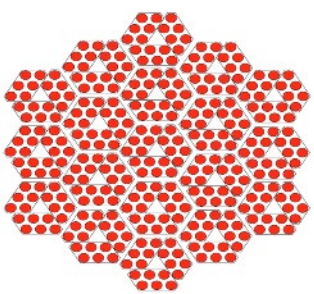
- NCAR/EOL developed radar wind profiler
- Operates at 449 MHz (other frequency options are also proposed)
- Spaced antenna for rapid wind measurement
- Modular design enables scalability and flexibility



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



Full Troposphere Configuration
19 antenna modules