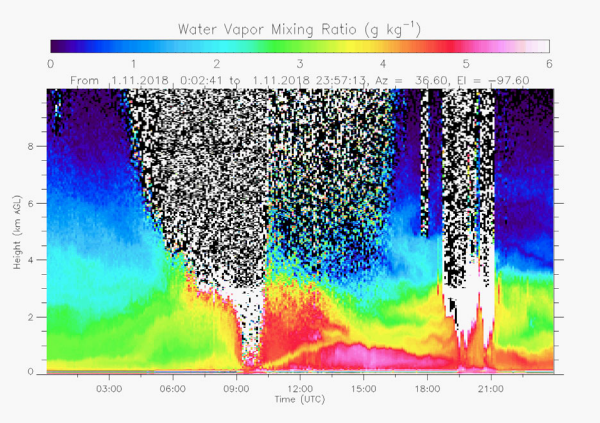
Compact Automatic Rotational Raman Lidar System for Continuous Day- and Nighttime Temperature and Humidity measurements

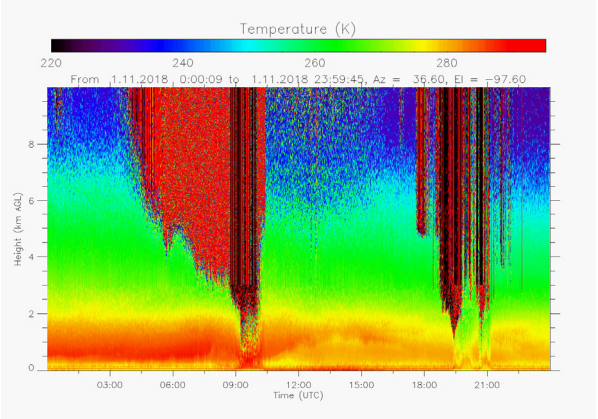
Volker Wulfmeyer, Diego Lange, Andreas Behrendt, Shravan Muppa
Institute of Physics and Meteorology (IPM)
University of Hohenheim (UHOH)
Stuttgart, Germany

MOSES
Modular Observation Solutions for Earth Systems

https://www.ufz.de/moses

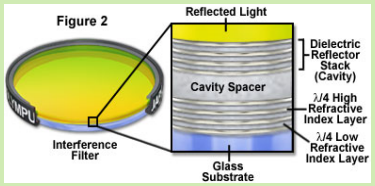
Helmholtz Centre for
Environmental Research (UFZ)





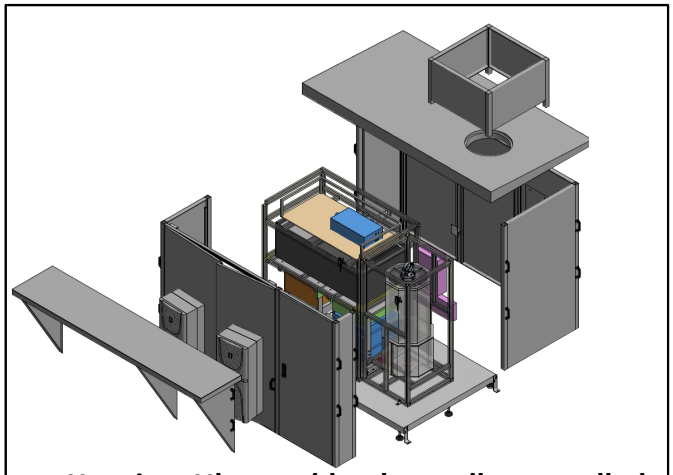
Severe gaps in the observation of thermodynamic profiles must be closed in order to advance our understanding of Earth system processes (*Wulfmeyer et al. Rev. Geophys. 2015*).

WV and T Raman lidar for MOSES



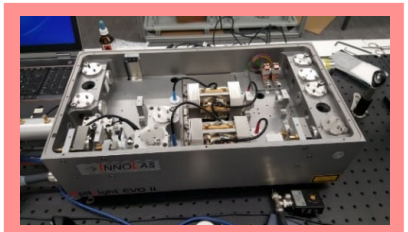
Interference filters:
Narrow-band, high transmission, side-band suppression
(e.g. *Hammann et al. ACP 2015*)

Scanner technology and appl.
(e.g. *Späth et al. AMT 2016*)

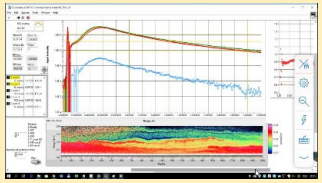


Housing: Ultra-stable, thermally controlled frame and housing

MOSES
Modular Observation Solutions for Earth Systems



Laser:
High-power, injection-seeded diode-laser
(e.g. *Wulfmeyer et al. OE 2000, Ostermeyer et al. AO 2005, Wagner et al. AO 2013*)
>100 days operation by now

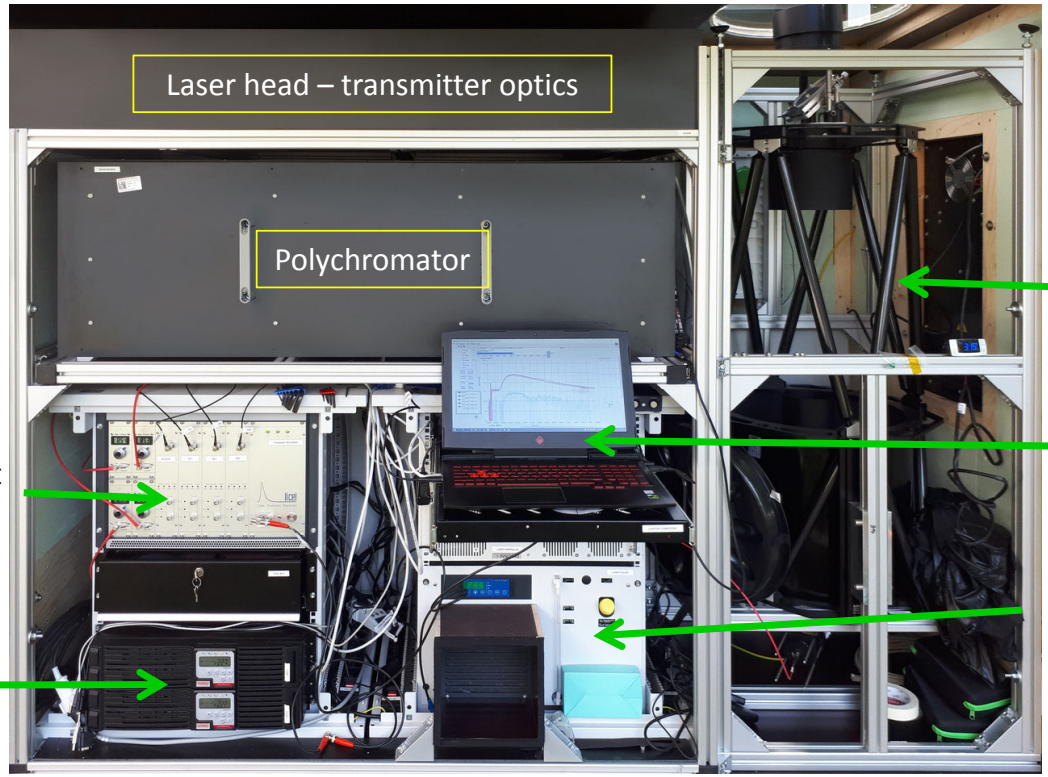


Real-time data processing with error propagation
(Lenschow et al. 2000, Wulfmeyer et al. JAS 2016)

Key features:

- **High accuracy and resolution of T and WV profiling day- and nighttime**
- **Fulfilling WMO Breakthrough and Goal Requirements for Nowcasting/VSRF in the lower troposphere**
- **Compact, operational, and robust**
- **Continuous operation with minor laser maintenance for > 3 years**
- **Remote control via mobile phone**
- **Eye safe**

MOSES Raman Lidar: Specifications



Transmitter
- Diode-pumped Nd:YAG laser
- 200 Hz, **20 W** @ 355 nm

Receiver
- **40 cm** primary-mirror telescope
- 4 channels:
  Elastic, RR1, RR2 and water vapor

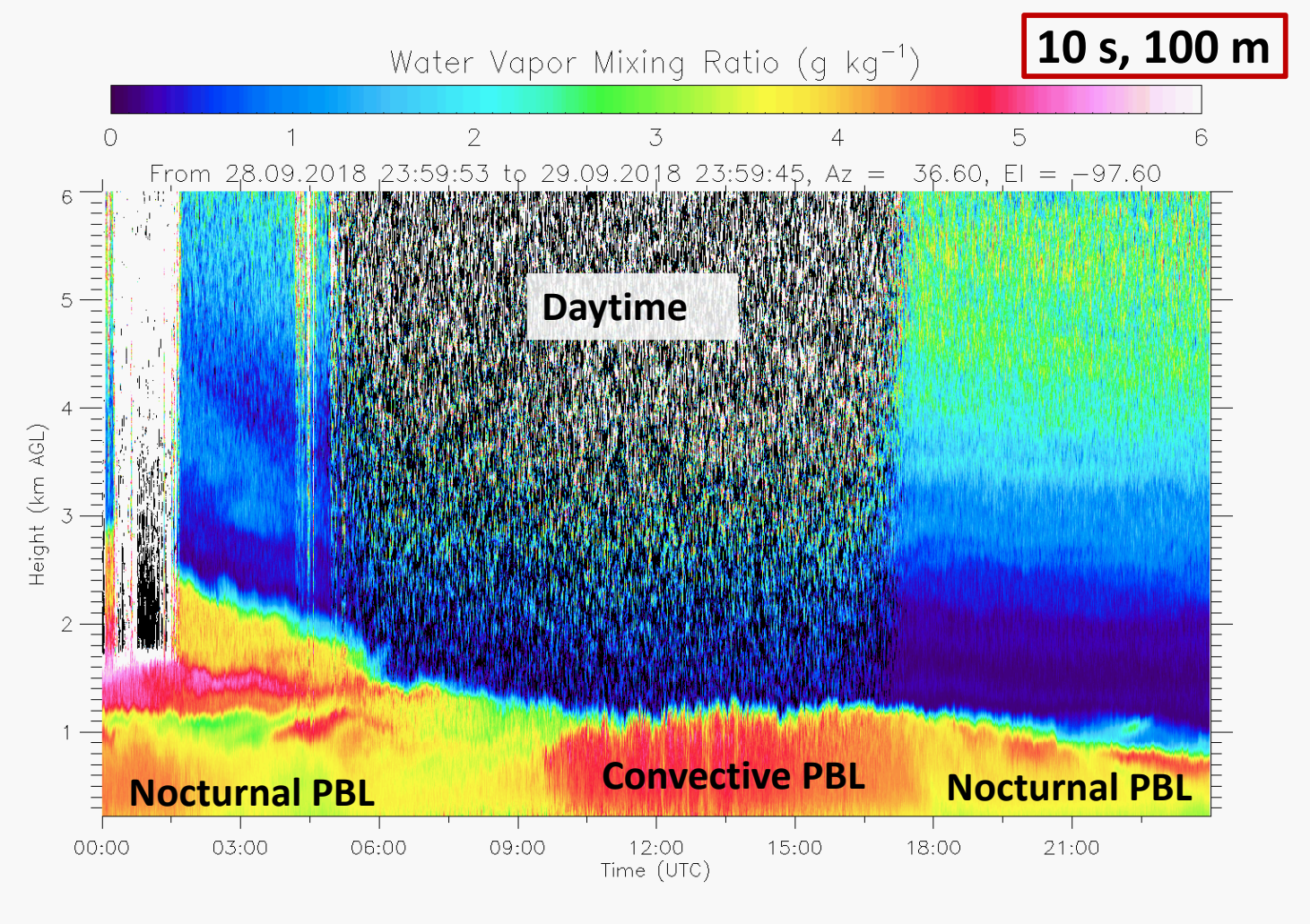
Elastic and Raman channels (Licel GmbH)
- **7.5 m, 1 - 10 s** (raw data)
- Both analog and photon counting mode

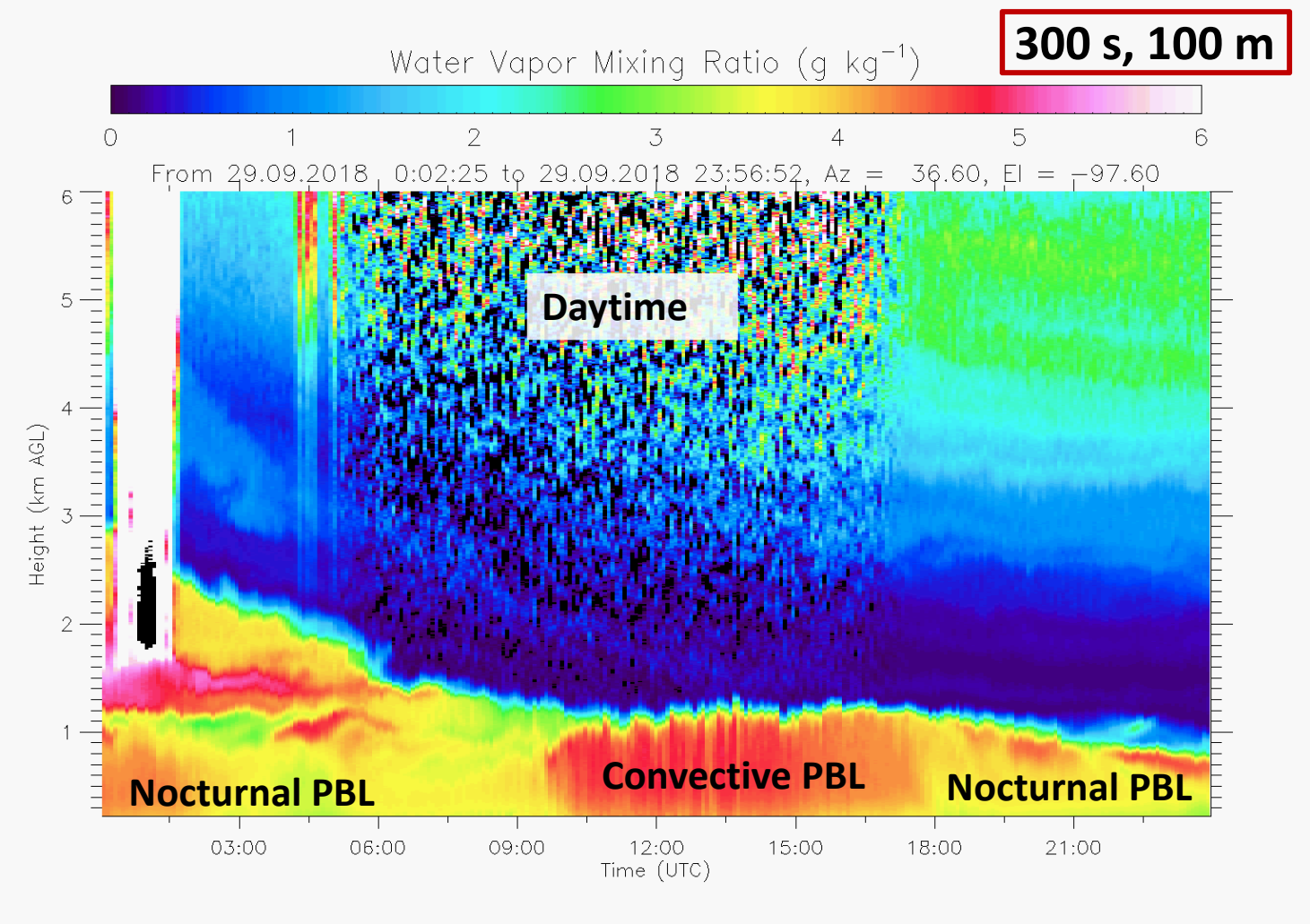
Primary Data Products:
- Temperature
- Water vapor mixing ratio
- Relative humidity
- Particle backscatter coefficient @ 355 nm
- Particle extinction coefficient @ 355 nm

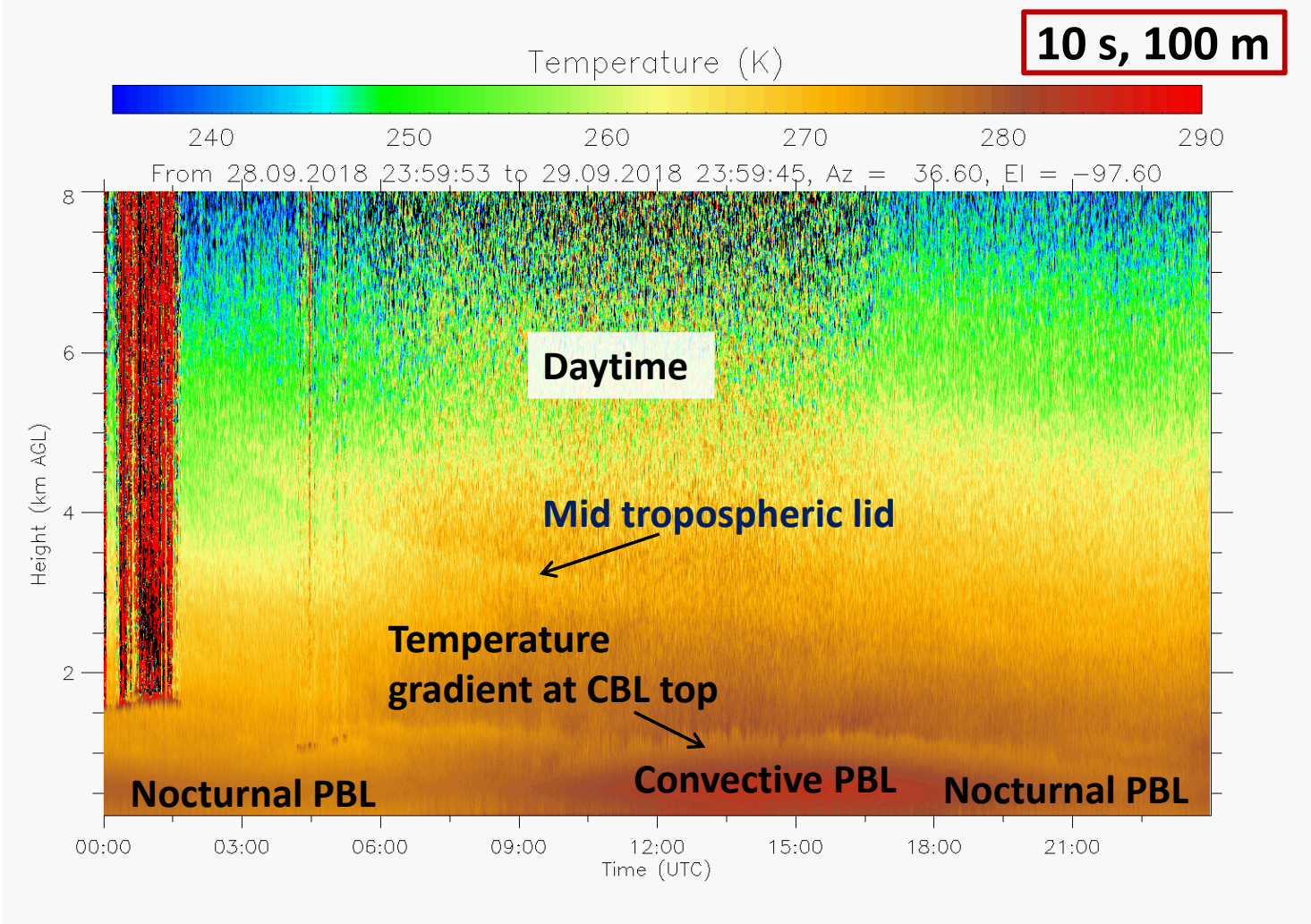
Dimensions:
Approx. 2.1m x 2.6m x 1.4m (H x W D)
Weight:
Approx. 900 kg

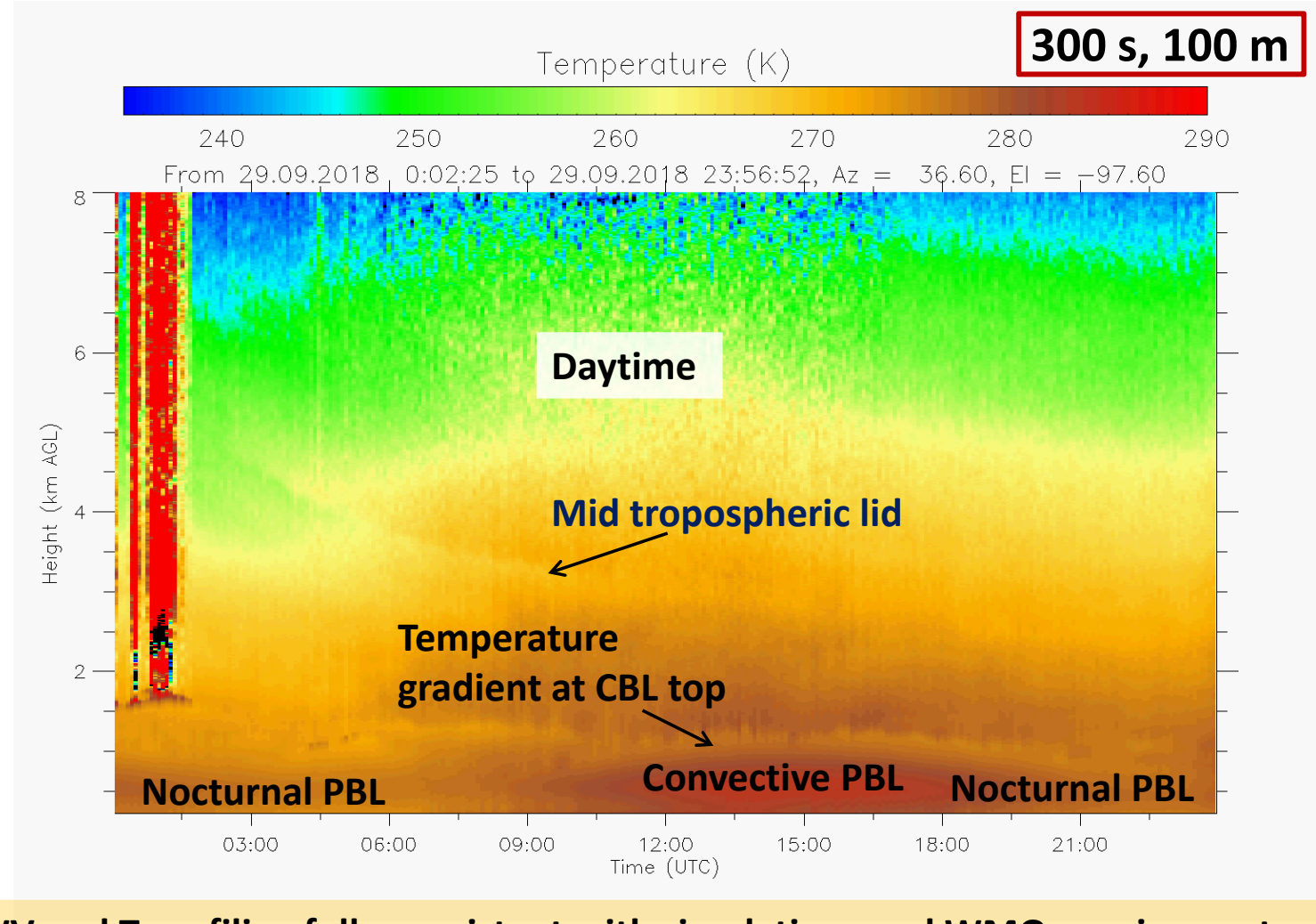
Operation temperature:
-20°C to 40°C
Power consumption:
Approx. 5 kW

WVTRL Performance




300 s, 100 m
Water Vapor Mixing Ratio (g kg^{-1})
0
1
2
3
4
5
6
From 29.09.2018 0:02:25 to 29.09.2018 23:56:52, Az = 36.60, El = −97.60
Height (km AGL)
1
2
3
4
5
6
Daytime
Nocturnal PBL
Convective PBL
Nocturnal PBL
03:00
06:00
09:00
12:00
15:00
18:00
21:00
Time (UTC)


10 s, 100 m
Temperature (K)
240
250
260
270
280
290
From 28.09.2018 23:59:53 to 29.09.2018 23:59:45, Az = 36.60, El = −97.60
Height (km AGL)
8
6
4
2
Daytime
Mid tropospheric lid
Temperature
gradient at CBL top
Nocturnal PBL
Convective PBL
Nocturnal PBL
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
Time (UTC)



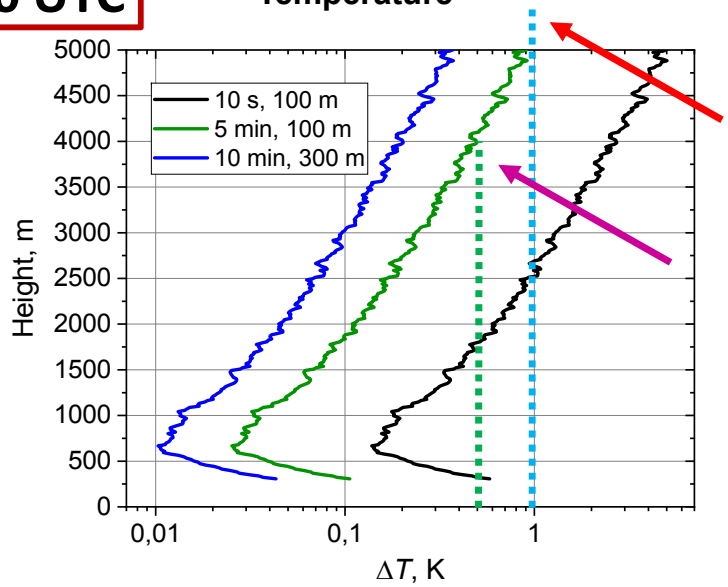
WV and T profiling fully consistent with simulations and WMO requirements.

Raman Lidar: Statistical Uncertainties

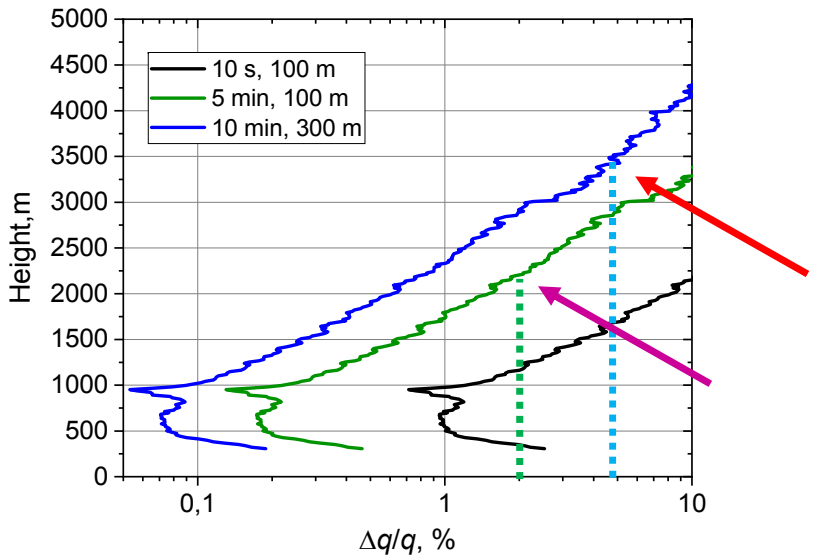
01.11.2018
15:00 – 16:00 UTC

Method of *Wulfmeyer et al. JAS 2016*

Temperature



Water Vapor Mixing Ratio



WMO Requirements for Nowcasting/VSRF in the Lower Troposphere:

"Breakthrough" requirement (10 min, 300 m):	
1 K *Fulfilled >> 5 km!*	***5%*** *Fulfilled up to 3.5 km!*
"Goal" requirement (5 min, 100 m):	
0.5 K *Fulfilled up to 4 km!*	***2%*** *Fulfilled up to 2.2 km!*

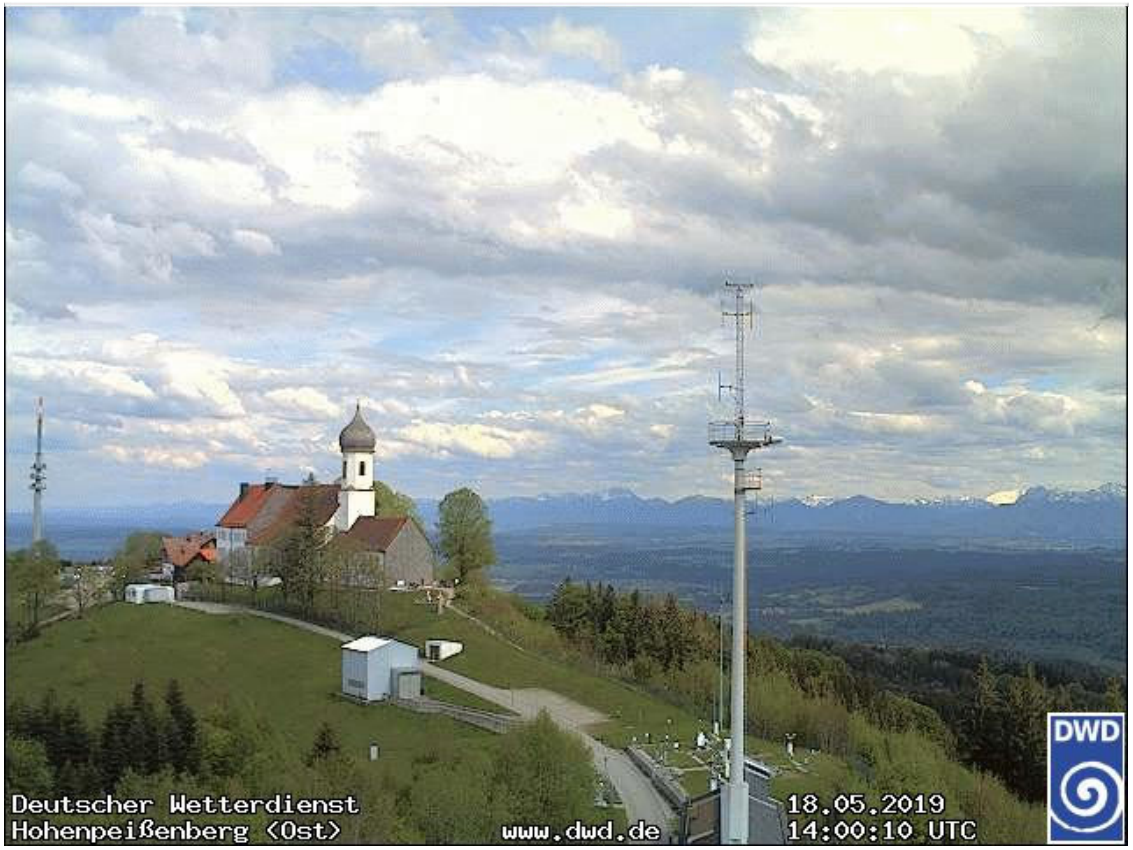
https://www.wmo-sat.info/oscar-staging/requirements

Scale-X Campaign – MOSES

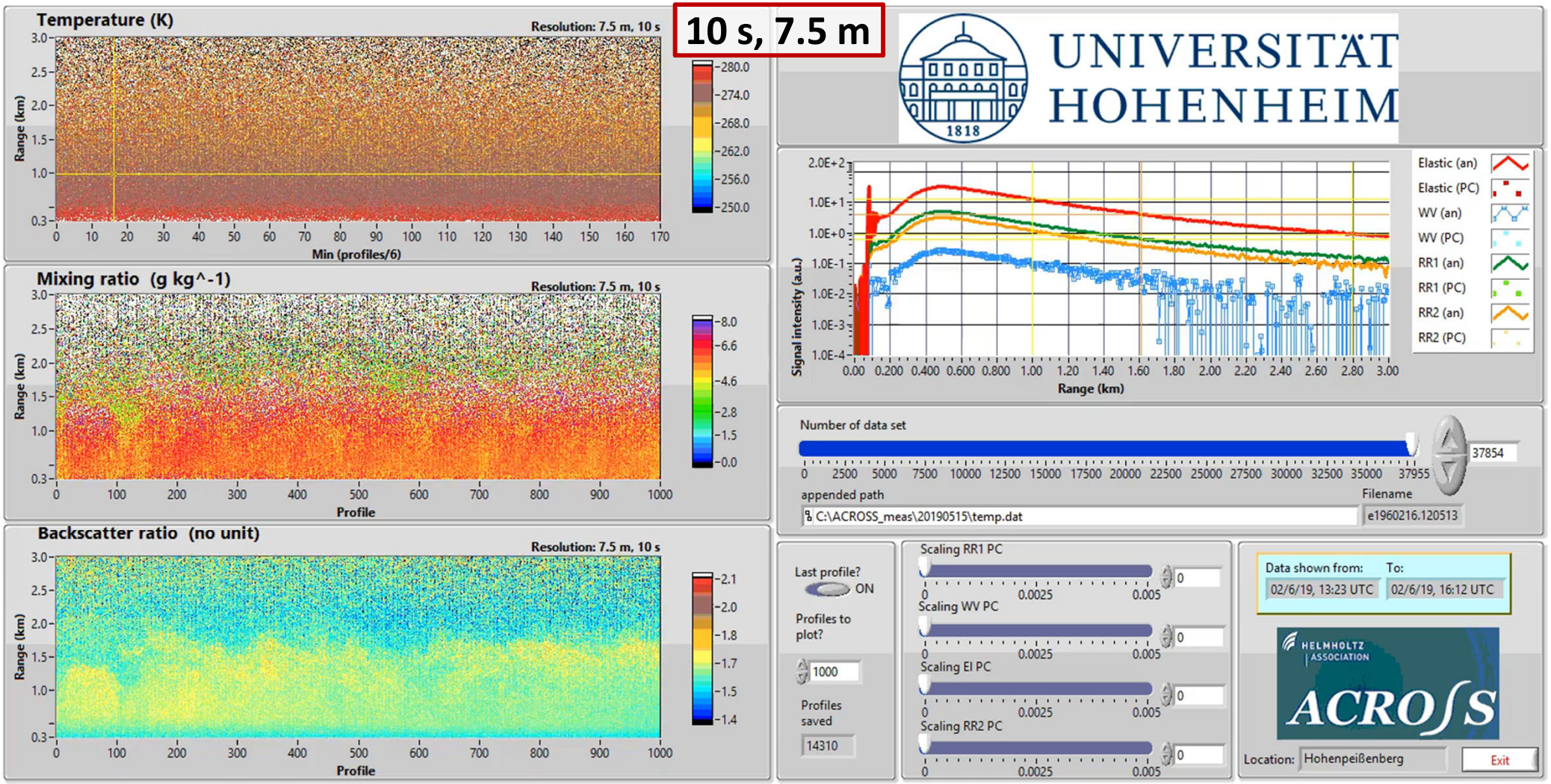
https://blogs.helmholtz.de/moses/de/

https://scalex.imk-ifu.kit.edu/#campaigns

Hohenpeißenberg – Bavaria, Germany



Real-Time Control: LabView Panel



Applications of new WVTRL

- Climate monitoring
- Model verification
- Verification of other observing systems
- Process studies and improvement of model physics:
  - Land-surface exchange
  - PBL turbulence research including entrainment
  - Mesoscale processes such as convection initiation
  - *Aerosol-cloud interaction*
- Nowcasting
- Data assimilation for numerical weather prediction
- Articifial intelligence and machine learning
- Airborne operation, …