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

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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

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

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

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

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

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

Housing: Ultra-stable, thermally controlled frame and housing
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 x D)

Weight:
Approx. 900 kg

Operation temperature:
-20°C to 40°C

Power consumption:
Approx. 5 kW
WVTRL Performance

Water Vapor Mixing Ratio (g kg⁻¹)


Daytime

Nocturnal PBL
Convective PBL
Nocturnal PBL

10 s, 100 m
Water Vapor Mixing Ratio (g kg\(^{-1}\))

From 29.09.2018, 0:02:25 to 29.09.2018 23:56:52, Az = 36.60, El = -97.60

- **Daytime**
- **Nocturnal PBL**
- **Convective PBL**

300 s, 100 m
Daytime

Nocturnal PBL

Convective PBL

Temperature gradient at CBL top

Mid tropospheric lid

Temperature (K)

Temperature (K)

From 29.09.2018, 0:02:25 to 29.09.2018, 23:56:52, Az = 36.60, El = −97.60

WV and T profiling fully consistent with simulations and WMO requirements.
Raman Lidar: Statistical Uncertainties

Method of Wulfmeyer et al. JAS 2016

WMO Requirements for Nowcasting/VSRF in the Lower Troposphere:

- "Breakthrough" requirement (10 min, 300 m): 1 K
  Fulfilled >> 5 km!

- "Goal" requirement (5 min, 100 m): 0.5 K
  Fulfilled up to 4 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

Temperature (K) Resolution: 7.5 m, 10 s

Mixing ratio (g kg^-1) Resolution: 7.5 m, 10 s

Backscatter ratio (no unit) Resolution: 7.5 m, 10 s

10 s, 7.5 m
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
- Artificial intelligence and machine learning
- Airborne operation, ...