Enhancing JOYCE-NF with Raman Lidar and Dual-Frequency Doppler Cloud Radar

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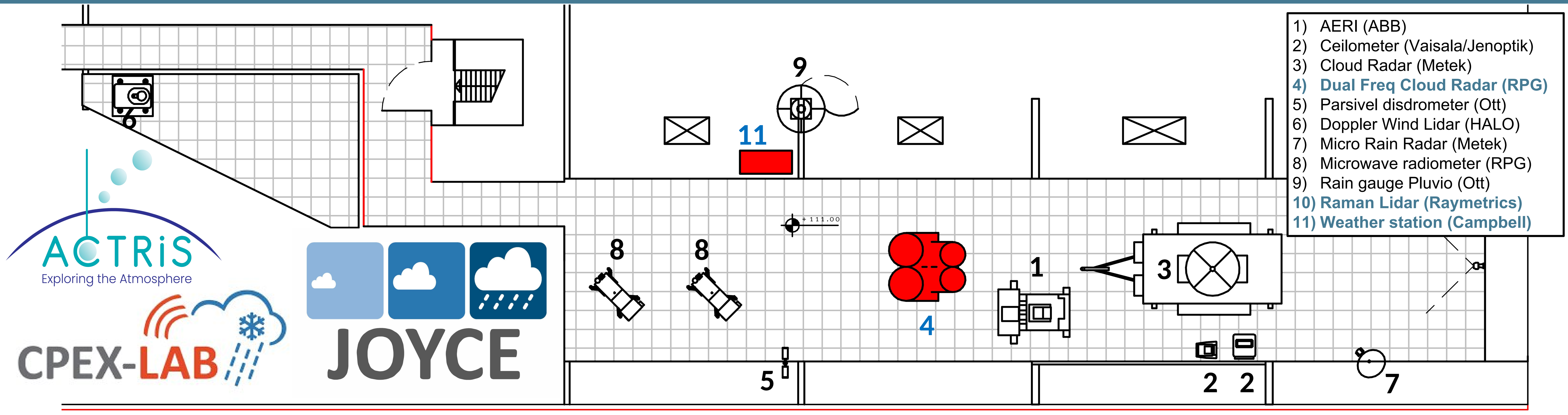
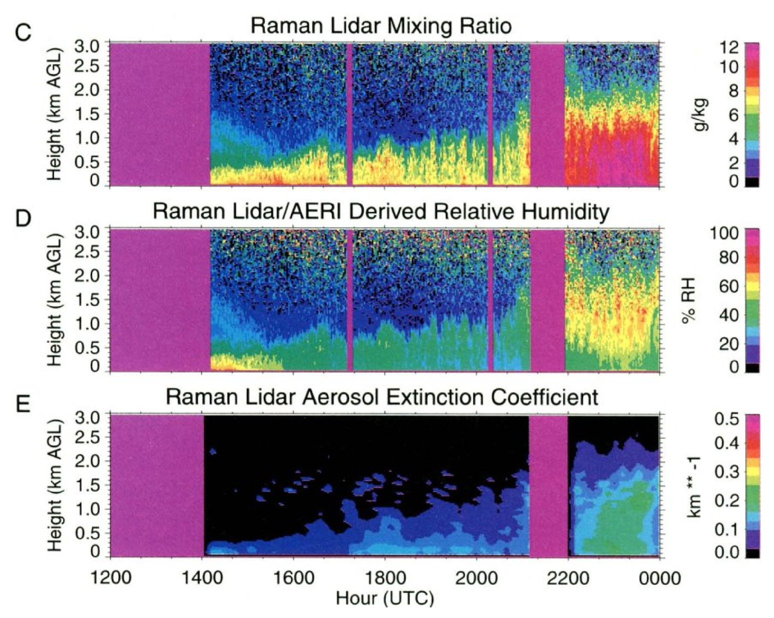


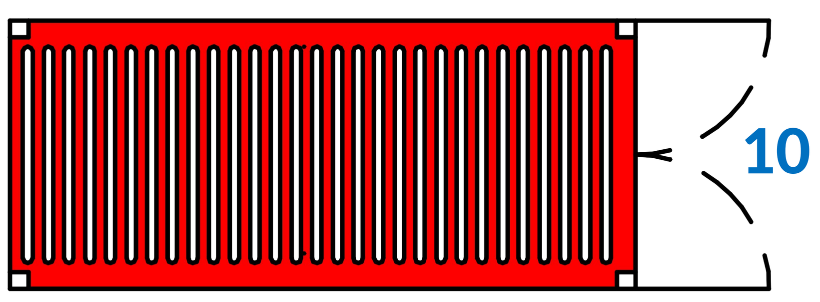
Motivation – Raman Lidar (RL)

High-resolution and continuous temperature and water vapor profiles in the ABL, through the entrainment zone and into the free troposphere during day and nighttime

- Better understanding of processes in the cloudy ABL throughout the diurnal cycle by synergistic retrievals using other JOYCE sensors (such as microwave radiometer, infrared spectrometer AERI, cloud radar)
- Investigation of the land-atmosphere interactions
- Data assimilation with ICON, Satellite evaluation (MTG-S)



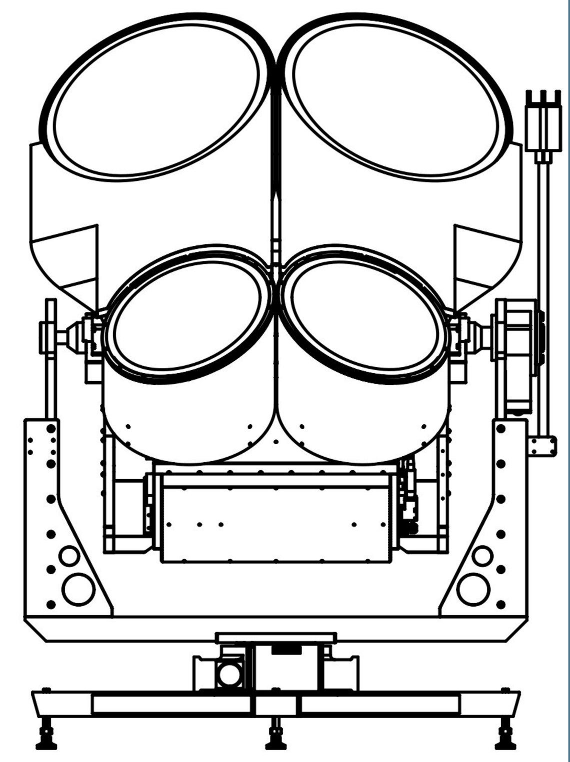
(D. Turner et al. 2000)



Motivation - Radar

Improve profiling of ABL clouds and gain deeper insight into ice & mixed-phase microphysics

- Use of dual wavelength radio
- Make use of the polarimetric radar variables
- Synergies with other remote sensing systems of JOYCE
- Develop new retrieval algorithms

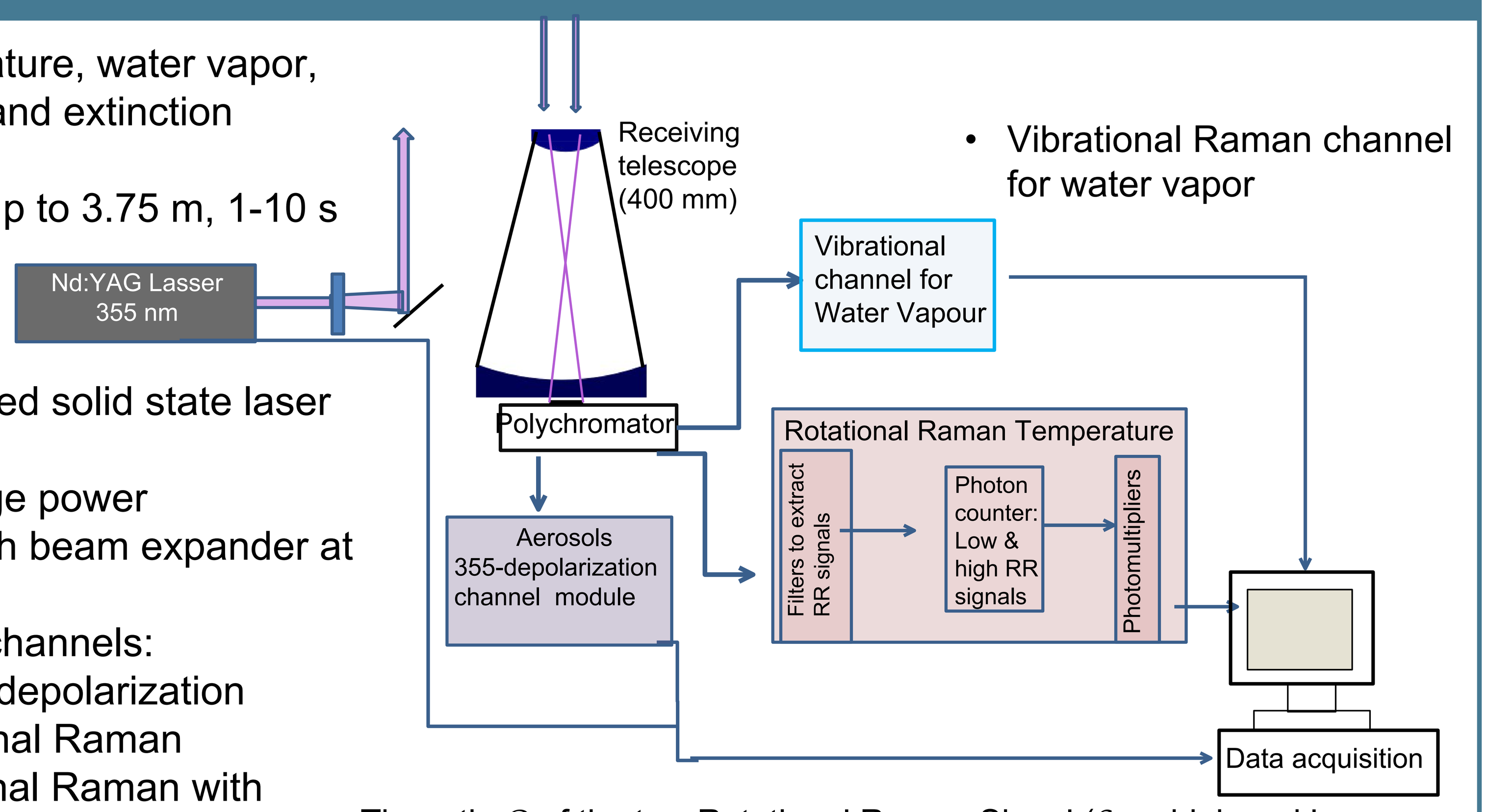


Specifications Raman Lidar

- 24/7 temperature, water vapor, backscatter and extinction profiling
- Resolution: up to 3.75 m, 1-10 s

- Diode-pumped solid state laser at 355 nm
- 20 W average power
- Eye-safe with beam expander at 200 m
- 5 receiving channels:
  - 2 elastic: depolarization
  - 1 vibrational Raman
  - 2 Rotational Raman with simultaneous analogue and photon counting

- Vibrational Raman channel for water vapor

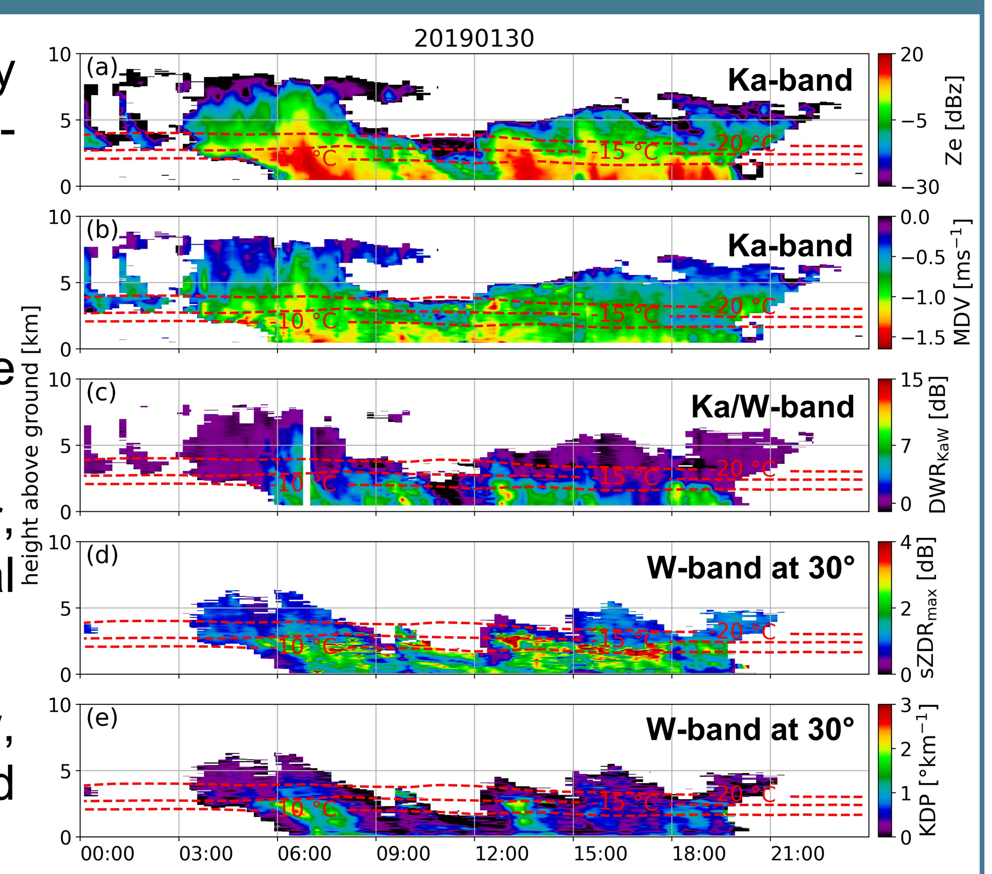


The ratio Q of the two Rotational Raman Signal (S_{RR1} high and low S_{RR2}) is a measure of temperature:

$$Q(T) = \frac{S_{RR1}}{S_{RR2}} = exp(a - \frac{b}{T}) \quad (a,b \text{ calibration constants})$$

Specifications - Radar

- FMCW Dual Frequency Polarimetric Cloud Radar at Ka- and W-band
- Full scanning capability
- Low power and robust (solid state transmitter)
- Both frequencies on one scanner, optimized beam matching for dual wavelength technique
- Measured variables: Ze, V_m, Sw, Skewness and Kurtosis and Doppler spectra
- Full Polarimetric capabilities in both channels: additional variables Zdr, Phi, K_{dp} and Rho_{HV} as well as spectral polarimetric information



(a) Ze and (b) MDV at Ka-band, and the (c) DWRKaW are shown as time-height plots. From polarimetric observations at W-band and 30° elevation angle (mapped to height above ground), the (d) maximum spectral ZDR sZDRmax and (e) KDP are presented. In (a–e), the dashed red lines depict the −20, −15 and −10 ◦C isotherms.

Plot from Van Terzi et al., 2022

Next Steps Raman Lidar

- Installation planned for Autumn/Winter 2023
- First experimental, then routine 24/7 observations
- Derive temperature and humidity profiles, evaluate with other JOYCE instrumentation
- Combine RL temperature and humidity profiles with Doppler Lidar velocities to derive profiles of sensitive and latent heat fluxes in the ABL

Next Steps Radar

- Installation planned for Autumn 2023, test setup, compare to MIRA-35
- Derive LWC profiles with dual-wavelength technique (O'Connor et al. 2005)
- Common scan-pattern with JuxPol (scanning X-band radar in JOYCE proximity) and investigate polarimetric radar variables for cloud microphysical process studies

References:

- von Terzi, L., Dias Neto, J., Ori, D., Myagkov, A., and Kneifel, S.: Ice microphysical processes in the dendritic growth layer: a statistical analysis combining multi-frequency and polarimetric Doppler cloud radar observations, Atmos. Chem. Phys., 22, 11795–11821, https://doi.org/10.5194/acp-22-11795-2022, 2022.
- Raymetrics Technical Proposal: Water Vapor and Temperature Raman Lidar for JOYCE, Technical Documentation
- O'Connor, E. J., Hogan, R. J., & Illingworth, A. J. (2005). Retrieving stratocumulus drizzle parameters using Doppler radar and lidar. *Journal of Applied Meteorology*, *44*(1), 14-27.
- Turner, D. D., Feltz, W. F., & Ferrare, R. A. (2000). Continuous water vapor profiles from operational ground-based active and passive remote sensors. *Bulletin of the American Meteorological Society*, *81*(6), 1301-1318.