Metadata file for the Payerne NDACC station, October 2024

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Instrument: RAman Lidar for Meteorological Observations (RALMO)
Site(s): Payerne

1 Measured Quantities

1. Water Vapour mixing ratio
2. Temperature
3. Relative Humidity
4. Backscatter coefficient

2 Contact information

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3 Instrument Description

Here, we provide a short overview of the fundamental operating principles of RALMO; for a detailed description of the temperature and humidity transceiver systems, the interested reader shall refer to the publications by Martucci et al. (2021) and Dinoev et al. (2013), Brocard et al. (2013), respectively. RALMO's output beam is a 354.7 nm pulsed laser emitted into the atmosphere at a repetition rate of 30 Hz, the atmospheric-backscattered signal returning to the receiver is an envelope of five Raman signals and one elastic-backscattered signal.

The five Raman raw signals are the $S0_{J_{\text{high}}}$ and $S0_{J_{\text{low}}}$ pure rotational Raman ($Q-$branches around the Cabannes line at 354.7 nm), the $S_{\text{H}_2\text{O}}$ vibrational Raman water vapour at 407.45 nm, the S_{N_2} vibrational Raman Nitrogen at 386.7 nm, the S_{O_2} vibrational Raman Oxygen at 375.4 nm and the elastic signal S_{el} at the Cabannes line at 354.7 nm. The polychromators are optical units that separate the incoming envelope of wavelengths into the five Raman and the elastic wavelength. They transmit them to dedicated PMTs and subsequently to the two acquisition systems: the National Instrument for J_{high} and J_{low} and Licel for the other signals. The data acquisition software has been developed to ensure autonomous operation of RALMO, real-time data processing and rapid ($\approx$1 h) T and q product availability in the MeteoSwiss database.
The full list of publications about RALMO fitting NDACC interest at least partially:Papanikolaou et al. (2024); Jayaweera et al. (2024); Farhani et al. (2023); Chouza et al. (2022); Martucci et al. (2021); Brunamonti et al. (2021); Hicks-Jalali et al. (2020); Leuenberger et al. (2020); Gamage et al. (2020); Hicks-Jalali et al. (2019); Navas-Guzmán et al. (2019); Sica and Haefele (2016, 2015); Brocard et al. (2013); Dinoev et al. (2013)

4 Operational Algorithm

The used algorithm to process the raw data measured by RALMO is called Automatic Data Treatment (ADT), a MATLAB-based processing software for the retrieval the measured quantities listed above. ADT releases (data processing version number):

1. 1.0 1.1.2008-31.12.2013
2. 2.0 1.1.2014-15.8.2015
3. 3.0 16.8.2015-20.6.2018
4. 4.0 21.6.2018-16.10.2019
5. 5.0 17.10.2019-16.12.2021
6. 5.1 17.12.2021-13.03.2022
7. 5.2 14.03.2022-15.03.2023
8. 5.3 16.03.2023-

5 Water Vapour Mixing Ratio

At any time t, the RALMO ("ral") profile of water vapour mixing ratio $q_{\text{ral}}(t, z)$, retrieved from the solar background and dead-time corrected Raman signals $S_{\text{H}_2\text{O}}$ and S_{N_2} at the atmospheric level z, is proportional to the ratio R of the water vapour signal to the nitrogen signal, $R = S_{\text{H}_2\text{O}}/S_{\text{N}_2}$, Eq. (1). $S_{\text{H}_2\text{O}}$ and

$S_{\mathrm{N_2}}$ signals are stored into profiles with raw temporal resolution of 1 min and raw vertical resolution of 3.75 m. The profile $q_{\mathrm{ral}}(\mathcal{T}, \mathcal{Z})$ is retrieved integrating the 1-minute profiles over a 30-minute interval and averaging within the vertical bin $[z-15, z+15]$ m around each grid point z resulting in grid spacing of 30 m for $\mathcal{Z}$. The total altitude range spans the interval between the altitude of RALMO (491 m amsl) and a user-defined upper-bound altitude $z_{\mathrm{end}} < 60$ km. The value of $q_{\mathrm{ral}}(\mathcal{T}, \mathcal{Z})$ depends also on the ratio α of the differential Raman extinction coefficients (one-way differential atmospheric transmission) at the wavelengths of $S_{\mathrm{H_2O}}$ and $S_{\mathrm{N_2}}$. The Eq. (1) can be simplified neglecting the Raman differential extinction as its contribution comes mainly from the aerosol extinction and is less than 10% in the troposphere.

$$\begin{aligned} q_{\mathrm{ral}}(\mathcal{T}, \mathcal{Z}) &= C_0 \frac{S_{\mathrm{H_2O}}(\mathcal{T}, \mathcal{Z})}{S_{\mathrm{N_2}}(\mathcal{T}, \mathcal{Z})} \frac{\exp\Big(-\int_{\mathcal{Z}_{min}}^{\mathcal{Z}_{max}} \alpha_{\mathrm{N_2}}(z')\, dz'\Big)}{\exp\Big(-\int_{\mathcal{Z}_{min}}^{\mathcal{Z}_{max}} \alpha_{\mathrm{H_2O}}(z')\, dz'\Big)} \\ &= C_0 R(\mathcal{T}, \mathcal{Z}) \frac{\exp\Big(-\int_{\mathcal{Z}_{min}}^{\mathcal{Z}_{max}} \alpha_{\mathrm{N_2}}(z')\, dz'\Big)}{\exp\Big(-\int_{\mathcal{Z}_{min}}^{\mathcal{Z}_{max}} \alpha_{\mathrm{H_2O}}(z')\, dz'\Big)} \\ &\approx C_0 R(\mathcal{T}, \mathcal{Z}) \end{aligned} \tag{1}$$

The RALMO profile of water vapour mixing ratio $q_{\mathrm{ral}}(\mathcal{T}, \mathcal{Z})$ is calibrated automatically every morning (in cloudless conditions) using the signal coming from the sun when it reaches an altitude of 19.80° elevation angleHicks-Jalali et al. (2020).

6 Pure rotational temperature

As for the retrieval of the the temperature T_{ral}, the $S_{J_{\mathrm{high}}}$ and $S_{J_{\mathrm{low}}}$ pure rotational Raman signals have raw temporal resolution of 1 min and raw vertical resolution of 2.4 m. The intensity of the rotational Raman lines J_{high} and J_{low} of $\mathrm{N_2}$ and $\mathrm{O_2}$ molecules depends on the atmospheric temperature. Reversely, the atmospheric temperature can be expressed as a function of the ratio of the two rotational Raman signals $Q = S_{J_{\mathrm{low}}}/S_{J_{\mathrm{high}}}$. The retrieval of the temperature at the atmospheric level $\mathcal{Z}$ and time $\mathcal{T}$ depends on Q and on two calibration coefficients, A and B.

$$T_{\mathrm{ral}}(\mathcal{T}, \mathcal{Z}) \approx \frac{A}{B + \ln Q(\mathcal{T}, \mathcal{Z})} \tag{2}$$

A and B are determined by calibration of $T_{\mathrm{ral}}(\mathcal{T}, \mathcal{Z})$ against the radiosonde observation $T_{\mathrm{rs}}(\mathcal{T}_{\mathrm{rs}}^{\mathrm{Night}}, \mathcal{Z})$ every night in cloudless conditions at $\mathcal{T}_{\mathrm{rs}}^{\mathrm{Night}} = 23$ UTC. Like for the water vapour mixing ratio, also for the temperature retrieval the solar background represents a source of error. Therefore, the temperature is calibrated only during the night. The retrieved temperature profile is calibrated automatically every night in clear-sky conditions using the colocated Payerne radiosounding at 23 UTC.

7 Expected Precision/Accuracy of Instrument

Water Vapour $q_{\mathrm{ral}}(\mathcal{T}, \mathcal{Z})$: within 5 to 10% of radiosonde values up to 8 km at night, and within 3% up to 3 km during the day. Temperature $T_{\mathrm{ral}}(\mathcal{T}, \mathcal{Z})$: 0.1 K bias and 0.5 K standard deviation in the first 10 km at night, and 0.2 K bias and 0.6 K in the first 5 km at daytime.

8 Instrument History

2007: Installation.
2008: Start measurements of water vapour.
2011: Start temperature and aerosol measurements.
2015: Change of acquisition system for temperature $S0_{J_{\mathrm{high}}}$ and $S0_{J_{\mathrm{low}}}$ channels, from Licel to FastCom.
2018: Change of laser source, from Excel to Litron.
2023: Installation of National Instrument acquisition cards for PRR temperature channels. The NI cards replace the previous Fastcom acquisition cards.
2024: Installation of the depolarization channel (not operational, only test mode).
2025: Expected start of operational mode of the the depolarization channel.

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