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GRUAN

VALIDATION AND UNCERTAINTY CHARACTERIZATION OF WATER VAPOR MIXING RATIO FROM RALMO

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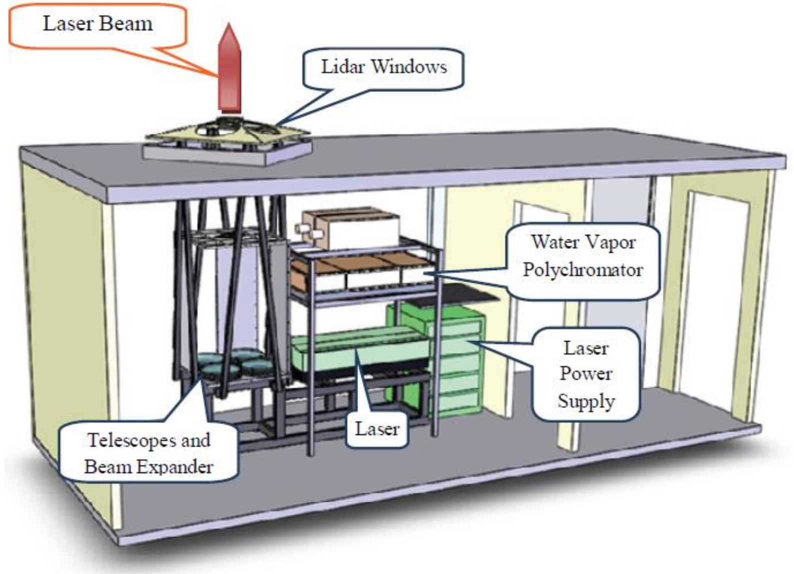
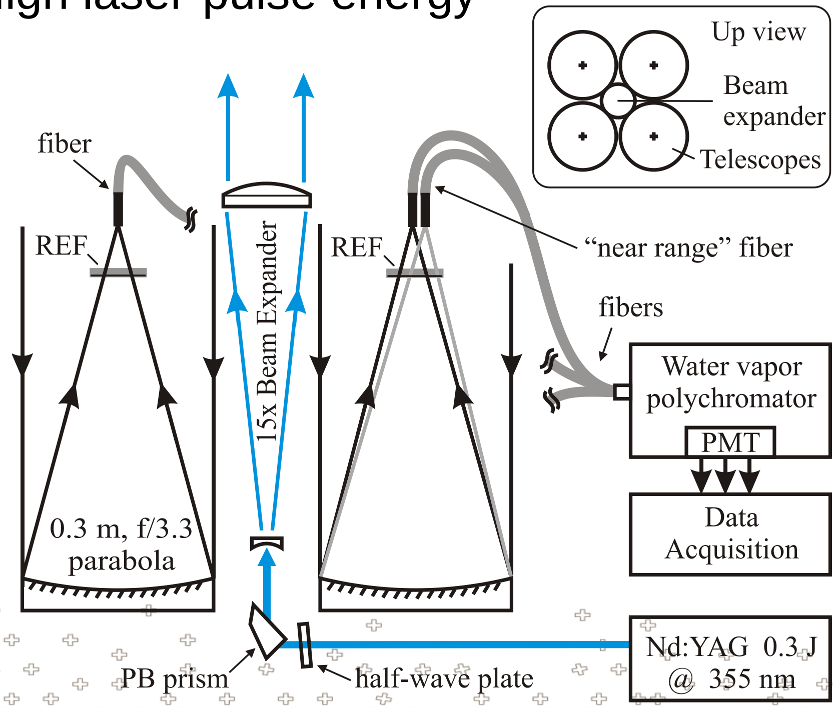
The RAman Lidar for Meteorological Observations - RALMO

- Operated in Payerne, Switzerland
- Since 2008
- Fully automatic Raman lidar

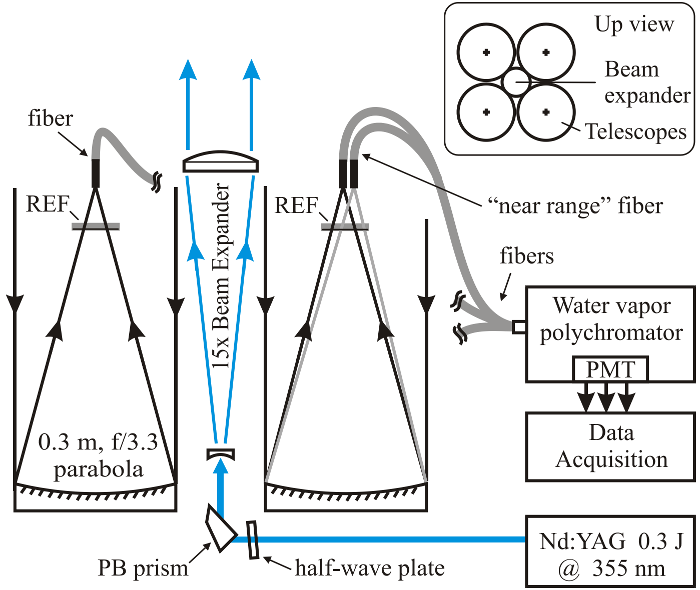
- Day and nighttime operation
- Narrow FOV and bandwidth
- High laser-pulse energy





Transmission

- The laser output at 355 nm is aligned onto the beam expander:



- The elastic and Raman light backscattered from the atmosphere is collected by 4 mirrors and focalized onto optic fibers.
- The H2O and N2 signals are separated by a razor-edge filter from the PRR, O2 and elastic signals.
- The two groups of signals are transmitted through fibers to two polychromators (both based on reflective holographic diffraction grating)
- The output signals from the T- and WV-polychromators are transmitted to dedicated PTs and then to the acquisition cards (FastCom for PRR and Licel for the others)

Automatic Data Treatment -ADT

- The Matlab multi-module on-line data software reads the FastCom and Licel raw data.
- The raw data are automatically saved in a folder where ADT load them every 30 minutes.
- Humidity H2O and N2 data are combined to provide uncalibrated WV mixing ratio.
  - ❑ The automatic solar-background calibration module runs autonomously and provides the calibration coefficient for the WV mixing ratio every day.
- The PRR signals are combined to provide uncalibrated atmospheric temperature.
  - ❑ An automatic module performs a calibration using radiosounding every night if the night is clear and applies the calibration coefficient for the next 48 profiles (24 hours). If no calibration has been performed, the last available calibration is used instead.

The equation (Weitkamp, Claus., 2005) describes the mixing ratio of a gas with respect to e reference gas. We use exactly this equation where $P_R(z)$ is the water vapour signal at 407.49 nm, $P_{Ref}(z)$ is the Nitrogen signal at 386.69 nm, C is the lidar calibration factor and α_{Ref} and α_R are the Raman extintion from N2 and H2O molecules.

$$m(z) = C \frac{P_{\mathrm{R}}(z)}{P_{\mathrm{Ref}}(z)} \frac{\exp[-\int_0^z \alpha_{\mathrm{Ref}}(\zeta)\mathrm{d}\zeta]}{\exp[-\int_0^z \alpha_{\mathrm{R}}(\zeta)\mathrm{d}\zeta]},$$

$$\Delta\tau = \frac{\exp[-\int_0^z \alpha_{\mathrm{Ref}}(\zeta)\mathrm{d}\zeta]}{\exp[-\int_0^z \alpha_{\mathrm{R}}(\zeta)\mathrm{d}\zeta]}$$

$\Delta\tau$ is the one-way differential atmospheric transmission at water vapor and nitrogen Raman wavelengths and depends on the profiles of the aerosol and molecular differential extinction

$$\Delta\alpha^{\mathrm{a}}(z) = \alpha^{\mathrm{a}}_{\mathrm{H_2O}}(z) - \alpha^{\mathrm{a}}_{\mathrm{N_2}}(z)$$ → 10% contribution

$$\Delta\alpha^{\mathrm{m}}(z) = \alpha^{\mathrm{m}}_{\mathrm{H_2O}}(z) - \alpha^{\mathrm{m}}_{\mathrm{N_2}}(z)$$ → calculated from model

The molecular extinction is calculated from atmospheric pressure and temperature profiles, measured by the lidar-collocated radiosounding. The aerosol contribution is below 10% even for hazy conditions (Whiteman, 1992; Whiteman et al., 2001) and is neglected in our retrieval.

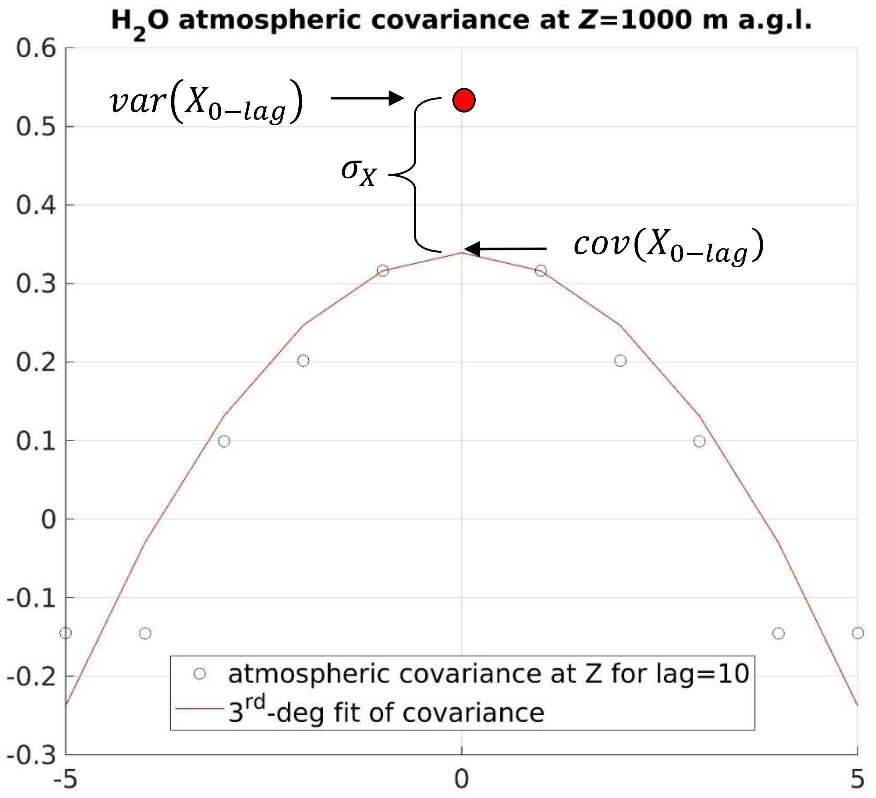
For the uncertainty, a development into Taylor's series of the equation of m(z) with (assumed independent) errors on P_R(z), P_{Ref}(z) and C is performed. The error units are the same as for the mixing ratio, i.e. g/kg.

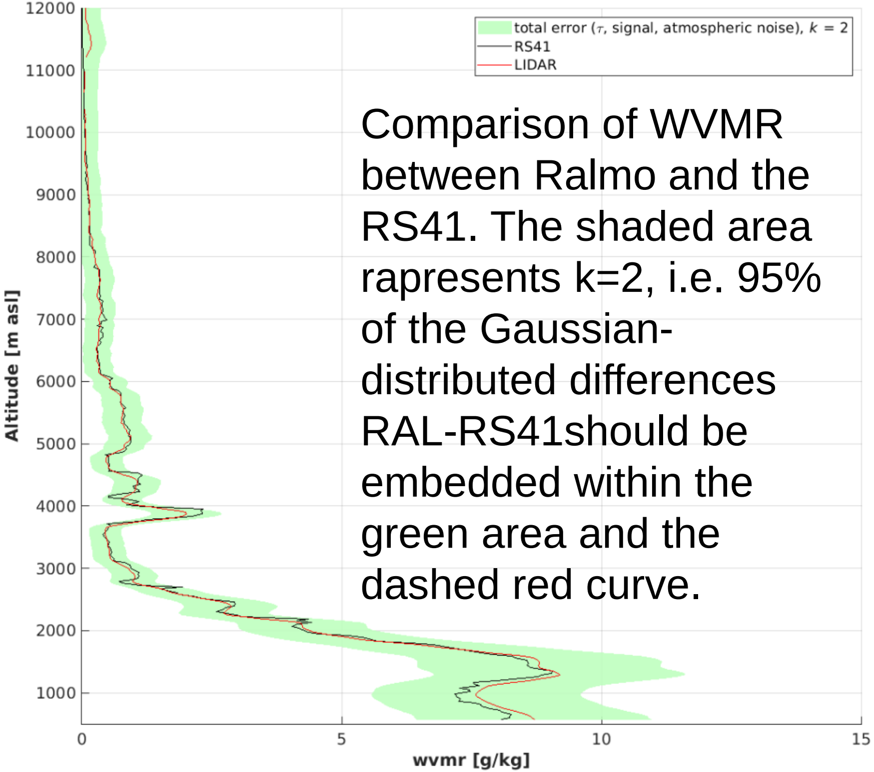
$$\sigma_{tot} = C\left(\frac{\sigma_{H2O}^2}{P_{N2}^2} + \frac{P_{H2O}^2\sigma_{N2}^2}{P_{N2}^4} + \sigma_C^2\frac{P_{H2O}^2}{C^2P_{N2}^2}\right)^{1/2} \cdot \Delta\alpha^m$$

$\Delta\alpha^m$ is the molecular contriibution to the differential extinction. The aerosol contribution is added to the total percentage error as 10%.

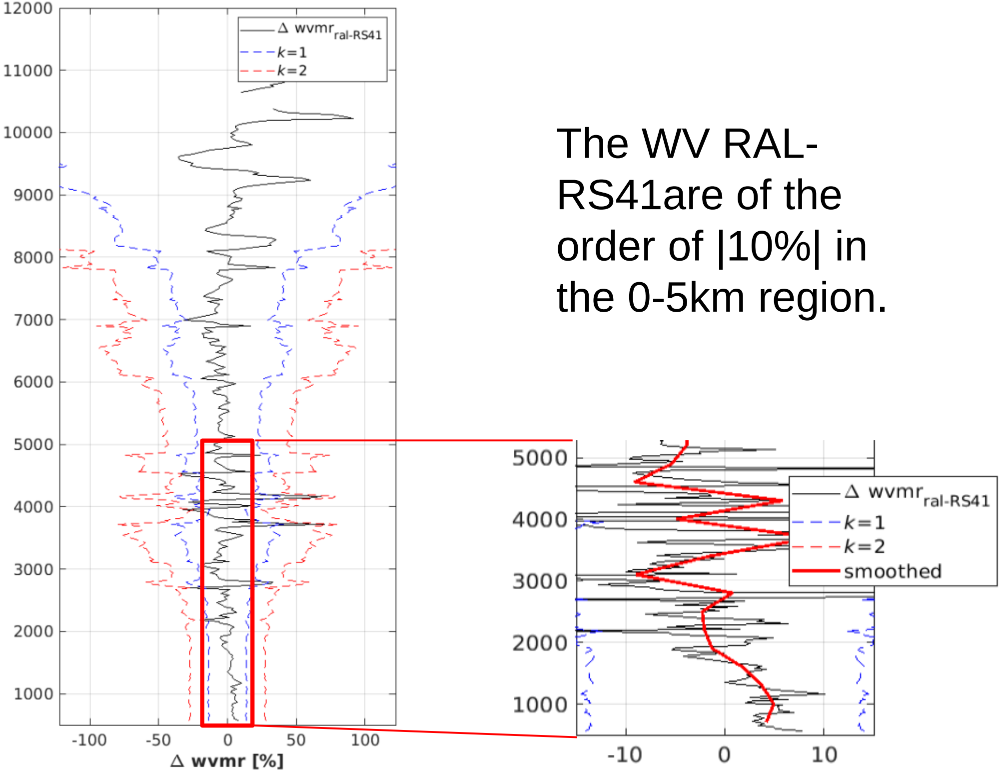
σ^2_{H2O} and σ^2_{N2} are the combination of two error contributions: the signal variance at time *i* (0-lag) and the atmospheric covariance of P_{N2} and P_{H2O} signals over a time-lag of 10 minutes (*i*-5 to *i*+5) at every altitude. The atmospheric component is subtracted from the 0-lag variance.

$$\sigma_X = var(X_{0-lag}) - cov(X_{0-lag})$$



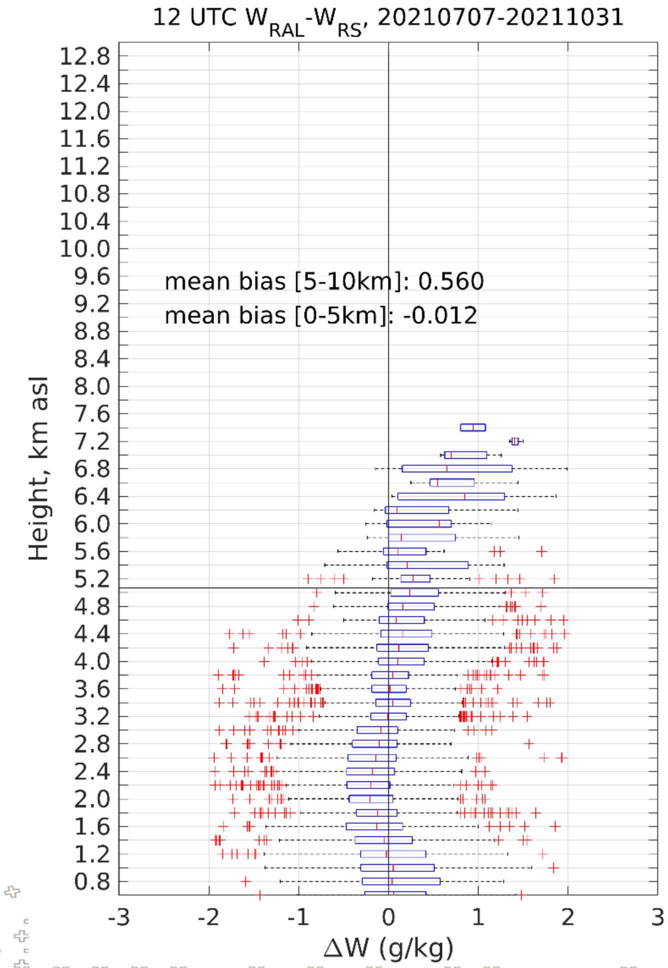


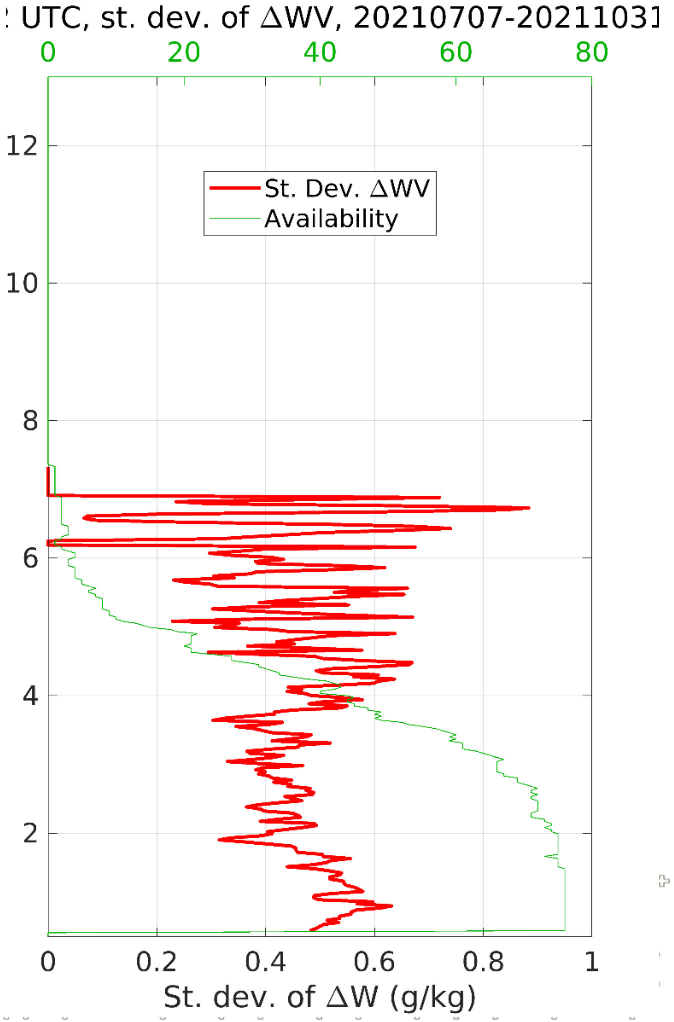
Comparison of WVMR between Ralmo and the RS41. The shaded area rapresents k=2, i.e. 95% of the Gaussian-distributed differences RAL-RS41should be embedded within the green area and the dashed red curve.



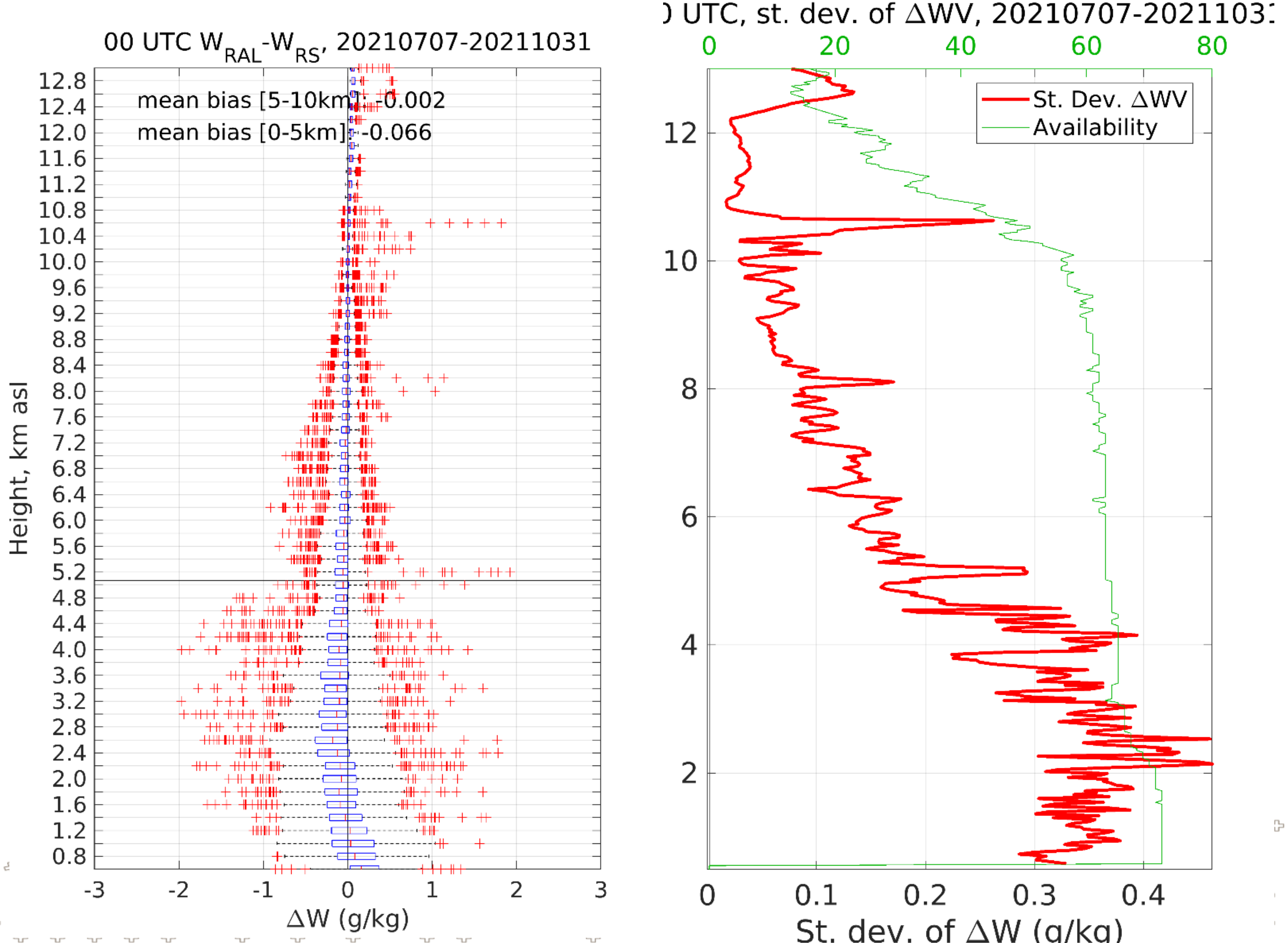
The WV RAL-RS41are of the order of |10%| in the 0-5km region.

From 7.7.2021 to 31.10.2021, profiles of WVMR have been compared to the profiles obtained by the operational sonde Vaisala RS41 at Payerne and assessed separately for daytime and nighttime (76 and 72, respectively) based on the bias and standard deviation

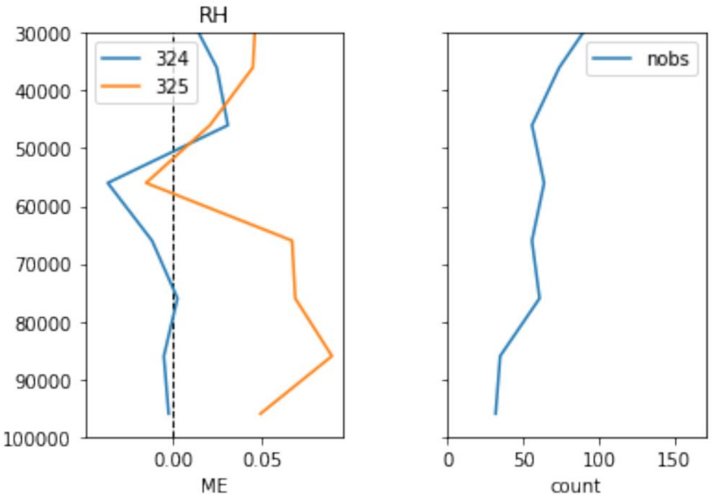




Both nighttime and daytime statistics show biases compatible with zero within k=1.
The Standard deviation is about 0.5 g/kg in the first 5 km for daytime and 0.3 g/kg for nighttime.



- RALMO finalized and QC-processed data (WVMR, T, β) are automatically saved into the MeteoSwiss Data Ware House (DWH).
- As soon as the data are into the DWH, they are available for assimilation into the NWP model COSMO.
- Since a few months the NWP team at MeteoSwiss is testing the impact of the humidity and temperature data on the weather forecasts. The impact is positive and the experiments will soon determine the start of the operational assimilation of RALMO data.



Towards operational assimilation of surface based remote sensing temperature and humidity profiler data at MeteoSwiss

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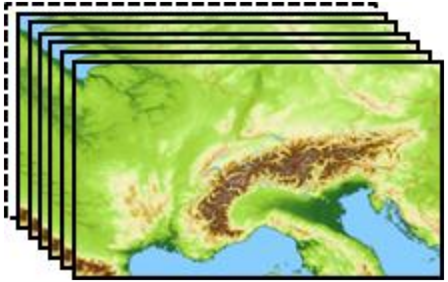
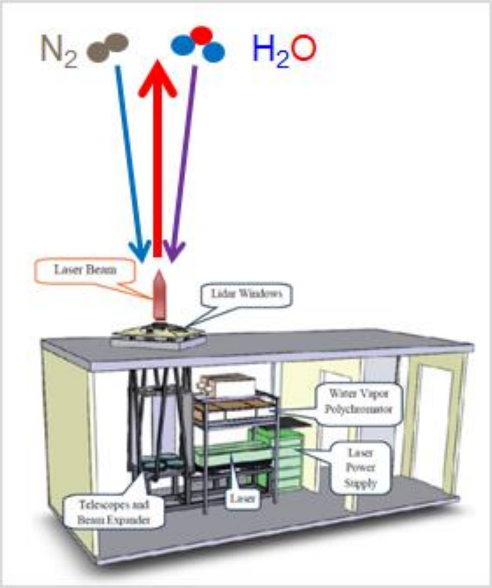
- Measurement gap in the atmospheric boundary layer, especially for temperature and humidity
- → Make use of ground-based remote sensing devices for assimilation in NWP models

COSMO-1E
+
KENDA-1

1.1 km ensemble data assimilation





Raman Lidar
One device in Switzerland
30 minutes
Active instrument
Temperature ; WV Mixing ratio profiles

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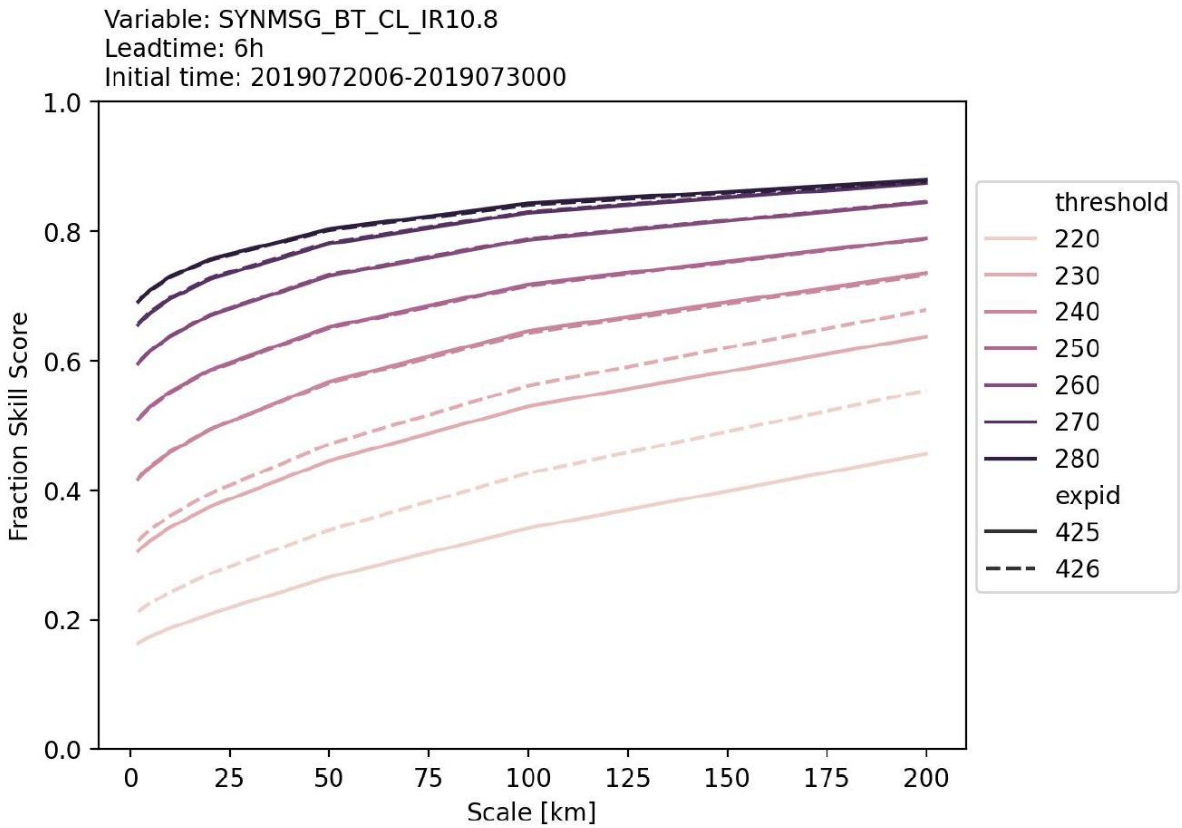
Satellite verification of forecasts (IR BT)

- The Fractions Skill Score (FSS) is a spatial verification measure that is used for assessing the performance of forecasts from numerical weather prediction models.
- Assimilation experiments from 20-30 July 2019 (convective period)
- Comparison between remote sensing observations and model analysis / first guess shows positive impact of the assimilation



In a nut shell…

- The operational WV mixing ratio measured by Ralmo during both daytime and nighttime is compatibe with the zero-bias with respect to the radiosounding within the WV mixing ratio uncertainty of 0.5 g/kg for daytime and 0.3 g/kg for nighttime.
- The first experiments of assimilation into COSMO-1E + KENDA-1 show the positive impact of assimilating temperature and humidity from Ralmo on the weather forecasts. The operational assimilation Ralmo into COSMO-1E + KENDA-1 is the next step.

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