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GRUAN

TEMPERATURE AND HUMIDITY FROM RALMO: STEPS TOWARDS A LIDAR GDP

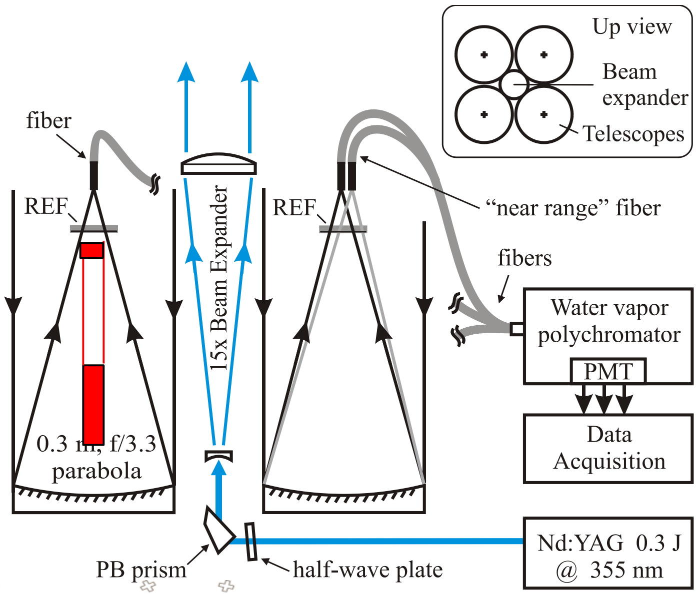
G. Martucci[1], R. Matthey[1,2], L. Renaud[1], A. Haefele[1,3], T. Leblanc[4], M. Sommer[5]

[1] Office Fédérale de Météorologie et Climatologie, MeteoSuisse, Payerne, Suisse
[2] University of Bern, Switzerland
[3] Department of Physics and Astronomy, The University of Western Ontario, London, Canada
[4] Deutscher Wetterdienst
[5] JPL-Table Mountain Facility

ICM-15, Bern-Payerne, 11-15.03.2024

- Fully automated
- Operated in Payerne since 2008
- Day and nighttime operation
- Analog and digital channels
- Holographic grating filter
- 450 mJ laser-pulse energy, 30 Hz

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



- The 355_{el}, depolarization ($355_{p,s}$) and Raman backscatter are collected by 4 mirrors and focused onto optic fibers.
- The H_2O, N_2, signals are separated from the PRR, O_2, 355_{el} signals by a razor-edge filter .
- The two groups of signals are transmitted through optical fibers to two polychromators (holographic diffraction grating).
- The output signals from the two polychromators are transmitted to dedicated PMTs and then to the acquisition cards (NI for PRR and Licel for the others).
- The $355_{p,s}$ receiver has dedicated photodetectors and are acquired onto Licel.

Payerne RALMO processing steps

Instrument description and traceability:

- Reference peer-reviewed instrument technical description.
- Reference peer-reviewed description of retrieval methods and validation.

Product calculation:

- Based on raw data.
- High quality, reference-level product data of the measured variables.
- Thorough uncertainty estimates.
- Retrieval at uncertainty-dependent vertical resolution and user-defined temporal integration (operational 30-minute, NDACC all-night)

Independent checks/calibrations:

- Calibration by radiosounding.
- Calibration by solar background.

Validation:

- Against co-located radiosounding.
- Against numerical models.

Payerne RALMO processing steps

Obs-B analysis (NWP):

- Identification of error and bias sources.
- Identification of random instabilities of the instrument.

Data full error calculation:

- Random and systematic error budget calculation
- Corrections (systematic)
  - Solar and electronic background
  - Dead time

Data flagging:

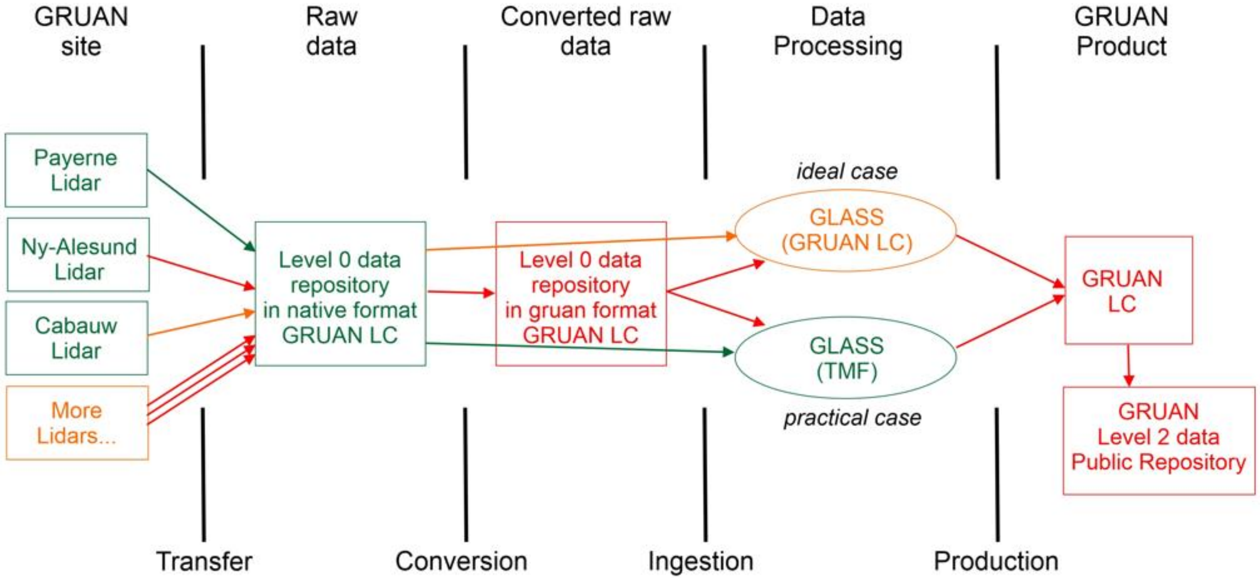
- Flagging of «uncertain» data:
  - Misalignment of optical receiver (telescopes, optic fibers, polychromators)
  - Saturation of the acquisition system.
  - Instabilities of the transceiver + acquisition units.

Steps to creation of a Ralmo lidar-GDP in a world of GLASS

green = Operational and/or automated
orange = Has happened, on a case-by-case basis, need to gear up
red = Not in place, need serious work efforts

Instrument description and traceability:

- Creation of GLASS configuration file
- Continuous update of GLASS configuration file based on instrument upgrades.



T. Leblanc talk, 3-4

Documentation

- Full technical documentation submitted to the LC

Data-flow

- Full integration of the RALMO data flow into the GRUAN data management.

What’s still needed?

(M. Sommer)

Definition of GDP file format and file content,
e.g. NetCDF, HDF,…: *defined by GLASS and GRUAN.*
Integration time: *different for each variable?*
vertical resolution: *different for each variable?*
Product for each variable?

- Humidity
- Temperature
- Ozone
- Aerosol backscatter

a standard GDP used for several different lidars, based on construction criteria?

…

MIXING RATIO

Mixing ratio of a gas with respect to a reference gas. **$P_R(z)$ is the water vapor 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 extinction** from N2 and H2O molecules.

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

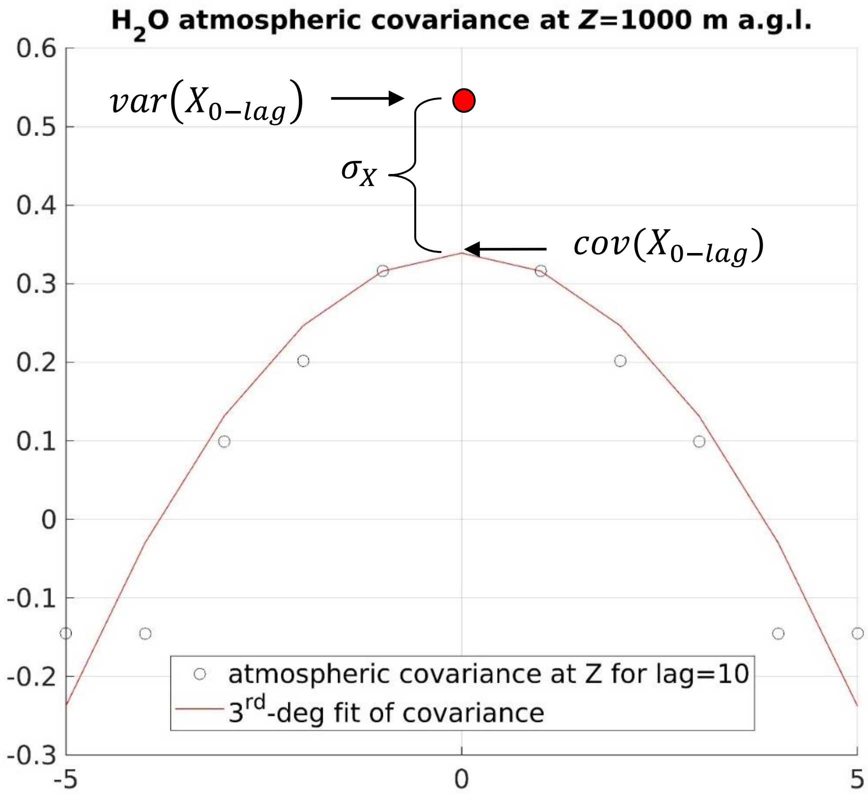
The random error is calculated developing into Taylor's series the equation of m(z) with (assumed independent) errors on $P_R(z)$, $P_{Ref}(z)$ and C is performed. The error units are the same as for the mixing ratio, i.e. g/kg.

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

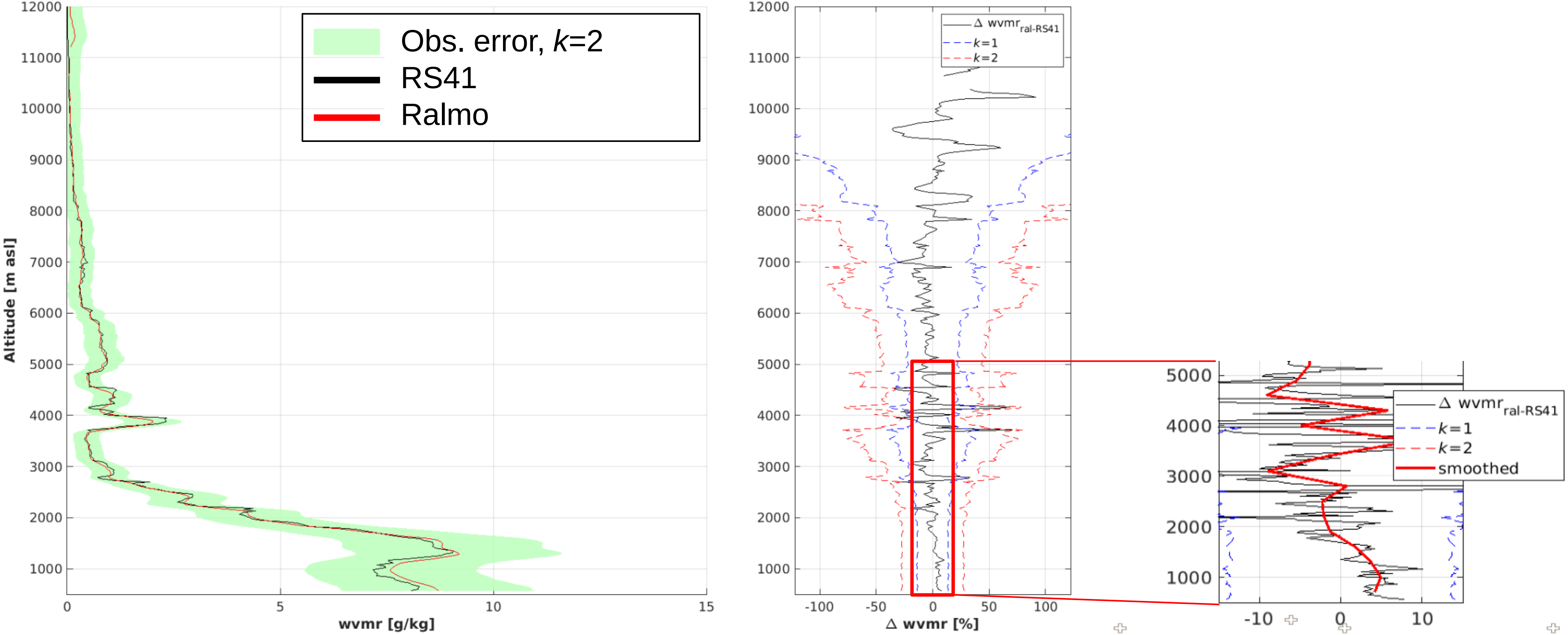
$\Delta\alpha^m$ is the differential extinction contribution accounting for maximum 10%

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.

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



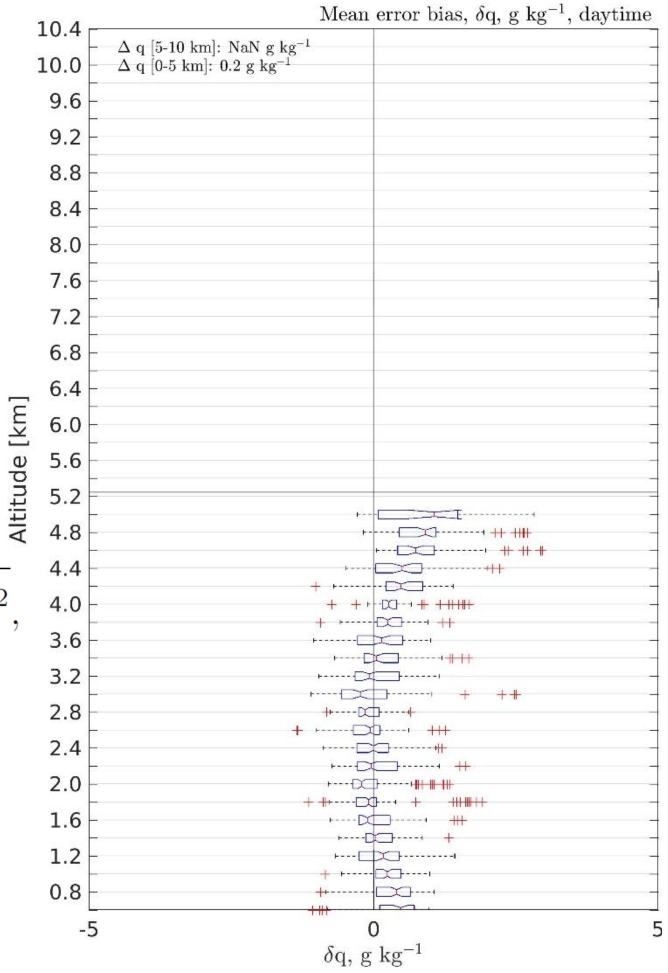
Calibration of WV using RS41, 28-Jul-2022, 23h00-23h30

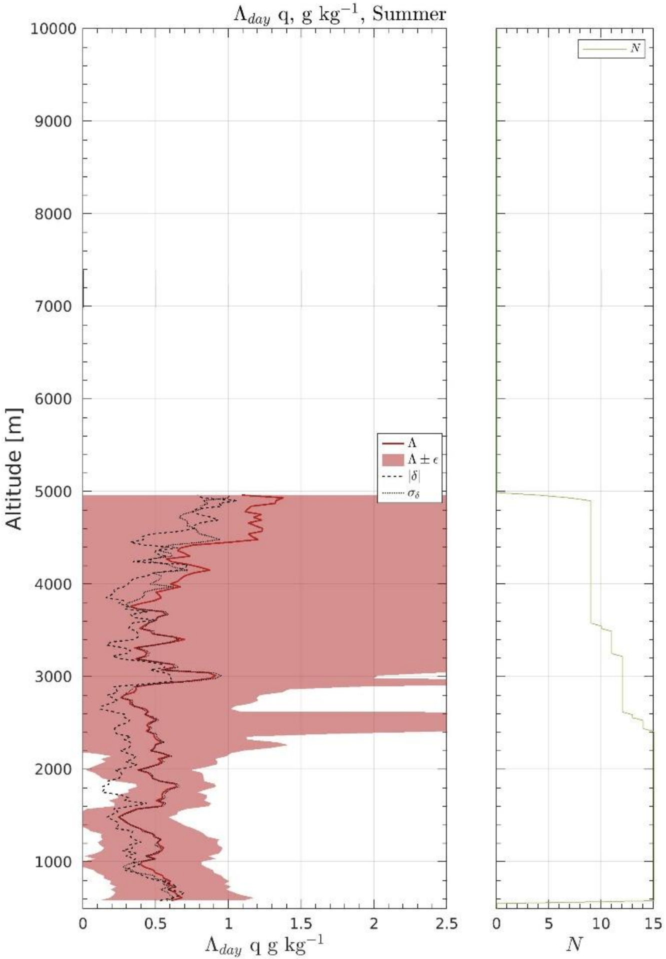


DAYTIME

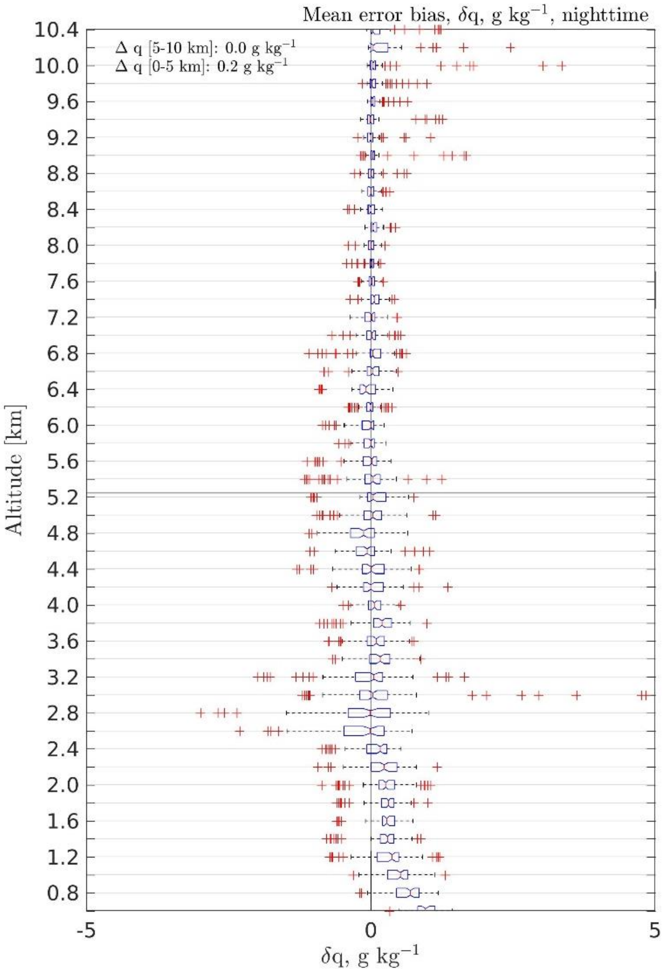
The shaded area: propagated total Ralmo error to the Lambda function:

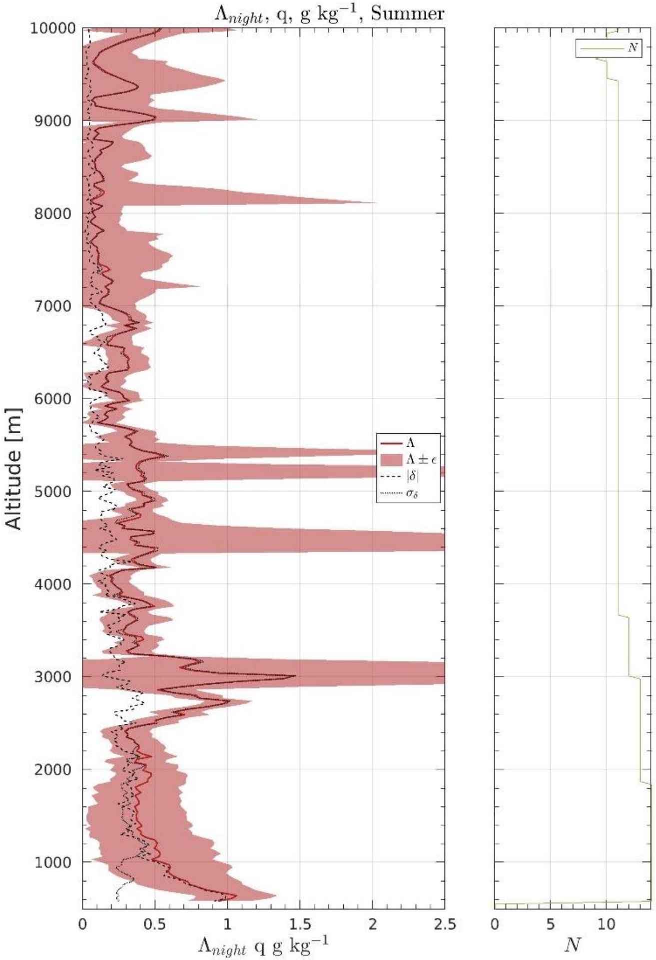
$$\Lambda_{\mathcal{T},\mathcal{Z}} = \sqrt{\frac{1}{J}\sum_{\substack{\mathcal{T}\in\mathcal{D}\\ z\in\mathcal{Z}}} \left(q_{\mathrm{ral},\mathcal{T},z} - q_{\mathrm{rs},\mathcal{T},z}\right)^2},$$





NIGHTTIME


Mean error bias, δq, g kg^{-1}, nighttime
Δ q [5-10 km]: 0.0 g kg^{-1}
Δ q [0-5 km]: 0.2 g kg^{-1}
Altitude [km]
δq, g kg^{-1}


Λ_{night}, q, g kg^{-1}, Summer
Altitude [m]
Λ_{night} q g kg^{-1}
Λ
Λ ± ε
|δ|
σ_δ
N

TEMPERATURE

$$T_{\mathrm{ral}} \approx \frac{A}{B + \ln Q}. \qquad Q(z) = J_{\mathrm{low}}(z)/J_{\mathrm{high}}(z)$$

Taylor's linear propagation with respect to the A, B coefficient and their related errors.

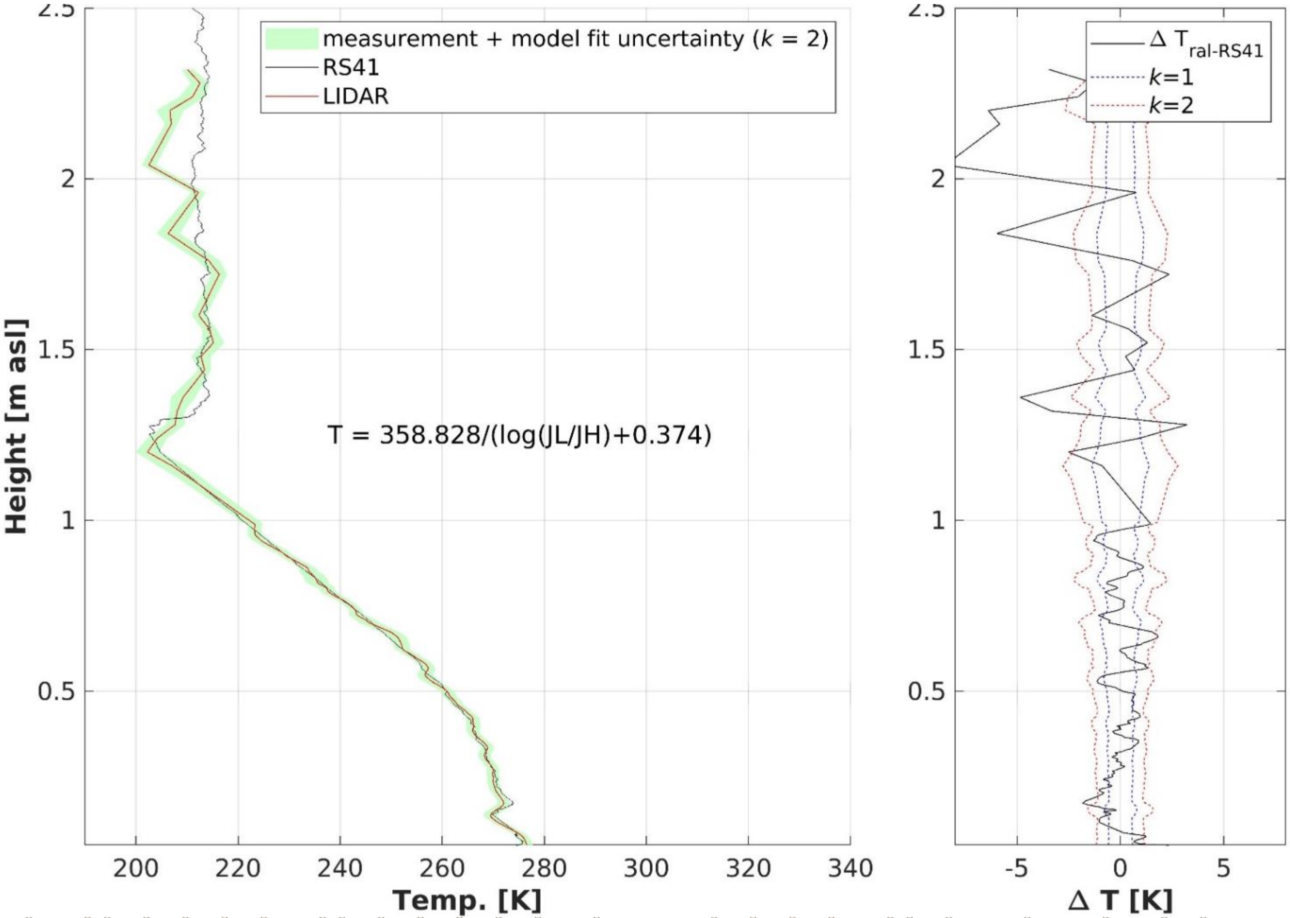
$$U_{\mathrm{fit}} = \frac{1}{(B + \ln Q)} \left[\sigma_A^2 + \frac{A^2 \sigma_B^2}{(B + \ln Q)^2} \right]^{\frac{1}{2}}.$$

Taylor's linear propagation of T equation w.r.t. the errors of J_{high}, J_{low} without the atmospheric contribution

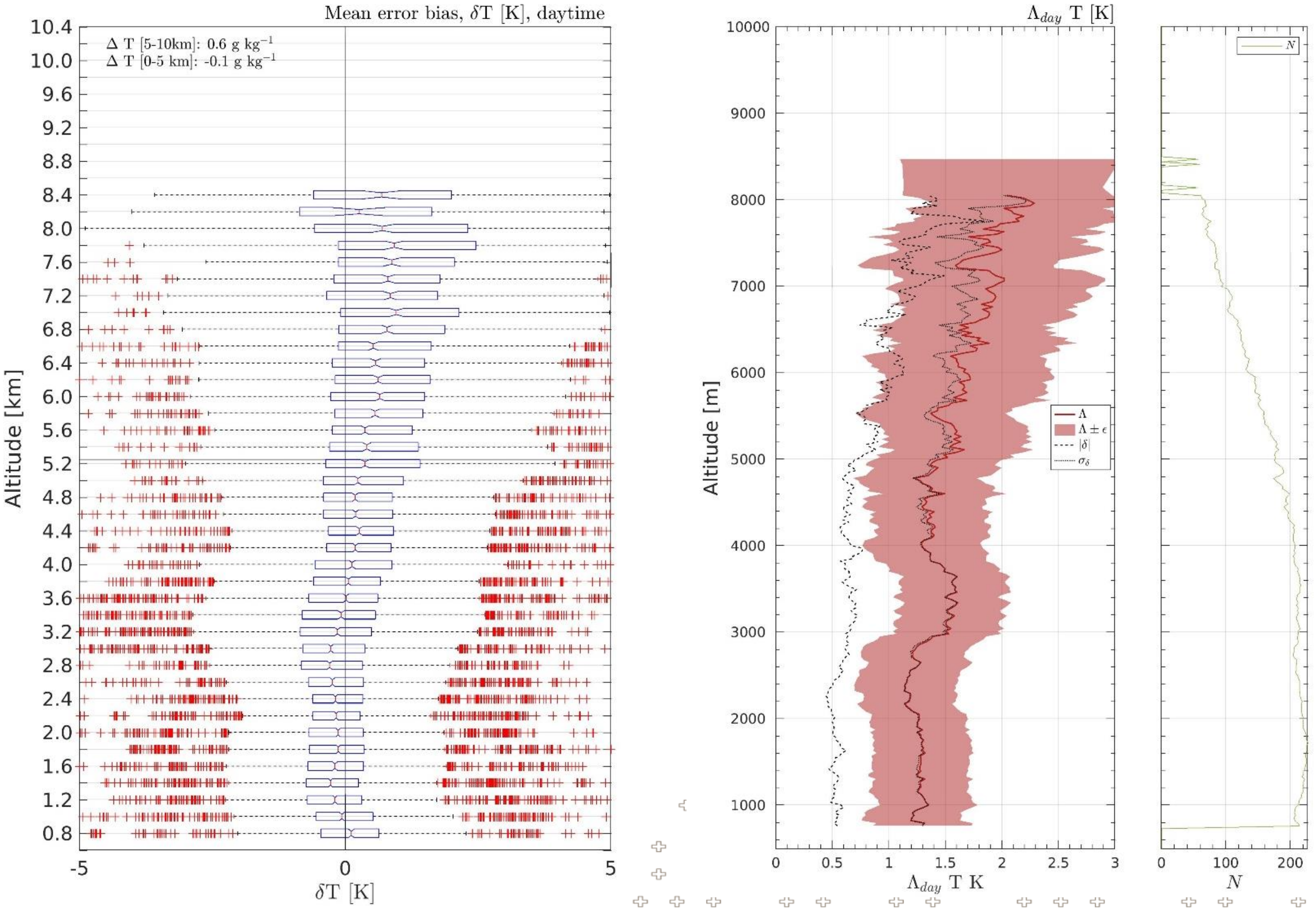
$$U_{\mathrm{sig}} = \frac{A}{(B + \ln Q)^2} \left[\frac{(\sigma_{JH})^2}{J_{\mathrm{high}}} + \frac{(\sigma_{JL})^2}{J_{\mathrm{low}}} \right]^{\frac{1}{2}}.$$

Total uncertainty: $U_T = \sqrt{U_{\mathrm{fit}}^2 + U_{\mathrm{sig}}^2}$

Calibration of T using RS41, 17-Jan-2022, 23h00-23h30

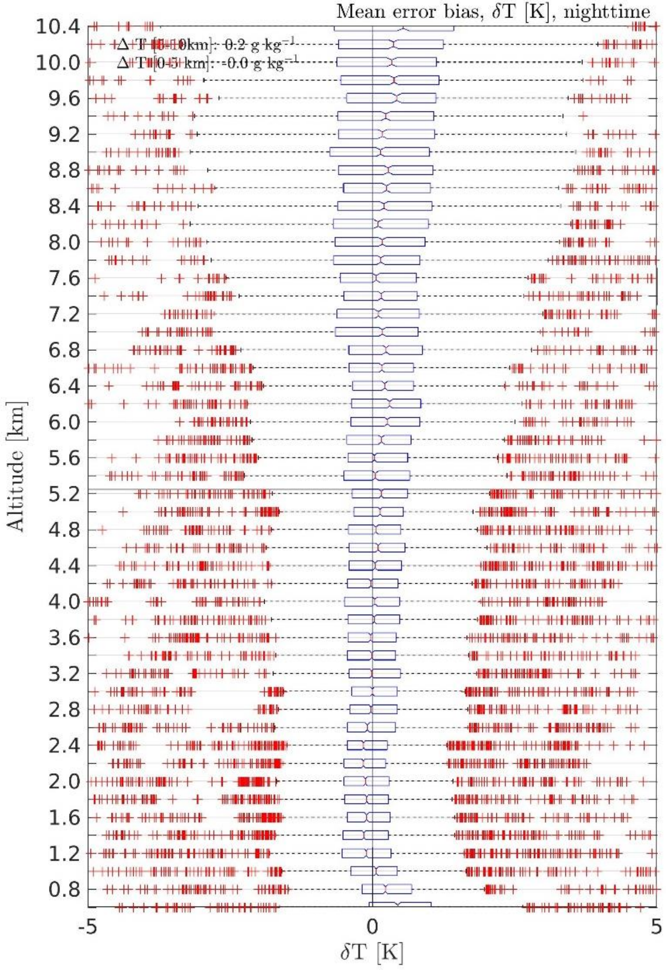


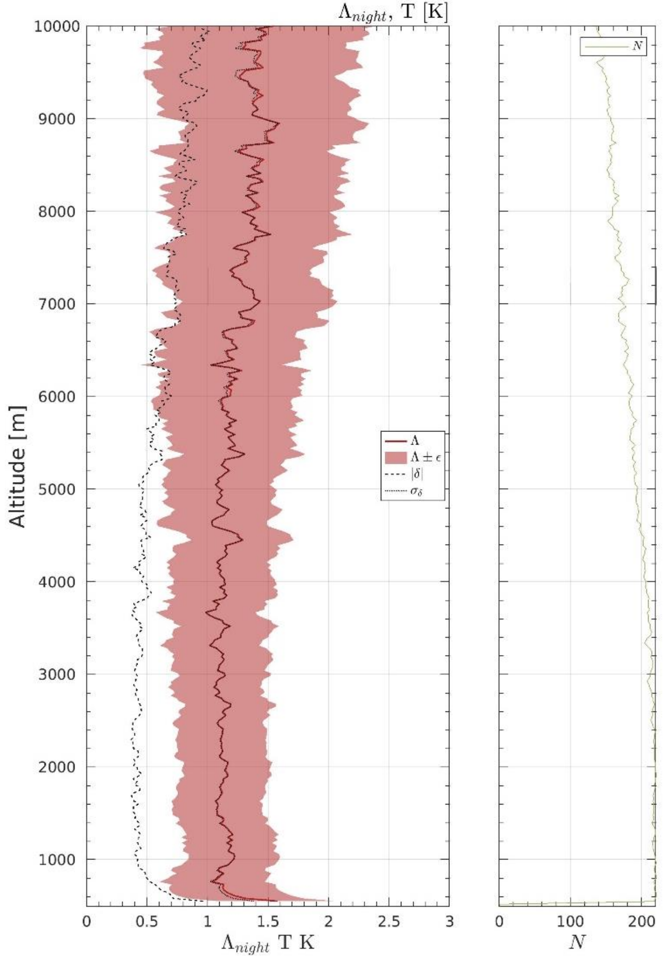
DAYTIME


Mean error bias, δT [K], daytime
Δ T [5-10km]: 0.6 g kg⁻¹
Δ T [0-5 km]: -0.1 g kg⁻¹
Altitude [km]
δT [K]
Λday T [K]
Altitude [m]
Λday T K
Λ
Λ ± ε
|δ|
σδ
N

Temperature: nighttime validation during 01.08.2021-31.08.2022

NIGHTTIME





Summary

GLASS and LC framework:

- The raw-data from RALMO are streamed automatically every day to the GRUAN LC since October 2023.
- The centralized GLASS retrieval software can process on case-based routine the RALMO data.
- The next steps is to set up the automatic processing of RALMO raw-data by GLASS and to generate the GDP in the framework of the GRUAN LC.

Payerne GDP-compliant RALMO data processing:

- RALMO data measuring and processing of temperature and humidity is automatic and 24/7.
- Data processing includes:
  - ❑ full error budget calculation,
  - ❑ correction for systematic biases and errors,
  - ❑ Calibration by independent reference measurements.