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Characterization of RALMO temperature and humidity data and error. A glimpse towards operational assimilation

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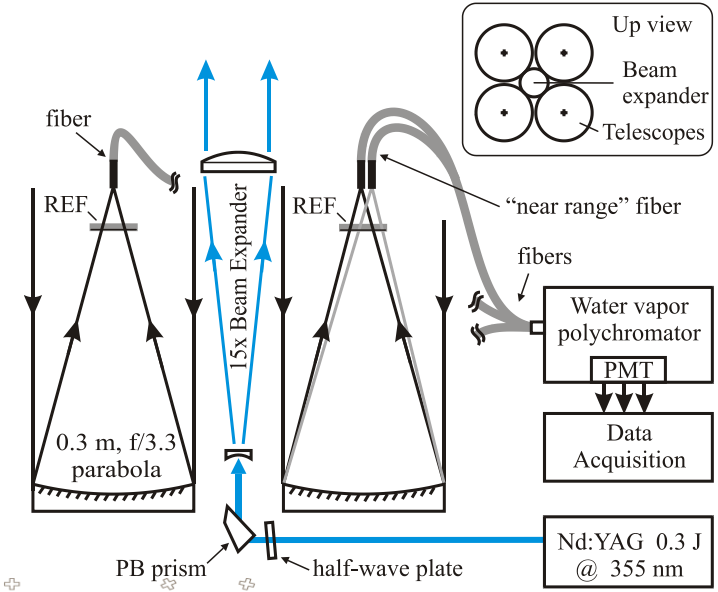
- Fully automated
- Operated in Payerne since 2008
- Day and nighttime operation
- Analog and digital channels
- Holographic grating filter
- 450 mJ laser-pulse energy
- The laser output at 355 nm is aligned onto the beam expander:



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

What's needed for a lidar GDP?

A first step taken towards lidar GDP. For temperature and humidity retrieved from lidar the following procedure is applied operationally:

- Instrument comprehensive characterization
- Random and systematic error budget calculation
- Corrections (systematic)
  - Solar and electronic background
  - Dead time (non-paralyzable condition)
- Flagging of «uncertain» data:
  - Misalignment
  - Uncorrectable saturation

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.

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

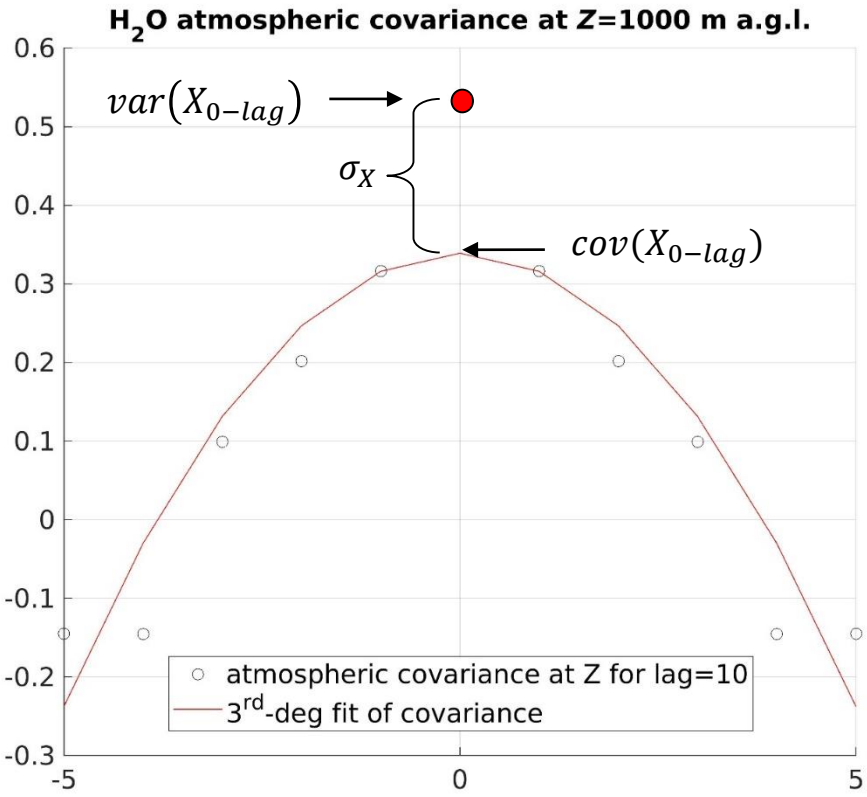
The random error is calculated developing into Taylor's series the equation of m(z) with (assumed independent) errors on $P_R(z)$, $P_{Ref}(z)$ and C is performed. The error units are the same as for the mixing ratio, i.e. g/kg.

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

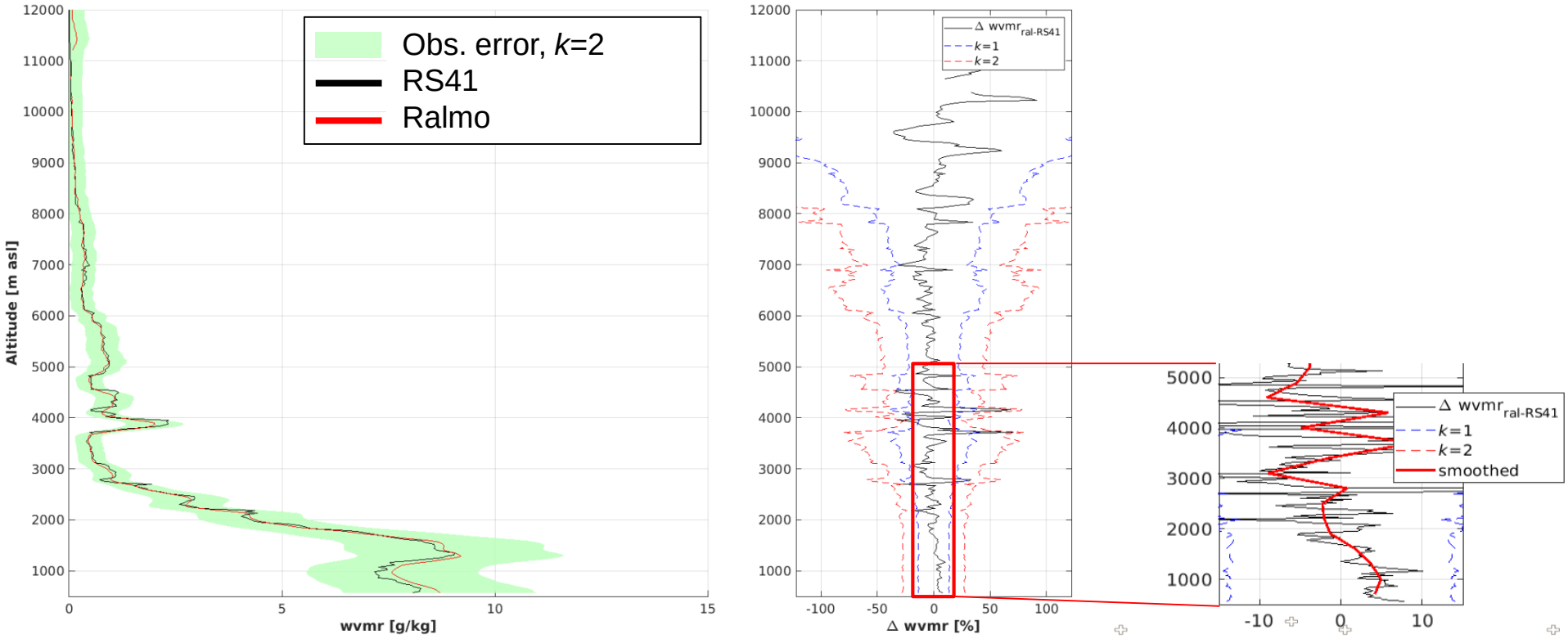
$\Delta\alpha^m$ is the differential extinction contribution accounting for 10%

σ_{H2O}^2 and σ_{N2}^2 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.

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

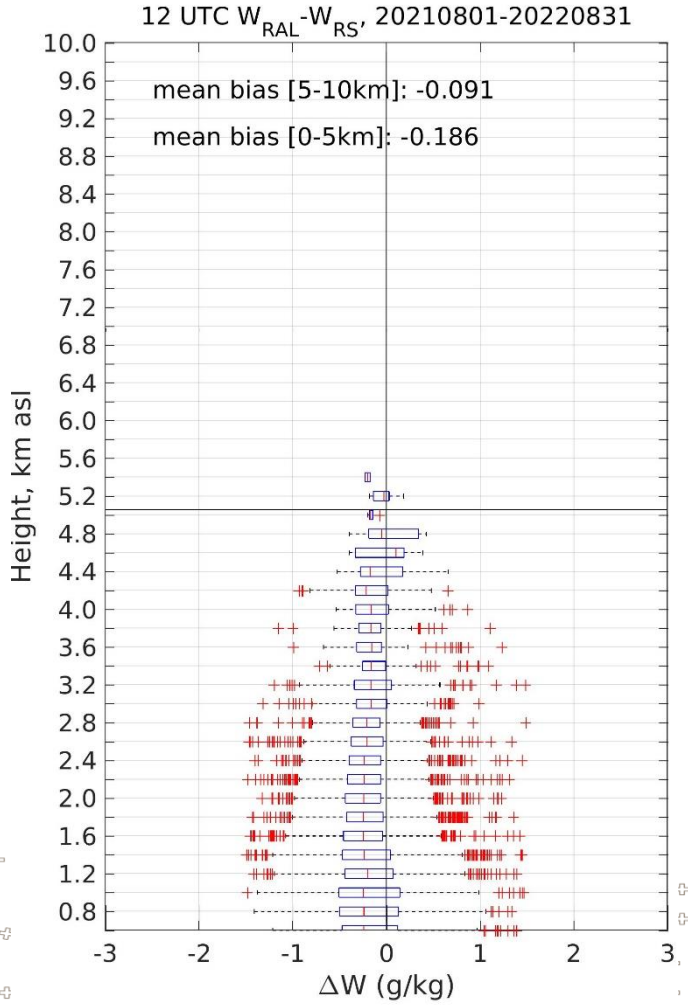


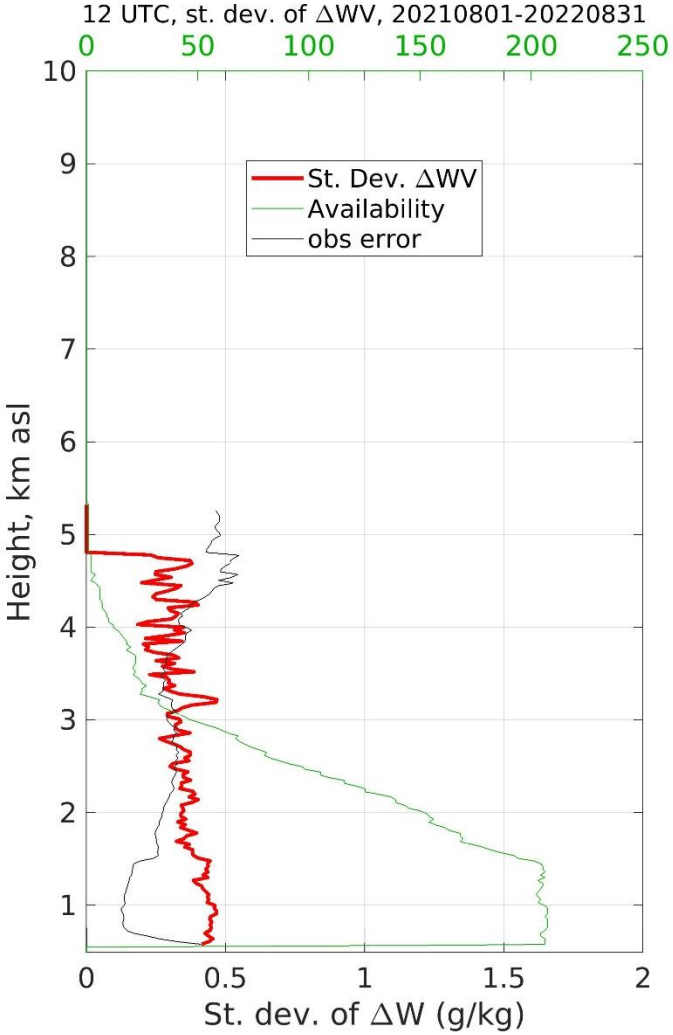
Calibration of WV using RS41, 28-Jul-2022, 23h00-23h30



Water vapor mixing ratio: daytime validation during 01.08.2021-31.08.2022

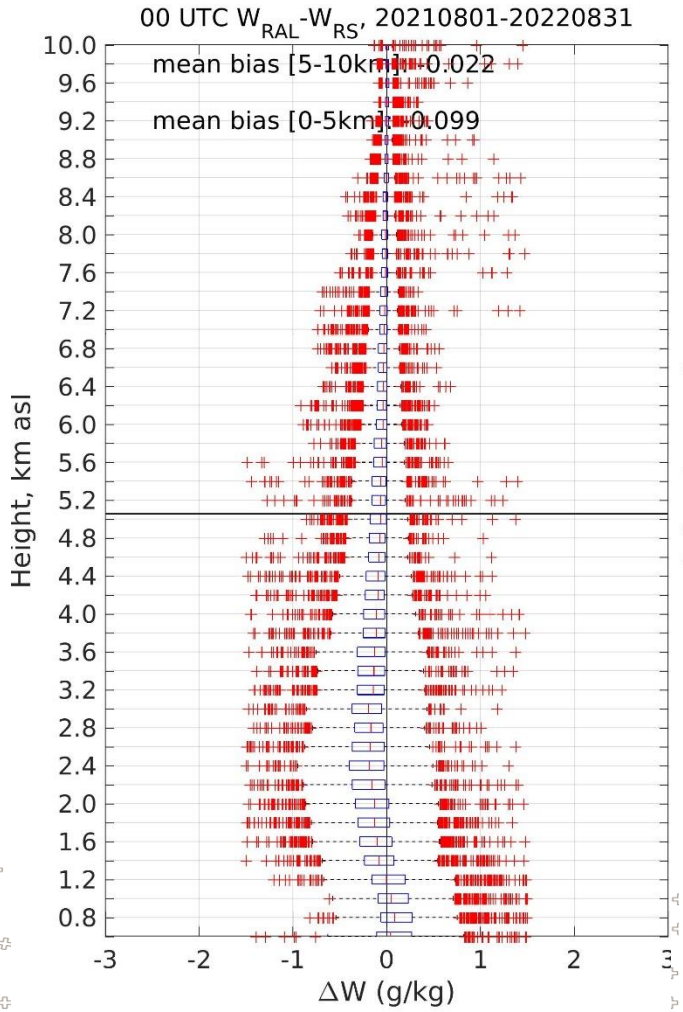
DAYTIME

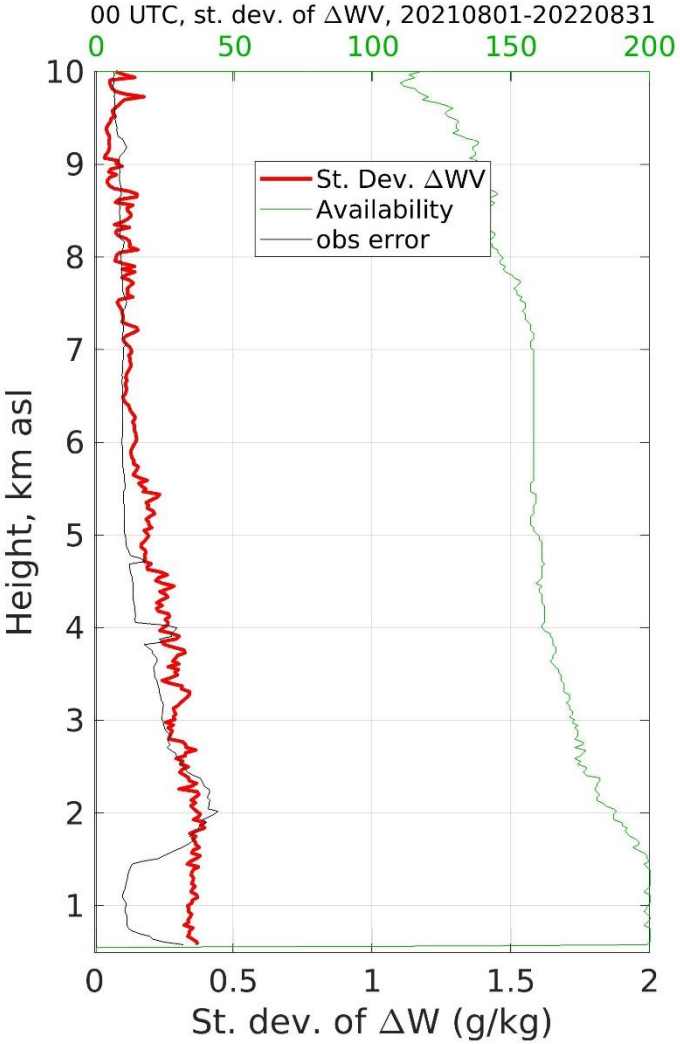




Water vapor mixing ratio: nighttime validation during 01.08.2021-31.08.2022

NIGHTTIME





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.

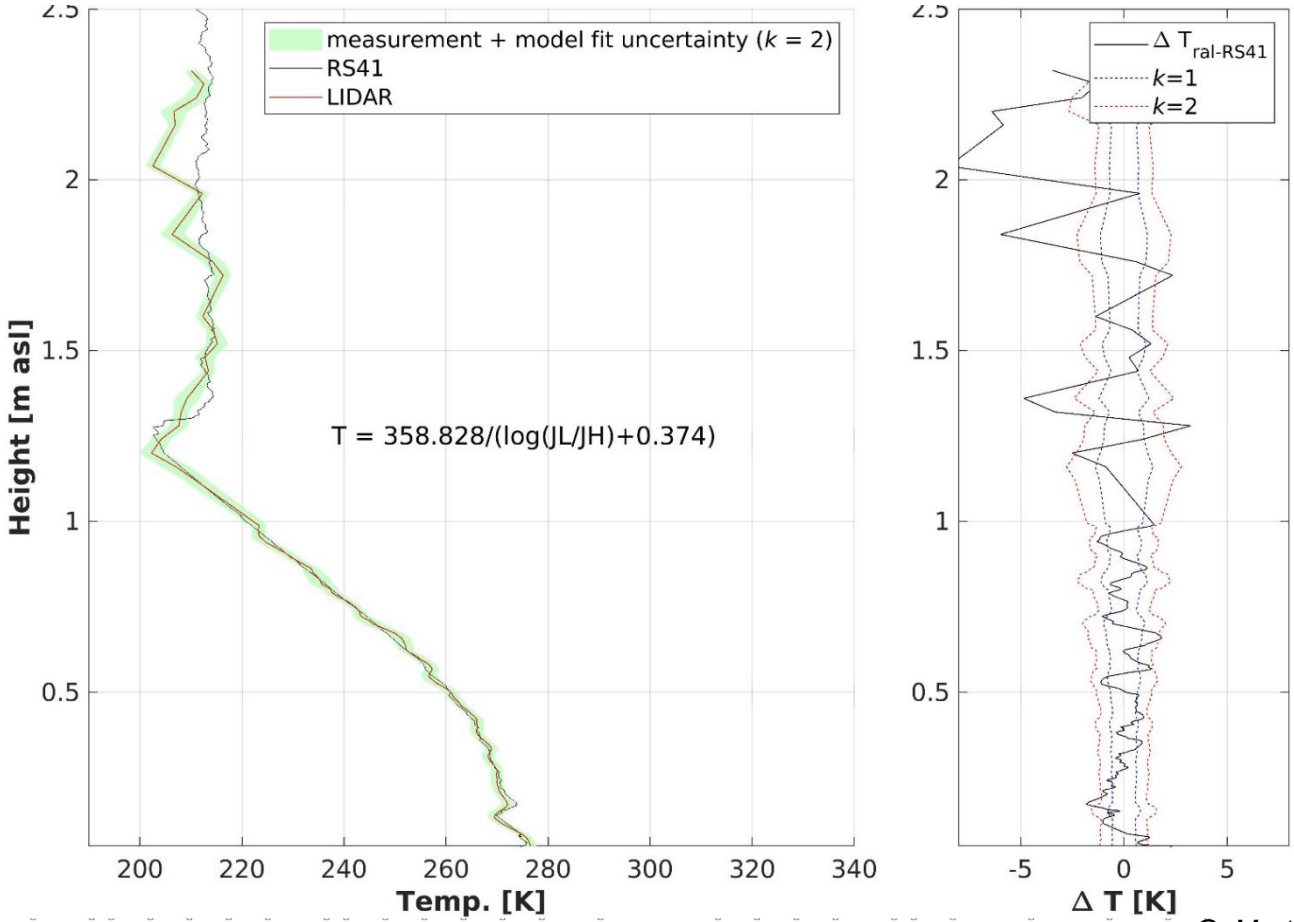
$$U_{\mathrm{fit}} = \frac{1}{(B + \ln Q)}\left[\sigma_A^2 + \frac{A^2\sigma_B^2}{(B + \ln Q)^2}\right]^{\frac{1}{2}}.$$

Taylor's linear propagation of T equation w.r.t. the errors of J_{high}, J_{low} without the atmospheric contribution (covariance of σ_{JH} and σ_{JL})

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

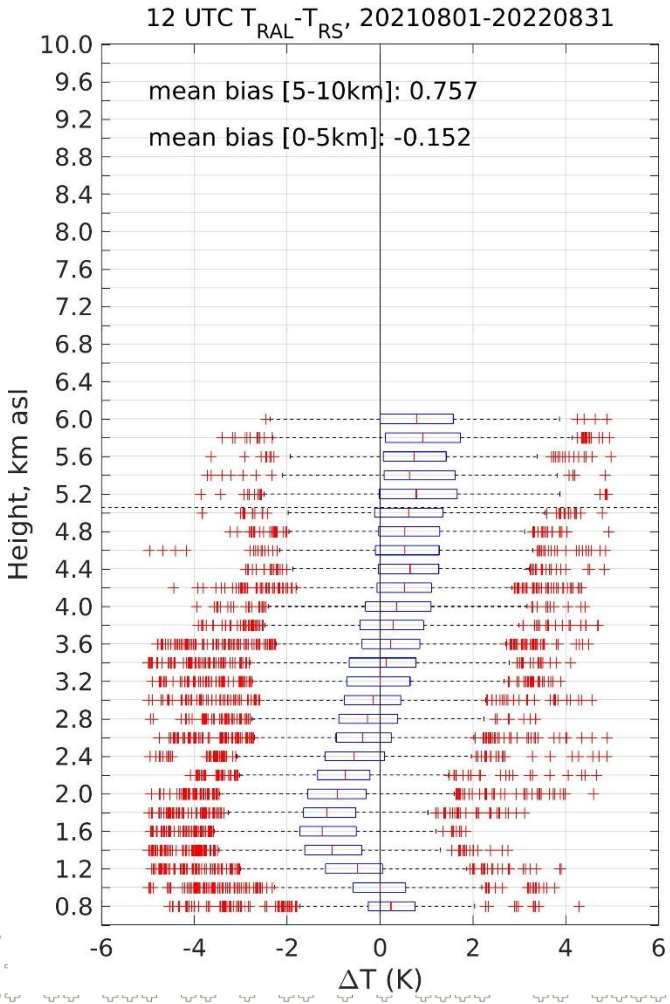
Random error: $\sigma_{rand\_T} = \sqrt{U_{\mathrm{fit}}^2 + U_{\mathrm{sig}}^2}$

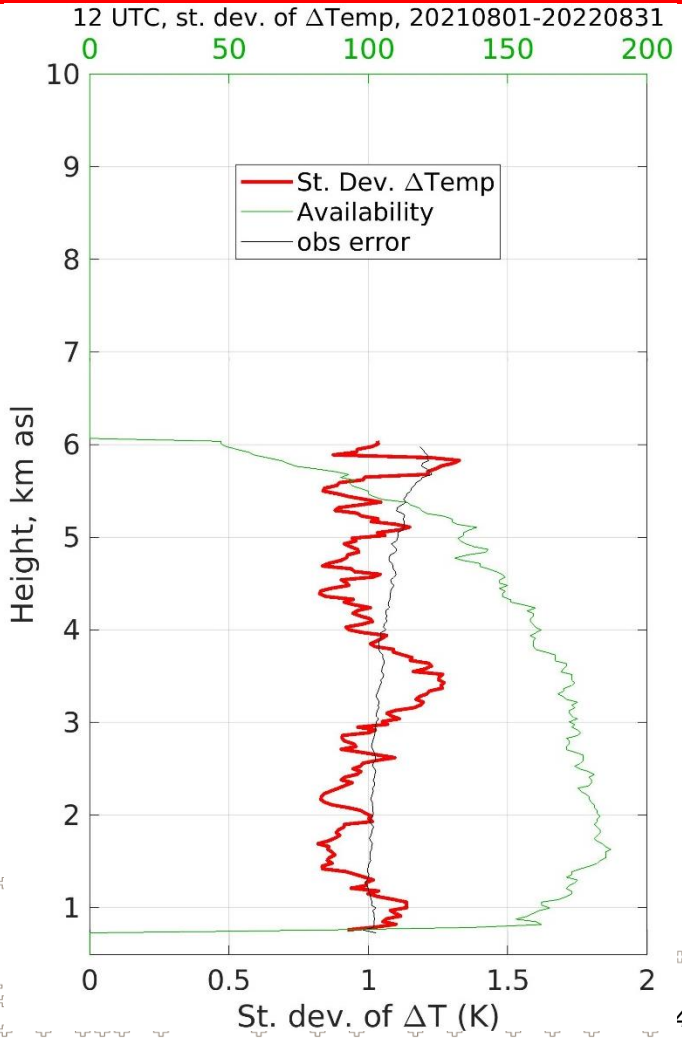
Calibration of T using RS41, 17-Jan-2022, 23h00-23h30



Daytime

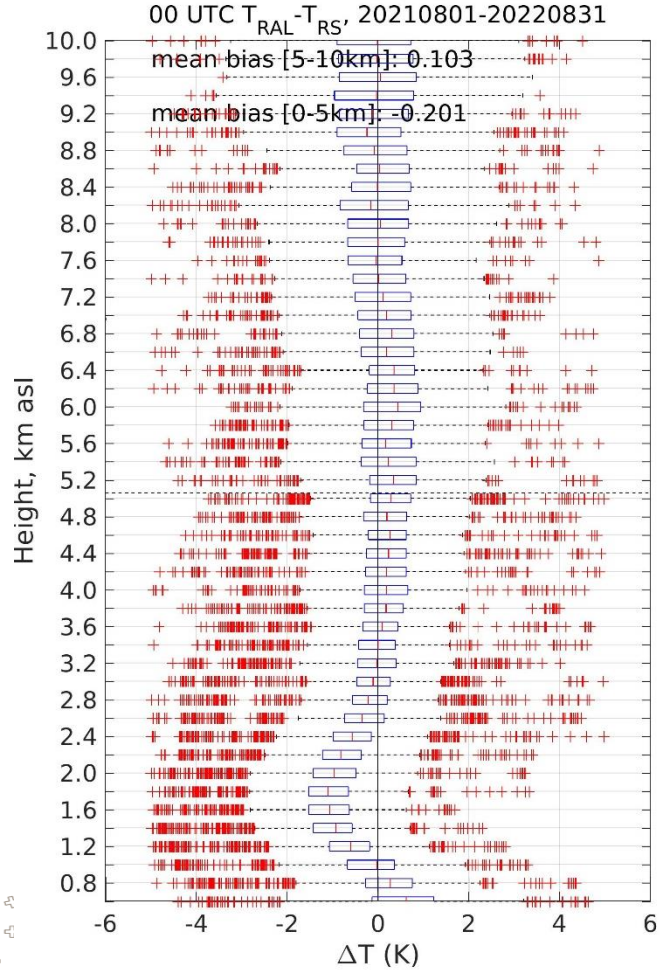
DAYTIME

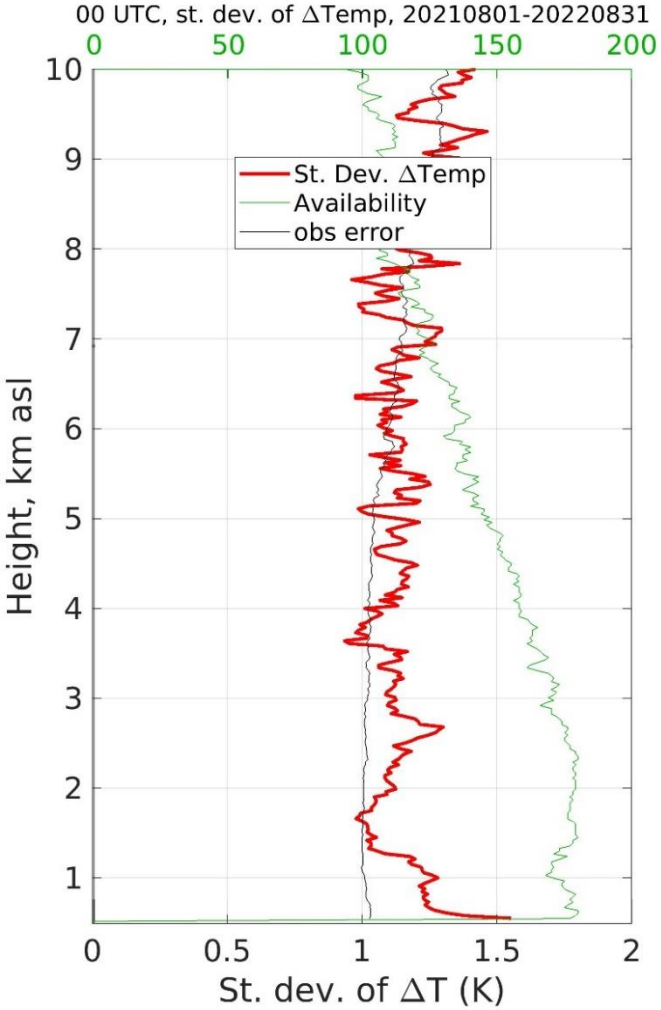




Temperature: nighttime validation during 01.08.2021-31.08.2022

NIGHTTIME



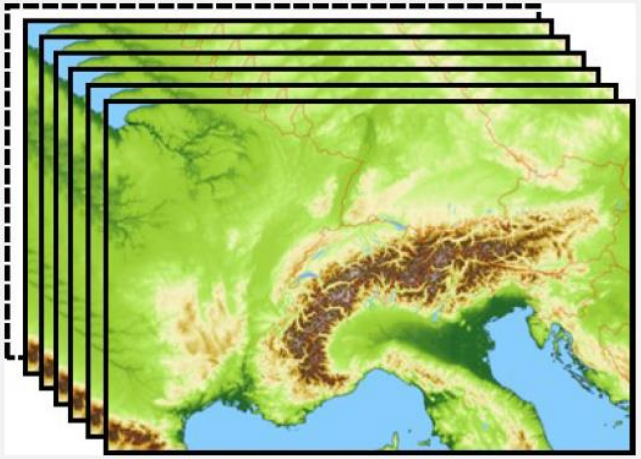


COSMO-1E

Data assimilation cycle and NWP system

KENDA/LETKF:

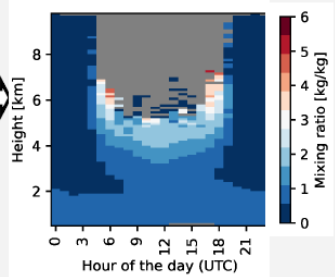
- 1.1km mesh size
- 40 members + deterministic
- hourly cycling
- observations: soundings, aircrafts (AIREP/MODE-S), surface stations, wind radars, weather radars (LHN)

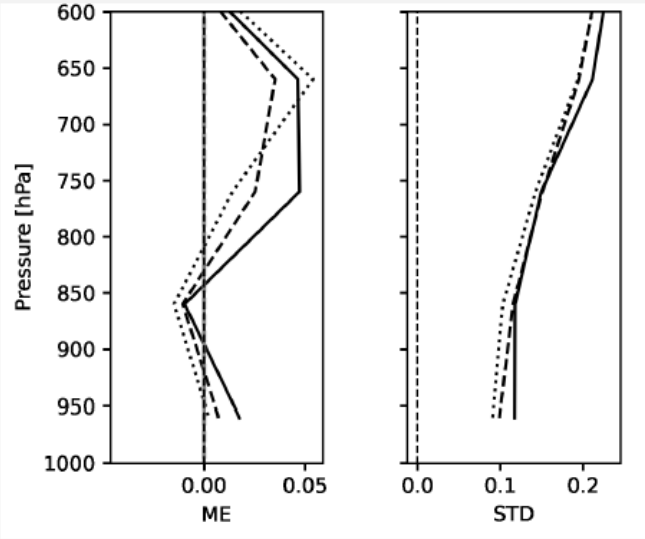


COSMO-1E/2E:

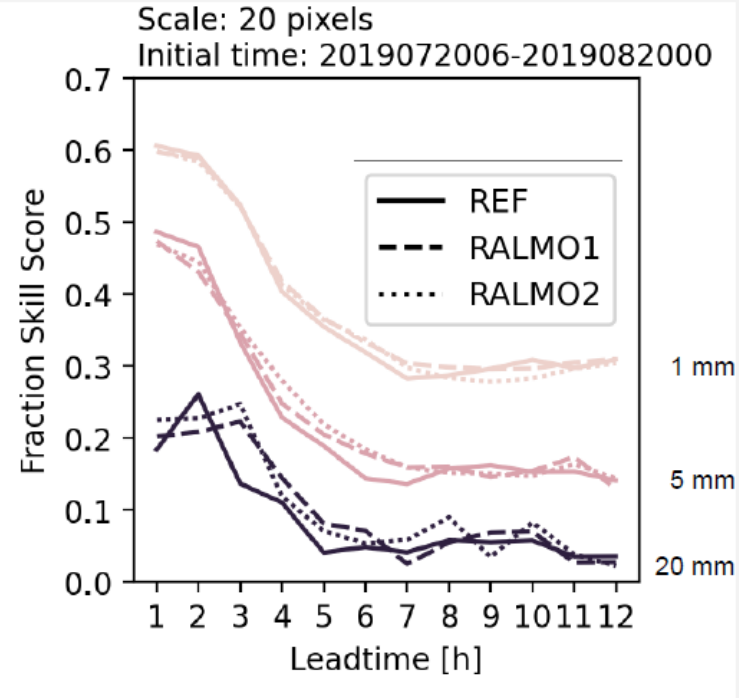
- 1.1km/2.2km mesh size
- 10 members/20 members + control
- 33 hours/5 days forecast, 8x/4x per day

REF	RALMO1	RALMO2
2.2km KENDA as opr. 20.07.-20.08.19	REF + RALMO with **constant obs. error** for mixing ratio of 1 g/kg and tempera-ture of 1K	REF + RALMO with **time-varying obs. error** for mixing ratio and temperature





Profile verification of the model first-guess against 60 radio soundings in Payerne shows **reduction of dry bias in model (left) and reduction in STD (right) for RH [0-1].**



Spatial verification of precip. forecasts against a radar-derived dataset shows **improvement** in fraction skill score for leadtimes 3-8 hours for **1h precipitation sums.**

Summary

- The data processing retrieves temperature and humidity profiles and calculates the associated observation error every 30 minutes.
- The calculated observation error represents main sources of error. T, WVMR and σ are validated by comparison with the co-located RS41 radiosounding over 13 months.
- The calculated observation error is in good agreement with the std(X_{RAL}-X_{RS41})
- The X_{RS41} and X_{RAL} agree within the errors.
- The validated X_{RAL} are assimilated into the 1.1-km mesh size KENDA-1 model. The impact is positive and MeteoSwiss moves towards the operational assimilation of X_{RAL} by the end of 2022.
- We observe a larger value of std(T_{RAL}-T_{RS41}) with respect to *Martucci et al. 2021*