GRUAN

(I) Progress in humidity time lag experiments

(II) Use of ground check results in RS41 GDP

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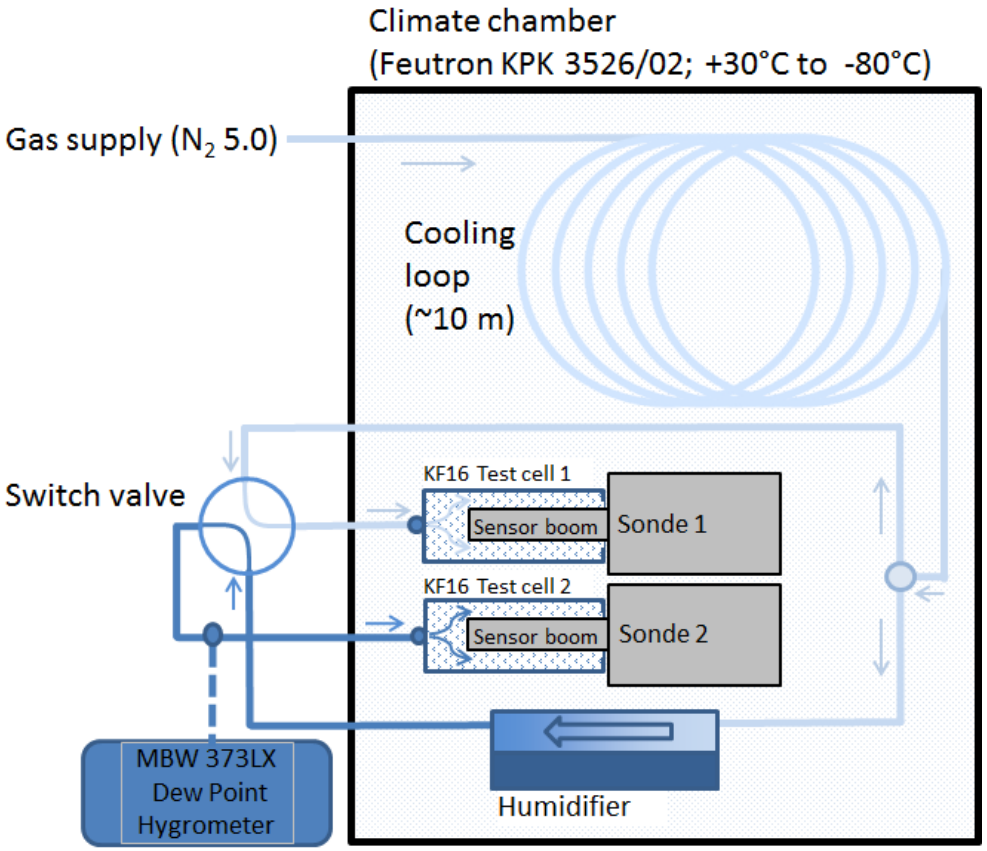
(I) Time-lag: Objective

- Slow Response time of humidity sensor at low T causes systematic error (smoothing + time lag)
- Approach:
  - Design of laboratory experiment for direct time-lag quantification:

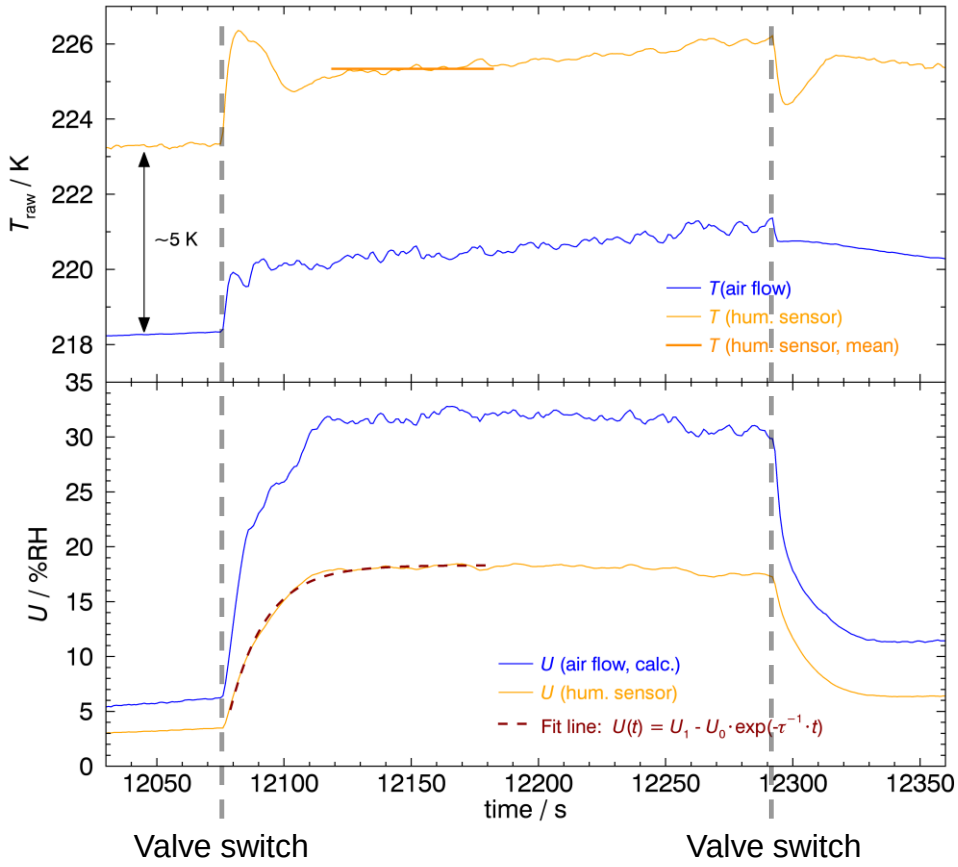
    - Measure response to step-like change in rel. humidity at various T-levels,
    - Read time constant λ (or 63%-time $\tau = 1/\lambda$) from response curves by fitting $U(t) = U_1 - \Delta U \cdot \exp(-\frac{t}{\tau})$
  - Parameterise response time $\tau(T)$
  - Apply correction of time lag in processing

(I) Time-lag: Setup (2015)



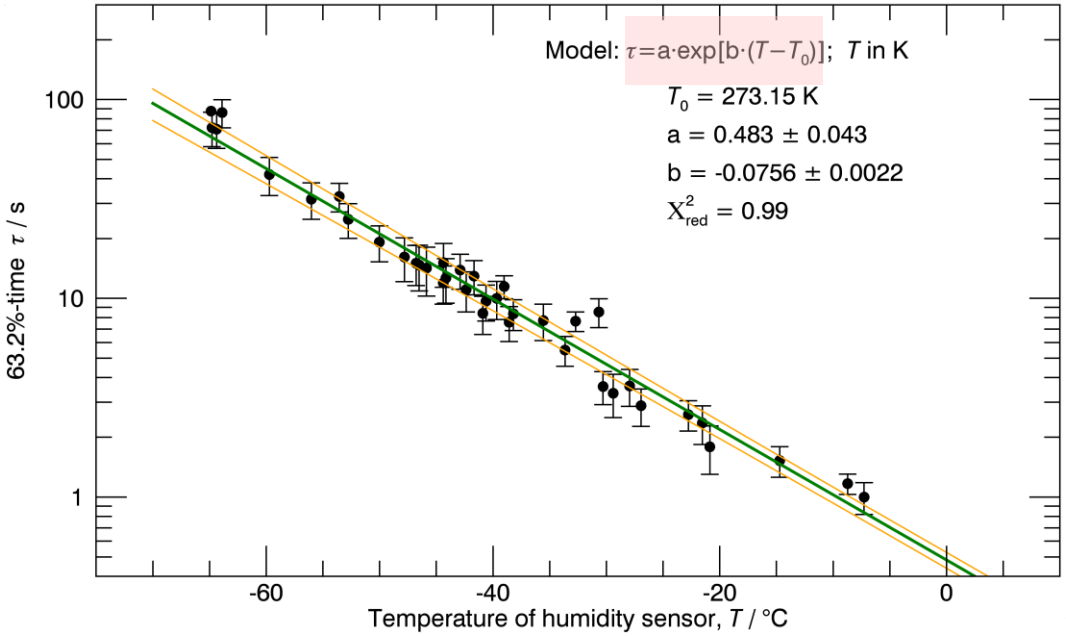
- RS41 U-sensor heated ~5 K

τ derived for 'internal' U
and related to 'internal' T of U-sensor



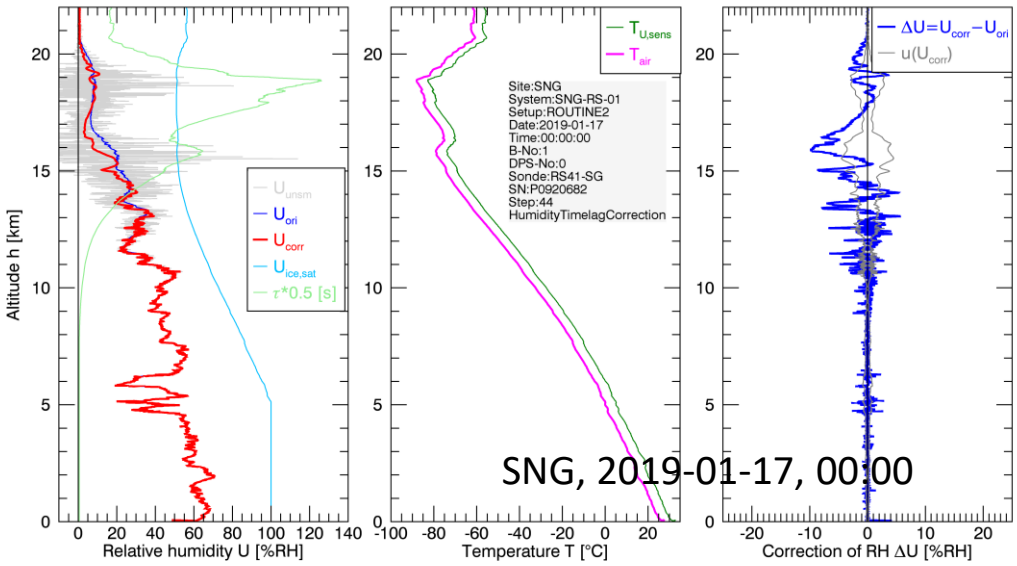
(I) Time-lag: Results (2015)

- Parameterization $\tau(T)$,
  based on re-evaluated measurements of 2015



- Correction, implemented in RS41-GDP.1

$$\Delta U_i = U_{i,c} - U_{i,m} = \sum_{j=0}^{i-1} (U_{i,m} - U_{j,c}) \exp\left(\frac{t_j - t_i}{\tau_i}\right)$$



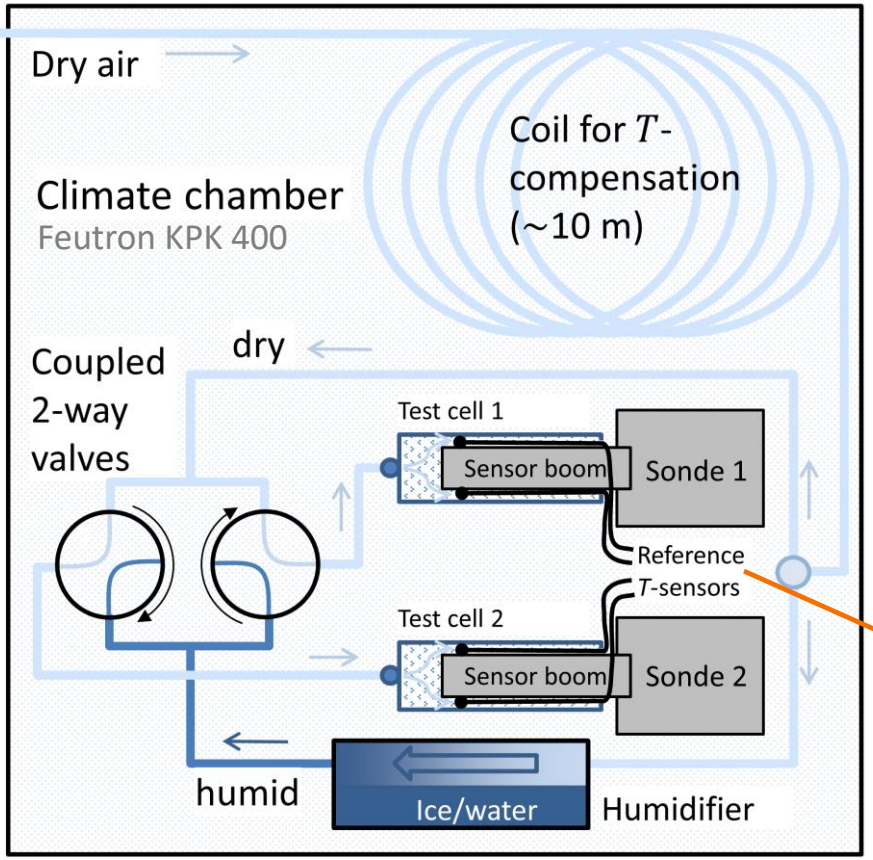
Reliable results, but still some issues to be ressolved:

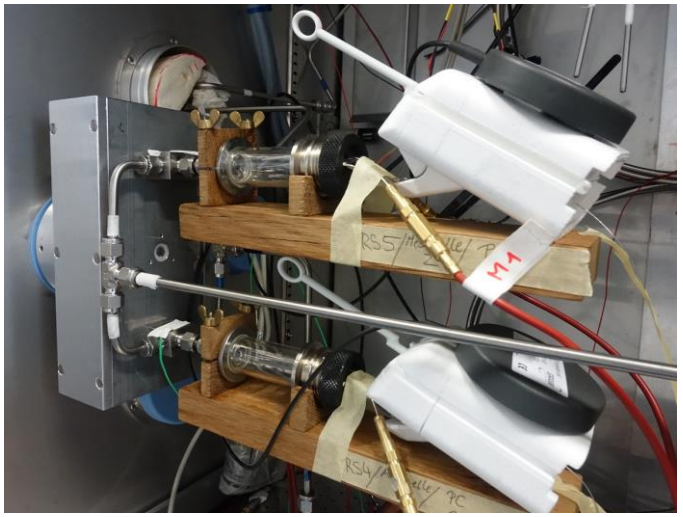
- T-stability
- Small step size (efficiency of humidifier)
- Only dry-to-humid steps evaluated
- Scatter

(I) Time-lag: Improved setup (2021)

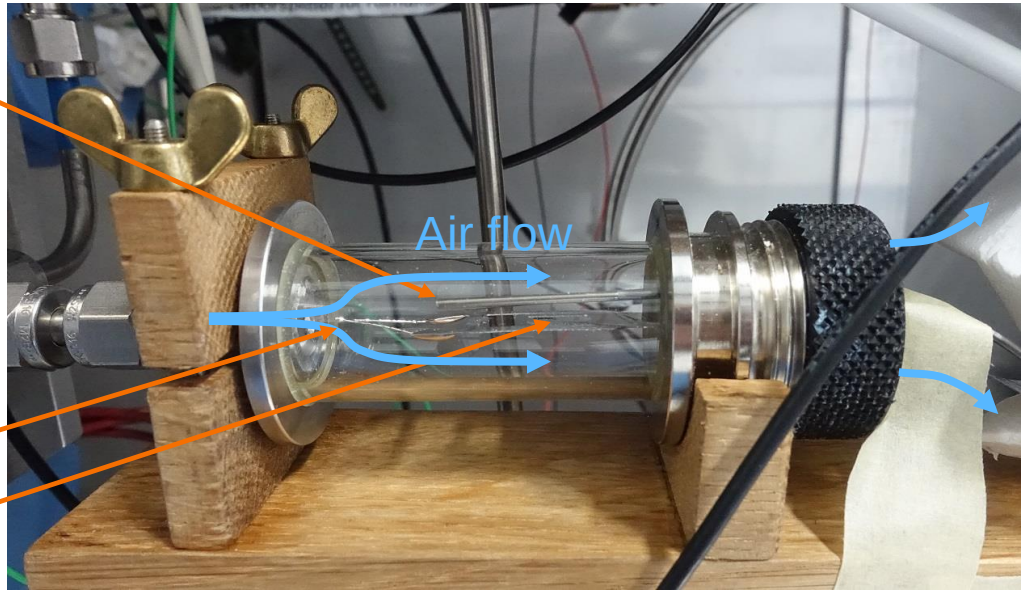
- New cell design (optimised size, visual control)
- Arrangement of all components including switch valve inside the chamber
- Automated T-programme: discrete T levels (−74 °C … +20 °C)
- Simultaneous tests in two cells with parallel switching in the same direction
- High T-stability during steps (~0.2 K)
- Larger U-steps (more efficient humidifier)
- Evaluation of both up and down humidity steps

(I) Time-lag: Improved setup (2021)





(Example foto Graw DFM-17)



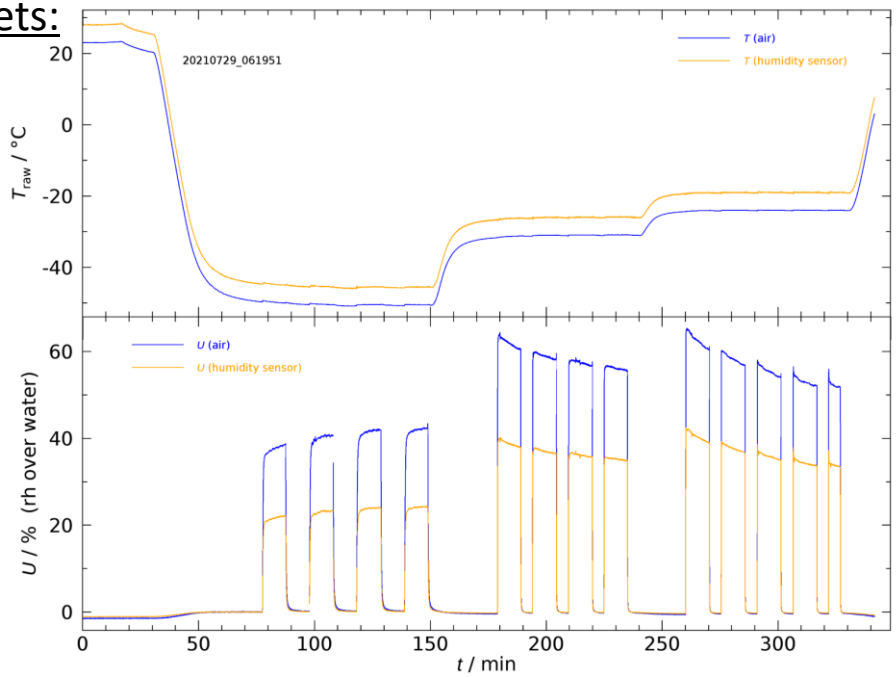
T-sensor sonde

U-sensor sonde

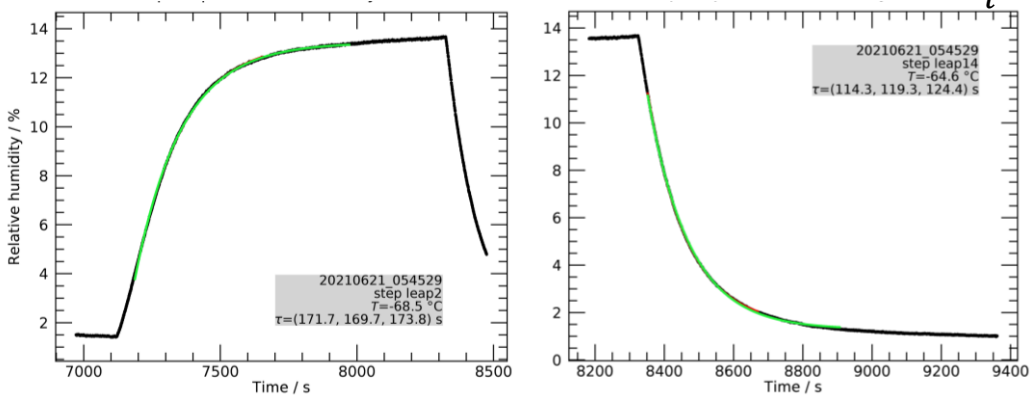
(I) Time-lag: Improved setup (2021)

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

Data sets:

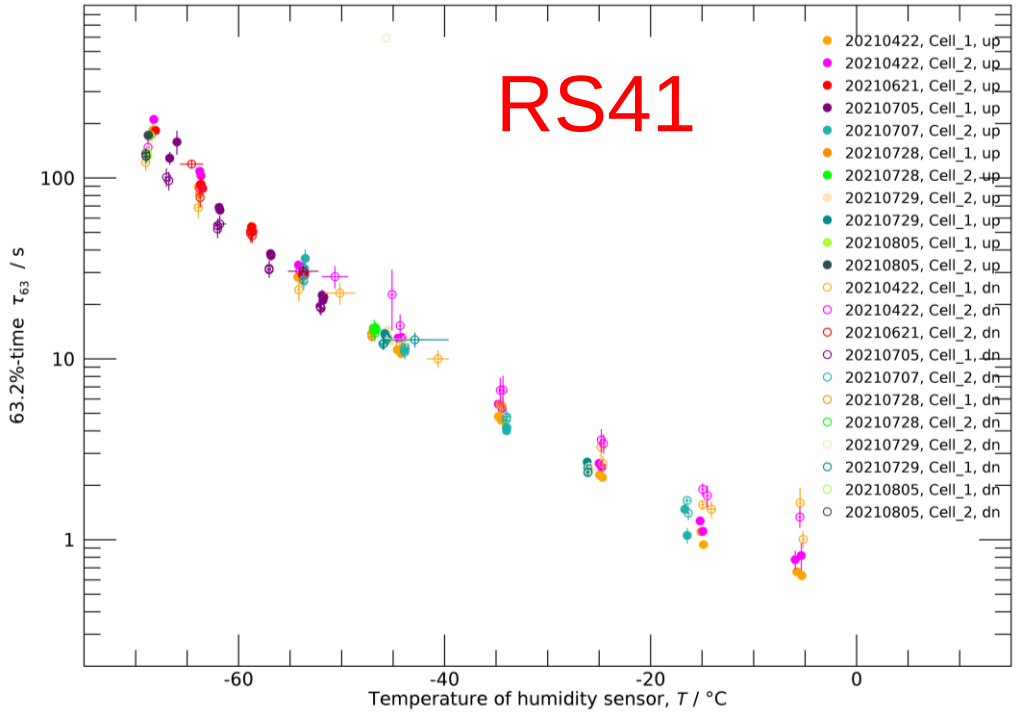


T-determination: fitting of $U(t) = U_1 - \Delta U \cdot \exp(-\frac{t}{\tau})$



Results (Preliminary):

- Good reproducibility, consistent overall picture, 2015-measurements essentially confirmed
- Further evaluation ongoing:
  - Small systematic differences up/down steps,
  - $\tau(T)$ not purely exponential with low T (?)
  - uncertainty estimates



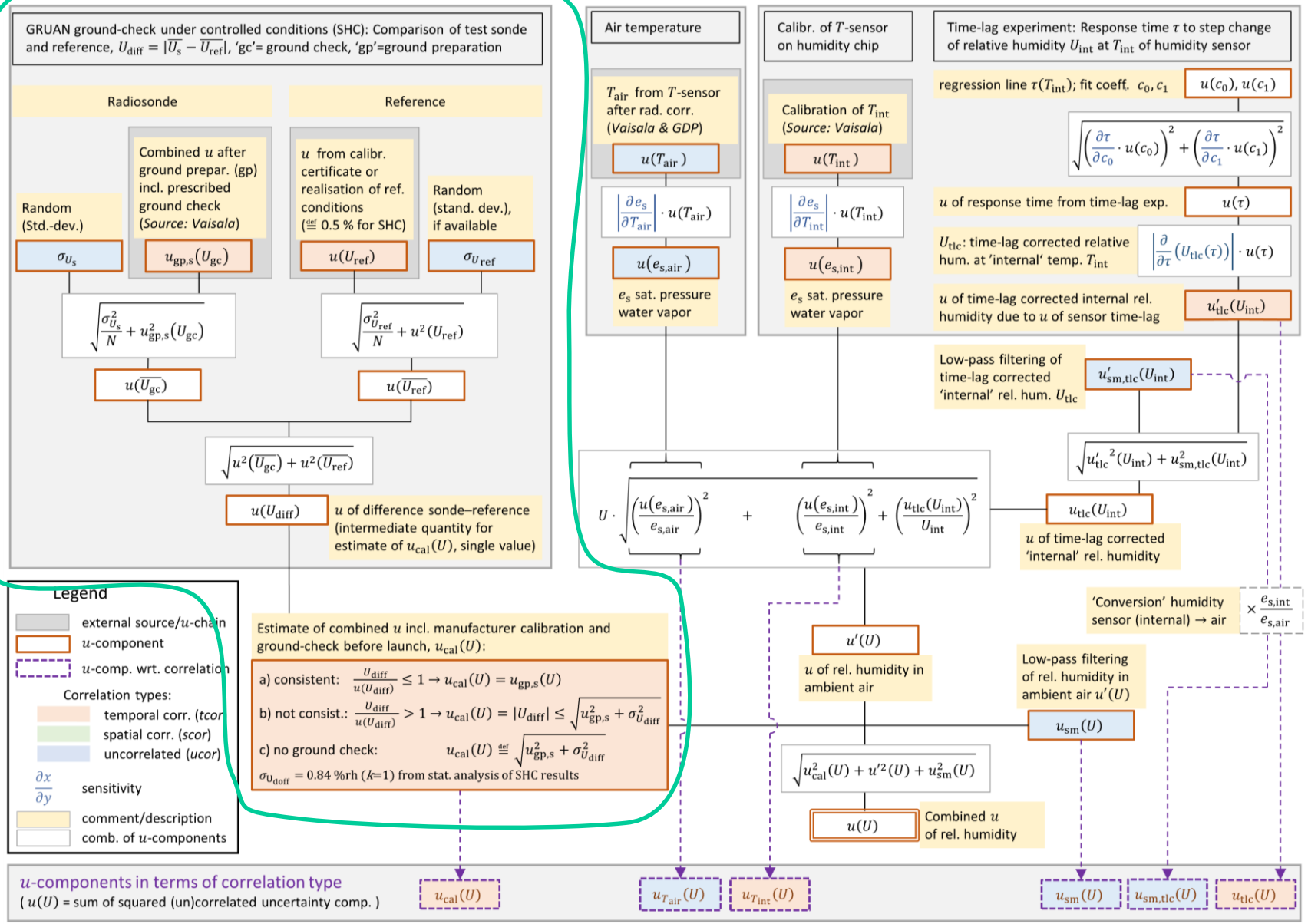
(I) Time-lag: Conclusions

- Current status:
  RH time-lag correction in actual RS41-GDP.1 based on re-analysis of existing data (2015) measured with ‘old’ setup
- 2021: substantial technical improvements, new measurements
- Evaluation of new RS41 results ongoing, implementation of updated time-lag correction in next version (RS41-GDP.2)
- Setup ‘ready’ for measurements with other radiosonde models;
  First data for Graw DFM17 and Vaisala RS92 available;
  Use in laboratory part of WMO intercomparison campaign (UAII-2022)

(II) GRUAN ground check: Objective

- GRUAN recommends routine manufacturer-independent ground check (GC) of physical sensors (U, T, p)
- GC should be performed after the manufacturer-prescribed GC as part of ground preparation procedure
- Motivation: check of manufacturer calibration, estimate of GC-related uncertainty
- Procedures explained here for the actual RS41 processing, but applicable to any radiosonde model

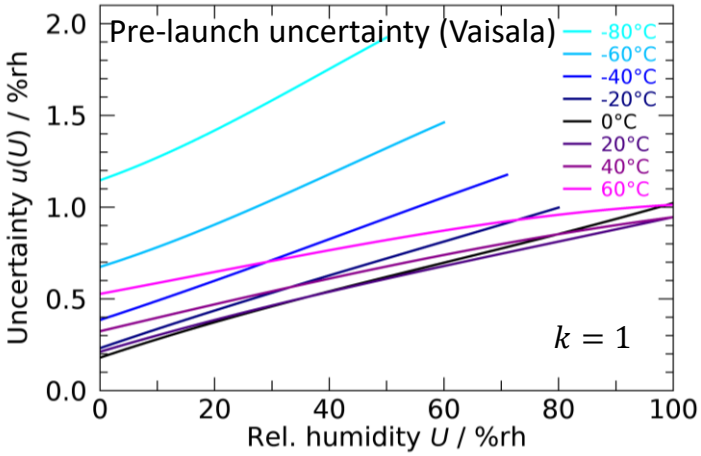
(II) Ground check
Relative humidity



(II) Ground check
Relative humidity

1. Manufacturer-GC (RI41):
   Reconditioning, check against 0 % by sensor heating,
   → Pre-launch u: $u_{\mathrm{gp,s}}(U)$ (Vaisala), see Figure

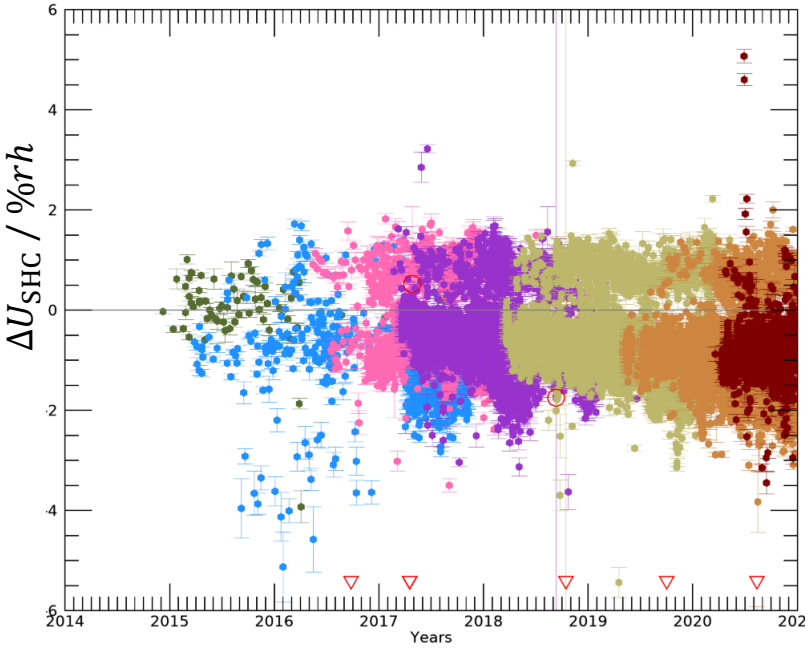
2. GRUAN-GC, in SHC:
   Measure $\Delta U_{\mathrm{SHC}} = \left|\overline{U_{\mathrm{s}}} - U_{\mathrm{ref,100}}\right|$ in 100 % RH environment for ~3 min, assign uncertainty $u(\Delta U_{\mathrm{SHC}})$



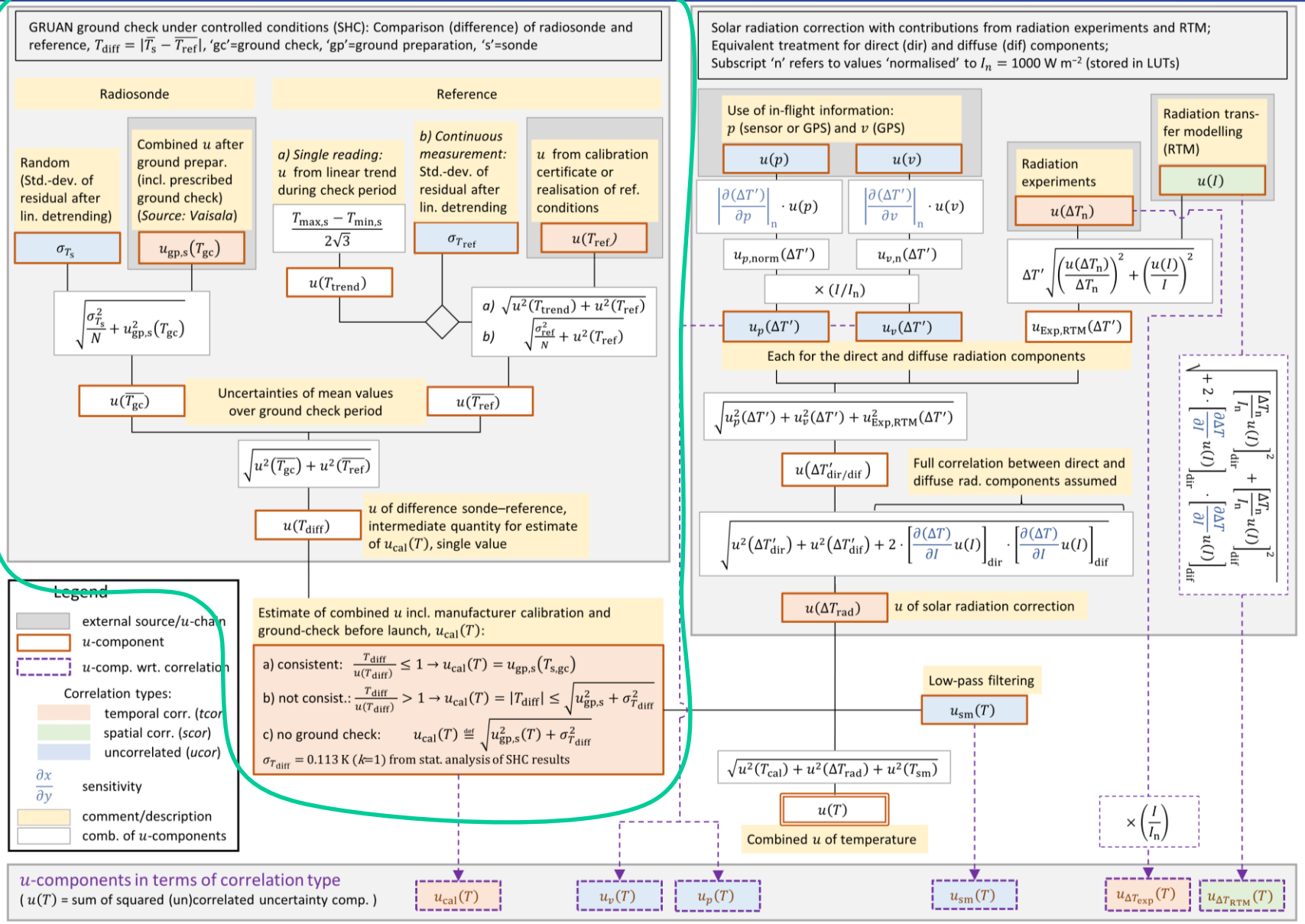
No correction applied, use GRUAN GC-result to assign overall pre-launch-uncertainty $u_{\mathrm{cal}}(U)$:

- $\frac{|\Delta U_{\mathrm{SHC}}|}{u(\Delta U_{\mathrm{SHC}})} \leq 1$: consistency, $u_{\mathrm{cal}}(U) = u_{\mathrm{gp,s}}(U)$
- $\frac{|\Delta U_{\mathrm{SHC}}|}{u(\Delta U_{\mathrm{SHC}})} > 1$: $u_{\mathrm{cal}}(U) = |\Delta U_{\mathrm{SHC}}|$,
  with upper limit $u_{\mathrm{cal}}(U) \leq \sqrt{u^2_{\mathrm{gp,s}}(U) + \sigma^2_{\Delta U}}$, and
  $\sigma^2_{\Delta U}$=0.84 %rh the standard deviation of the mean of existing GRUAN-GC results (N=23271)

If no SHC-GC available: Set $u_{\mathrm{cal}}(U) = \sqrt{u^2_{\mathrm{gp,s}}(U) + \sigma^2_{\Delta U}}$



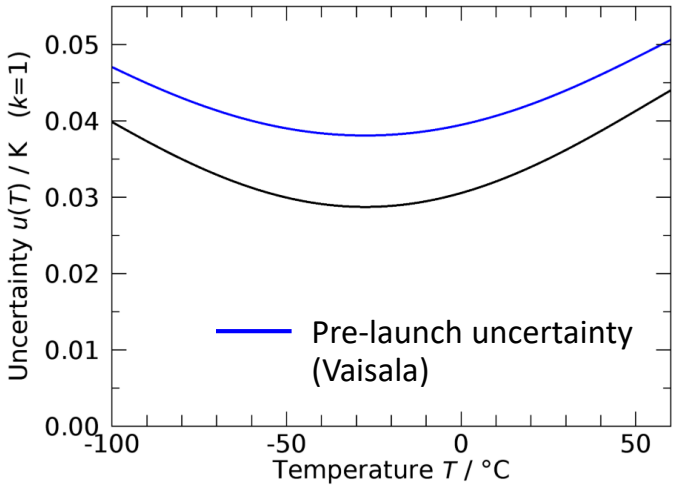
(II) Ground check Temperature



(II) Ground check Temperature

1. Manufacturer-GC (RI41):
   Functionality check
   (no comparison to reference, no correction applied)
   → Pre-launch u: $u_{\mathrm{gp,s}}(T)$ (Vaisala), see Figure

2. GRUAN-GC in SHC (in parallel with U-check):
   Measure $\Delta T_{\mathrm{SHC}} = |\overline{T}_{\mathrm{s}} - T_{\mathrm{ref}}|$ with uncertainty $u(\Delta T_{\mathrm{SHC}})$

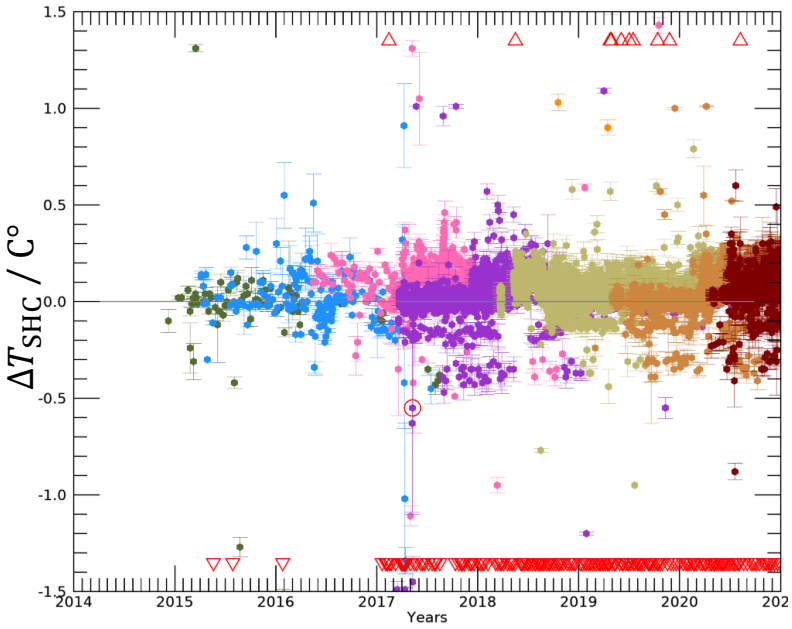


No correction applied, use GRUAN GC-result to assign overall pre-launch-uncertainty $u_{\mathrm{cal}}(T)$:

- $\frac{|\Delta T_{\mathrm{SHC}}|}{u(\Delta T_{\mathrm{SHC}})} \leq 1$: consistency, $u_{\mathrm{cal}}(T) = u_{\mathrm{gp,s}}(T)$
- $\frac{|\Delta T_{\mathrm{SHC}}|}{u(\Delta T_{\mathrm{SHC}})} > 1$: $u_{\mathrm{cal}}(T) = |\Delta T_{\mathrm{SHC}}|$,

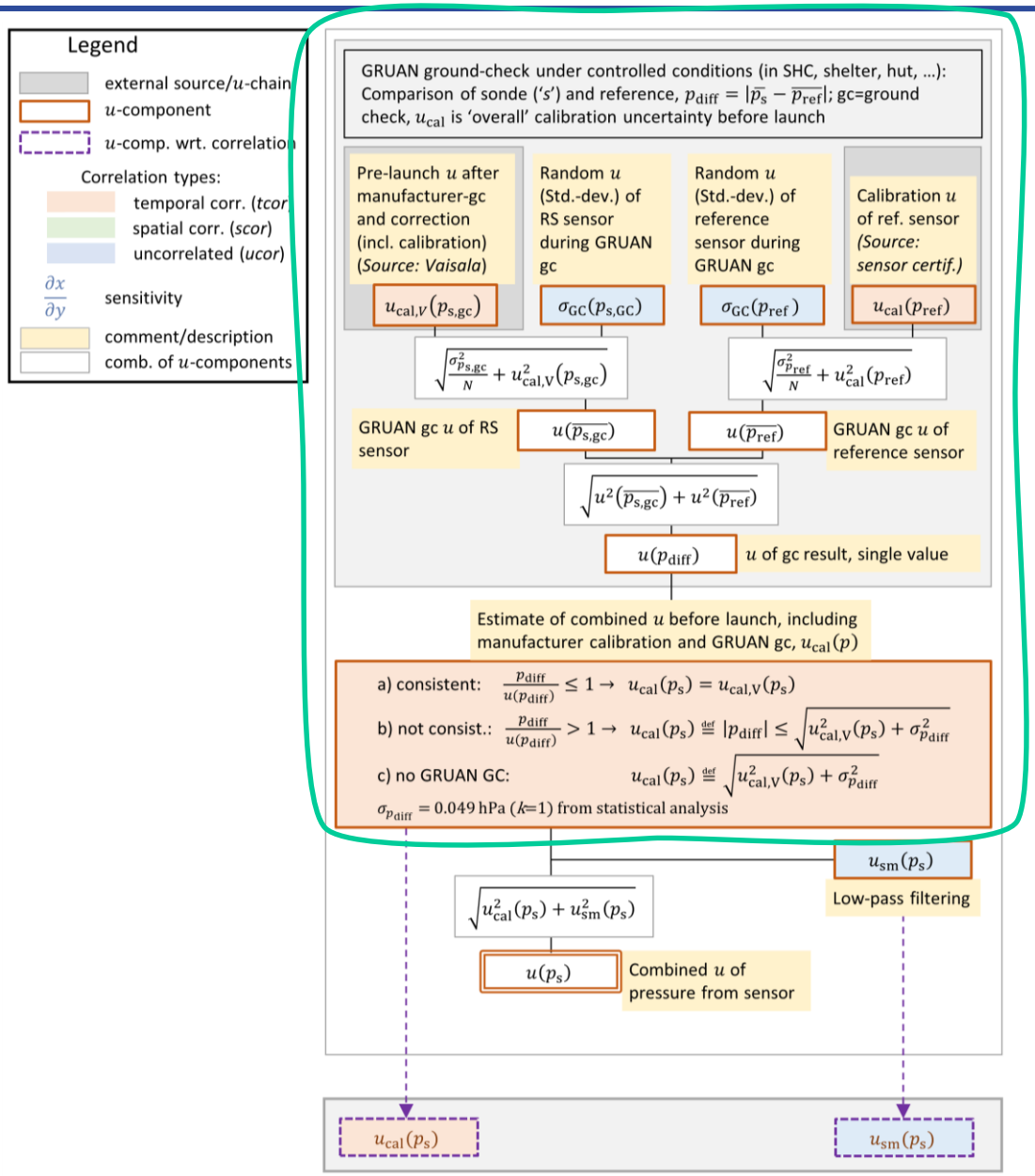
  with upper limit $u_{\mathrm{cal}}(T) \leq \sqrt{u^2_{\mathrm{gp,s}}(T) + \sigma^2_{\Delta T}}$, and

  $\sigma^2_{\Delta T}$=0.113 K the standard deviation of the mean of existing GRUAN-GC results (N=9269)



If no SHC-GC available: $u_{\mathrm{cal}}(T) = \sqrt{u^2_{\mathrm{gp,s}}(T) + \sigma^2_{\Delta T}}$

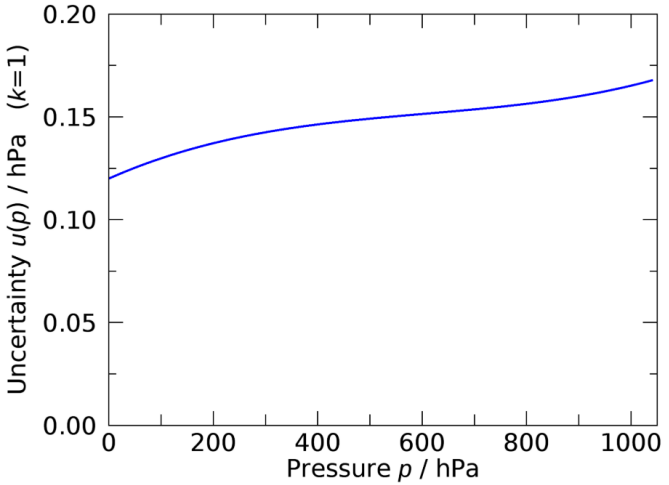
(II) Ground check Pressure (RS41-SGP)



(II) Ground check Pressure (RS41-SGP)

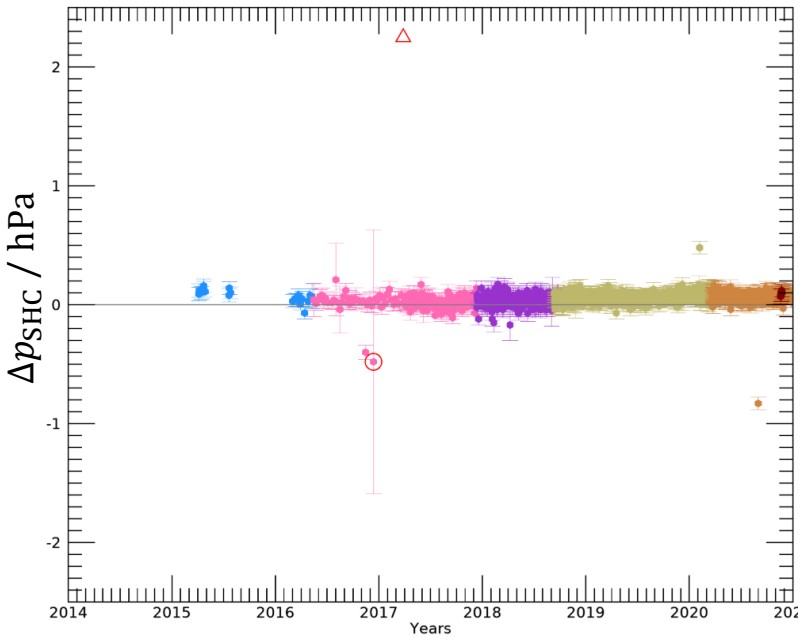
1. Manufacturer-GC (RI41):
   Comparison with ref. barometer (RI41-B or station barometer), correction factor applied,
   → Pre-launch uncertainty $u_{\mathrm{cal,V}}$ (Vaisala), see Figure

2. GRUAN-GC under controlled conditions
   (e.g. in SHC in parallel with U-check):
   Measure $\Delta p = \left|\overline{p_s} - p_{\mathrm{ref}}^{\mathrm{GRUAN}}\right|$ with uncertainty $u(\Delta p)$



Assign overall pre-launch-uncertainty $u_{\mathrm{cal}}(p)$:

- $\frac{|\Delta p|}{u(\Delta p)} \leq 1$: consistency, $u_{\mathrm{cal}}(p) = u_{\mathrm{cal,V}}(p)$
- $\frac{|\Delta p|}{u(\Delta p)} > 1$: $u_{\mathrm{cal}}(p) = |\Delta p|$,
  with upper limit $u_{\mathrm{cal}}(p) \leq \sqrt{u_{\mathrm{cal,V}}^2(p) + \sigma_{\Delta p}^2}$,
  and $\sigma_{\Delta T}^2$=0.049 hPa (N=23271)



If no GRUAN-GC available: $u_{\mathrm{cal}}(T) = \sqrt{u_{\mathrm{cal,V}}^2(p) + \sigma_{\Delta p}^2}$

(II) Ground check: Conclusions

- GRUAN recommends independent ground check of U, T, p as part of pre-launch procedures
- Currently only practicable at manually operated stations
- Presented approach for use of ground check results accounts for missing checks (lack of information) by adding an uncertainty component
- Approach is transferrable to any other ground check environment