Progress with laboratory experiments for radiosonde GDPs

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16th GRUAN Implementation and Coordination Meeting (ICM-16)
Session 7, 20 Nov 2024

Outline

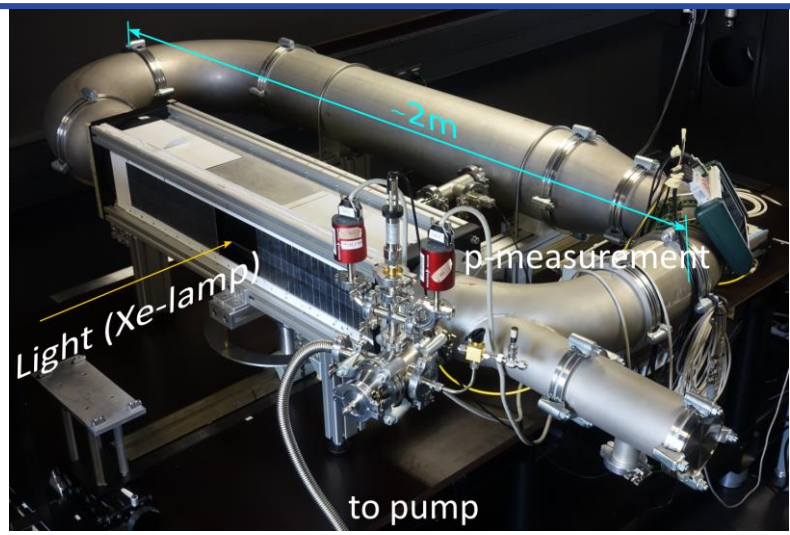
- **Radiation sensitivity of RS sensors**
  - Radiation correction for T-sensor in GDPs (RS41, M10)
  - New experimental results:
    - Radiation error, RS92 (LC3), DFM-17 (GA2)
    - Reproducibility rad. error (RS41, RS92, DFM-17, M10)
  - RH-sensor:
    - Radiation dry bias RS92 (LC3)

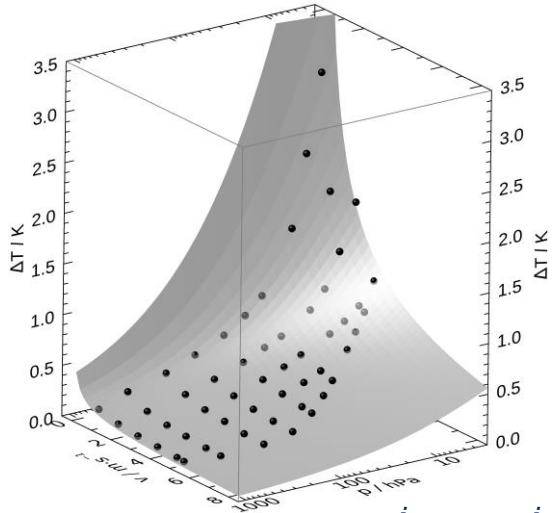
- **Time-lag RH-sensor**
  - Ventilation effect → setup modification
  - Results RS92 (LC3)

Radiation error T-sensor

Radiation T-correction in GDP (RS41, M10)

- Laboratory:
  Measurement of radiation sensitivity ΔT at fixed I_a and selected α using SISTER
- Combine data in expressions $\Delta T(p, v)$ for each α
- GDP processing:
  - Correction of RS-measured T_{raw}, based on:
    - lab-based $\Delta T(p, v)$ (p, v from measured RS profile; sun elevation during sounding)
    - RTM-simulated actinic flux





$$\Delta T(p, v) = \sum_{i,j} c_{ij} \left(\frac{1}{p^{1/2}}\right)^{i} \left(\frac{1}{v^{1/2}}\right)^{j}$$

10.5194/amt-15-383-2022

Results rad. sensitivity T-sensor RS92

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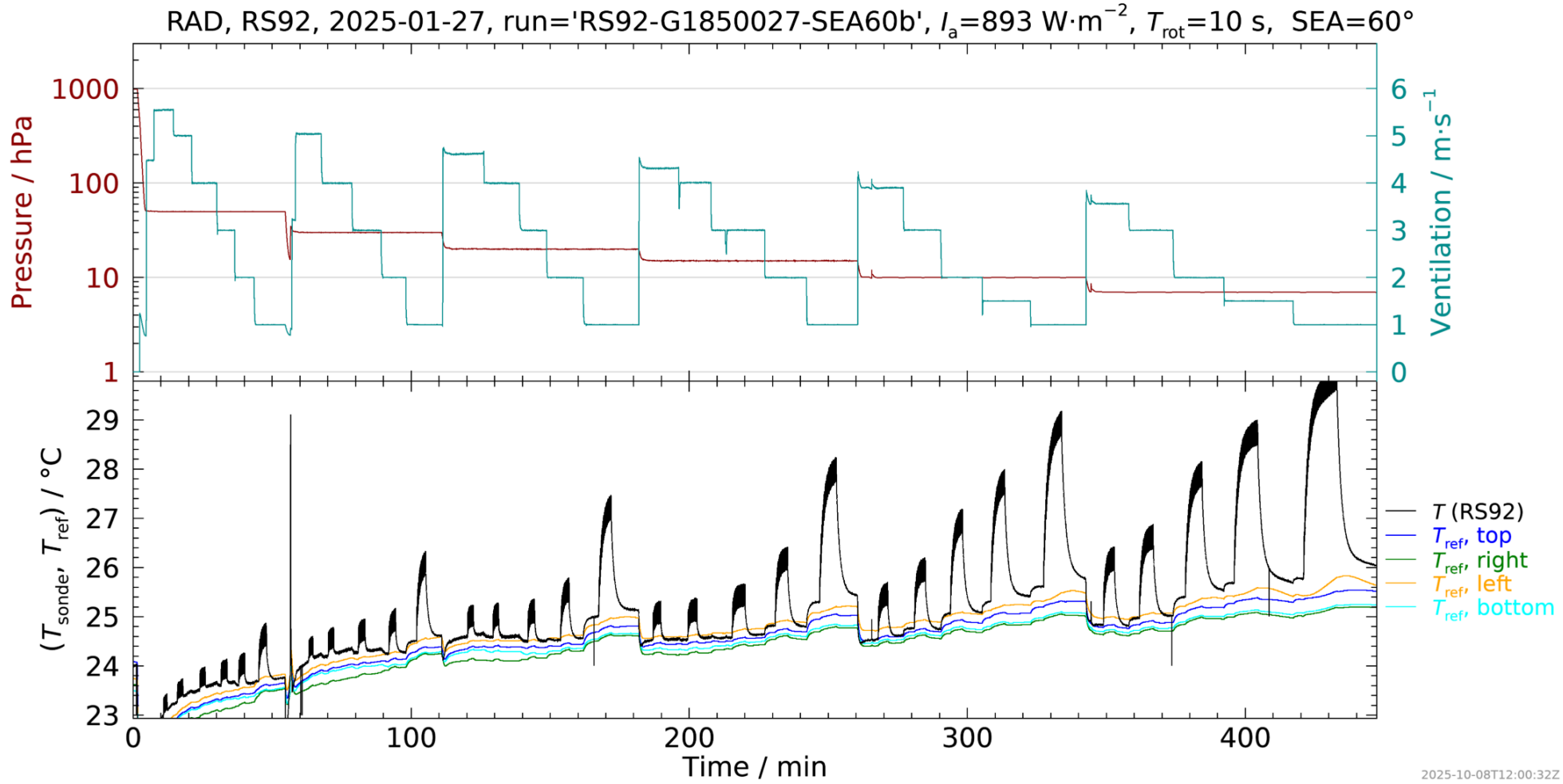
Wetter und Klima aus einer Hand

- Example raw data record (one measurement day):



Results rad. sensitivity T-sensor RS92

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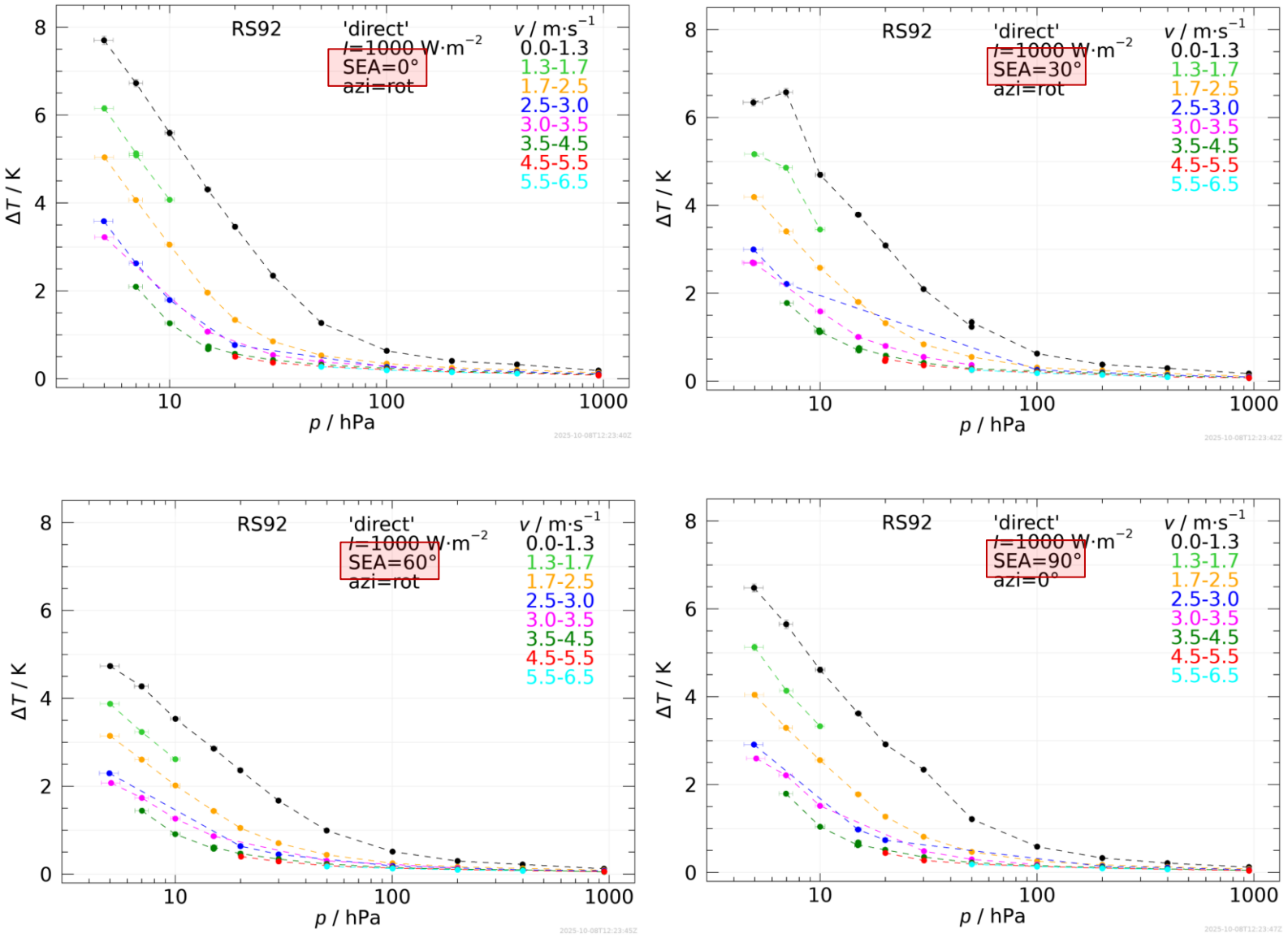
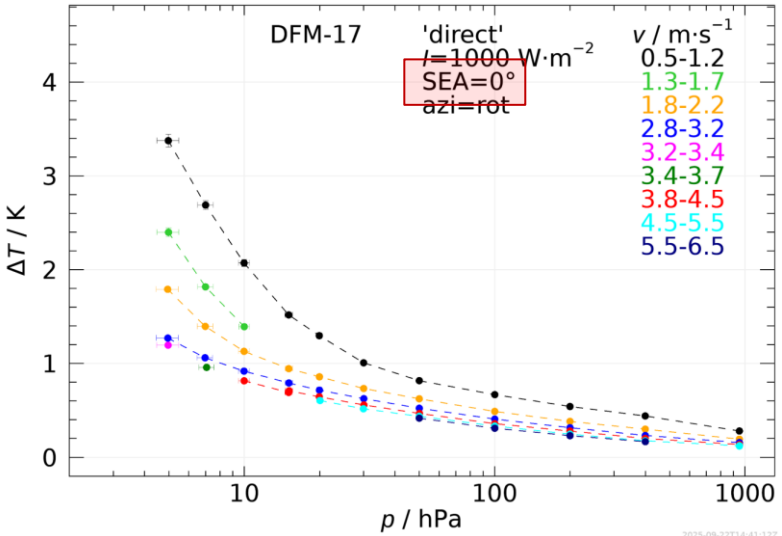
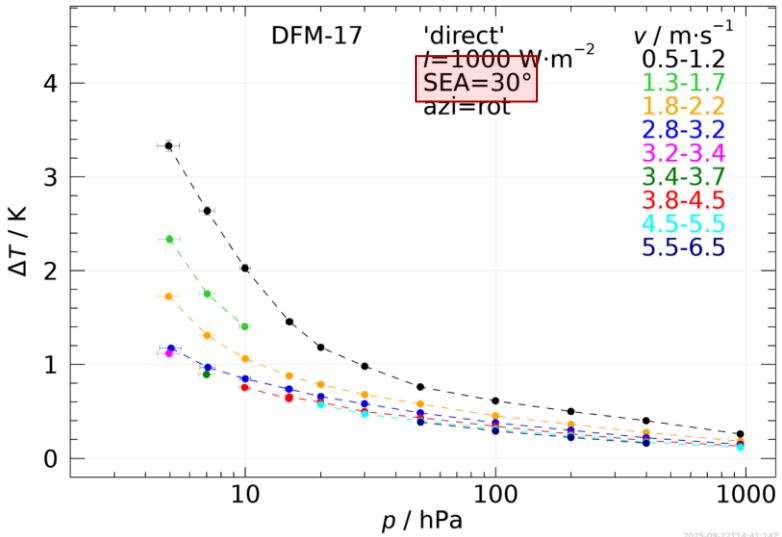
- ΔT, linearly scaled to $I_a = 1000$ W·m^{-2}
- Systematic increase of ΔT at low p and v
- Systematic change of ΔT with solar elevation
- 380 points

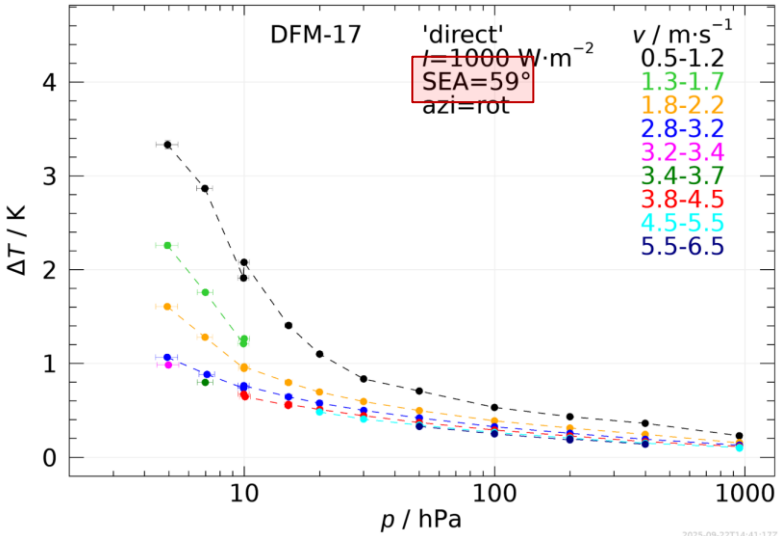


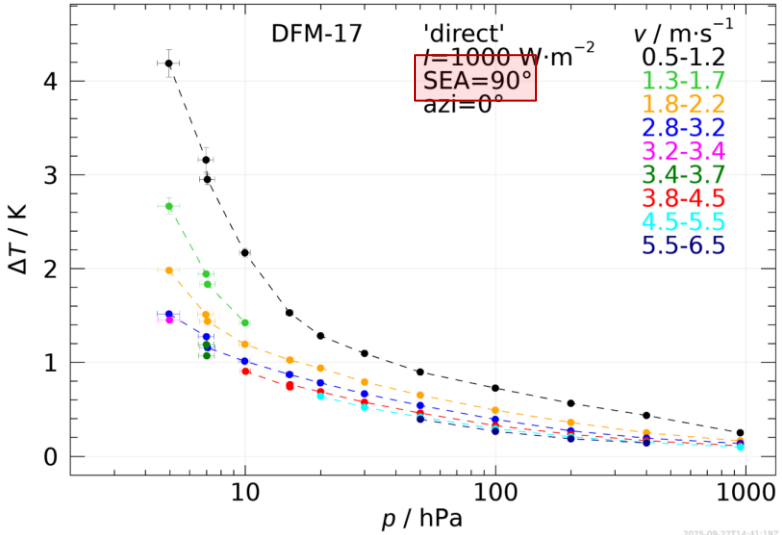
Results rad. sensitivity T-sensor DFM-17

- ΔT, linearly scaled to $I_a = 1000$ W·m^{-2}
- Systematic increase of ΔT at low p and v
- Systematic change of ΔT with solar elevation
- 435 points









RS92 RH dry bias

- RS92 RH-sensor heated by solar radiation
  → RH dry bias (relative effect up to 50% at 15 km

  Problem: RH-sensor heating unknown.
  RS92-GDP.v2: **ΔT_{RH} estimated by linking to rad. error of T-sensor:** $\Delta T_{\mathrm{RH}} = f \cdot \Delta T(I_a, p, v)$

- New experimental approach using SISTER:
  - Expose RH-sensor
  - **Measure RH dry-bias (ΔRH)**
  - Calculate sensor heating ΔT_{RH} from measured ΔRH using sat. vapour pressure equations:

$$e_s(T_{\mathrm{air}} + \Delta T) = e_s(T_{\mathrm{air}}) \cdot \frac{\mathrm{RH}_{\mathrm{air}}}{\mathrm{RH}_{\mathrm{air}} + \Delta\mathrm{RH}}$$

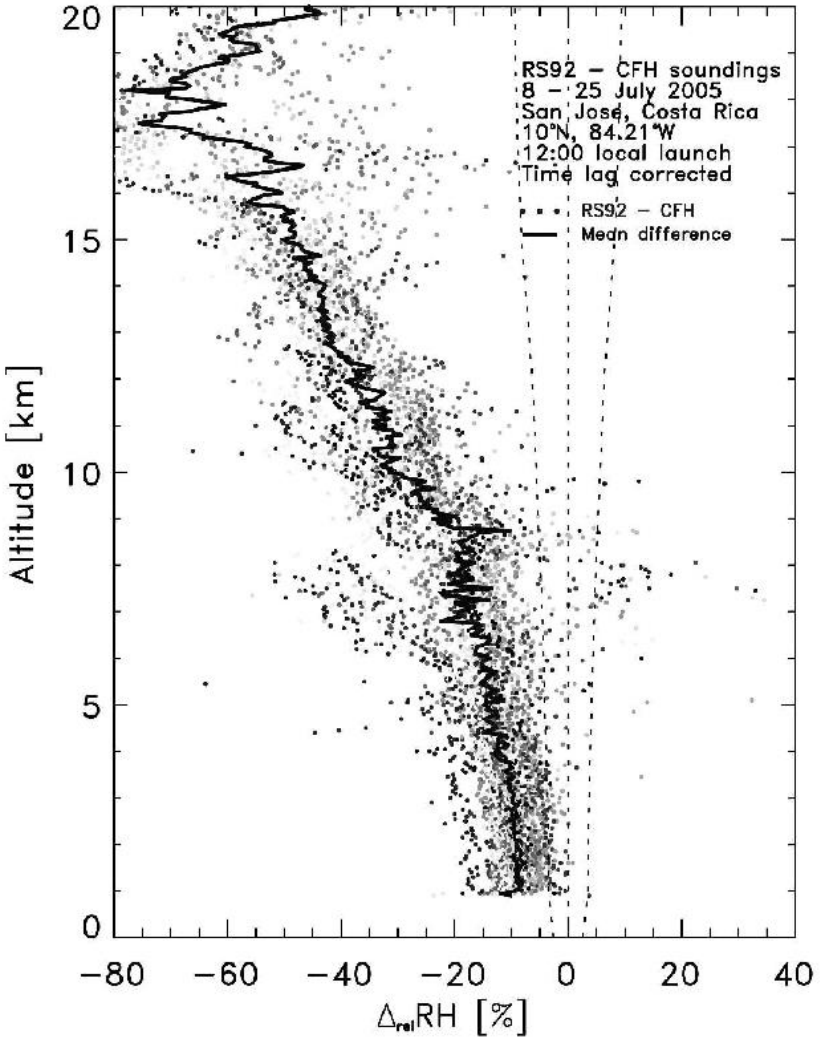


FIG. 6. Relative difference between the Vaisala RS92 and CFH daytime RH.

Vömel et al., 2007, AMT

RS92 RH dry bias, Measurement results

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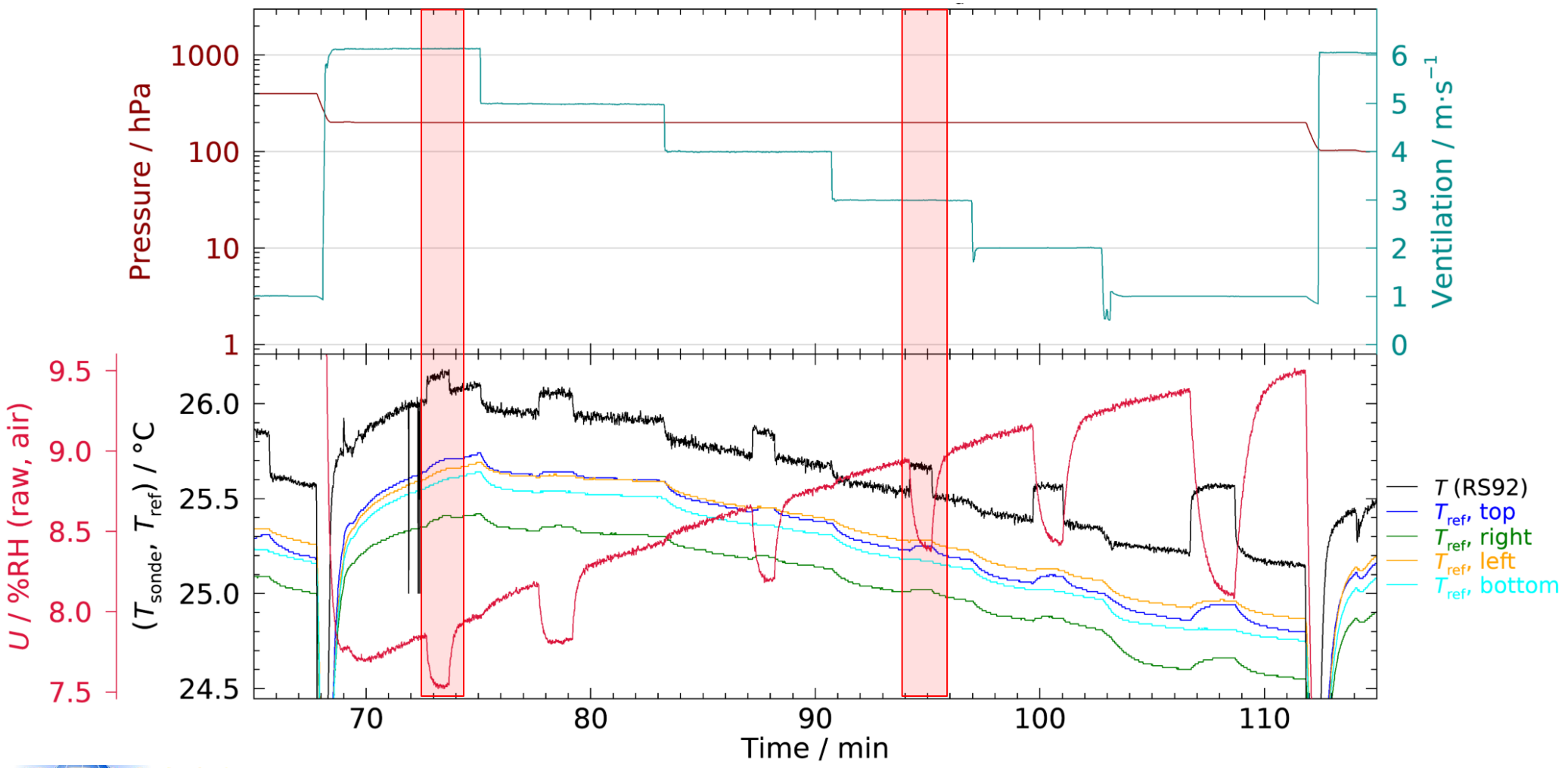
Example of measured raw data, (p = 200 hPa, $I \approx$ 950 W·m^{-2})



RS92 RH dry bias, Measurement results

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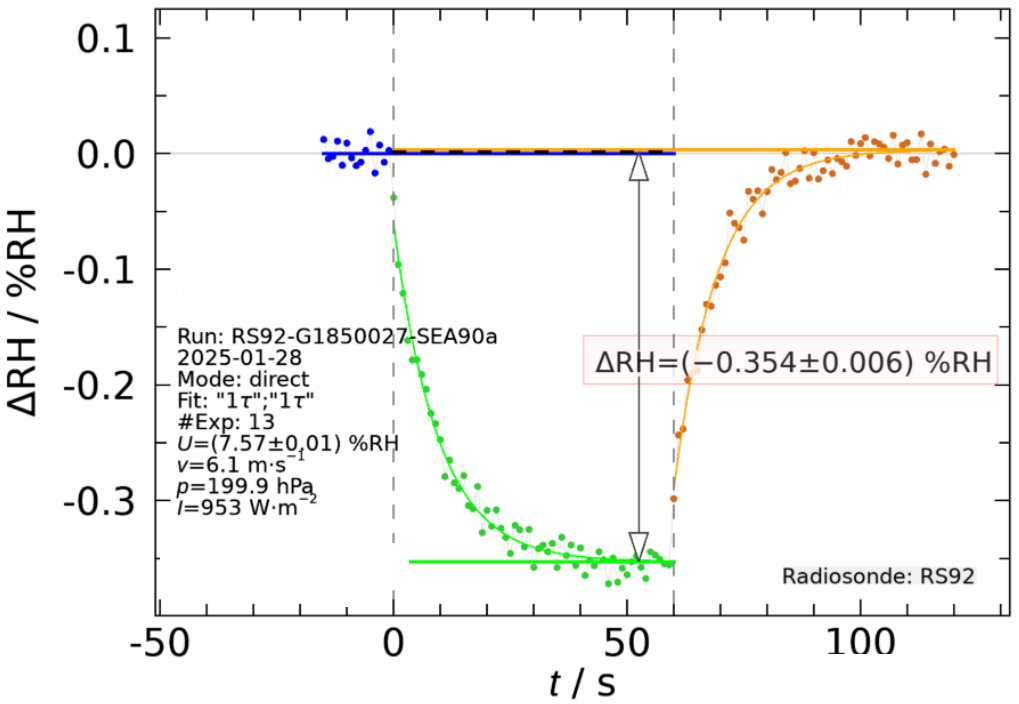
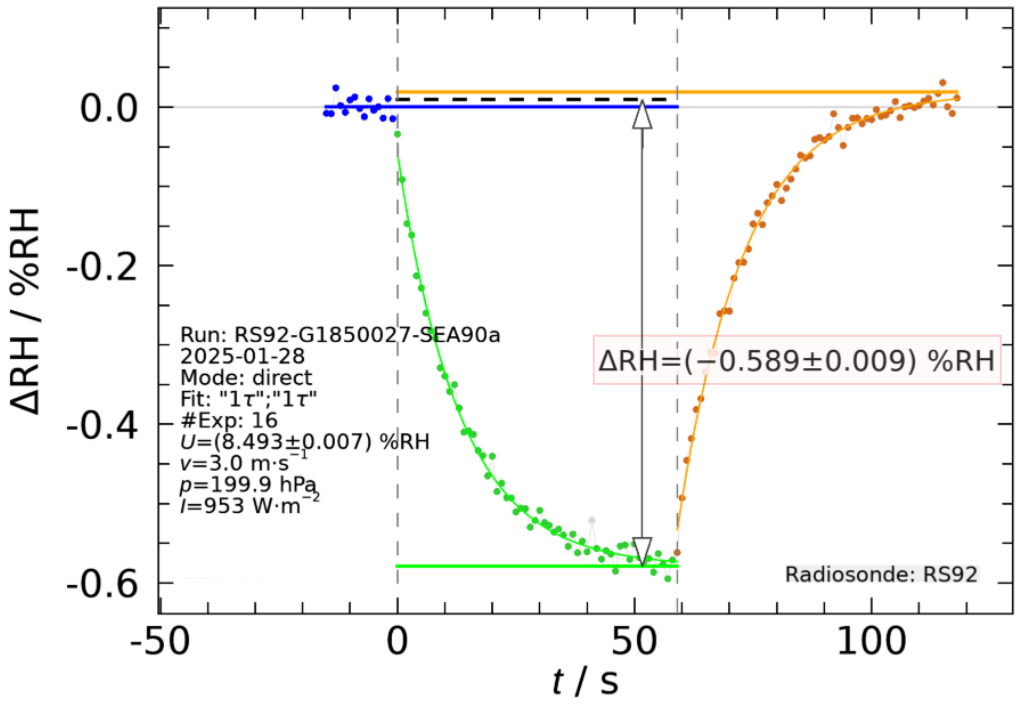
Two examples ($p = 200$ hPa)

$v = 6.1$ m·s^{-1}, RH = 7.6 %, ΔRH = −0.35 %



$v = 3.0$ m·s^{-1}, RH = 8.5 %, ΔRH = −0.59 %



RS92 RH dry bias, Measurement results: $\Delta T_{\mathrm{RH}}(p)$

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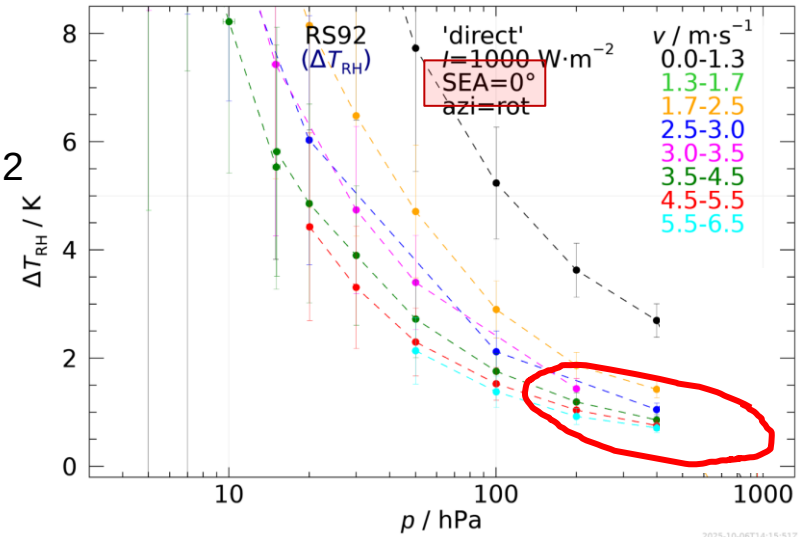
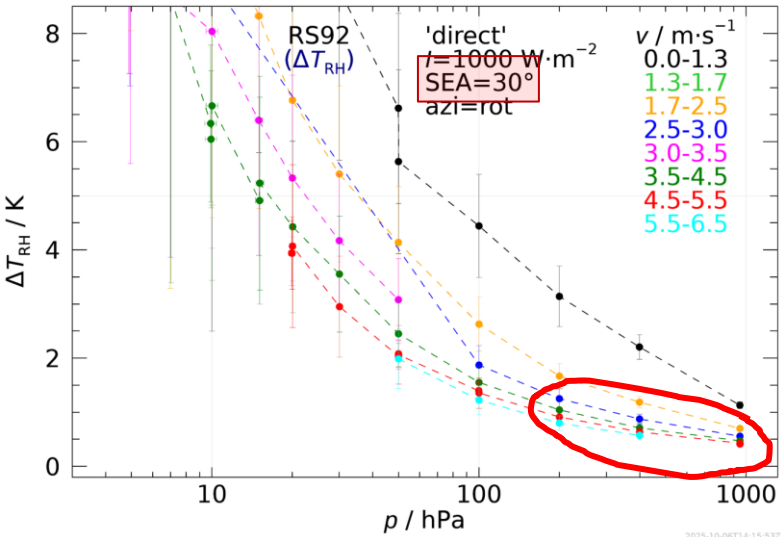
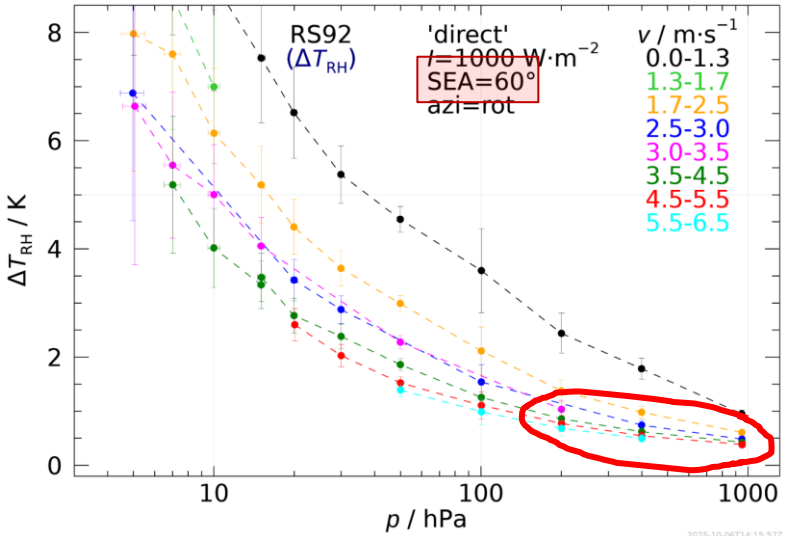
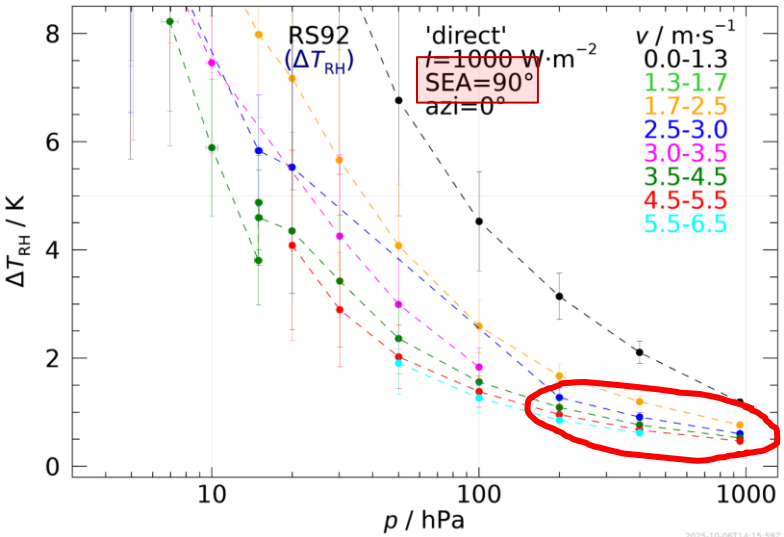
- ΔT, linearly scaled to $I_a = 1000$ W·m^{-2}
- Systematic increase of ΔT at low p and v
- Systematic change of ΔT with solar elevation



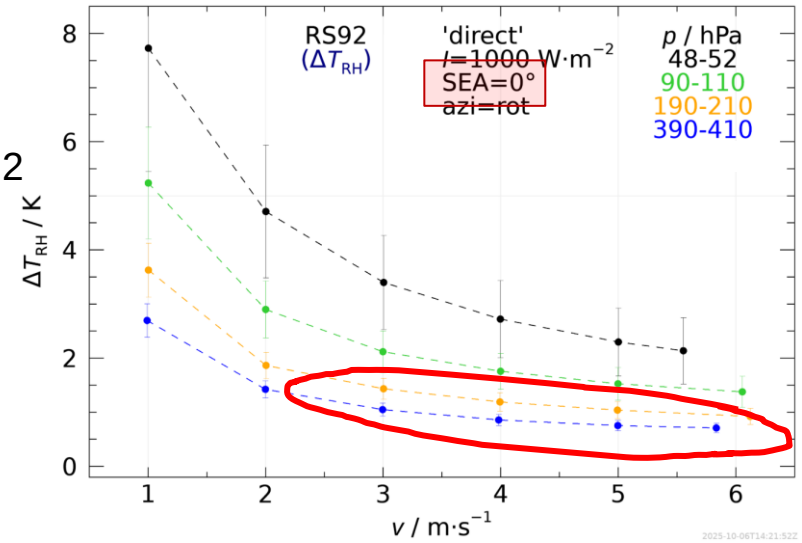


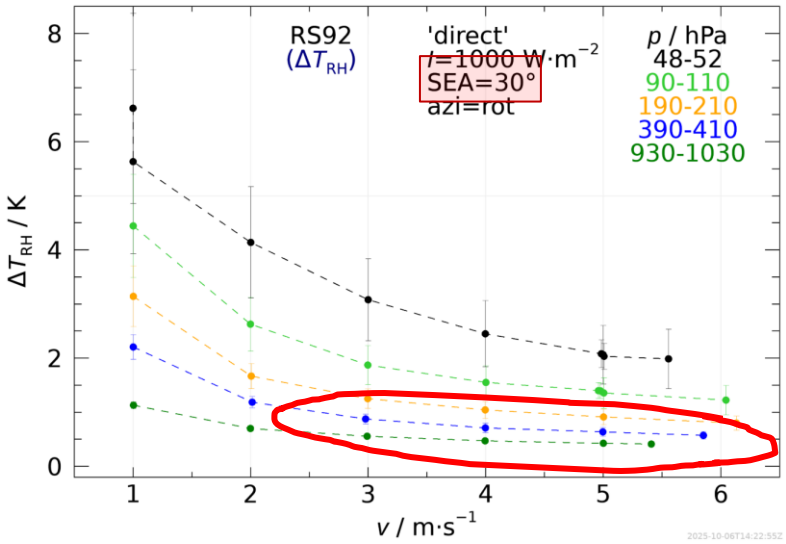


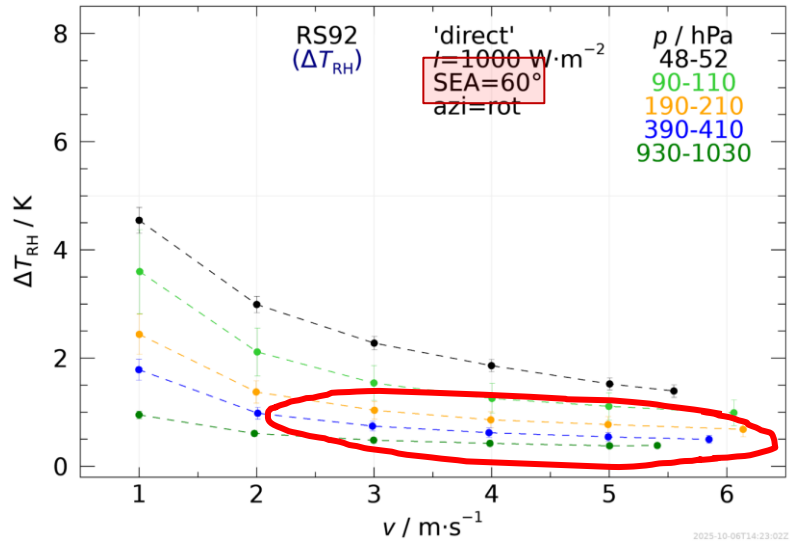


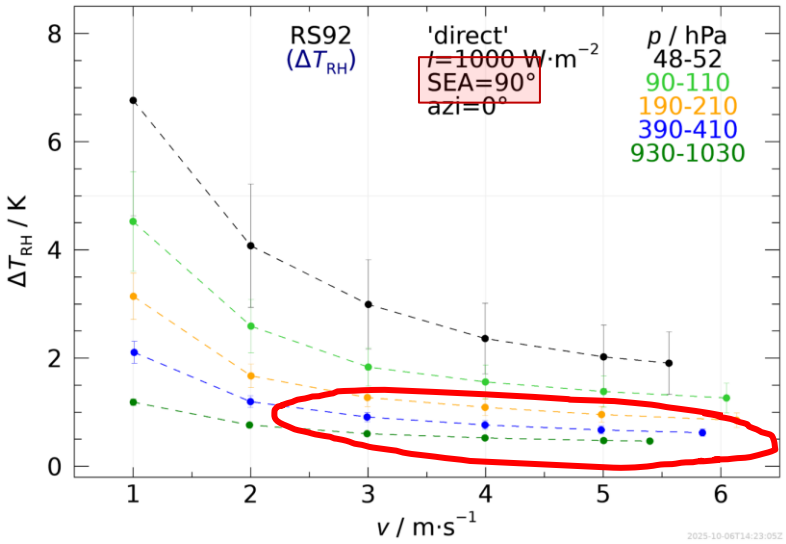
RS92 RH dry bias, Measurement results: $\Delta T_{\mathrm{RH}}(v)$

- ΔT, linearly scaled to $I_a = 1000$ W·m^{-2}
- Systematic increase of ΔT at low p and v
- Systematic change of ΔT with solar elevation









Rad. sensitivity RH-sensor RS92, next steps

- Measured data sets $\Delta T_{\mathrm{RH}}(p, v)$ to be fitted to create working expressions
- RH dry bias correction to be implemented in RS92-GDP.v3 processing using working expressions for $\Delta T_{\mathrm{RH}}(p, v)$, RTM-modelled actinic flux I_a, RS-measured T, RH, p, v, and conversion to $\Delta\mathrm{RH}$ using sat. pressure $e_{\mathrm{s}}(T)$
- Approach in principle independent of actual relative humidity set in the experimental setup, *but*:

  ΔT_{RH} estimate sensitive to systematic deviations in $\mathrm{RH_{air}}$ measured by RS (e.g. calibration), in particular at low $\mathrm{RH_{air}}$

$$e_{\mathrm{s}}(T_{\mathrm{air}} + \Delta T) = e_s(T_{\mathrm{air}}) \cdot \frac{\mathrm{RH_{air}}}{\mathrm{RH_{air}} + \Delta\mathrm{RH}}$$

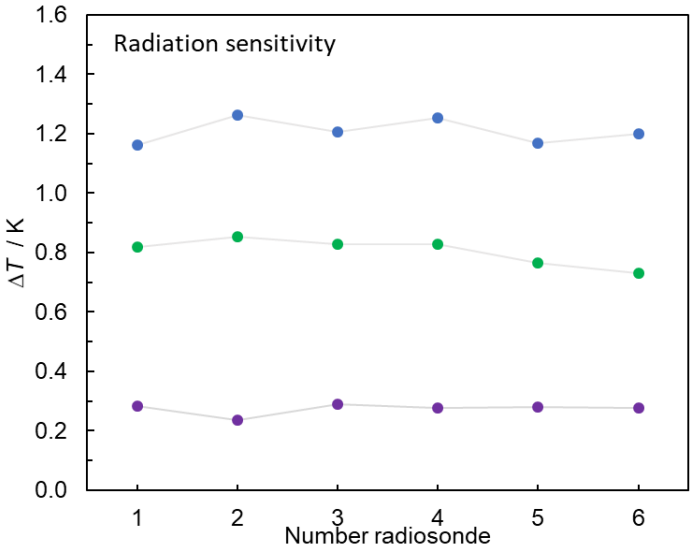
Radiation sensitivity T: Reproducibility

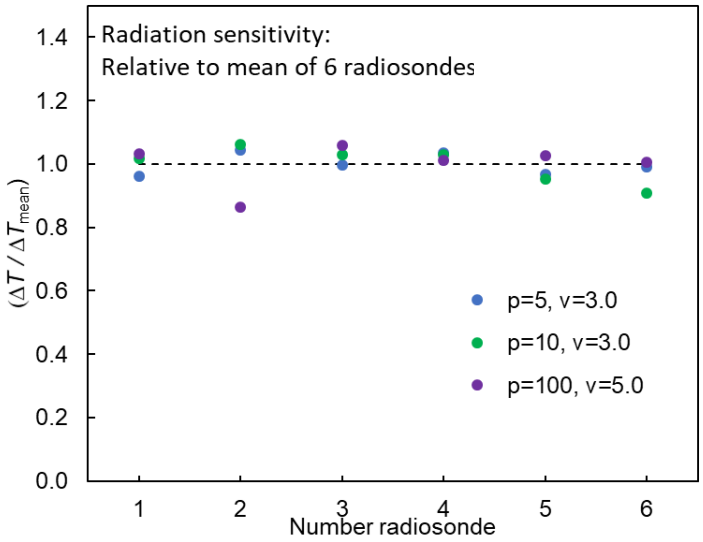
- LC radiation correction for T based on measurements with a **single radiosonde unit** (for consist data)
- Variability in radiation sensitivity expected across different units of the same RS model
  (Production-related variation of shape and size of sensors, quality and thickness of coating, small changes of sensor boom construction, …)
- LC performed reproducibility tests of rad. error across different units (RS41, RS92, DFM-17, M10)
- Results (reproducibility) to be included as random uncertainty component in GDPs

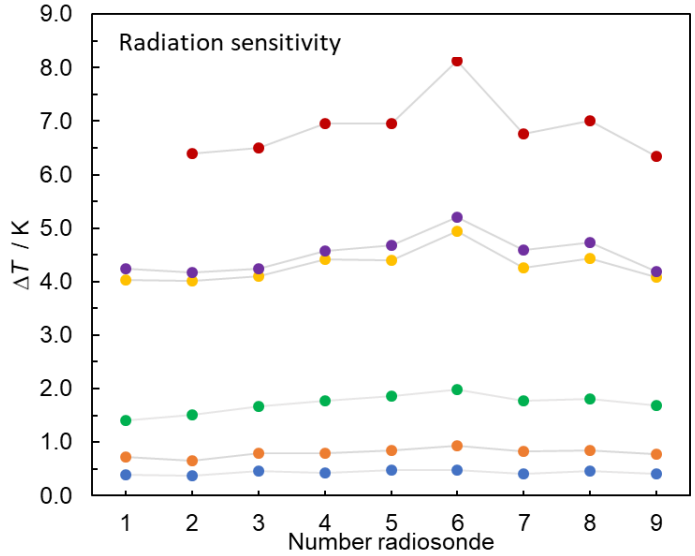
Radiation sensitivity T: Reproducibility (RS41, RS92)

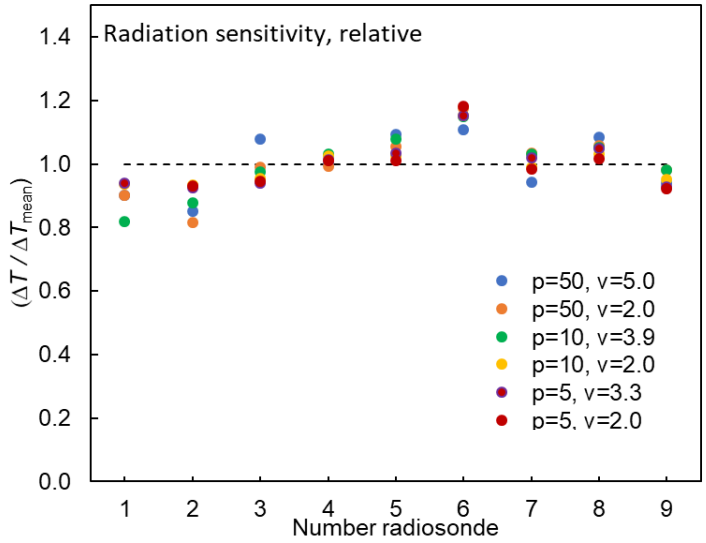
Relative standard deviation (average)

- RS41
  $\sigma = 5.3\ \%$
- RS92
  $\sigma = 8.8\ \%$









Radiation sensitivity T: Reproducibility (DFM-17, M10)

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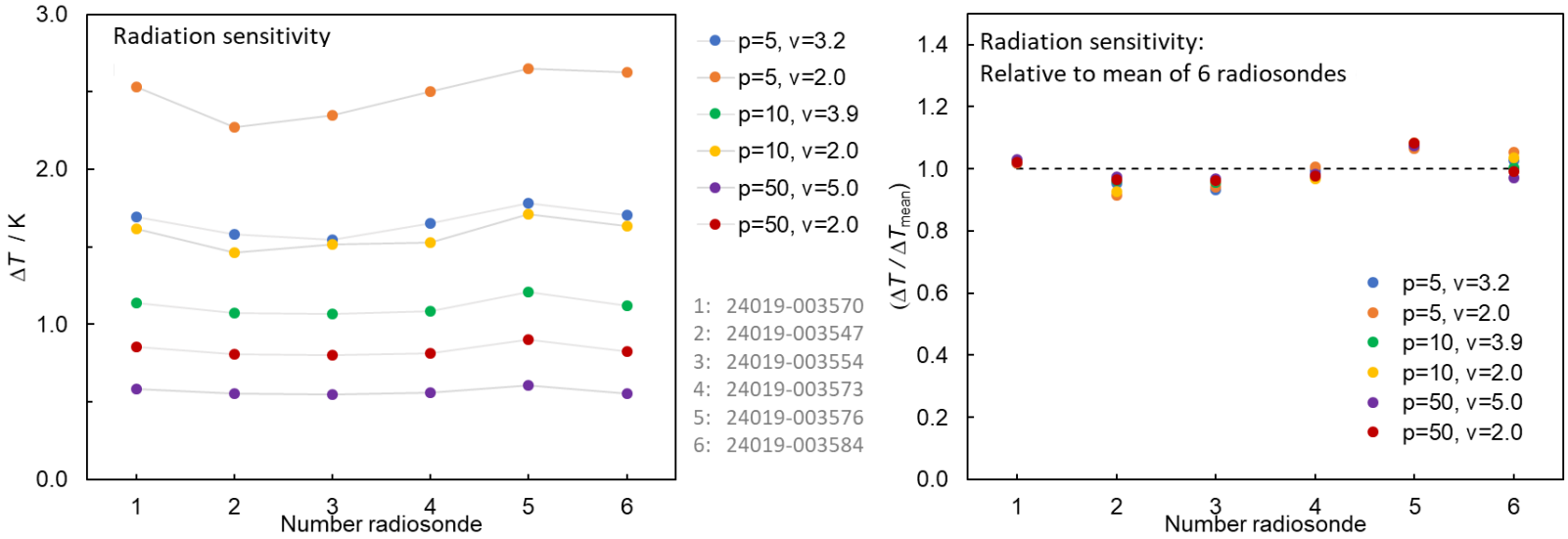
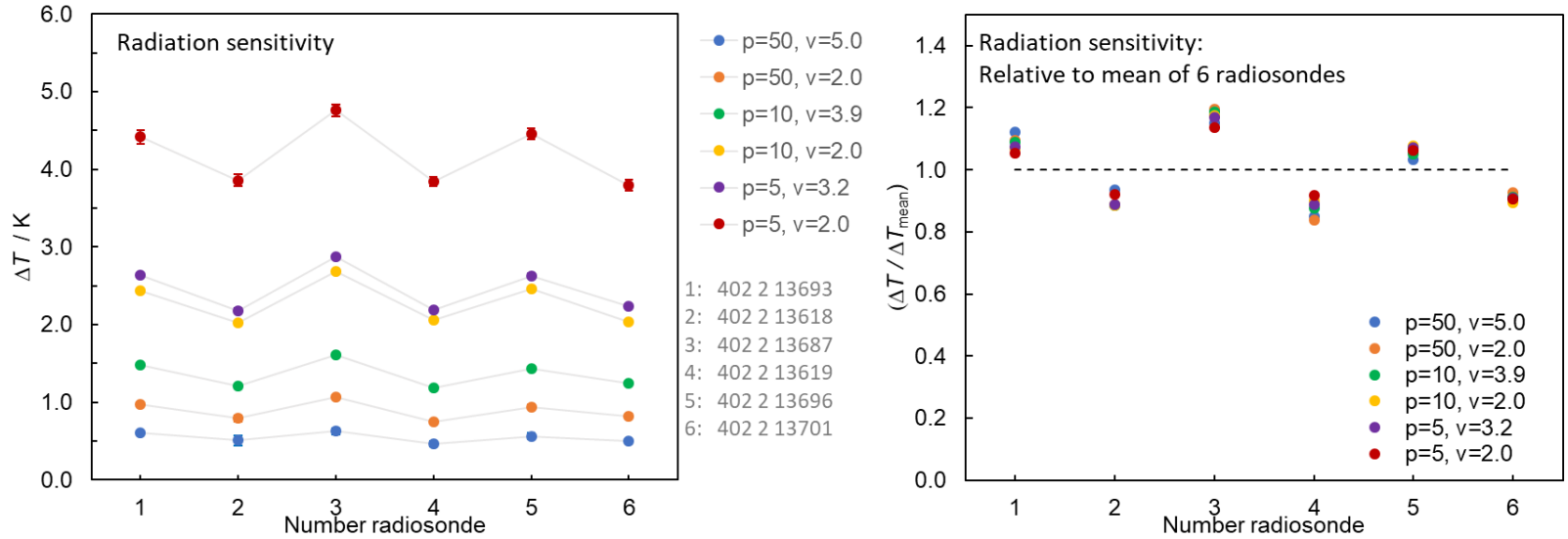
Relative standard deviation (average)

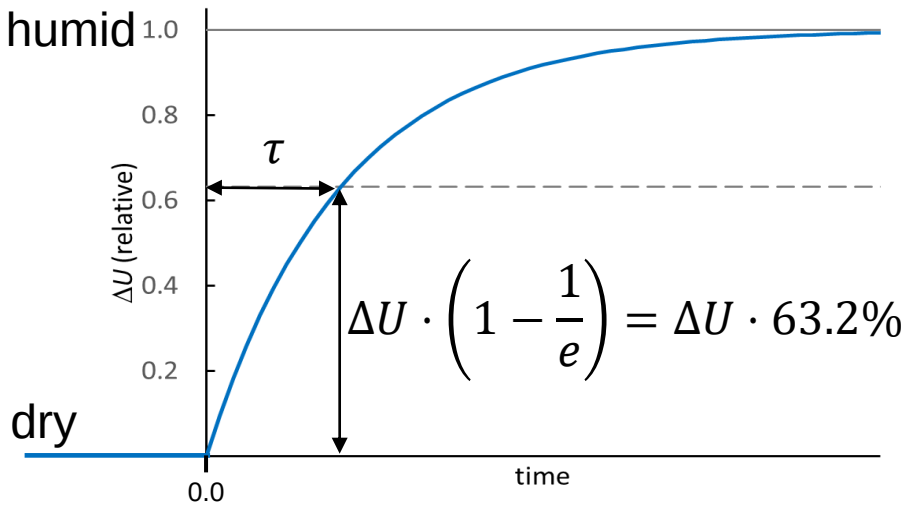
- DFM-17
  $\sigma = 5.1\ \%$
- M10
  $\sigma = 10.9\ \%$



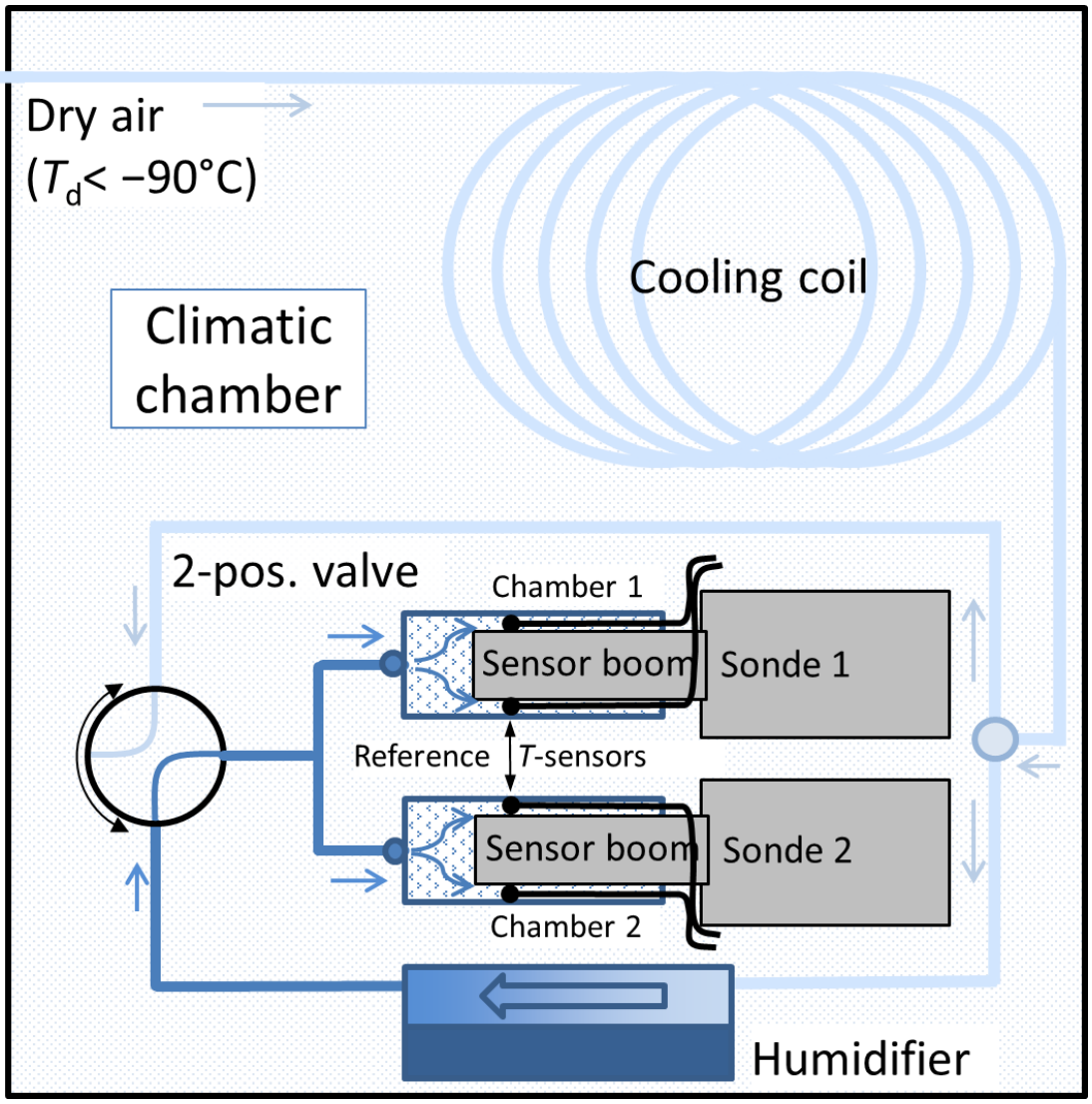


RH time lag RS92: Setup & principle

- Observe response of RH sensor to step-like changes RH

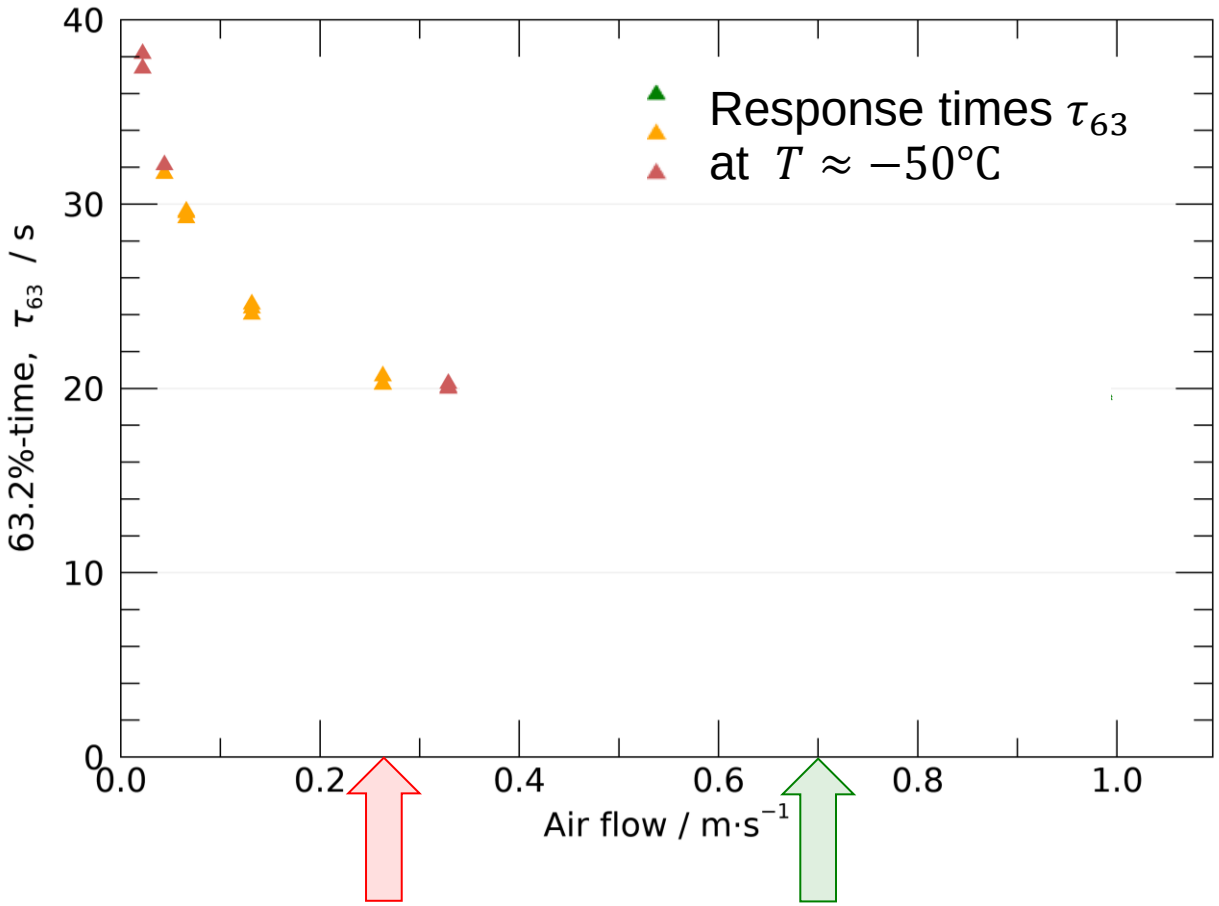


- Two radiosondes tested in parallel



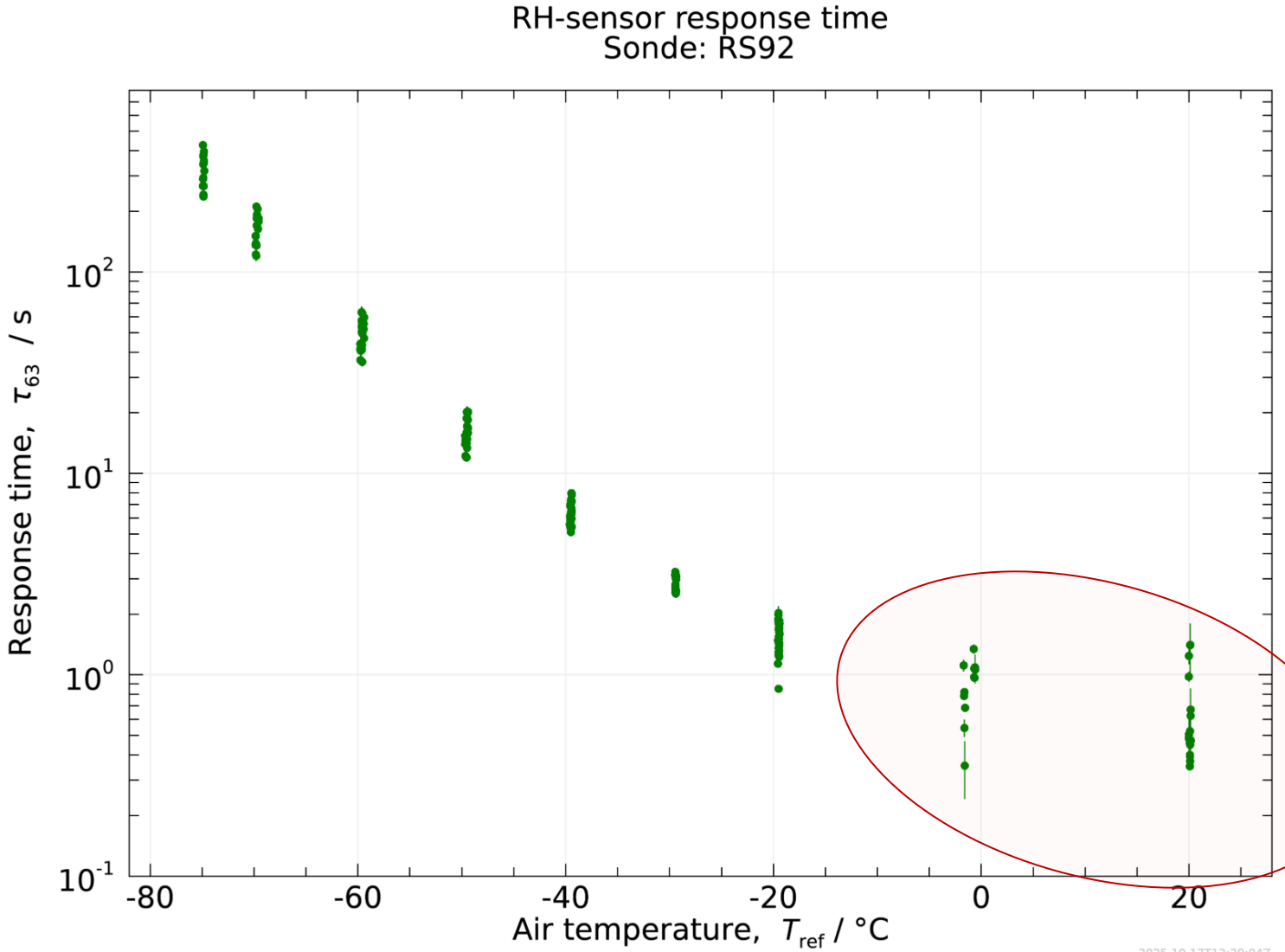
RH time lag RS92, Effect of ventilation speed

- RH response time enhanced at low ventilation
- → Modification of the setup to enable higher ventilation speeds (Adaptation of supply line and valve dimensions)
- Constant τ at $v > 0.4$ m s^{-1}



RH time lag RS92: Measurement results

- Data collected from **four** RS92 units
- T-range: $-75 \ldots +20$ °C
- Ventilation speed: ≈ 0.7 m s^{-1} (≈ 15 l min^{-1})
- RH-response time: < 400 s (-75 °C), ≈ 1.5 s (-20 °C)



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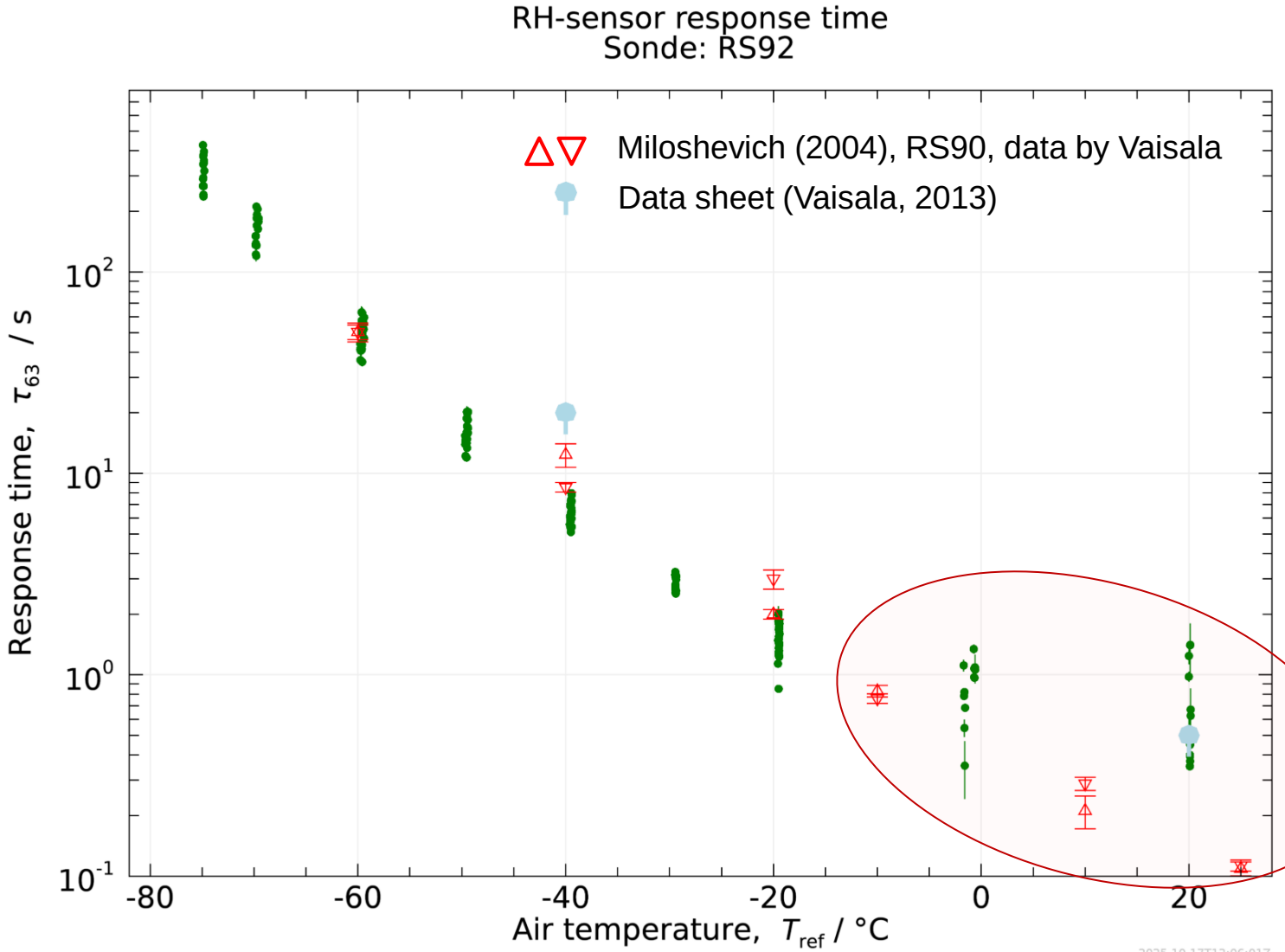

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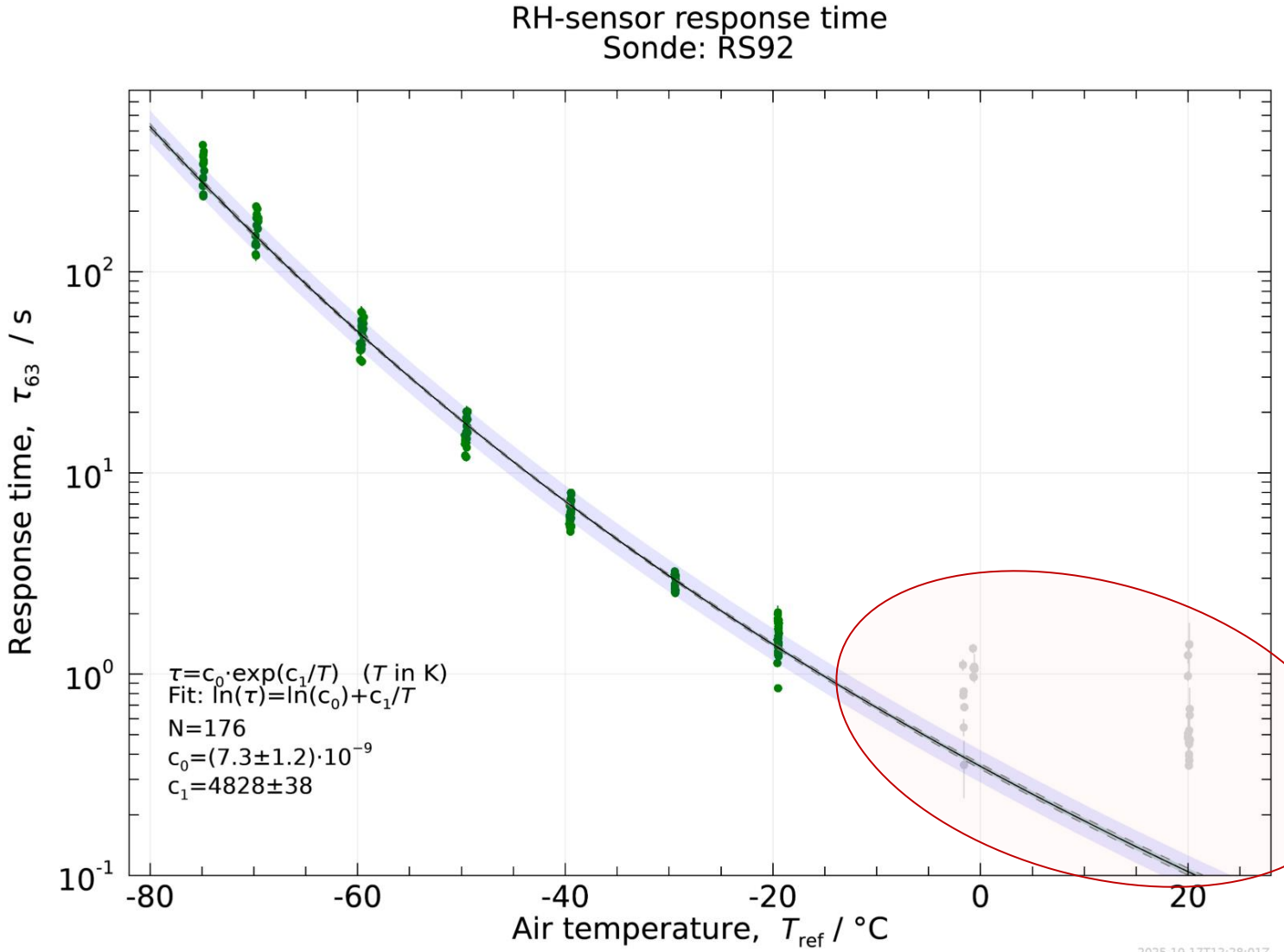

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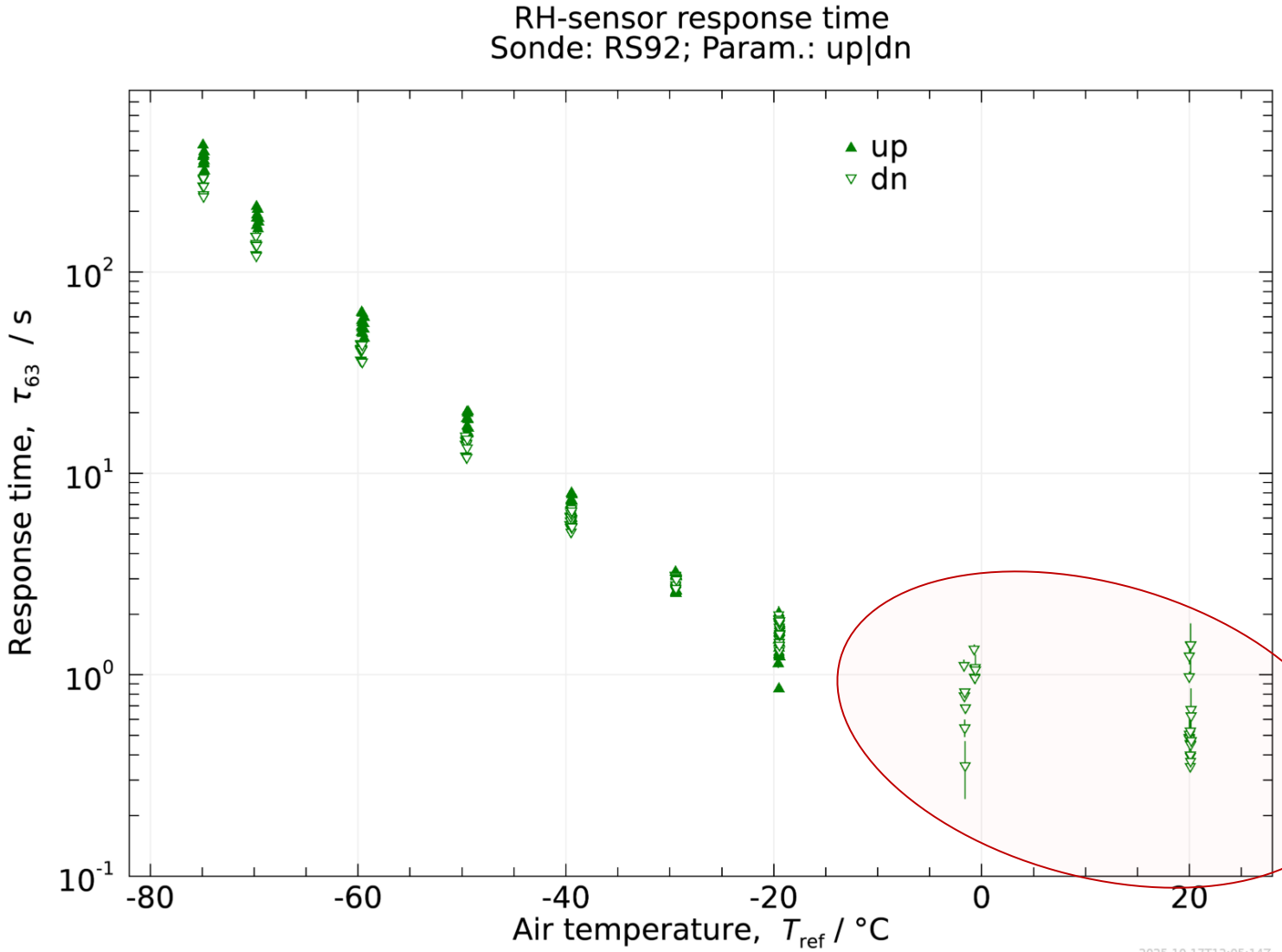
  ≈ 2 s (-20 °C)



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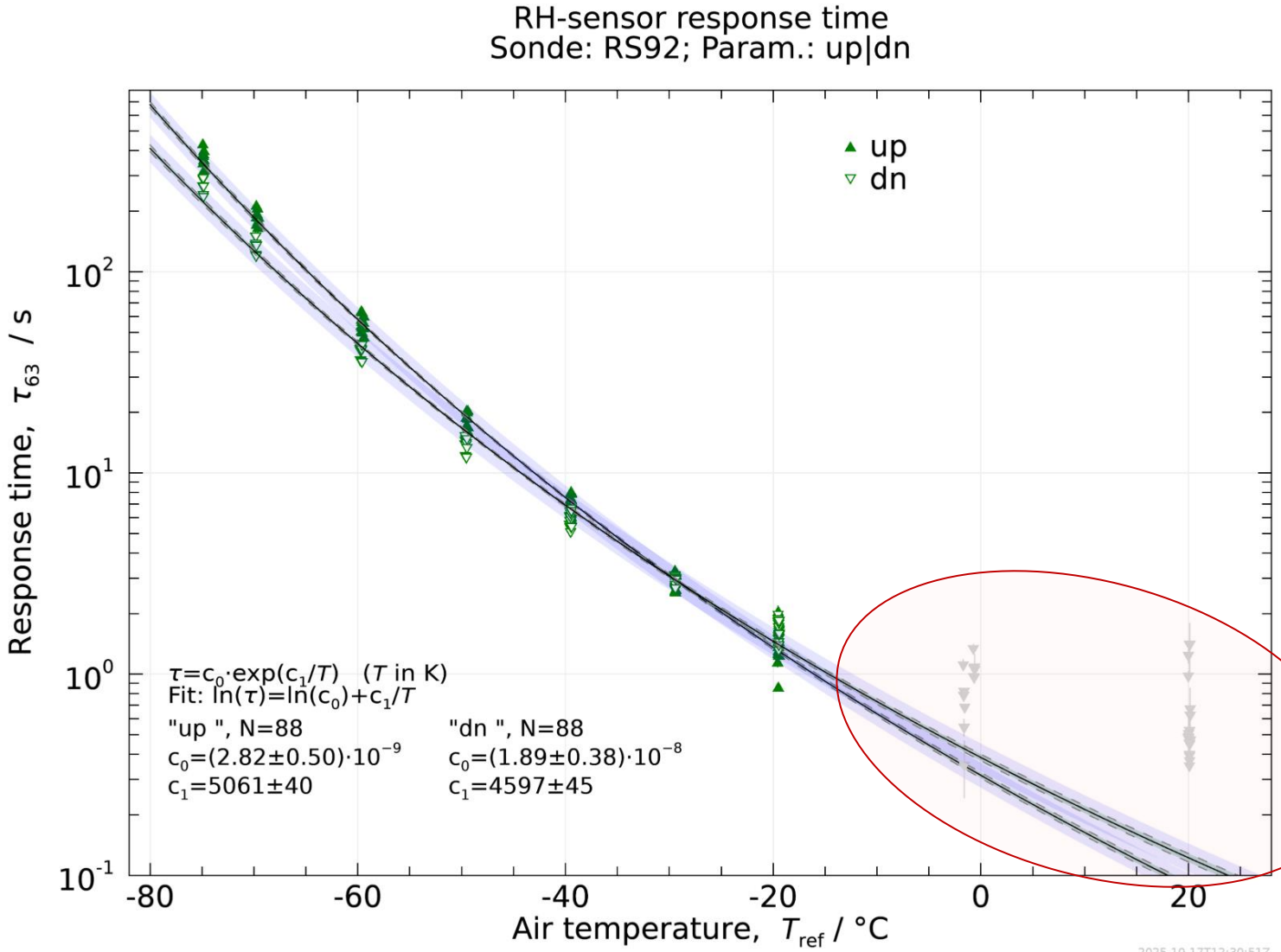

Summary
Status Radiosonde GDPs in GRUAN

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RS model	Lab experiments		GDP			TD	Pub	Certif.
	T solar rad.	RH time lag	Data processor existing	Implem. of lab results	Evaluation & Compar.			
RS92 (v2)	☺	☺	☺ (LC)	☺	☺	☺	☺	☺
RS41	☺	☺	☺ (LC)	☺	☺	☺	☺	☺
iMS-100 / RS11G	☺	☺	☺ (JMA)	☺	☺	☺	☺	☺
M10	☺	☺	☺ (IPSL)	☺	☺	😐	☺	😐
RS92 (v3)	☺	☺	☺ (LC)	☹	😐	?	😐	☹
DFM-17	☺	😐	☺ (LC)	☹	😐	☹	☹	☹
DFM-09	☹	☹	☺ (LC)	☹	😐	☹	☹	☹
GTH3	😐	😐	? (CMA)	☹	😐	?	?	☹

Thank you for your attention!