Sensitivity of Modem M10 temperature measurement to sensor orientation and quality of reflective coating

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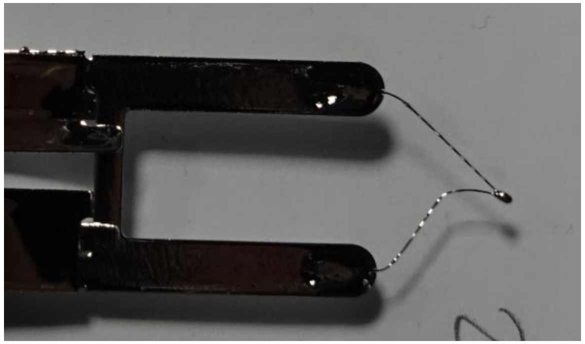
Subject

- **Observation:**
  T-inconsistencies (~1 K) in daytime dual soundings with radiosonde Modem M10

- **Assumptions / hypotheses:**
  1) T-bias due to bent sensor (thermistor, lead wires)
     → Change of solar heating of T- sensor (?)
  2) Damages / abrasions of reflective coating on thermistor identified (microscopic pictures)
     → Expectation: warm bias



- **Investigations:**
  – M10 dual soundings Nov. 2023 – Jan. 2024 in Lindenberg (8)
  – Laboratory experiments using SISTER (13-15 Feb. 2024)

M10 dual soundings

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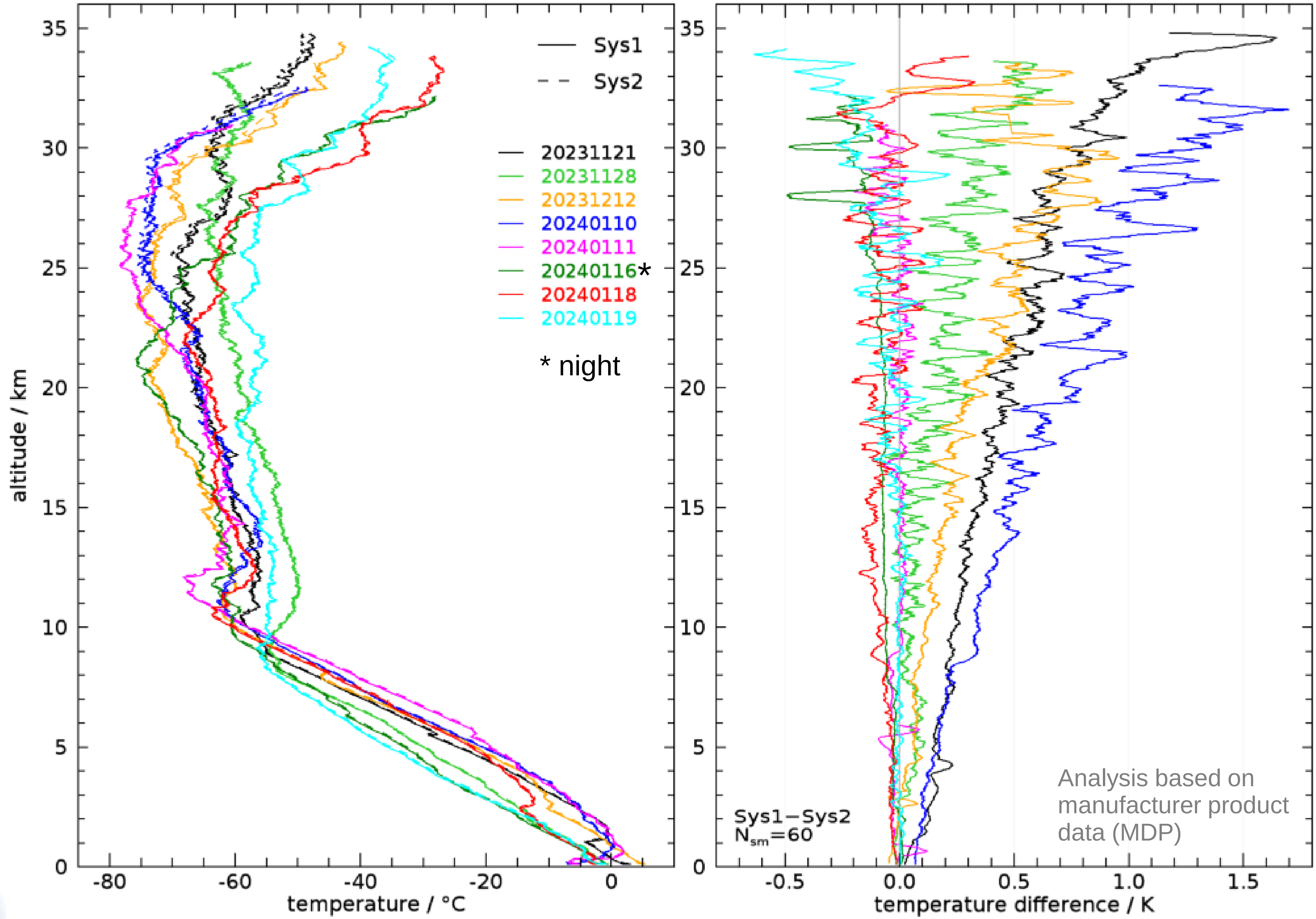
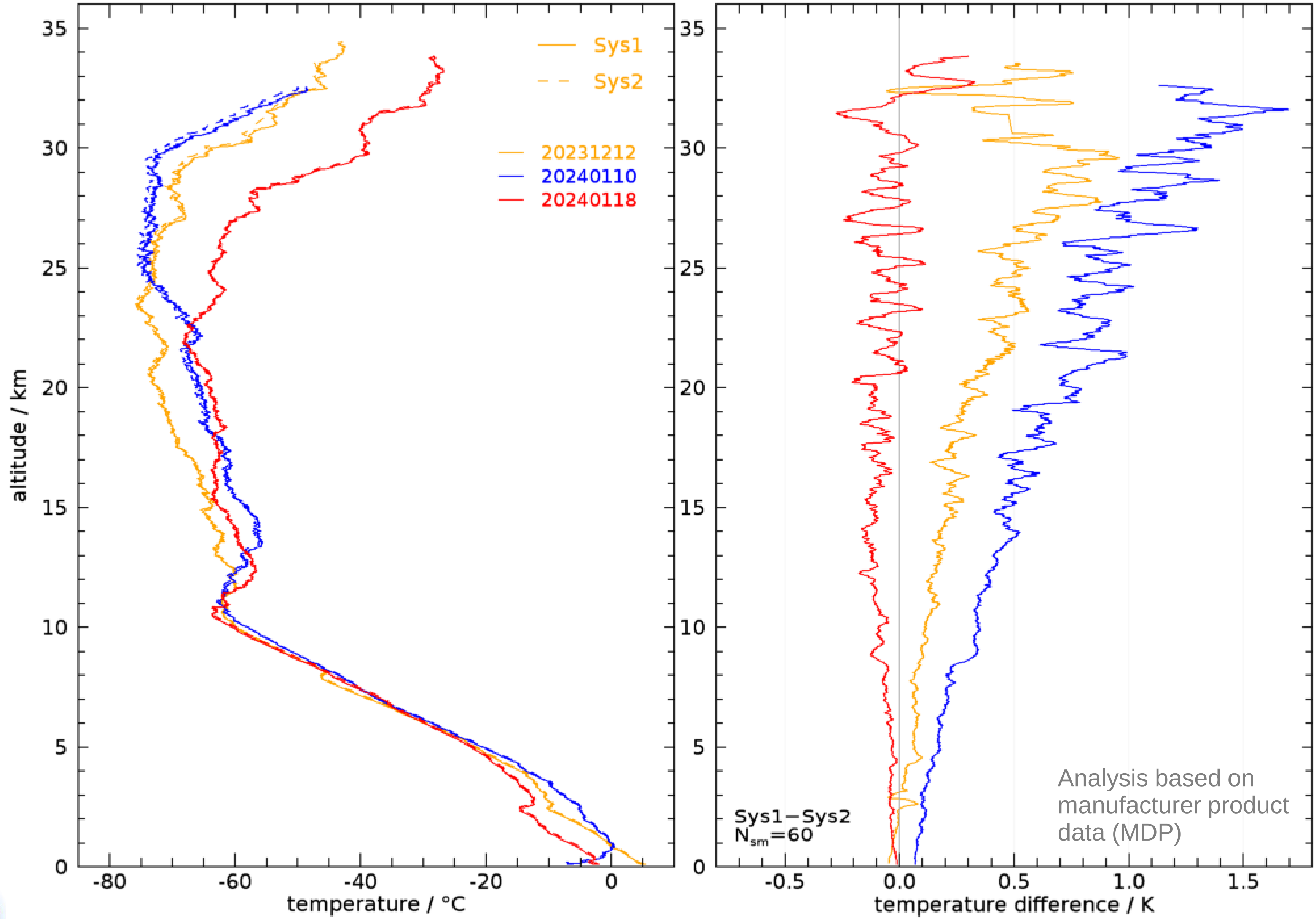


1) Sensor coating



1) Sensor coating

No.	Launch / UTC	Cond. Coating	Summary
1	2023-11-21 10:45 (day)	-	Max. T-diff. >1 K
2	2023-11-28 10:52 (day)	-	Max. T-diff. ~0.5 K
3	2023-12-12 10:56 (day)	☺ ☹	Max. T-diff. ~0.8 K Sensor with damaged coating *colder*
4	2024-01-10 09:37 (day)	☺ ☹	Max. T-diff. ~1.5 K Sensor with damaged coating *colder*
5	2024-01-11 10:46 (day)	☺ ☺	Good
6	2024-01-16* 16:55 (night)	☺ ☹	Good, sensor with damaged coating (little) warmer
7	2024-01-18 10:50 (day)	☺ ☹	Good, in contrast to 3) and 4)
8	2024-01-19 10:48 (day)	☺ ☺	Good

1) Sensor coating: Laboratory measurements

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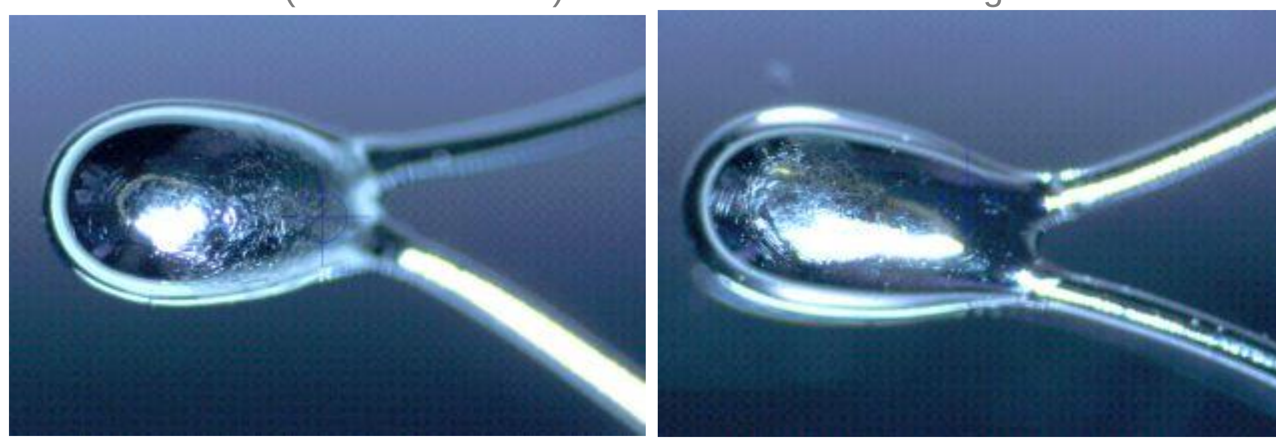
Experimental settings:
- I =1073 W m^{-2}
- Constant RS rotation: T =15 s (ΔT averaged)
- Horizontal incidence (low solar elevation angle)

- Measurement program:

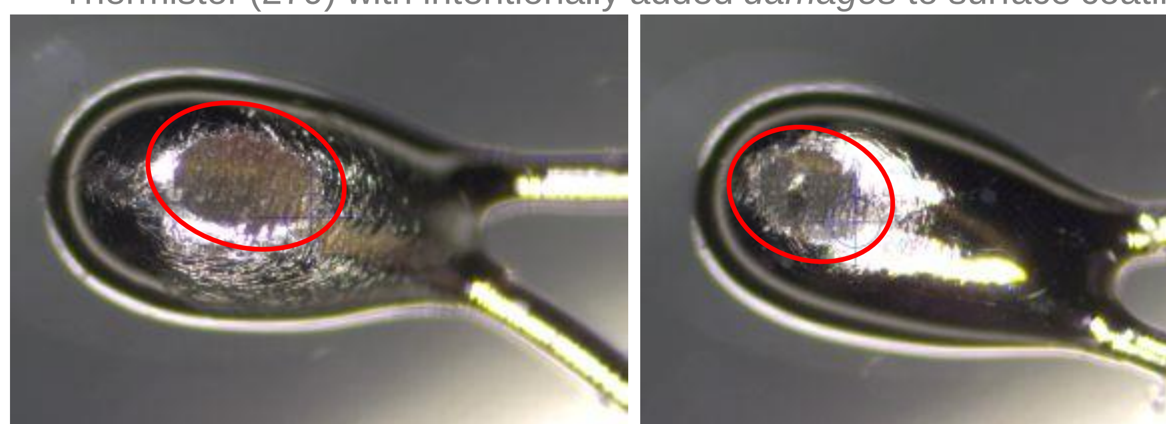
p / hPa	v / m s^{-1}
50	5.0; 2.0
20	4.5; 2.0
10	3.8; 2.0
5	3.2; 2.0

- One RS with intact coating: 279
- Three radiosondes with damaged coating: 279 (damage intent. caused), 109, 257

Thermistor (radiosonde 279) with *intact* surface coating



Thermistor (279) with intentionally added *damages* to surface coating



1) Sensor coating: Results

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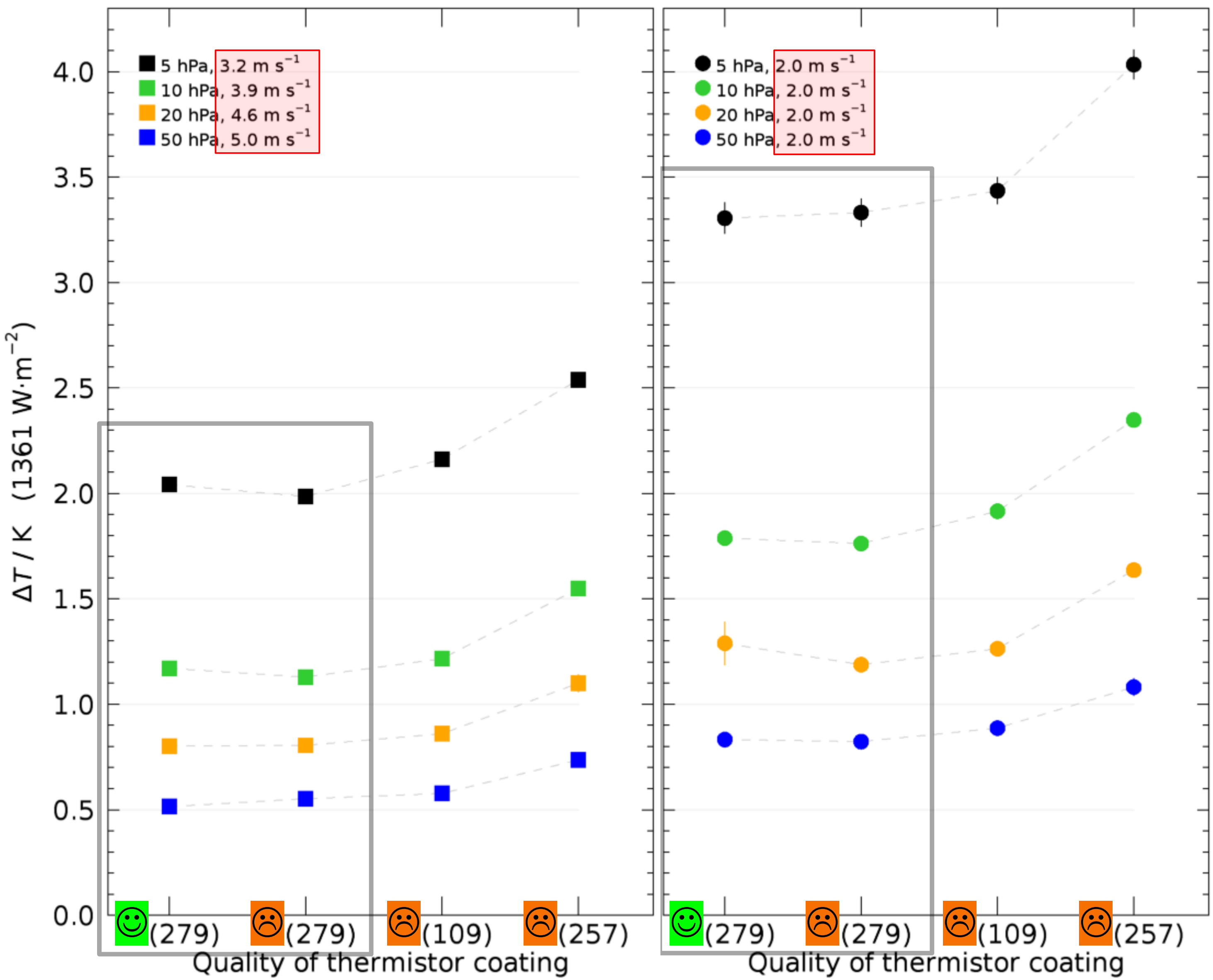
- ΔT linearly scaled acc. to irradiance of 1361 Wm^{-2}
- Alignment of boom and sensor as in normal operation (40°)
- Observed variance in ΔT: 0.0 K … 0.6 K



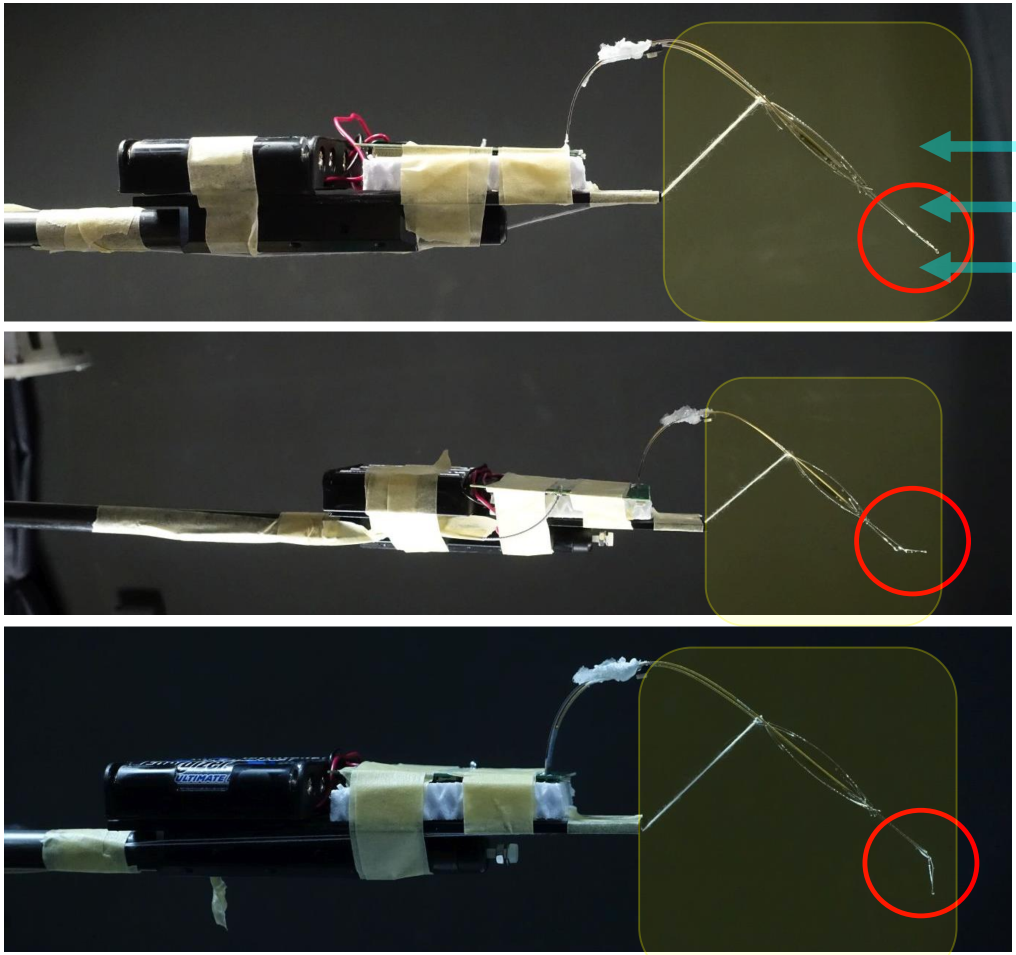
2) Sensor orientation: Laboratory measurements

Experimental settings:
- I =1073 W m^{-2}
- Rotation: T =15 s (ΔT evaluated as average over rotation
- Horizontal incidence (low solar elevation angle)
- Same unit (Ser.-No. 205 2 12**279**)

- Measurement program:

p / hPa	v / m s^{-1}
50	5.0; 2.0
20	4.6; 2.0
10	3.8; 2.0
5	3.2; 2.0

- Measurement runs for three orientation settings of the sensor tip



2) Sensor orientation: Results

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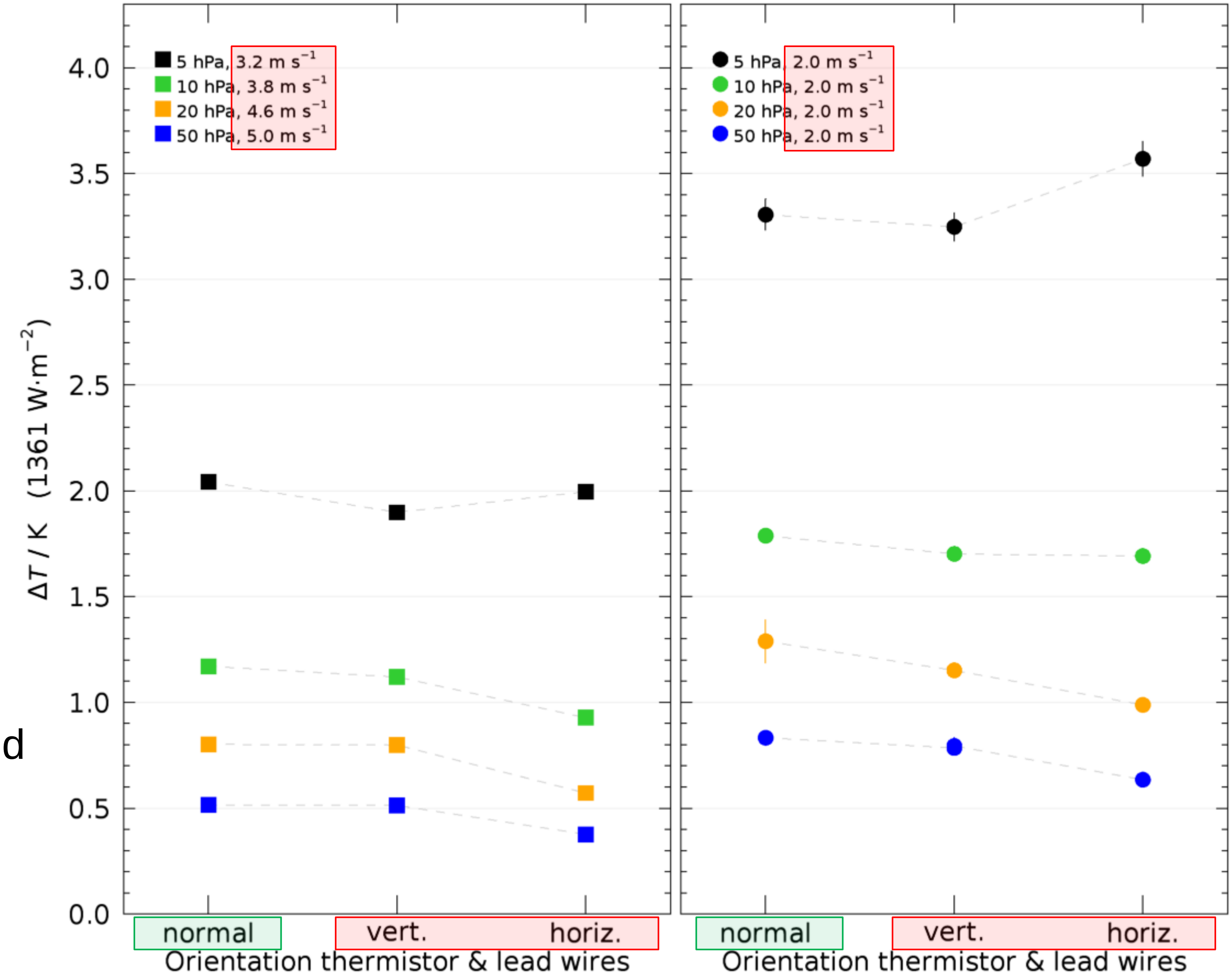
- ΔT linearly scaled to I =1361 Wm^{-2}
- Variance in ΔT: $\leq$ 0.3 K
- ΔT = *combined* effect of rad. heating (linear in I) and conv. cooling (nonlinear in p, v)

- Albedo: diffuse radiation → other directional sensitivity (smaller?)
- Lateral bending of thermistor not investigated



Summary

- **Effect of coating damages**
  - Warm bias expected
  - Finding: Inconsistent picture from both dual soundings and laboratory tests
  - → (Small) coating damages of minor significance?

- **Orientation**
  - Bending the sensor systematically changes response to direct radiation in experiments
  - → Effect too small to fully explain observed T-biases in dual soundings

Explanation/Hypothesis: Sensor size effect

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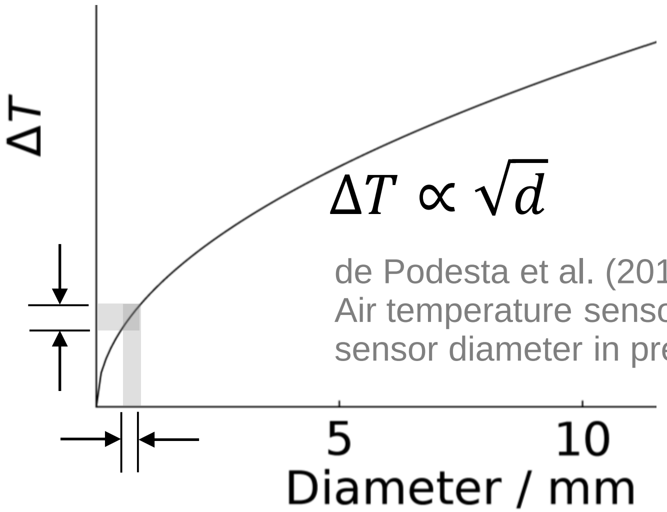
- Radiation error may vary significantly with (small) variation in **sensor size**:



de Podesta et al. (2018), Metrologia 55, 10.1088/1681-7575/aaaa52:
Air temperature sensors: dependence of radiative errors on sensor diameter in precision metrology and meteorology

- → Laboratory tests to be set up to quantify the variability of the radiative error over a sufficient number (of batches) of radiosondes under constant conditions. (→ any RS model)

Conclusions

- Operational radiosoundings in GRUAN:

  Proper orientation of sensor and sensor boom important!
  (→ any RS model)

- Potential usage of *existent* Modem M10 T-measurements in GRUAN:

  – Can a "representative" uncertainty be estimated which reflects the T-biases observed in the comparing flights?
    (→ assumption: cause of bias is ‘random’)

  – Can a daytime T-correction be applied?
    (→ requires systematic effect)

- What (overall) uncertainty for a variable can be accepted in GRUAN?
  (→ any measurement instrument)