Deutscher Wetterdienst
Wetter und Klima aus einer Hand

Radiation experiments with radiosondes: Current status

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Outline

- Sensor warming ΔT (shortwave solar radiation)
- Evidence from observations
- Quantitative estimate of ΔT
  - Chamber experiments
  - Approach for radiation correction of temperature in soundings
  - Discussion of shortcomings / limitations
- New experimental setup
- Conclusions

Effect of short wave solar radiation on sonde temperature sensors (ΔT)

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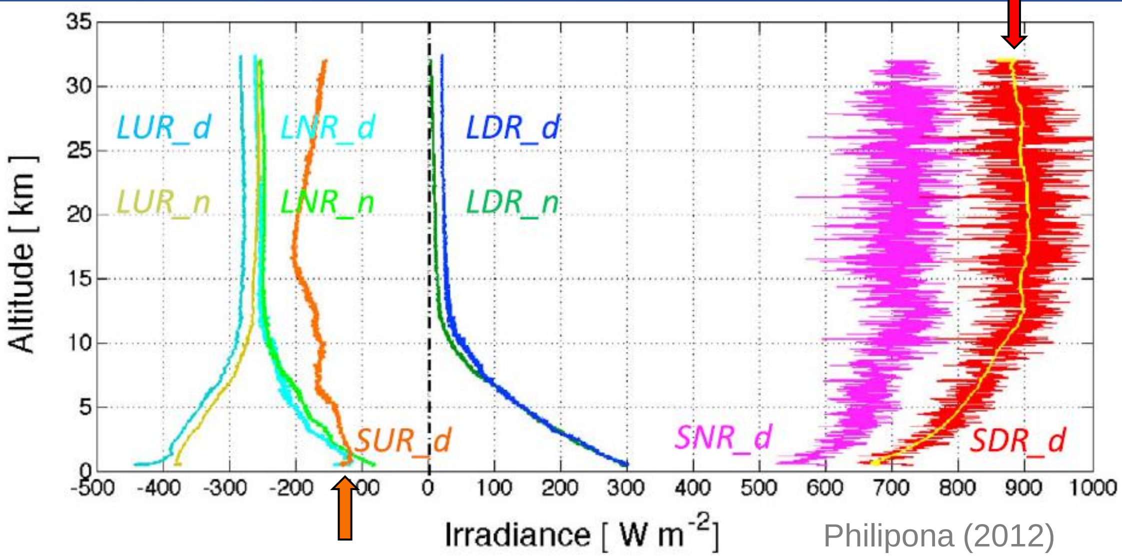
Shortwave (solar) radiation

Downwards (↓)

- direct
- diffuse
  (small in stratosphere)

Upwards (↑), (albedo)

- diffuse



Philipona (2012)

Actual T-bias (warming) result of:

- Magnitude of actinic flux (↓+↑)
- Surface and material properties:
  - reflectance, thermal conductivity, shape (boom & sensor)
  → *differential warming, conduction,*
  → complex response (*more than one time constant*)
- Heat exchange with air (ventilation)
  - *air density (altitude)*
  - *ascent speed*
  → most of all cooling
- Direction of irradiation:
  - *SEA*
  - *angle of sensor boom*
  - *azimuth angle (rotational motion)*
  - *deflection angle (pendulum motion)*
- Longwave cooling (?)

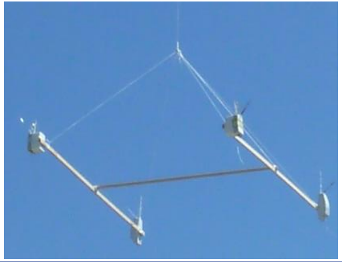
→ Lack of information to calc. T-bias by solving heat balance equation

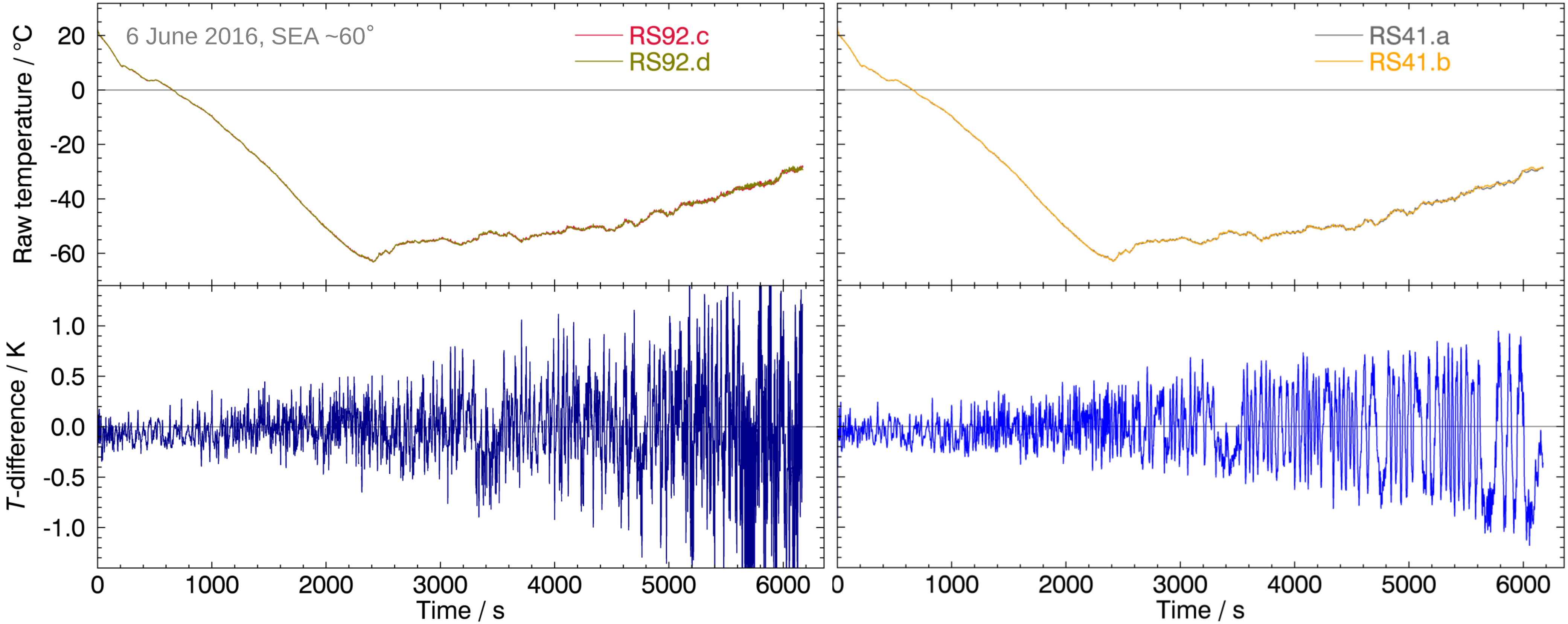
→ Semi-empirical approach for *average* bias as function of *known* parameters (I_a, v, p)

→ Laboratory measurements as quantitative basis

Orientation dependence of T-effect with direct solar irradiation,

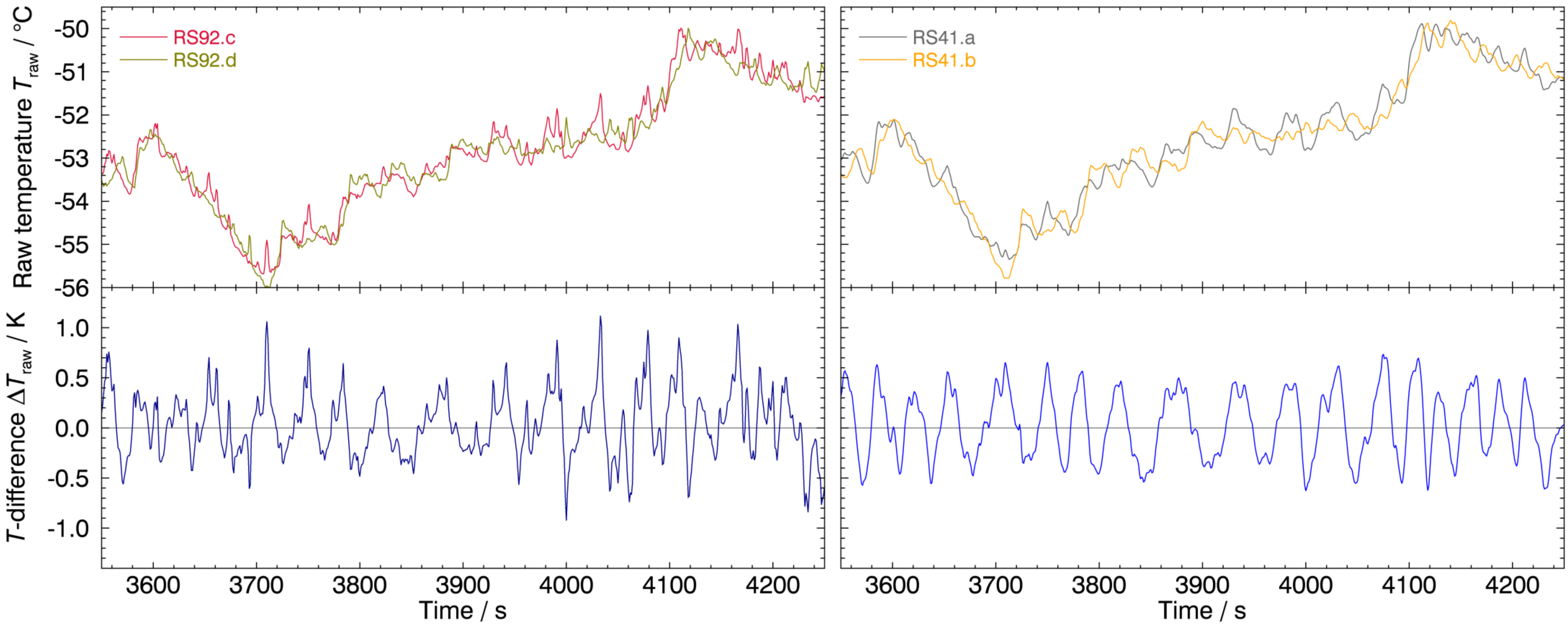
dual flight, sensors facing in opposite direction





- T-differences up to **1.5 K** for **RS92**, **1 K** for **RS41**, caused by different orientations relative to sun
- Absolute T-bias may be larger (includes warming from diffuse radiation)

Orientation dependence of *T*-effect with direct solar irradiation,
dual flight, sensors facing in opposite direction



- Two types of rig movements (rotation, pendulum)
- Different temporal responses of RS92 and RS41

Experimental approach
Lindenberg radiation chamber

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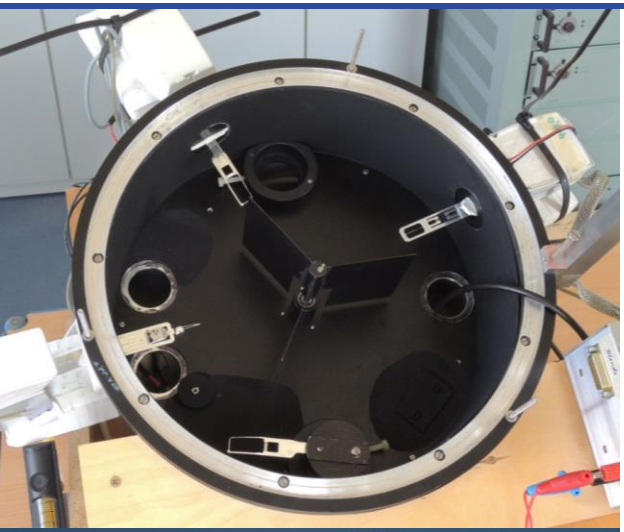
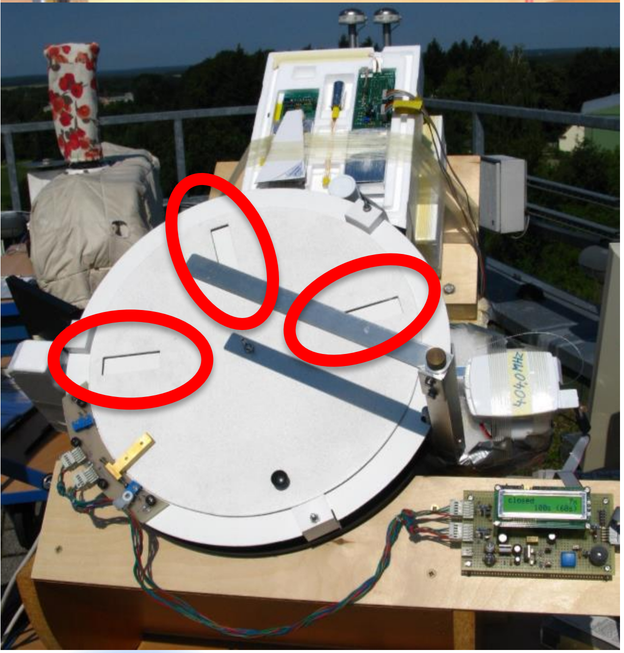
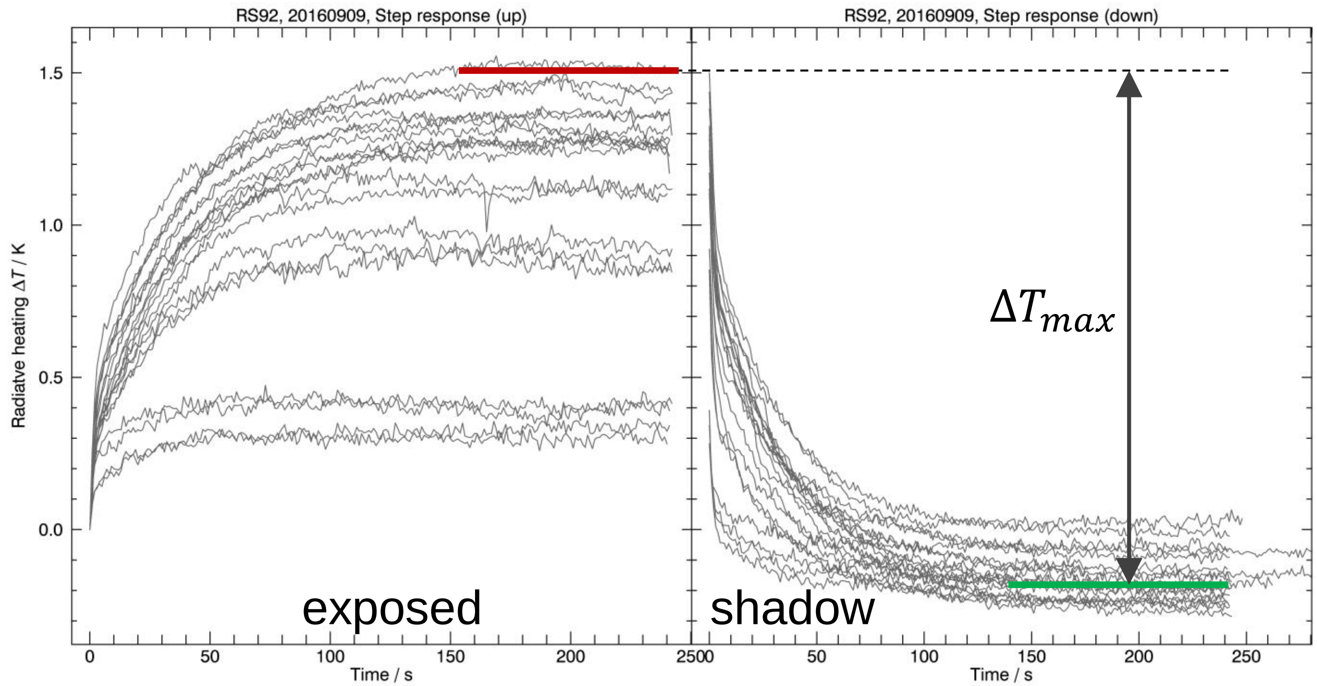




- Sun as light source (direct)
- Vertical irradiation, major part of sensor boom
- Controlled parameters:
  Irradiance I: (200–1000) W·m^{-2}
  Pressure p: (3–1020) hPa
  Ventilation v: (0–10) m·s^{-1}
- ΔT_{max} = T(test sonde) – T(reference sonde, shadow)
  (thermal equilibrium)



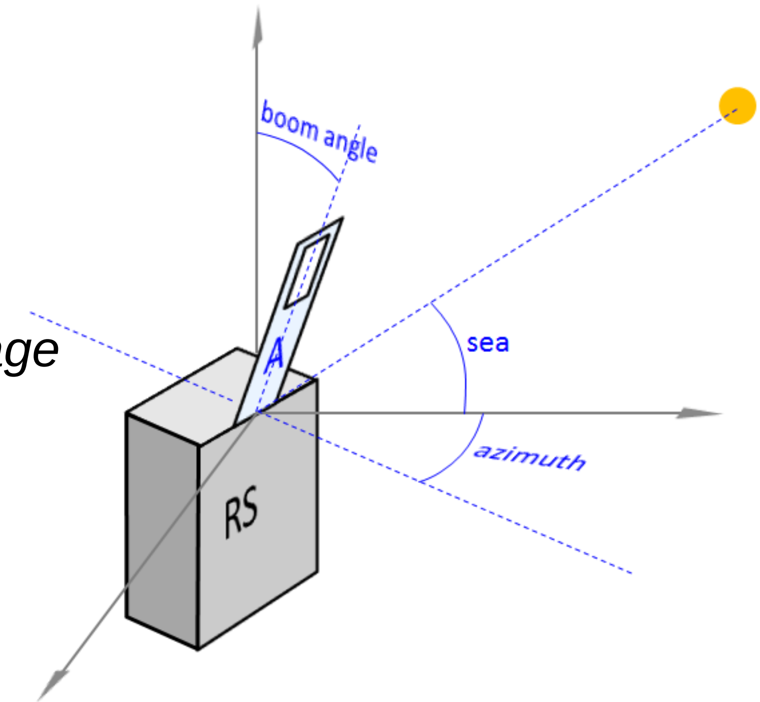
Radiation correction, initial approach

- Lab experiments: $\Delta T_{max}(I,p,v) = a \cdot \left(\frac{I}{p^j \cdot v^k}\right)^b$

  a, b, j, k from fits to experimental data

- Relate exp. results to conditions during soundings:
  - Separate components of actinic flux (I_{dir}, I_{diff})
    (RS92 GDP: Streamer model, representative scenario)
  - Sonde rotation: Scaling of I_{dir} with effective *average* surface A of sensor boom exposed to sun

$$I_a = I_{\text{diff}} + f_{\text{geo}} \cdot I_{\text{dir}}$$



- T-bias (correction): $\Delta T = a \cdot \left(\frac{I_a}{p^j \cdot v^k}\right)^b$

- Results:

Sonde	RS92	RS41
ΔT_{max}/K	2.80	0.89

p = 10 hPa, v = 5 m·s^{-1}, I_a = 1000 W·m^{-2}

→ large for RS92 (p < 100 hPa)
Inconsistencies: RS92/RS41 dual flights: T-differences after bias correction **>** raw T-diff.
Day-night comparisons: daytime-T after bias correction **<** nighttime-T

→ Model assumptions / limitations of experimental setup

Experimental approach
Lindenberg radiation chamber, limitations

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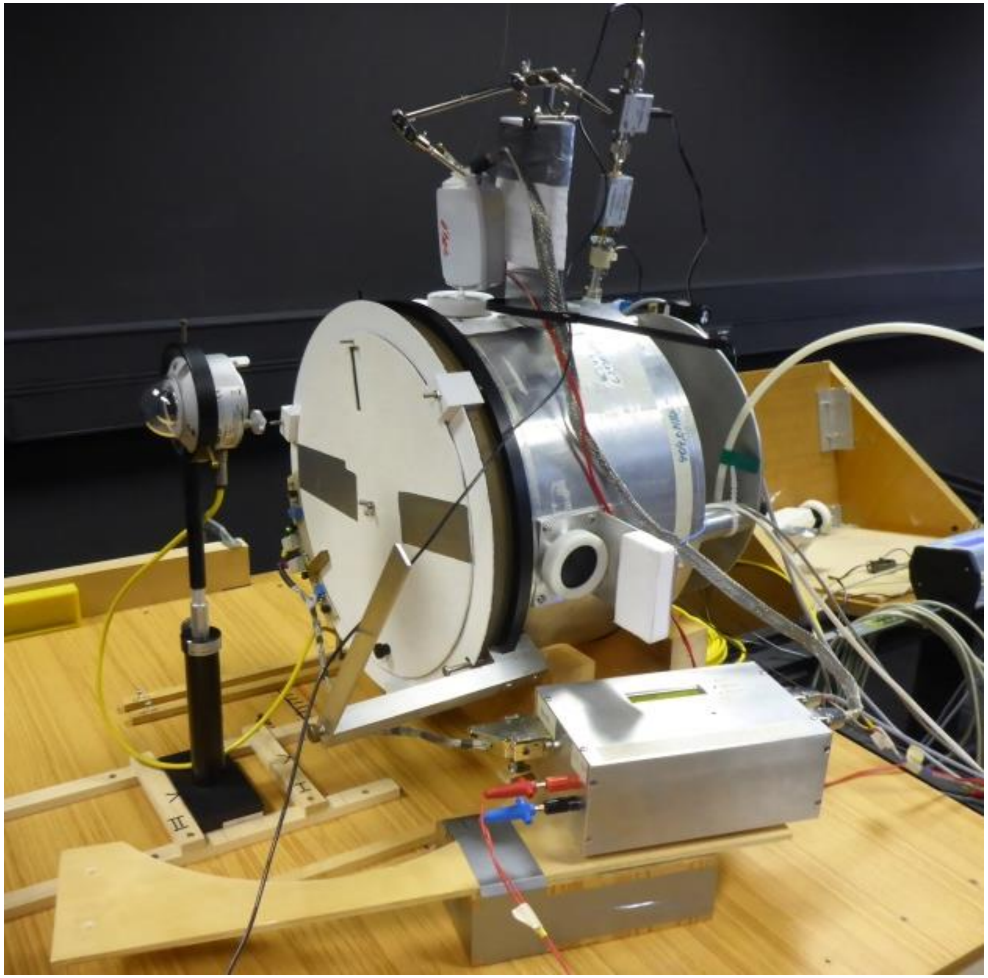
Assumptions for actual correction approach:

- Uniform response of T-sensor and boom to radiation (→ use of f_{geo})
  - Top and bottom side of boom behave the same
- I_a (modelled actinic flux during sounding) can directly be related to I_{exp}
- Response the *same* for *diffuse and direct radiation*
- Warming by diffuse radiation *independent of orientation*
- Not taken into account: Temporal response
  (T-sensor not in thermal equilibrium!);
  pendulum motion; effects by thermal radiation

Technical/conceptual limitations of experimental setup:

- Radiation incident angle fixed (vertical) (*next slides*); single side
- Air flow: direction not sufficiently well defined (mainly lateral);
  magnitude controlled by fan voltage (not stable)
- No tests with diffuse radiation
- Tests at ~300 K (no simulation of cold atmospheric temp.)

Latest experimental results (lab): ΔT as function of angle of radiation incidence



- Xe-lamp
- I_a= 1478 W·m^{-2}
- v = 5 m·s^{-1}
- p = 9.6 hPa

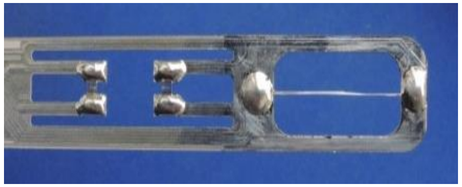
RS92 **RS41**

a) Irradiation of sensor boom

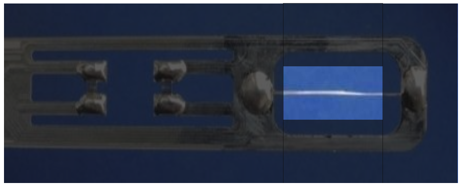
b) Irradiation of sensor element only

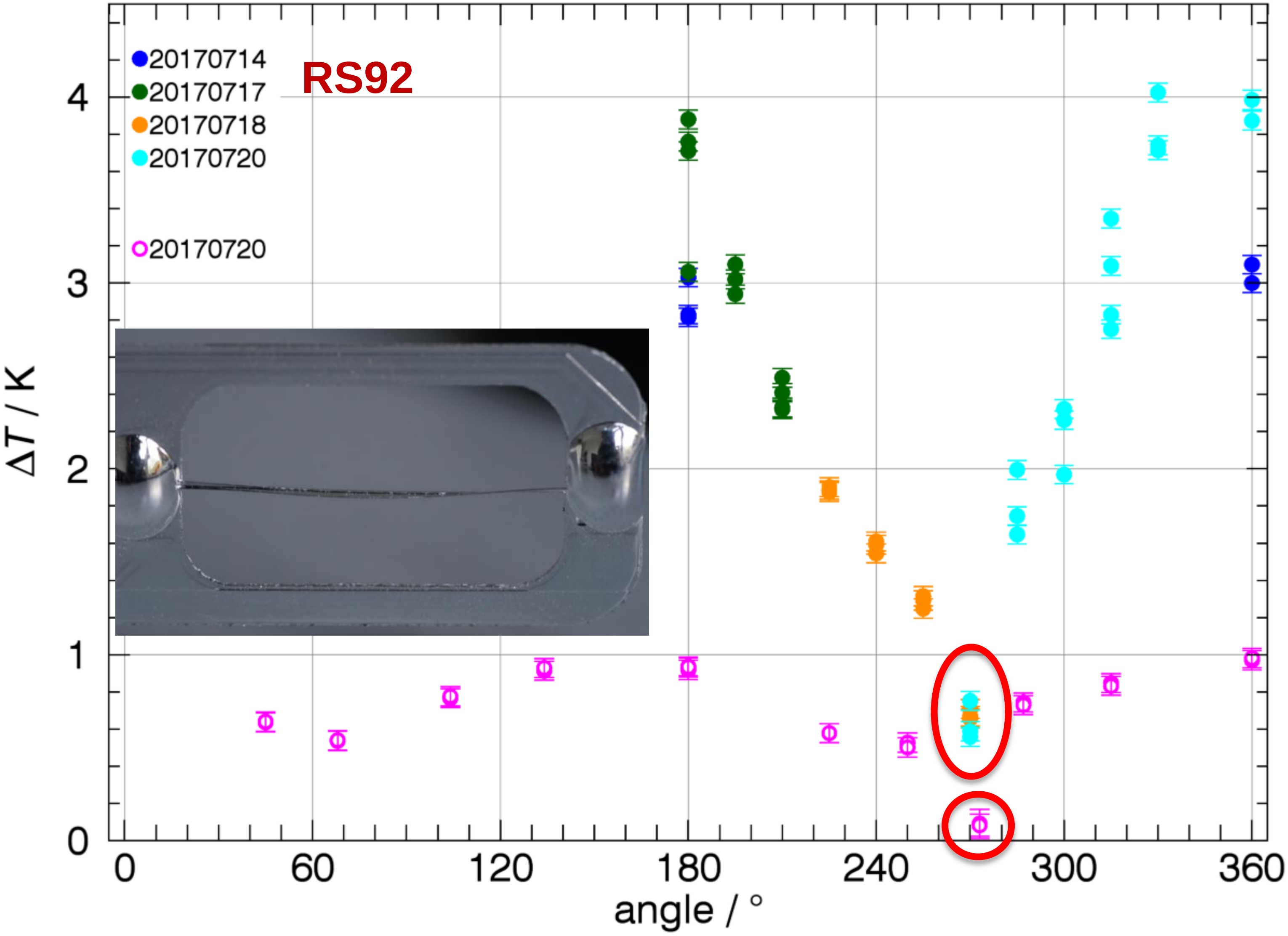
Latest experimental results: ΔT as function of angle of radiation incidence

a)



b)





Latest experimental results: ΔT as function of angle of radiation incidence

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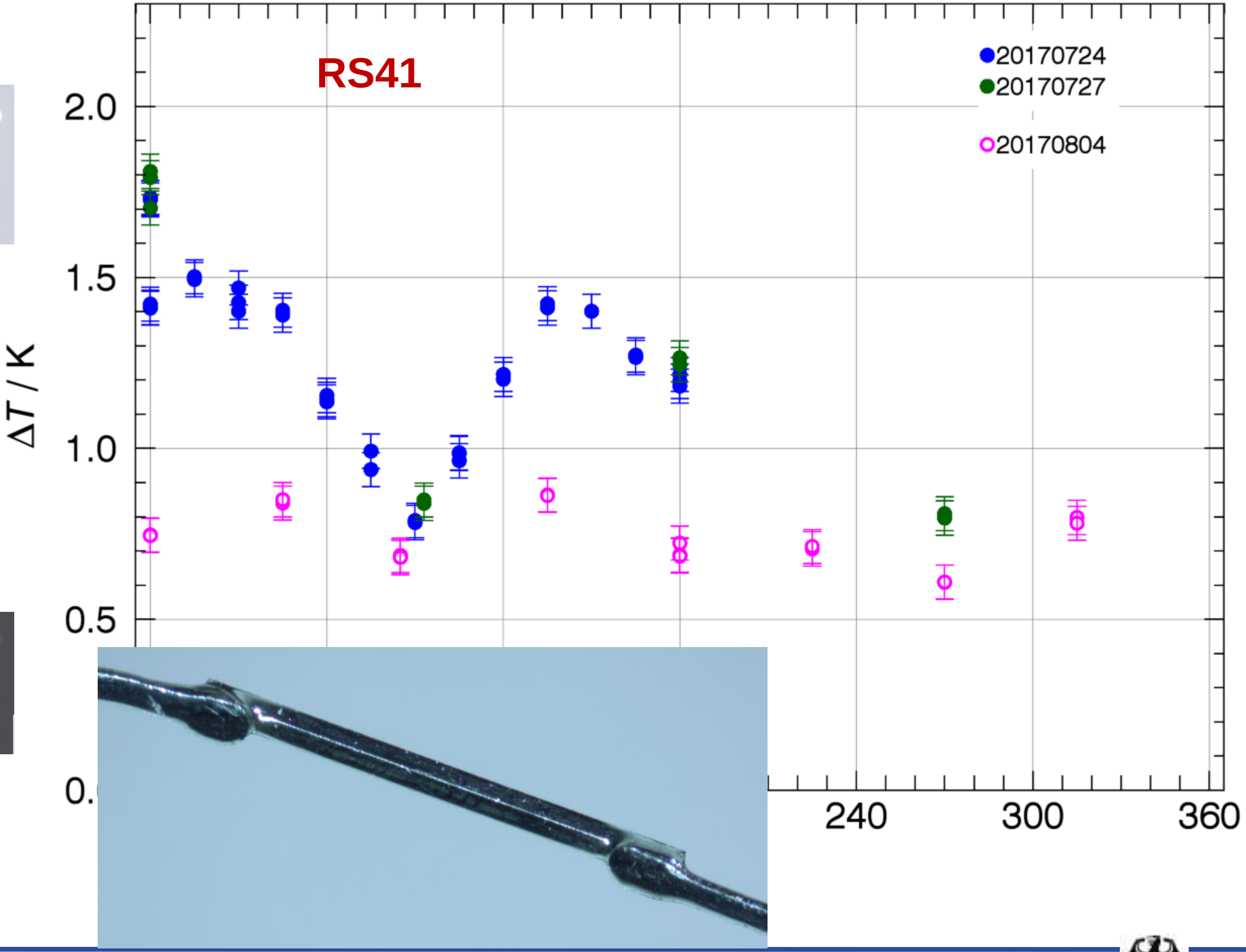
a)

b)



Latest experimental results: ΔT as function of angle of radiation incidence

Results:

- Minor part of variation in ΔT due to shape of sensor element
- Major part from radiative response and shape of boom; boom acts as *heat source* for sensor element (heat *conduction*)

→ Care! Flow resistance of boom (i.e. cooling rate) and effective irradiation simultaneously changed with varying sonde angle (not separable)!

- Experiment: Steady state (thermal equilibrium)
- Sounding: *changing* conditions (sonde rotation and pendulum motion)
  → Interference of different heat exchange processes in view of sensor (different time constants)

New experimental setup

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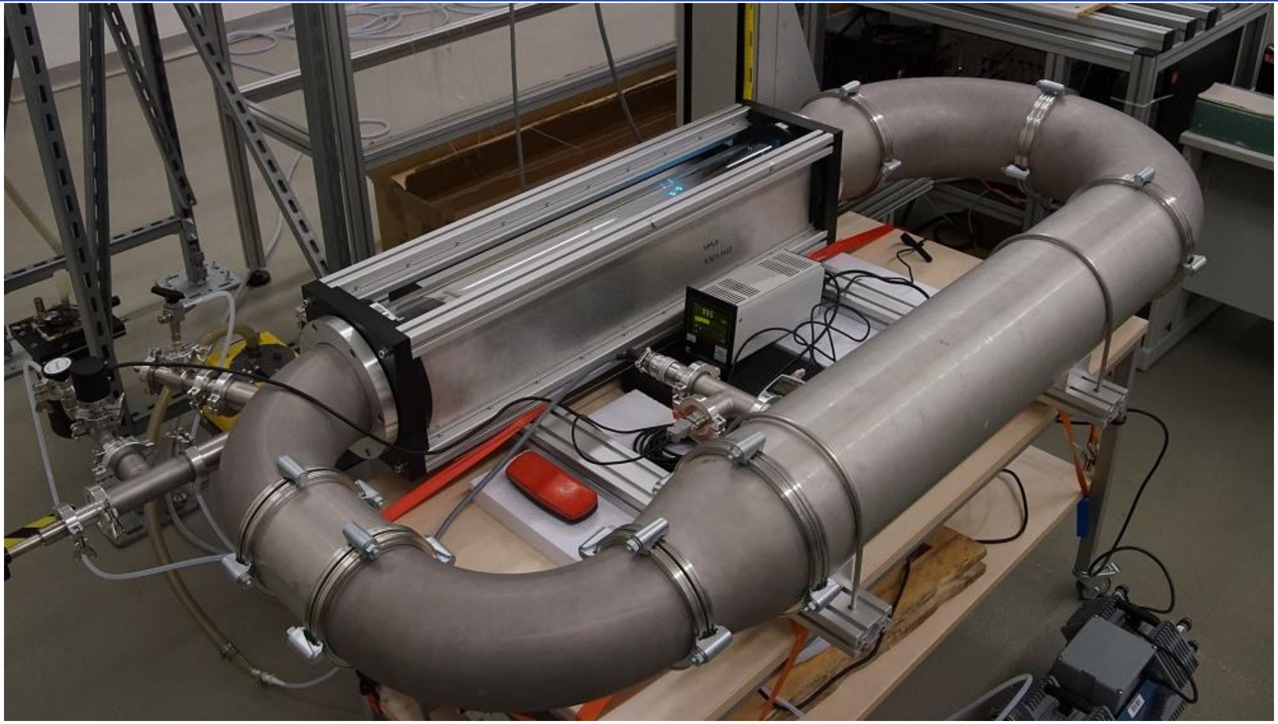


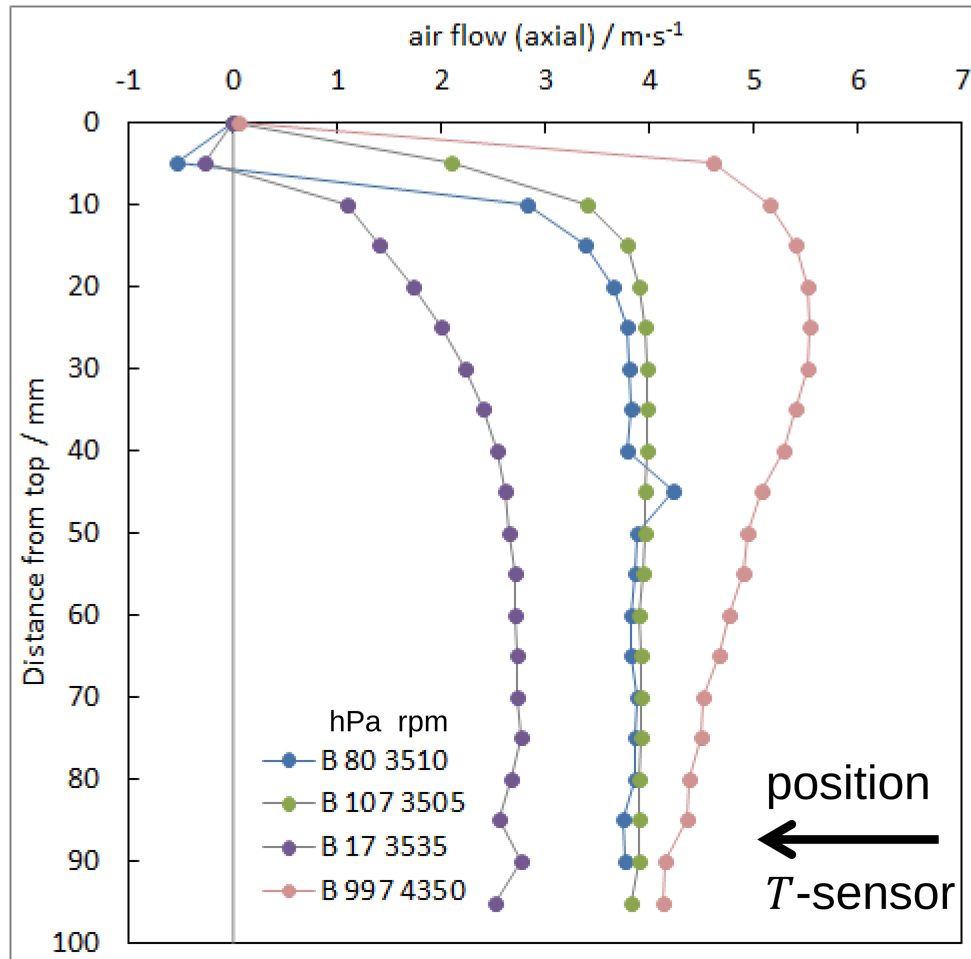
- Design as evacuable wind tunnel
- Larger dimensions: less susceptible to perturbations (T, p, I)
- Quartz glass tube (l=1 m, Ø180 mm) as test volume: installation boom + electronics + dummy corpus; can be radiated through (less absorption); tests with direct & diffuse light
- Air flow: parallel stream lines; realistic boom ventilation; control by fan revolution
- Variable angles of incident radiation: free rotation of sonde (azimuth), simulation of SEA

Overall: more realistic simulation of ascent conditions; independent testing for individual parameters

New experimental setup

Characterization of flow field
(Laser Doppler Anemometry)

First test of functionality and shape of flow profile



Conclusions

- GRUAN radiation correction should rely on independent experiment-based estimates of T-effect
- Work with "old" chamber: experience; limitations
  → Development of new experimental setup
- "New" experiments:
  - Can results from "old" chamber be reproduced?
  - Include sonde rotation in testing (dynamic measurement)
  - Compare effects for diffuse and direct irradiation
- Correction model:
  - How to average over sonde rotations (to derive *"effective" T-bias*)?
  - How to estimate orientation-derived *uncertainty of T-bias*?
    (= largest uncertainty contribution in RS92 GDP!)
- Time line:
  - Characterization of flow field (LDA) finished in May 2018
  - First measurements planned for Spring/Summer 2018

Thank you for your attention