RS41 Solar Radiation Correction

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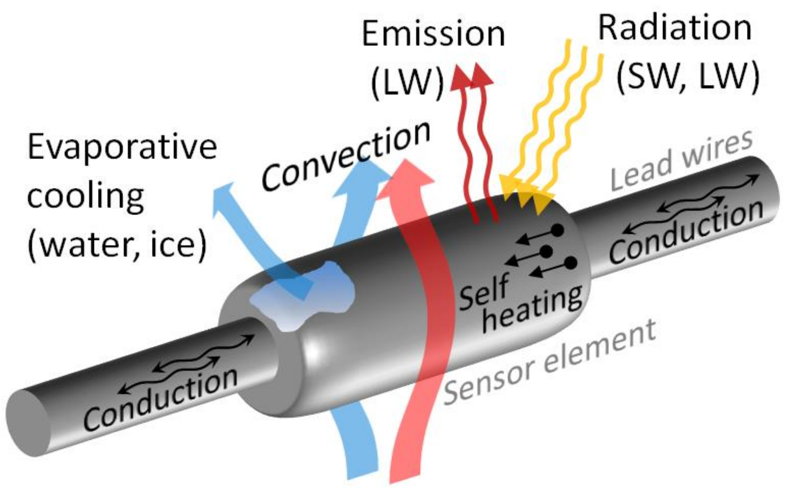
Outline

- Experimental Setup
  - Concept, Description, Results
- Solar radiation estimate using RTM
- Operational correction for RS41 GDP
  based on experiment and modelled radiation
- Short comparison with Vaisala
- Conclusions

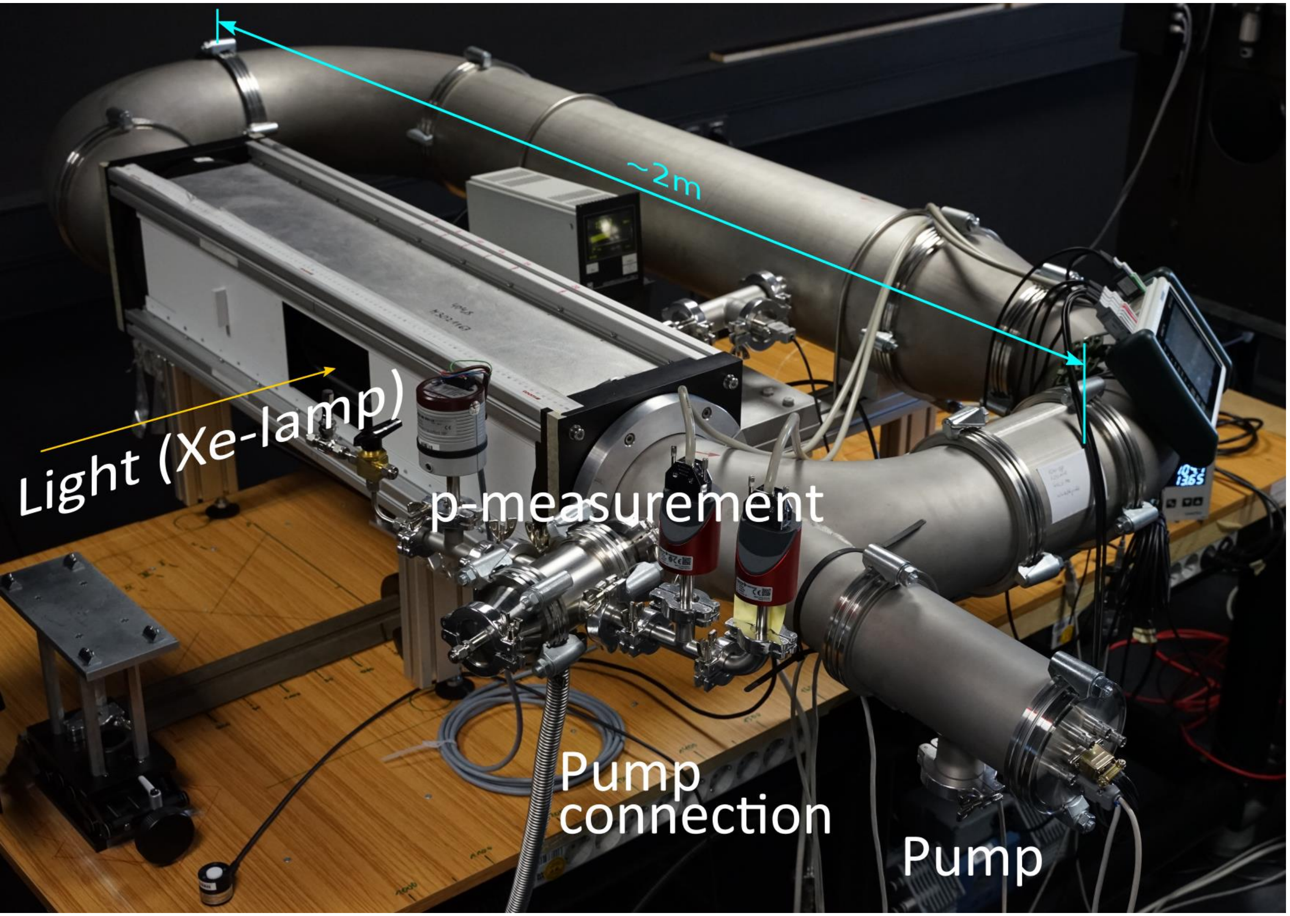
Measuring Radiation Error Concept



- ΔT is a composite effect from various heat flow components
- → Idea: Measure ΔT taking into account thermal interaction between sensor and boom
- Vary *pressure*, effective *ventilation speed*, and angle of irradiation (solar elevation)
- Irradiate entire sensor boom;   Average over sonde rotation

Experiment:
MOL wind channel setup

Deutscher Wetterdienst
Wetter und Klima aus einer Hand



- Closed wind tunnel, ~2 m x 1 m
  Circulating air flow, driven by fan
- Test sonde installed in quartz glass tube (l=1m, Ø18cm) as test chamber
- Full pressure control
- Xe-plasma lamp (2500 W) as light source
- Variable irradiation angles:
  - Free azimuth sonde rotation
  - Simulation of SEA

Experiment:
MOL wind channel setup

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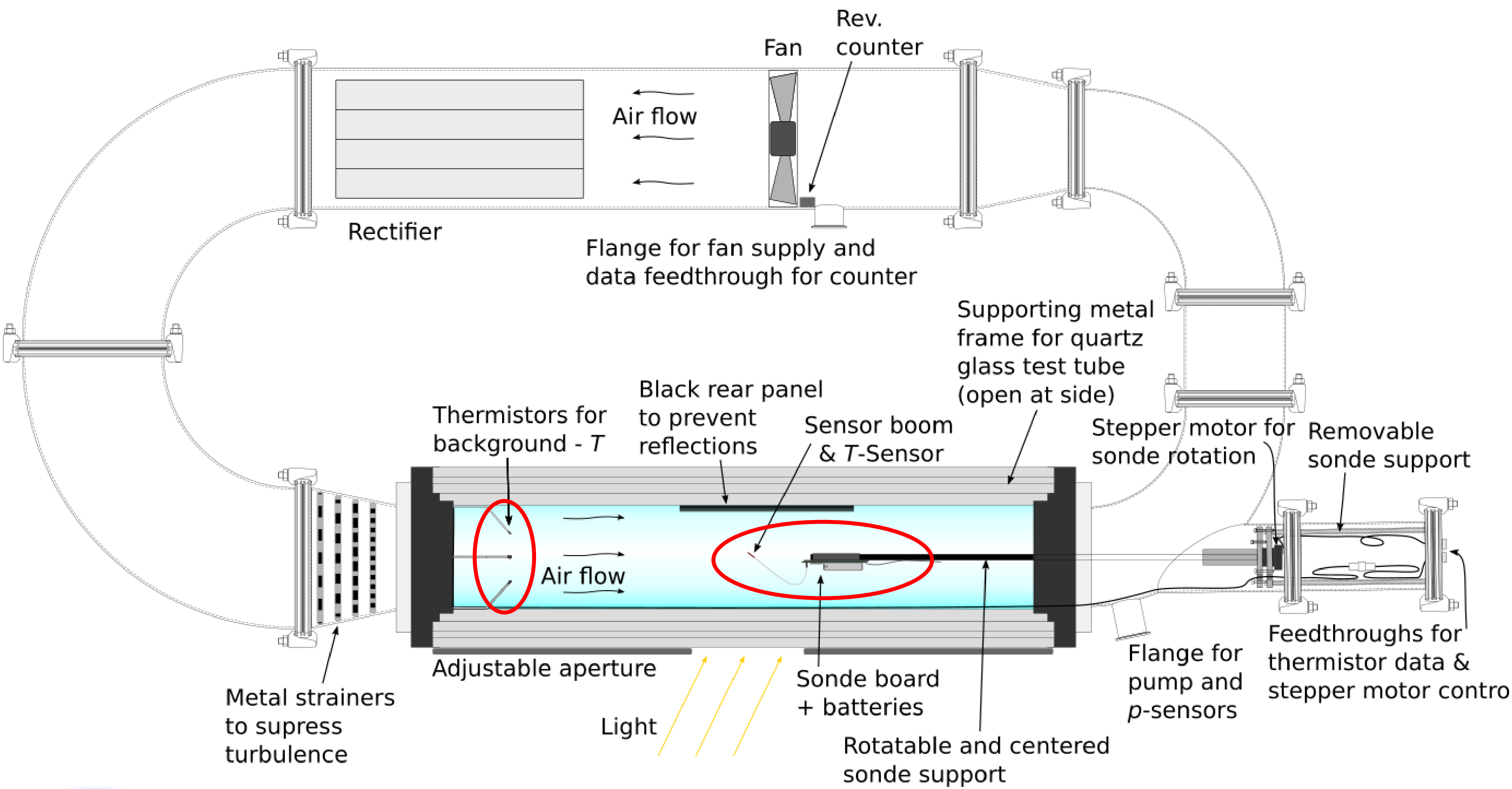

Experiment: Simulation of sun elevation

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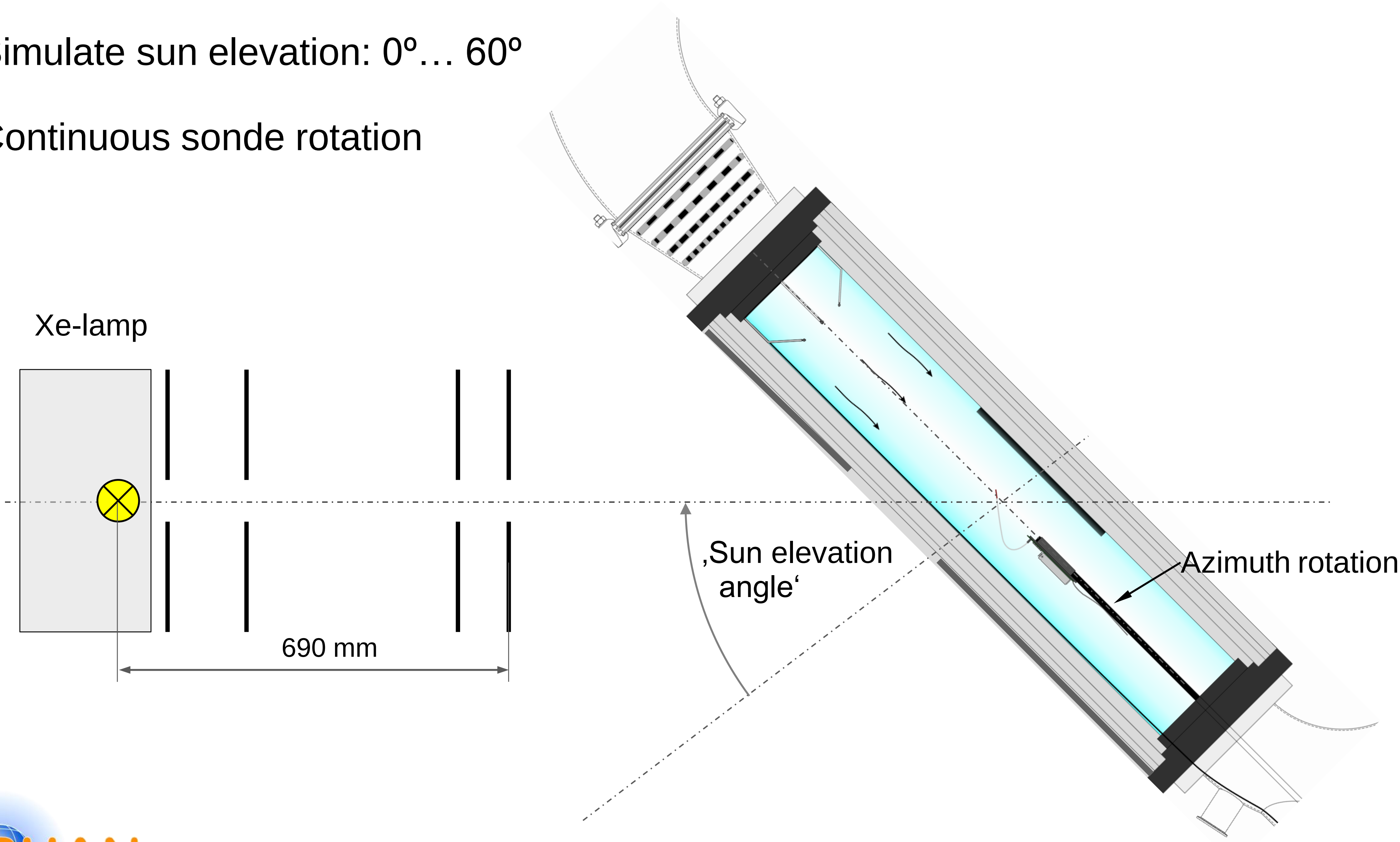
- Simulate sun elevation: 0º… 60º
- Continuous sonde rotation



Experiment:
Simulation of sun elevation

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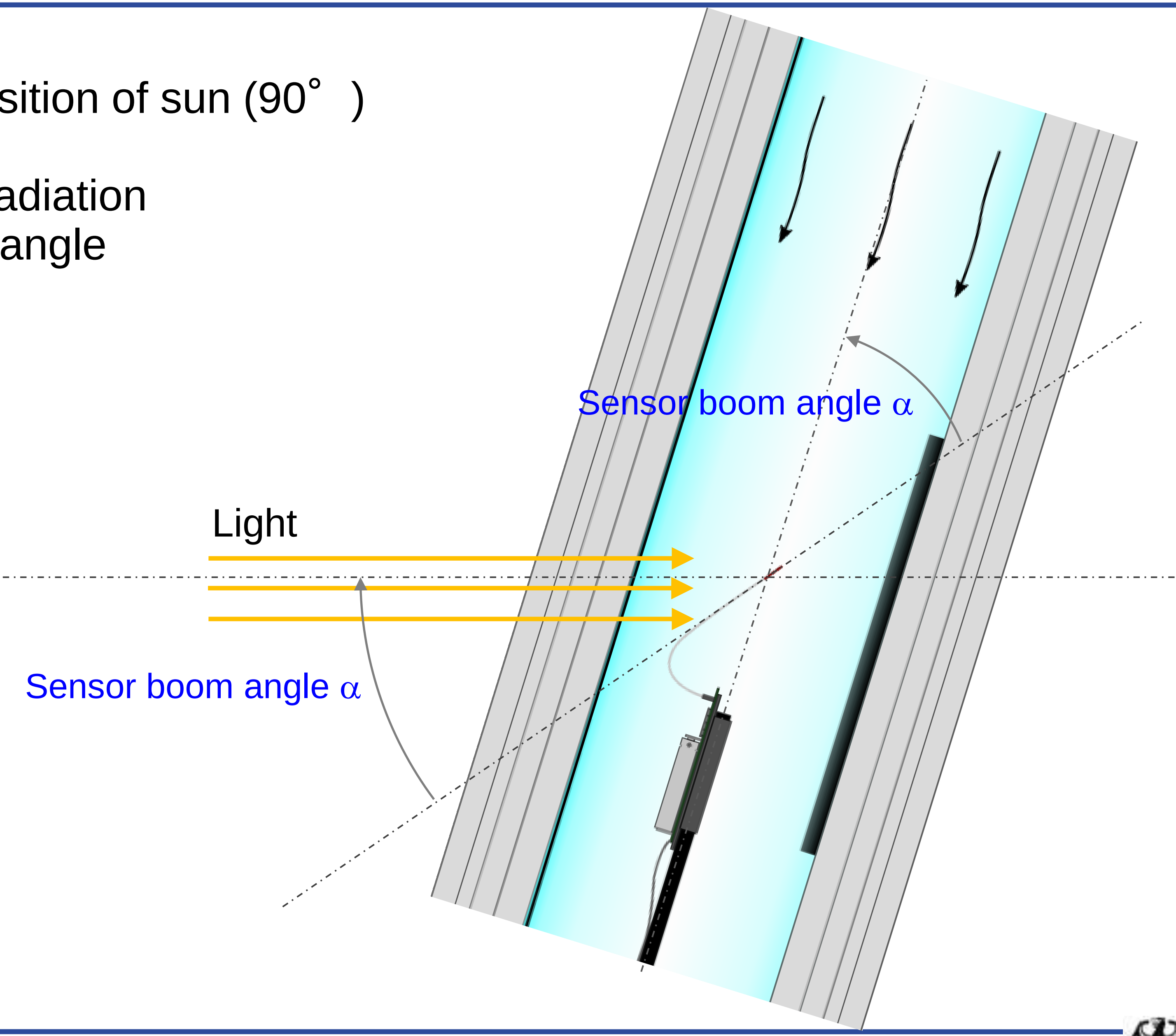
- Simulate zenith position of sun (90°)

  → angle of direct radiation
  = sensor boom angle

- No sonde rotation



Experiment
Simulation of diffuse radiation

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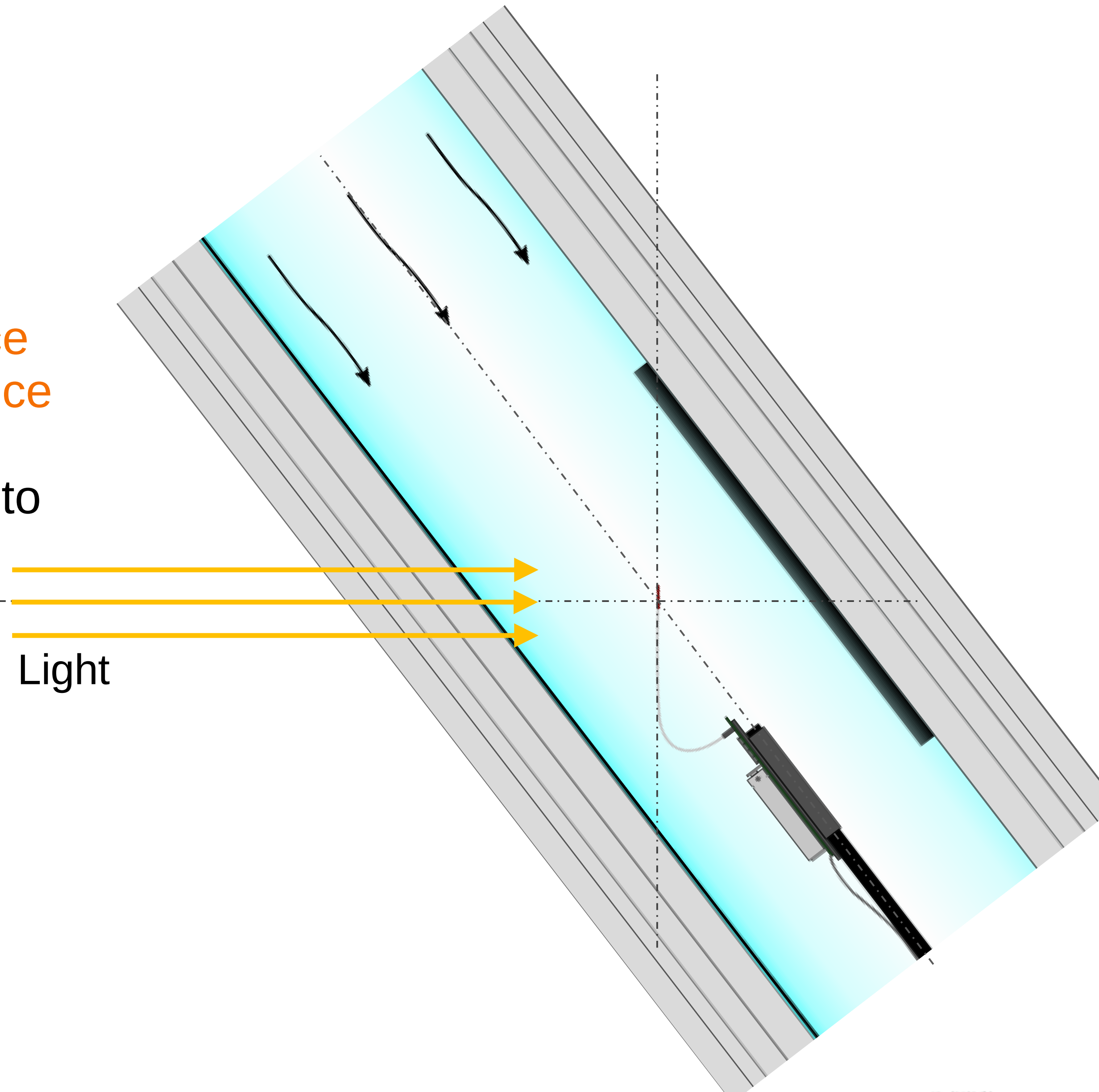
- Effect of diffuse radiation

  Assumption:
  direct and diffuse radiation induce the same ΔT at constant irradiance

  Radiation applied perpendicular to sensor boom

- No sonde rotation



Experiment: MOL wind channel setup

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- Adjustable parameter ranges and typical uncertainties

Quantity	Value	Uncertainty
Pressure	Surf. to 3 hPa	(0.4 to 0.6) hPa
Ventilation	(0 to 6) $\mathrm{m\,s^{-1}}$	0.4 $\mathrm{m\,s^{-1}}$
Irradiance	(0 to 2000) $\mathrm{W\,m^{-2}}$	3 %
'Sun elevation'	(0 to 90) $^{\circ(*)}$	2 °
Sonde rotation	fixed at 16 s	–

(*) (0 to 60)° continuously adjustable; 90 ° fixed

- RS41 measurement program:
  - 8 different configurations for irradiation angle
  - For each configuration and fixed radiances (~1100 $\mathrm{Wm^{-2}}$; diffuse: ~530 $\mathrm{Wm^{-2}}$):

    - ΔT measured for ~11 p-settings, and ~6 v-settings for each p
  - Overall 468 data points for ΔT

Experiment: Measurements

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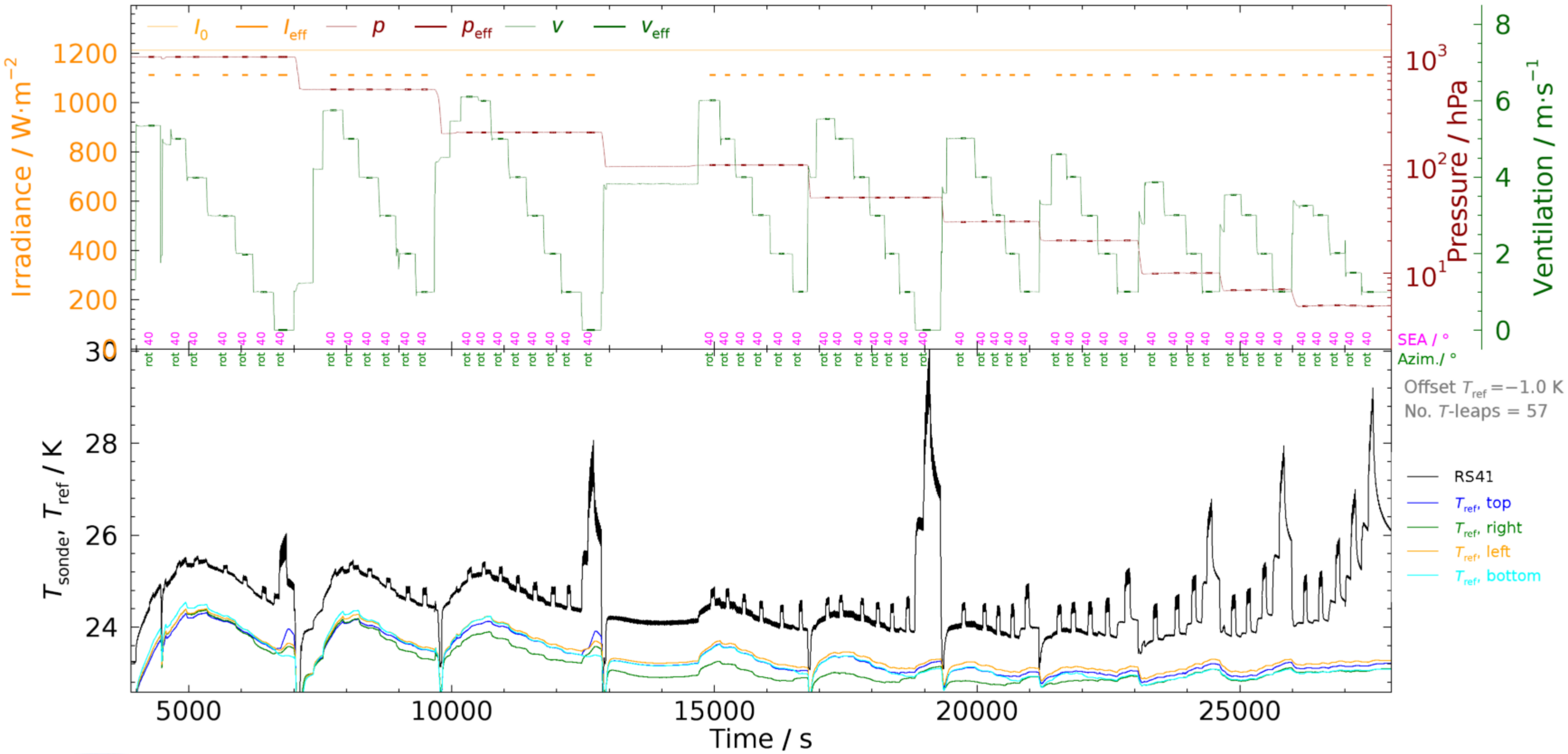
Example for sun elevation 40° (one measurement day)



Experiment: Determination of ΔT

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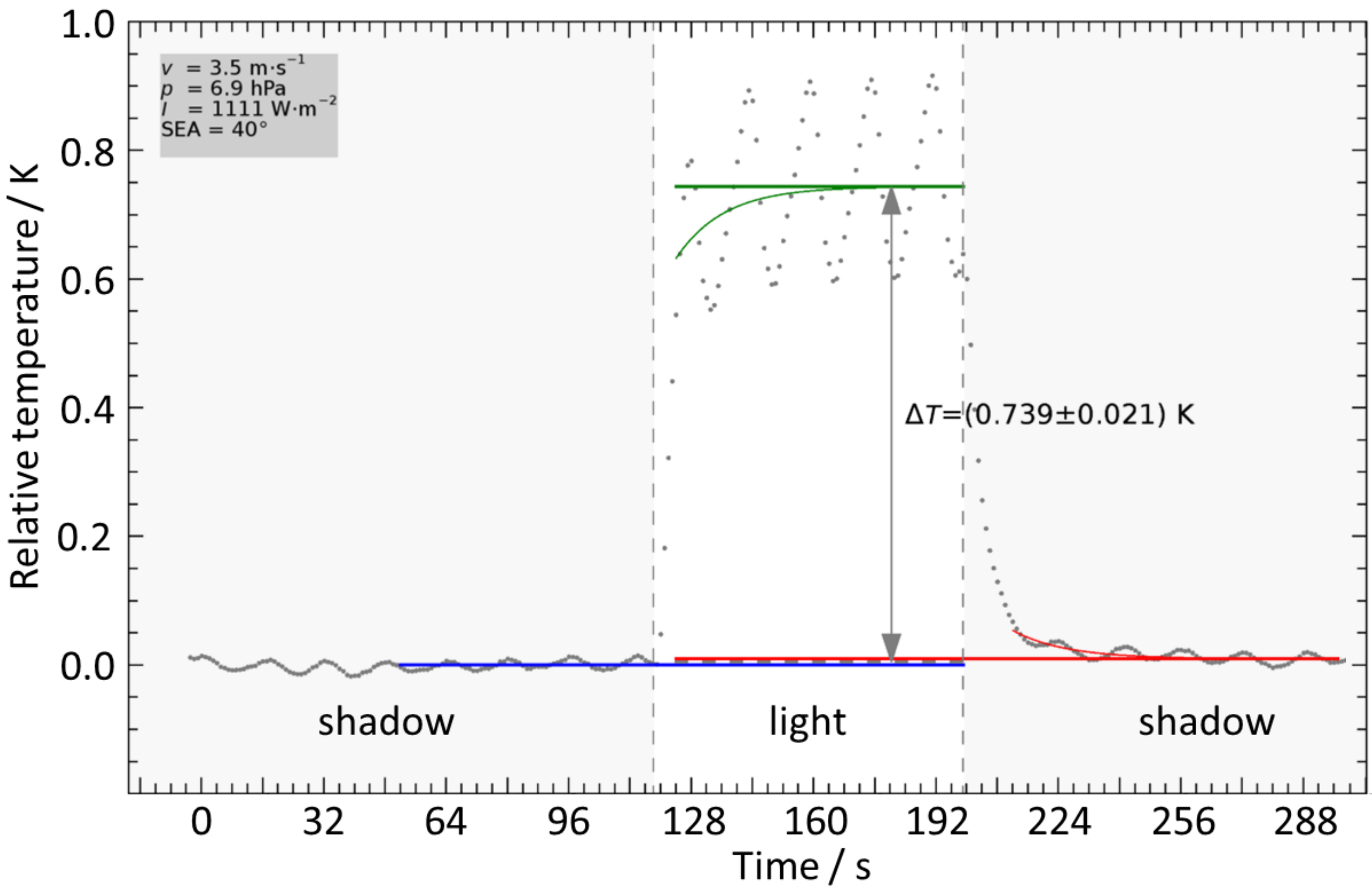
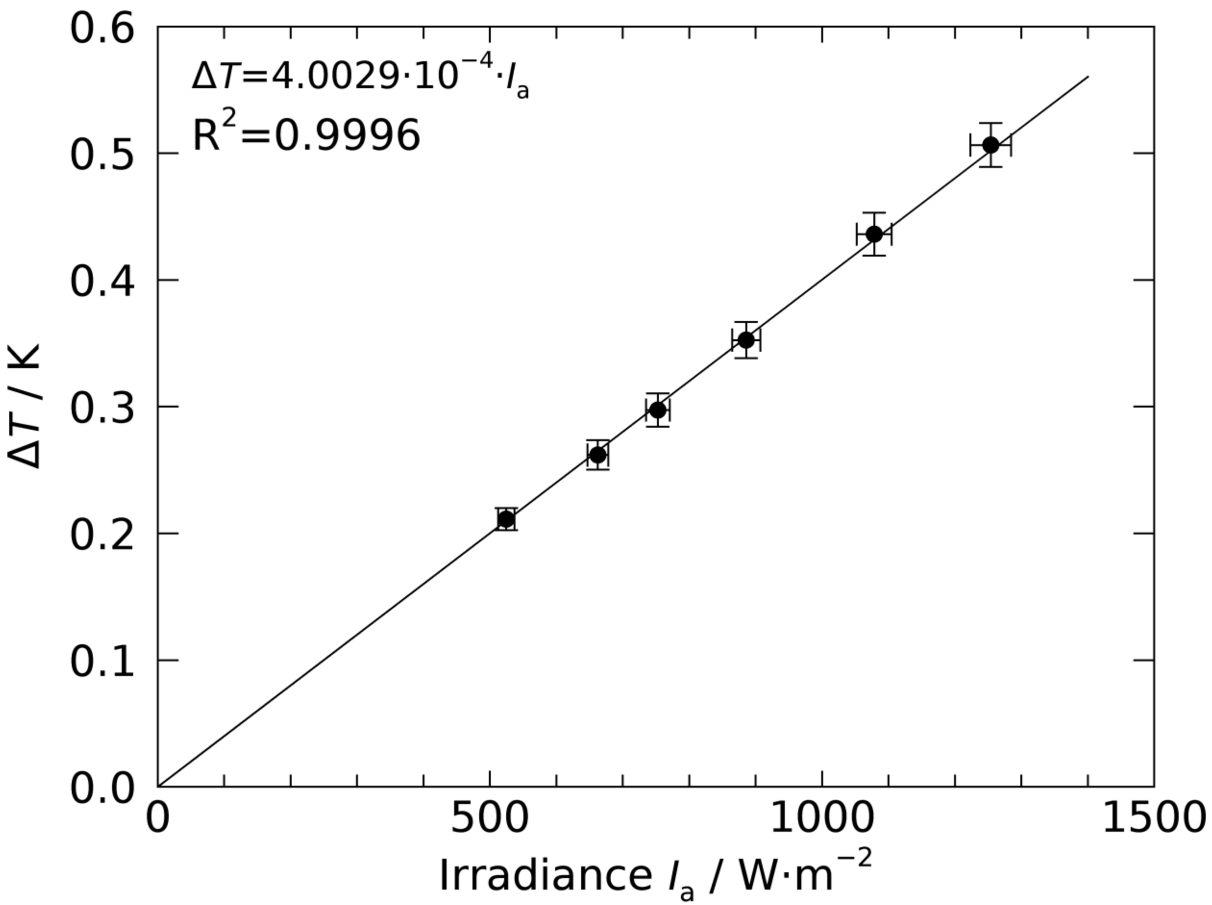
For each light exposure:

- Subtract shadow-T
- Fit expression
  $$y = c_0 + c_1 e^{-c_2 t}$$
  to asc. and desc. flanks, c_0 represents mean T for 'light' and 'shadow'
- → $\Delta T = T_{\text{light}} - T_{\text{shadow}}$
- Method averages ΔT over sonde rotation



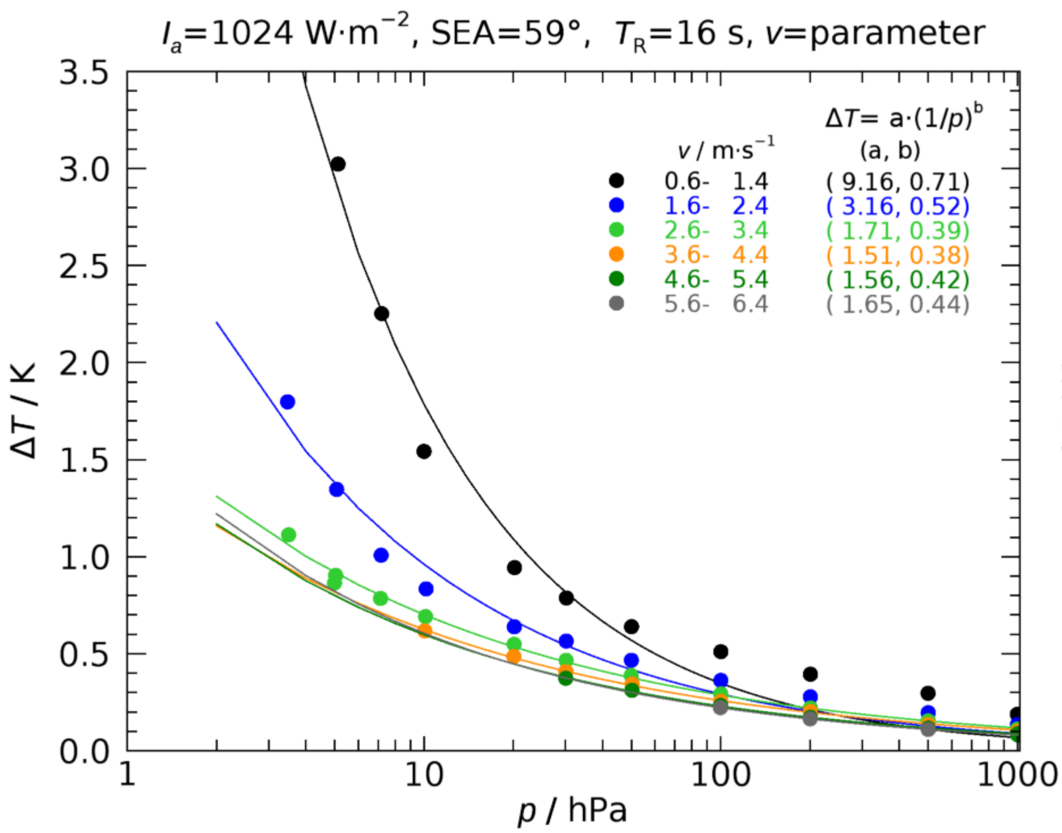
Experiment:
Relation of ΔT with irradiance



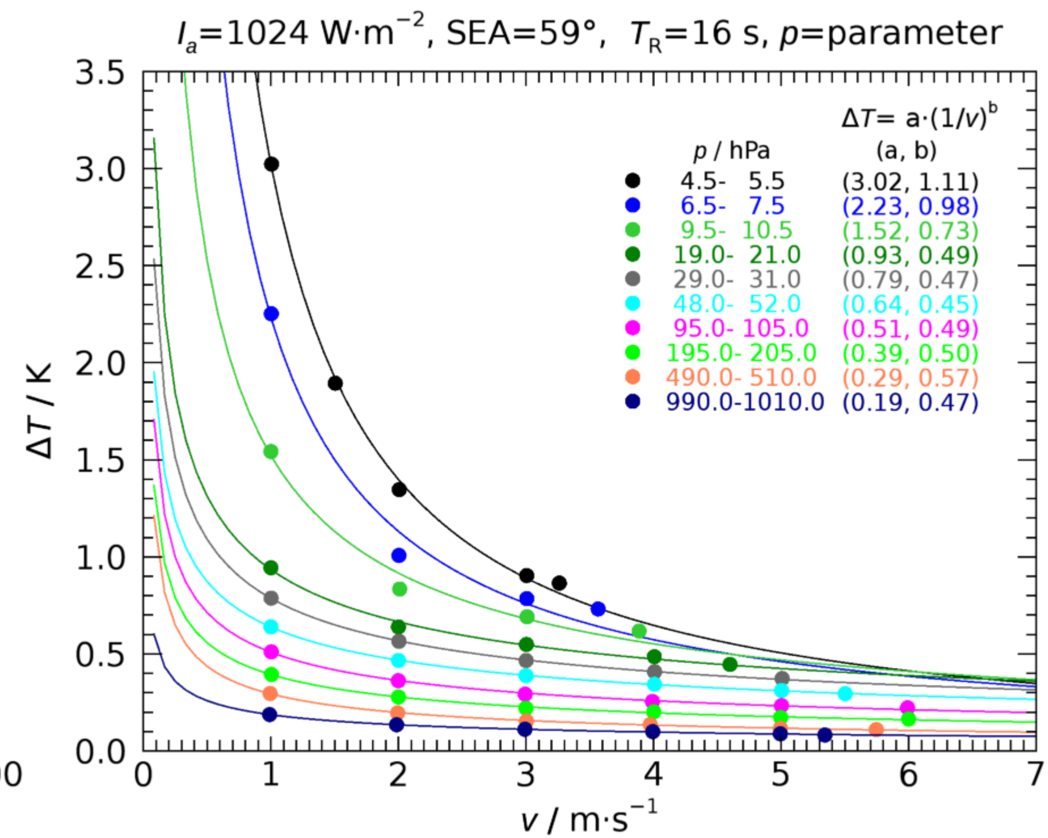
- ΔT linear with radiance I_a
- → ΔT-measurements done for only one fixed value of I_a at each of the 8 settings of irradiation angle

Experiment: Results

- ΔT – pressure



- ΔT – air speed



- 'Smooth' and well reproducible dependence of ΔT on v and p
- Low ΔT at high ventilation ($\Delta T \sim a \cdot (1/x)^b$)

Experiment: Results

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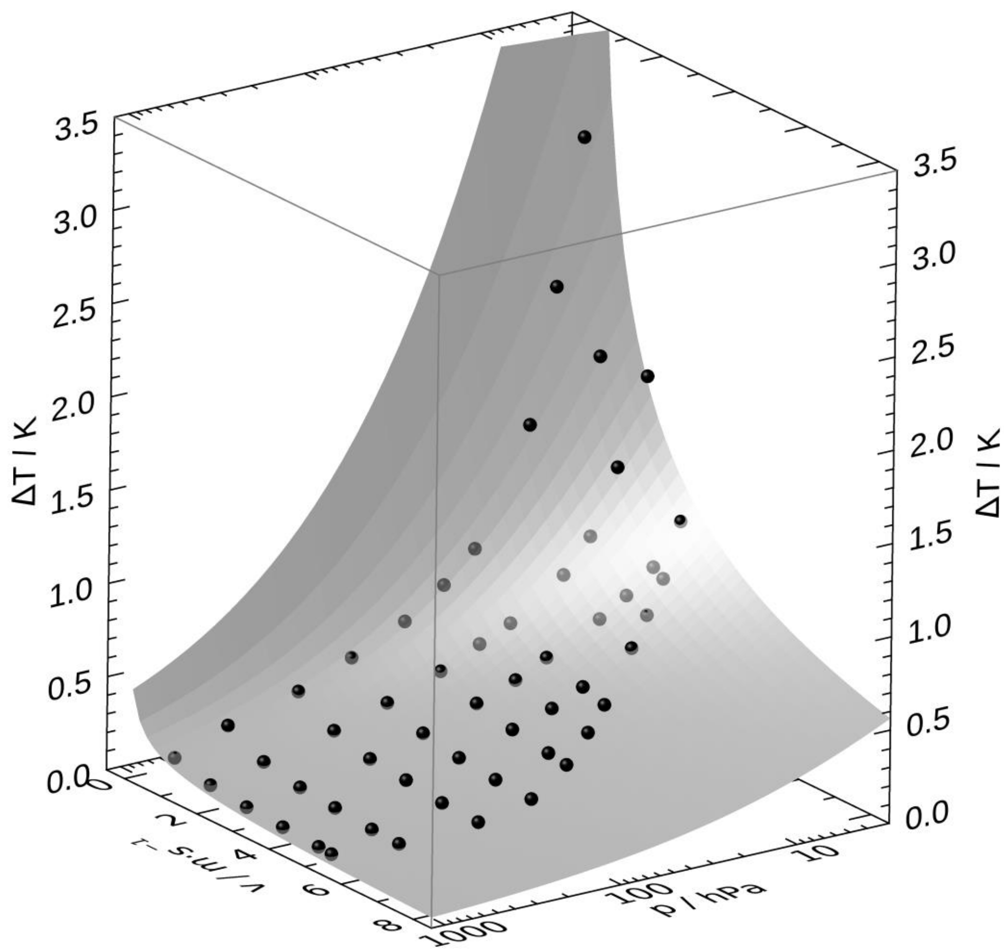
- Polynomials fitted to each of the 8 $\Delta T(p, v)$ data sets:

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

(6 coefficients)



Same data as in previous slide

Experiment: Uncertainty

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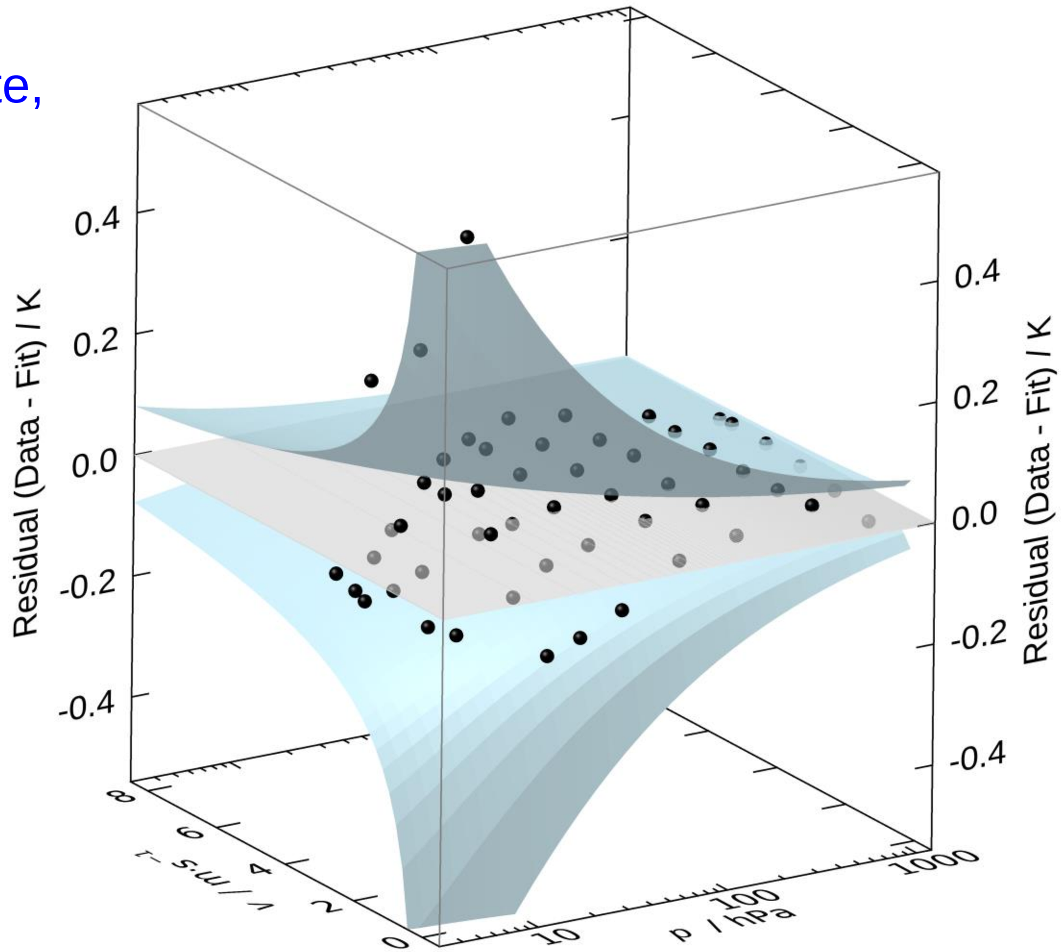
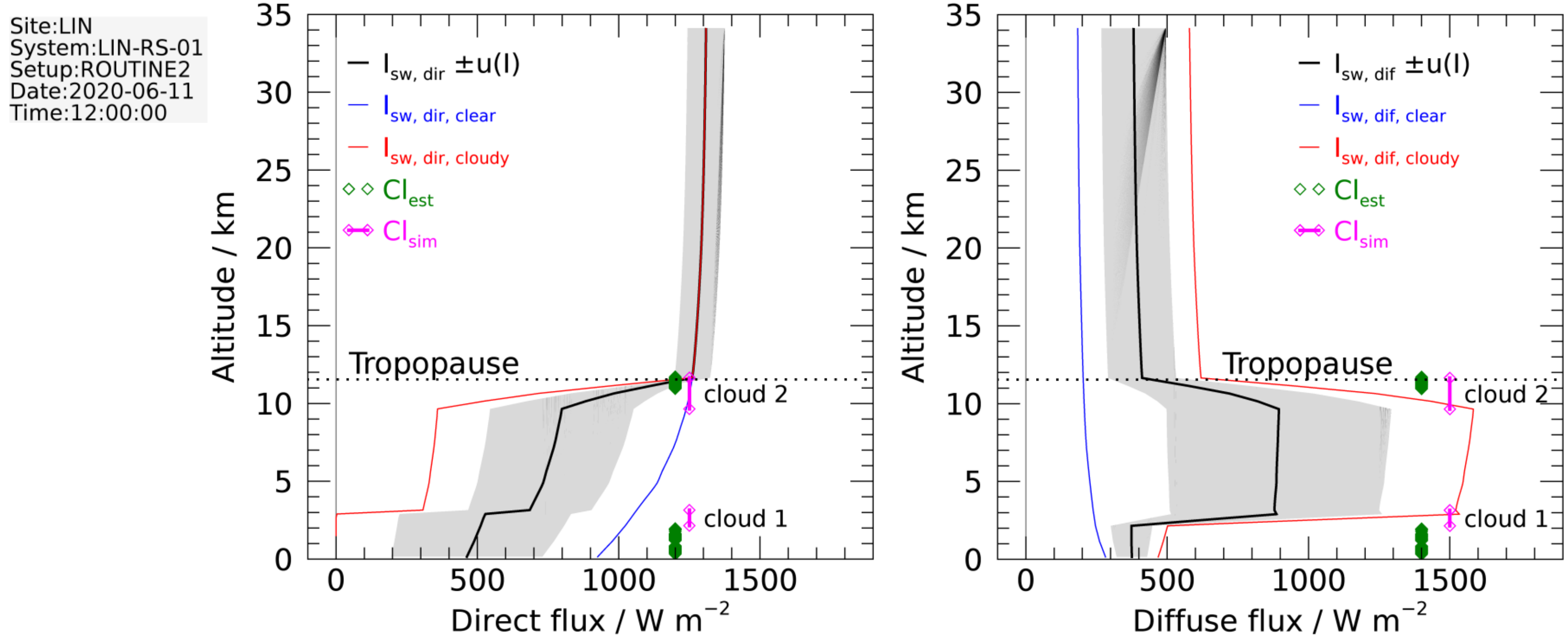
- ‘Minimum-maximum’ uncertainty estimate, Justified by
  - monotony of ΔT in terms of p and v
  - systematic (correlated) nature of $u(p)$ and $u(v)$
- → Equivalent polynomial fits to
  $u_+(\Delta T) = \Delta T[p + u(p), v + u(v)]$
  $u_-(\Delta T) = \Delta T[p - u(p), v - u(v)]$
  (bluish surfaces)
- Results stored in LUT_{exp}



Radiation modelling

- Radiation simulated using RTM, individually for each sounding
- Model output:
  - Profiles for direct radiation (I_{dir})
  - Profiles for diffuse radiation $(I_{\mathrm{dif}_{\uparrow}}, I_{\mathrm{dif}_{\downarrow}})$
- Simulations include:
  - p, T, U from actual profile
  - Regional surface albedo information (from global CM-SAF data)
  - Calculations for 2 scenarios:
    - Cloud scenario with 2 cloud layers
    - Clear-sky scenario
- Results saved in $\mathrm{LUT}_{\mathrm{RTM}}$ as mean over scenarios

Radiation modelling: Results



- From LUT_{RTM} by interpolation
  - Profile for direct radiation
  - Profile for diffuse radiation (sum of ‘up’ and ‘down’ components)
- Effective fluxes as mean over scenarios
  (= Input for radiation correction)
- Uncertainty: range over the scenarios and model sensitivity estimates

Radiation correction
Example

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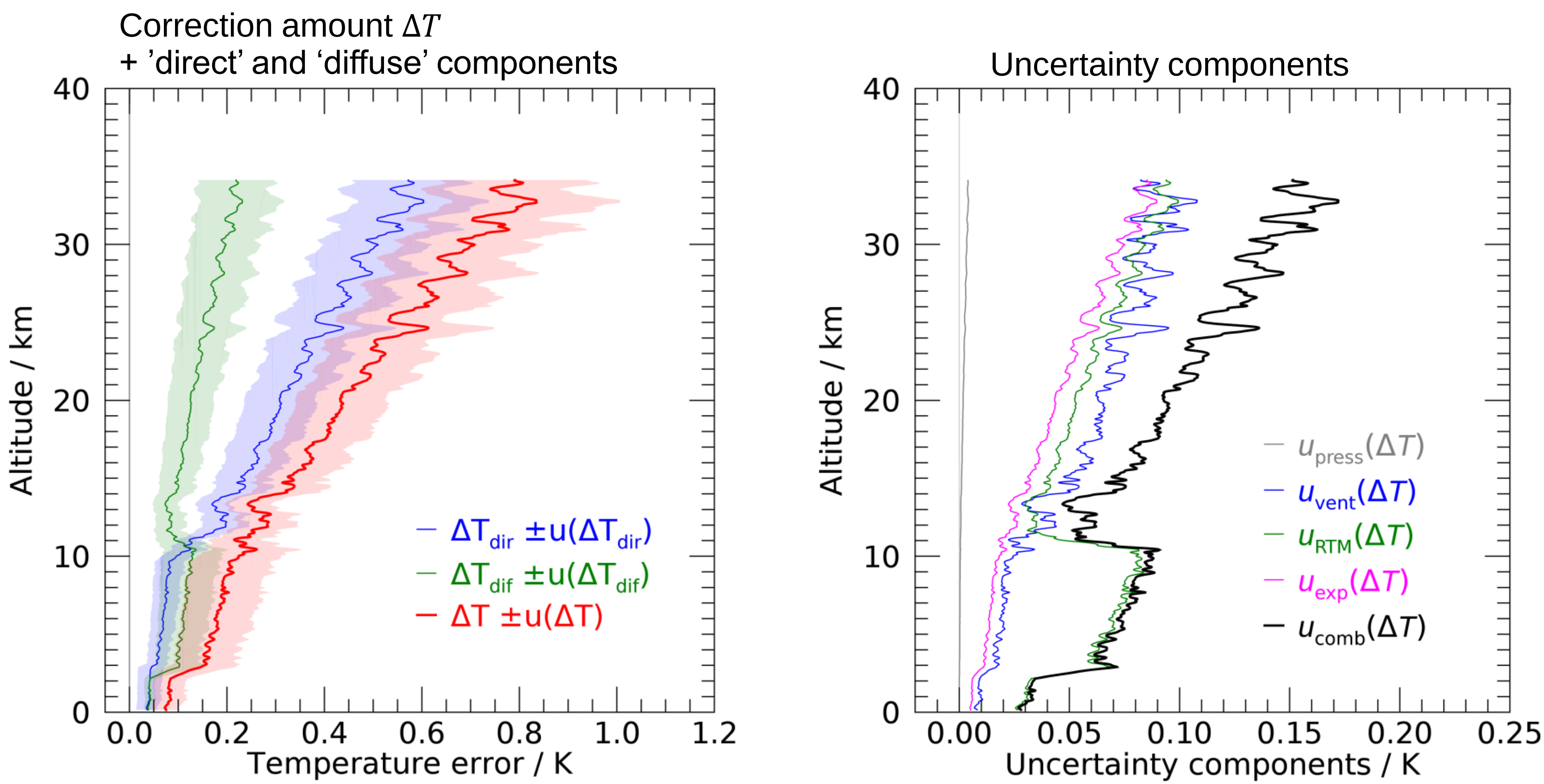
- $\Delta T_{\mathrm{exp}}(p, v)$ interpolated from $\mathrm{LUT}_{\mathrm{exp}}$ (direct + diffuse)
- Linear scaling of $\Delta T_{\mathrm{exp}}(p, v)$ according to RTM (direct + diffuse)
- Overall T-correction: $\Delta T_{\mathrm{rad}} = \Delta T_{\mathrm{dir}} + \Delta T_{\mathrm{dif}}$



LIN, 2020-06-11, 12:00 UTC, uncertainties for k=1

Radiation correction
Comparison with Vaisala

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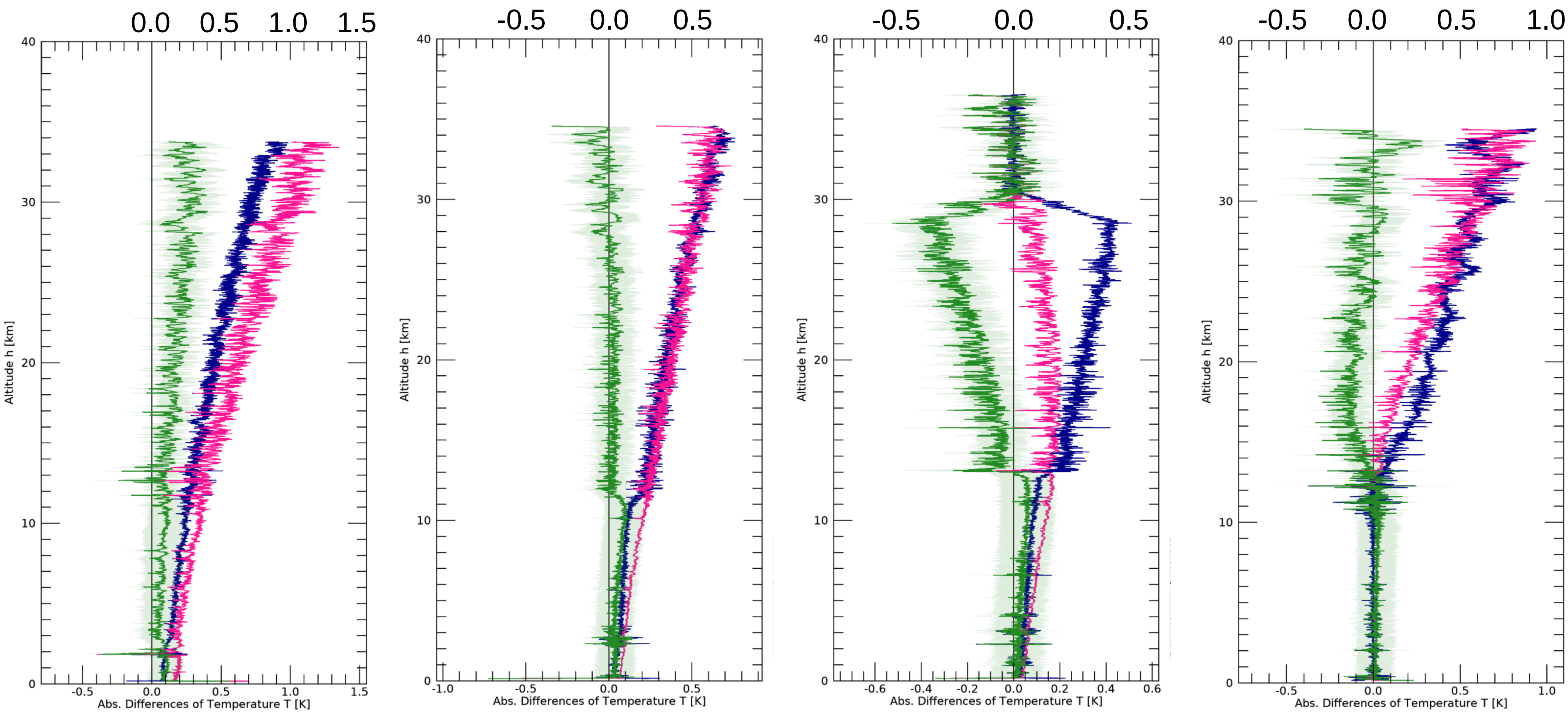
T_{raw}-T_{GRUAN} T_{raw}-$T_{Vaisala}$ T_{GRUAN}-$T_{Vaisala}$

LIN 2020-08-10, 12:00 (day light) | LIN 2020-08-07, 18:00 (late afternoon) | LIN 2020-09-04, 18:00 (sun set) | LIN 2020-10-26, 06:00 (sun rise)



Conclusions/Outlook

- Solar temperature correction implemented in GRUAN RS41 processing, based on
  - Experimental data for ΔT measured with the MOL radiation setup
  - Individual modelling of direct and diffuse radiation

  → First approach for an experimental-based ΔT-estimate with close-to-reality simulation of ascent conditions
- Modem M10, Graw DFM-09 and DFM-17 measured; RS92 for GDP v3 planned
- Outlook:
  - Comprehensive comparison analysis
  - Role of absolute temperature (KRISS experiments)
  - Information about sonde movements (rotation)
  - Contents of this talk included in the RS41 certification paper (AMT, ~70%, submission Q1 2021)