RS92 data stream specifications, performance and characteristics of early data flow

Ruud Dirksen
GRUAN Lead Centre, DWD

6th GRUAN Implementation and Coordination Meeting (ICM-6)
Greenbelt, MD, USA
10 March 2014

RS92 reference product

GRUAN processing:

- Documented corrections
- Uncertainty estimates

Uses calibrated raw data (FRAWPTU)

Major error sources for RS92

- Temperature
  - Radiation
- Humidity:
  - Radiation
  - Calibration
  - Sensor time-lag

Radiation error

Laboratory experiments to establish relation ΔT <-> I_a,p,v

GRUAN correction model: $\Delta T = a(I_a/p.v)^b$

I_a estimated from radiative transfer simulations

Uncertainties:

- albedo ($I_{a,cloudy} - I_{a,cloudfree}$)
- sensor orientation (I_a)
- parameters a & b
- ventilation (pendulum motion)

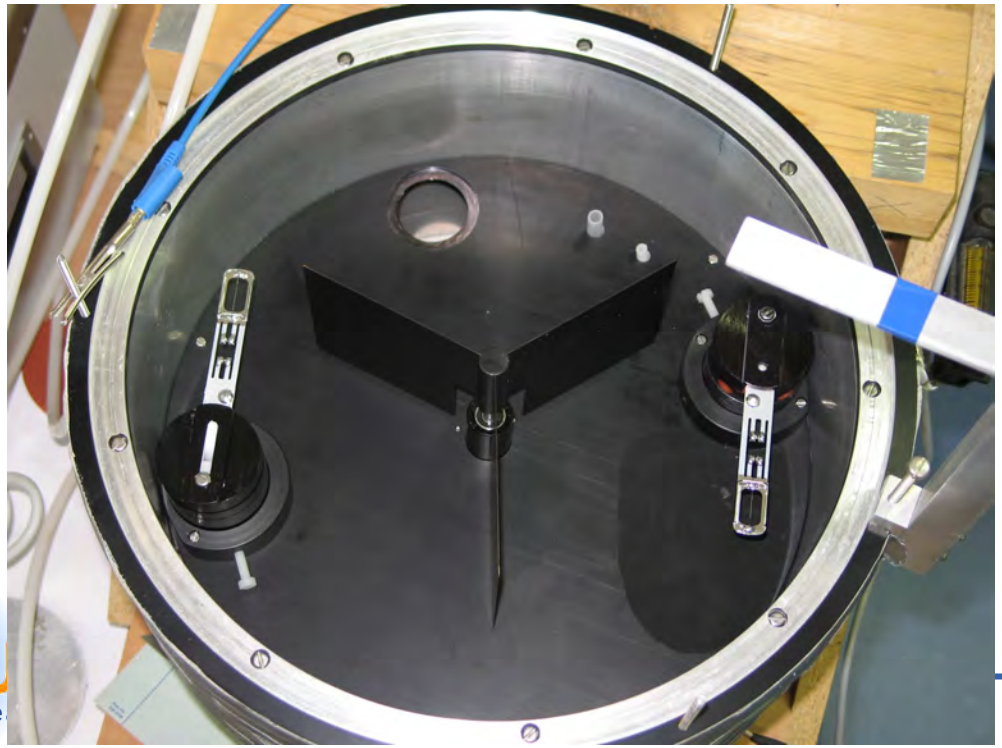
Laboratory experiments

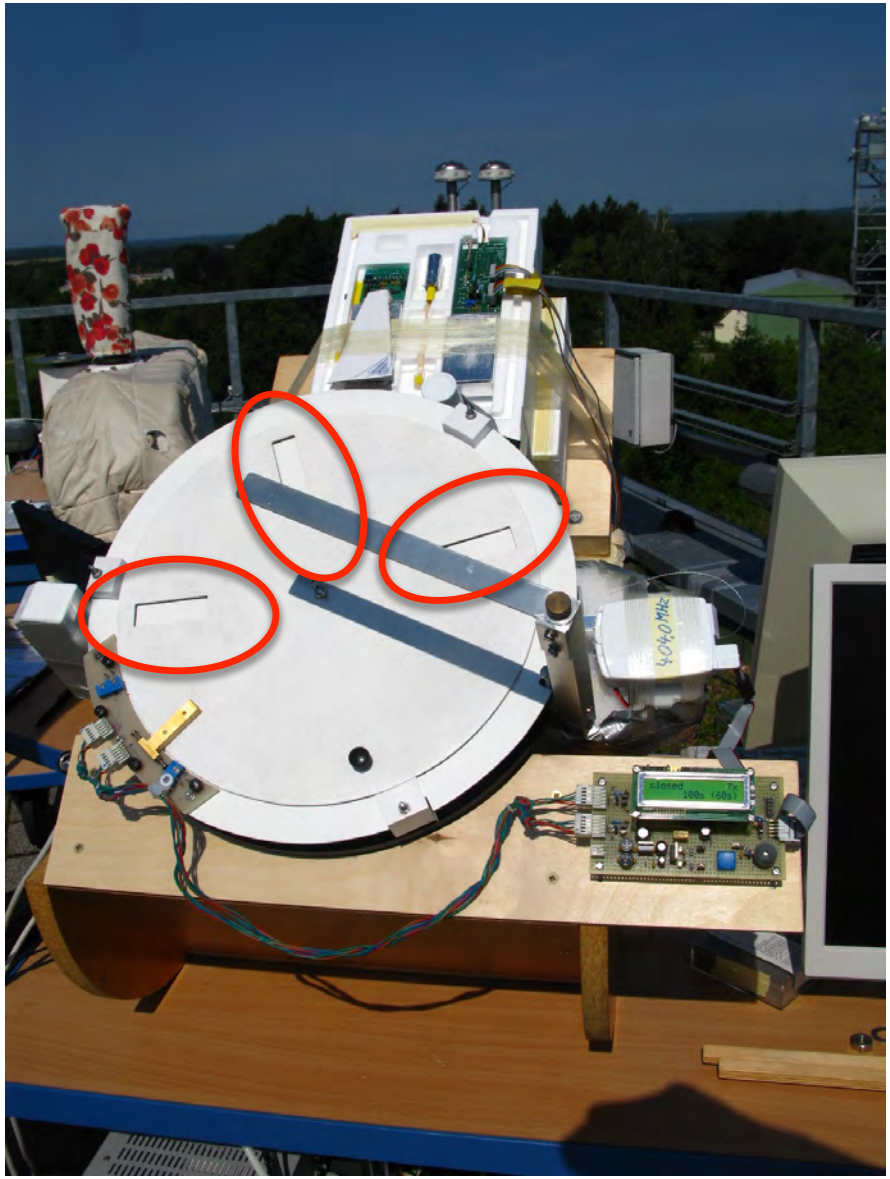
Deutscher Wetterdienst
Wetter und Klima aus einer Hand

Shadow RS92 records background temperature & ambient pressure

Simultaneous testing of 3 radiosondes

p=[3 hPa , ambient]

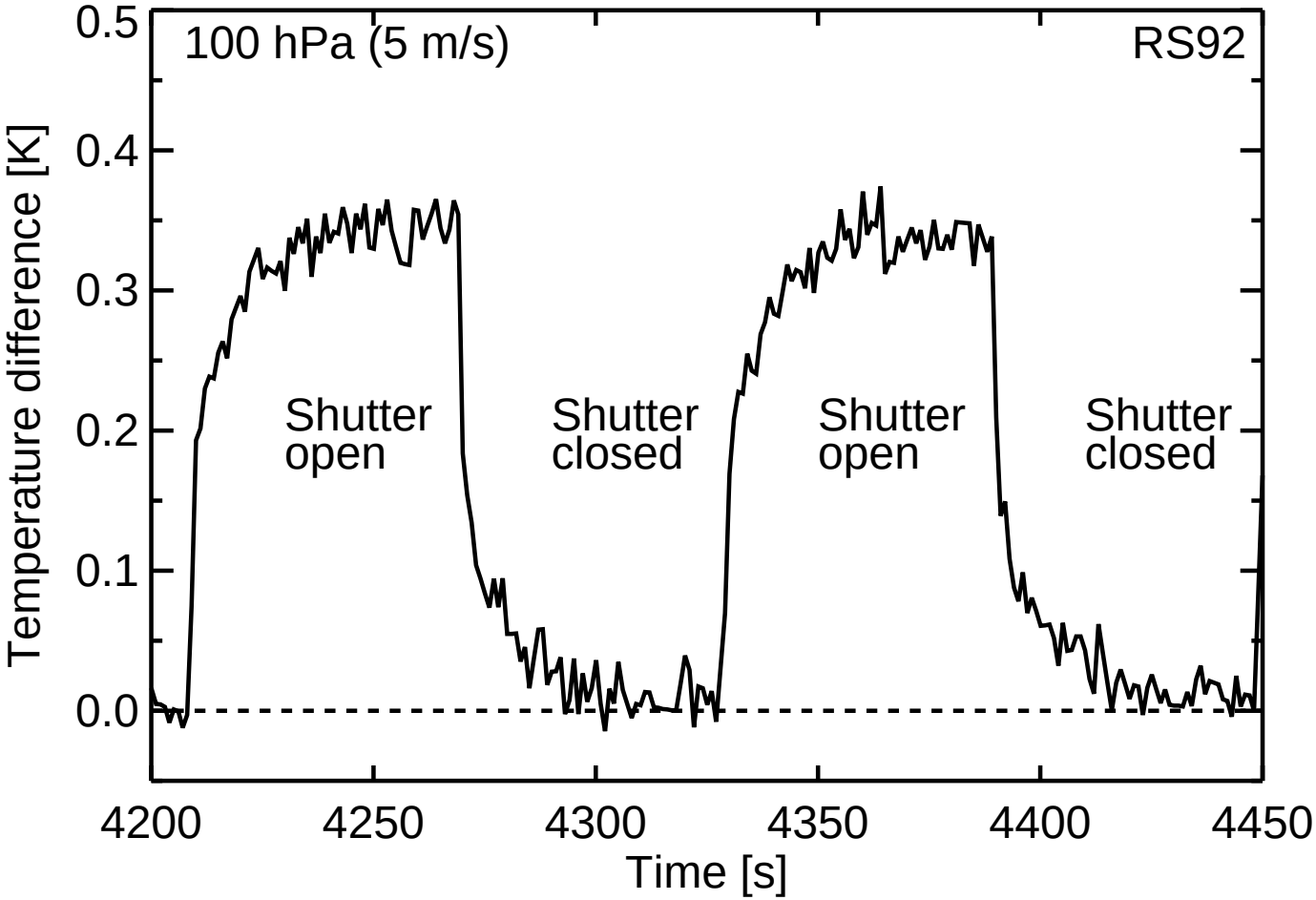




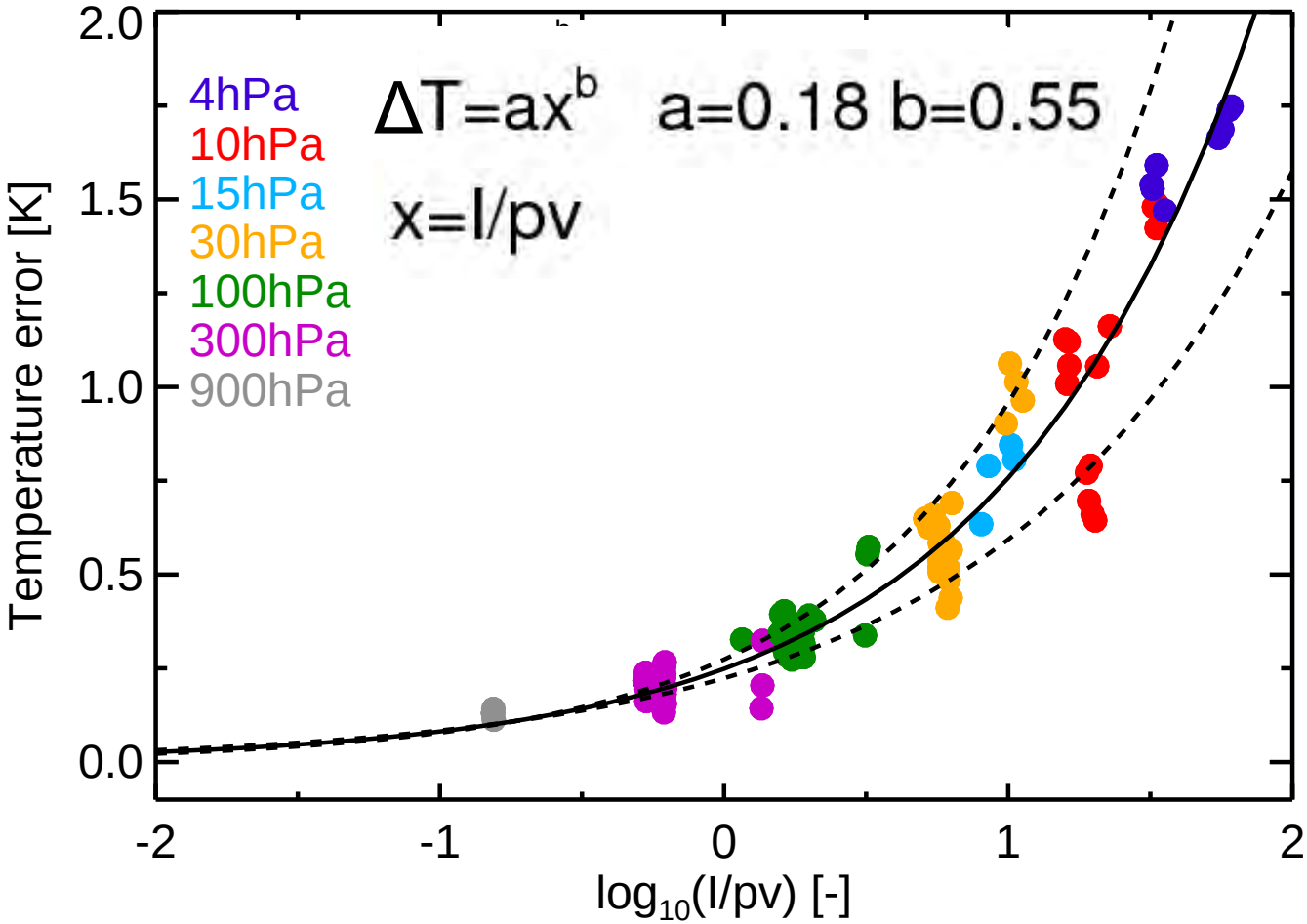
Radiation experiment

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

Difference illuminated – background radiosonde



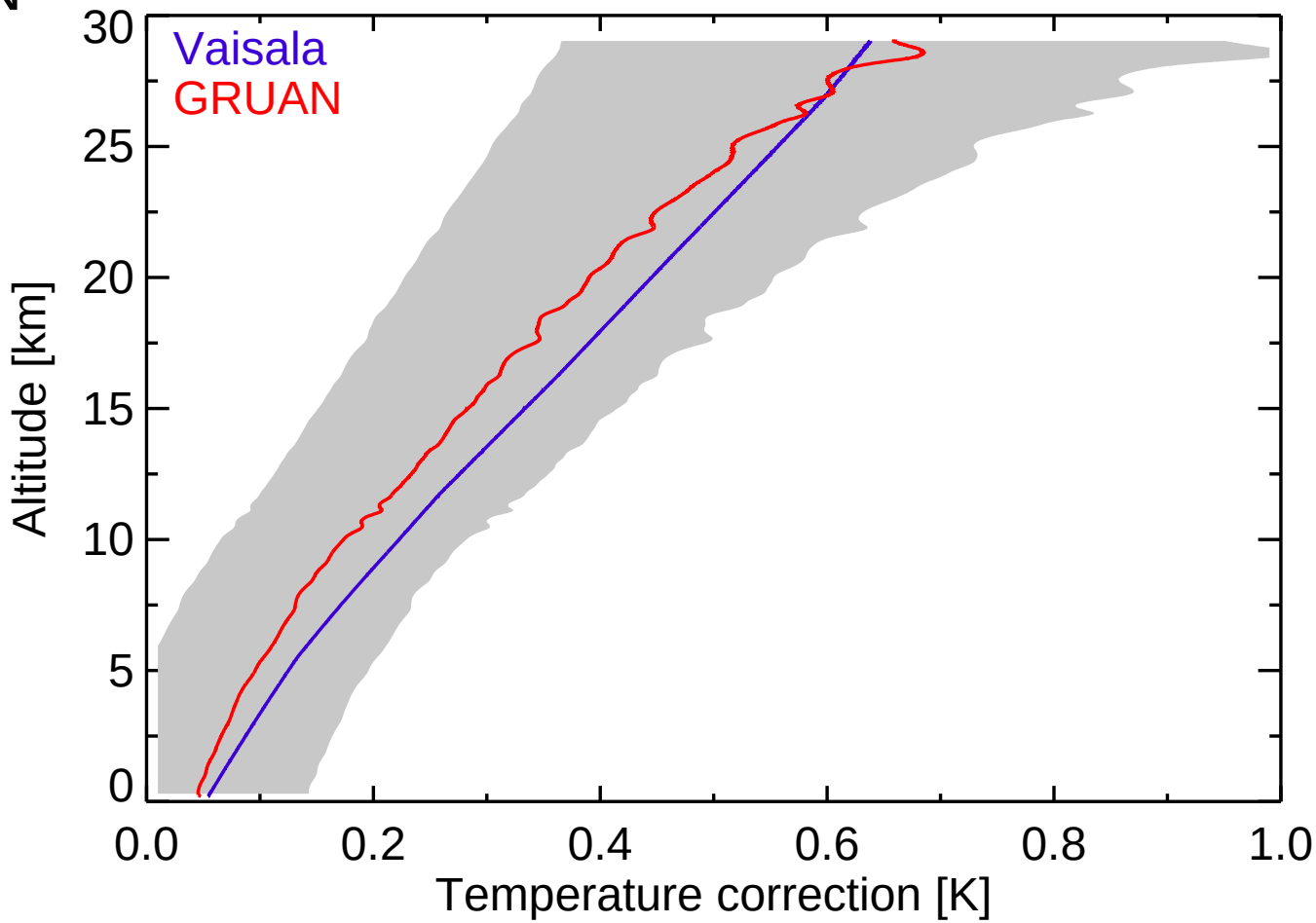
Radiation error correction model



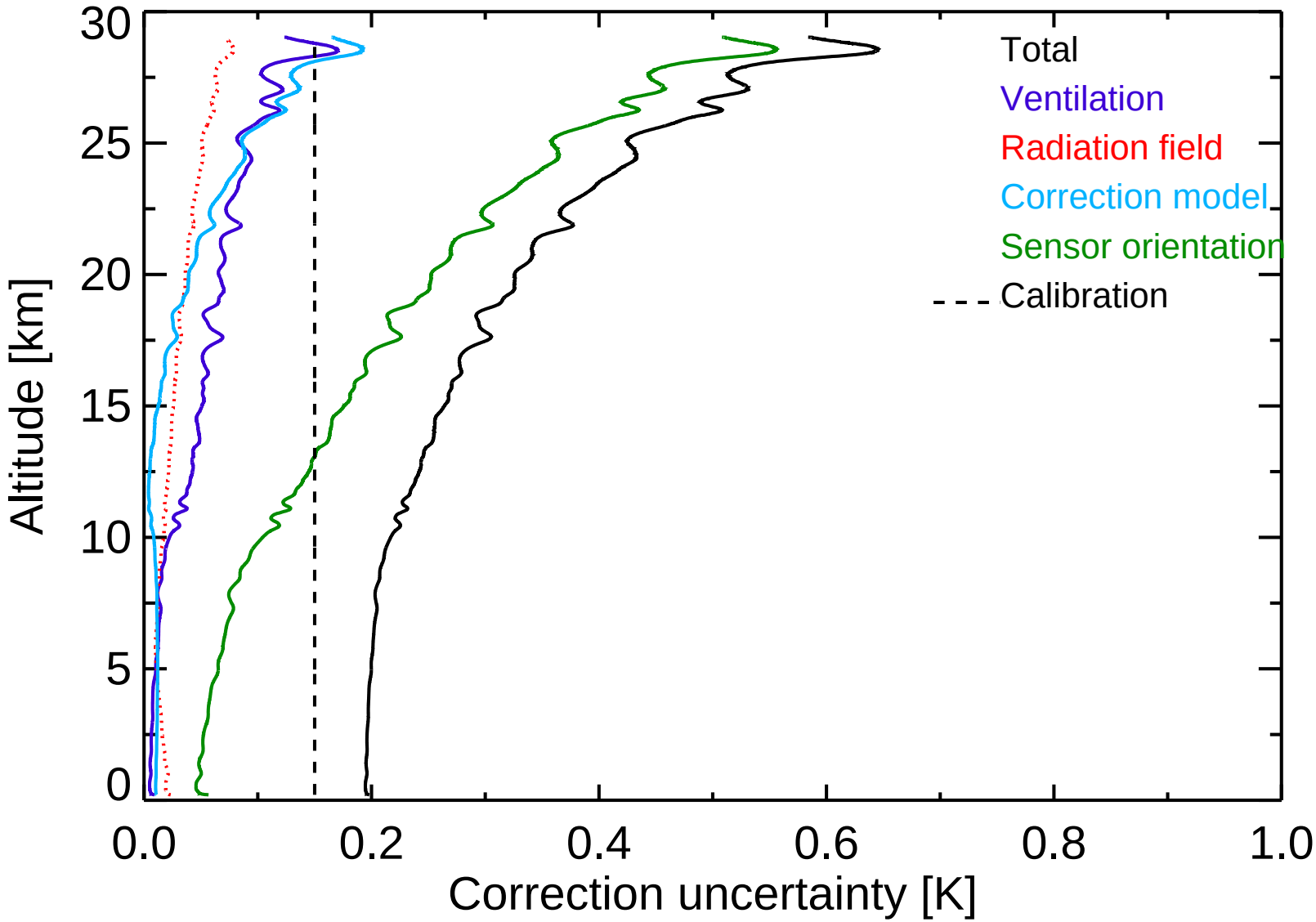
T-correction profile

In processing: average of Vaisala and GRUAN correction

- Update in version 3



Temperature: Uncertainties

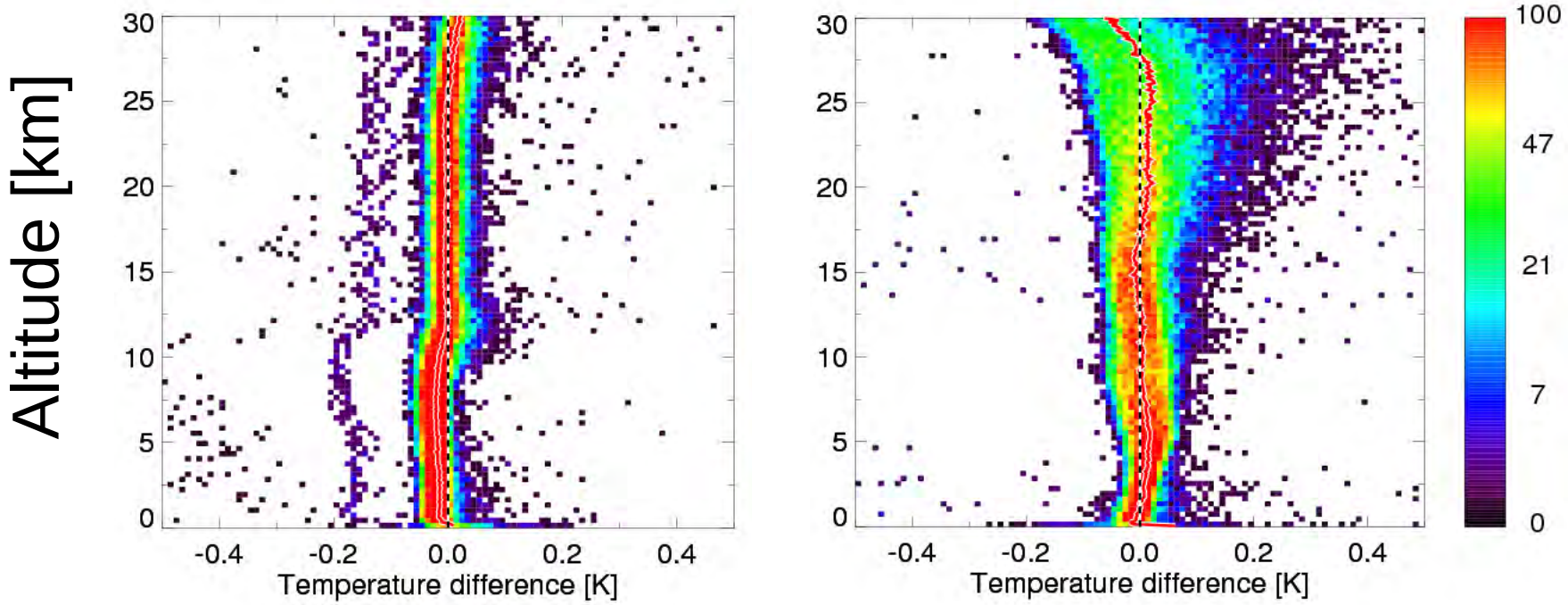


Comparison GRUAN - Vaisala

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

Lindenberg (2012)

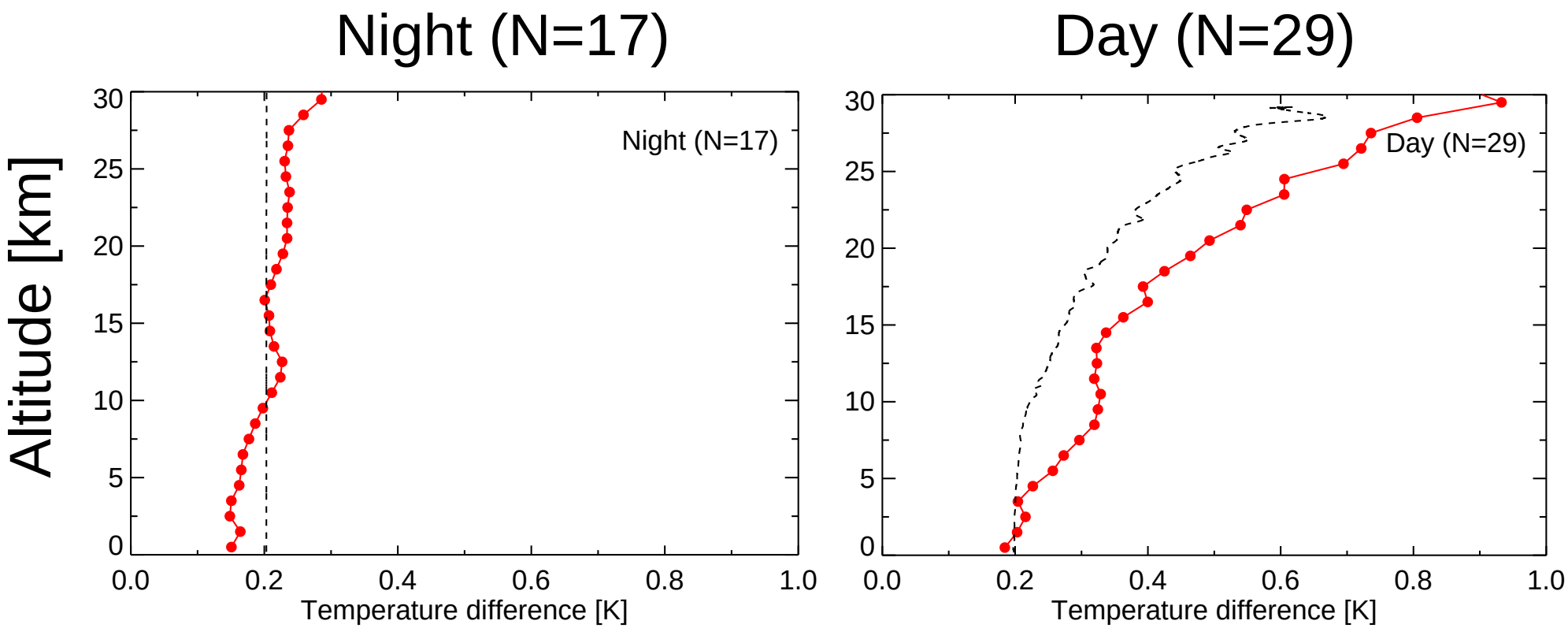
Night (N=277) Day (N=258)



RS92 dual sounding

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

Estimated uncertainty vs observed differences



Humidity

Undo RH recalibration

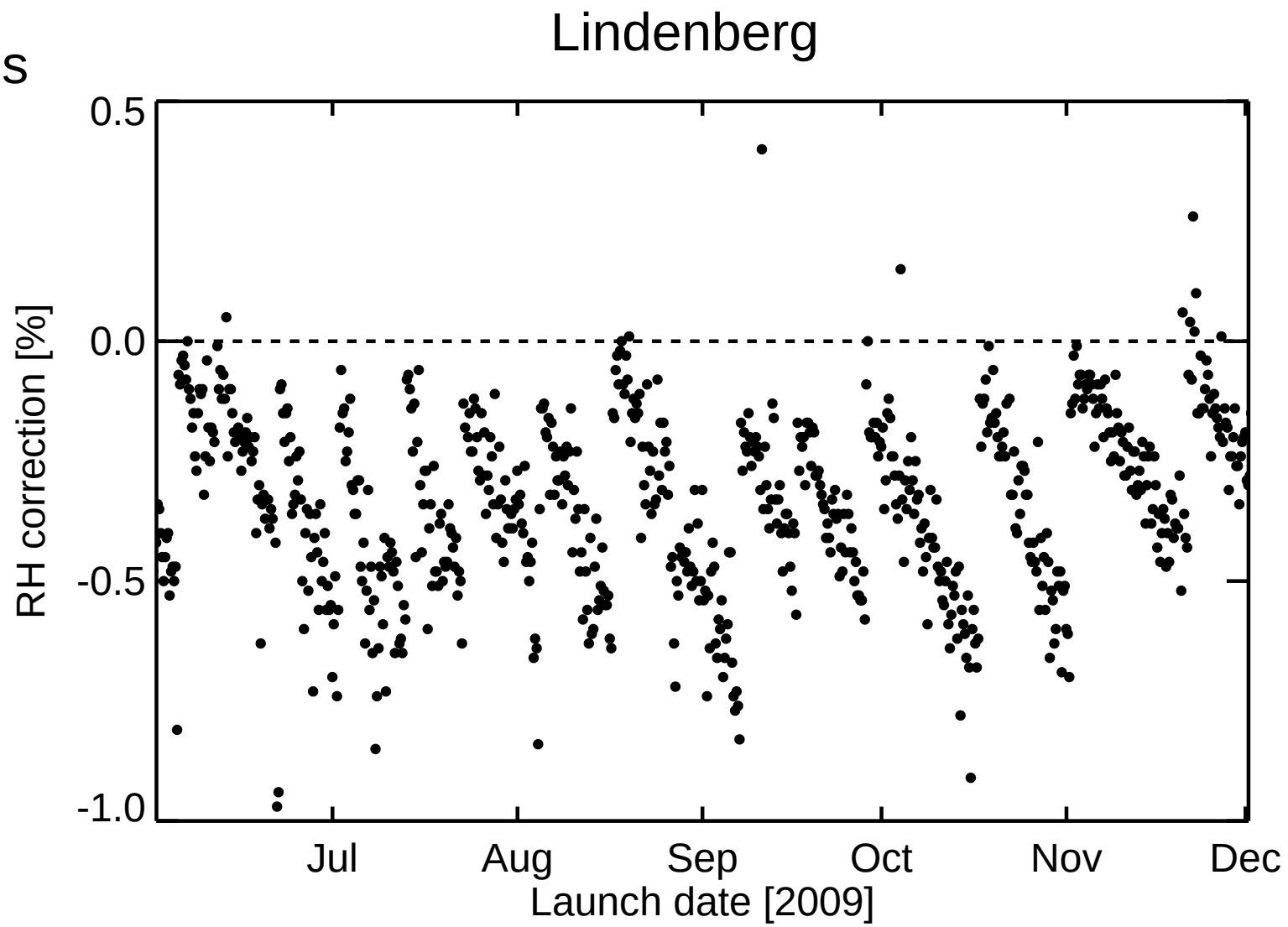
Errors

- T-dependent calibration
- Dry bias
- Time lag

GC25, RH recalibration

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

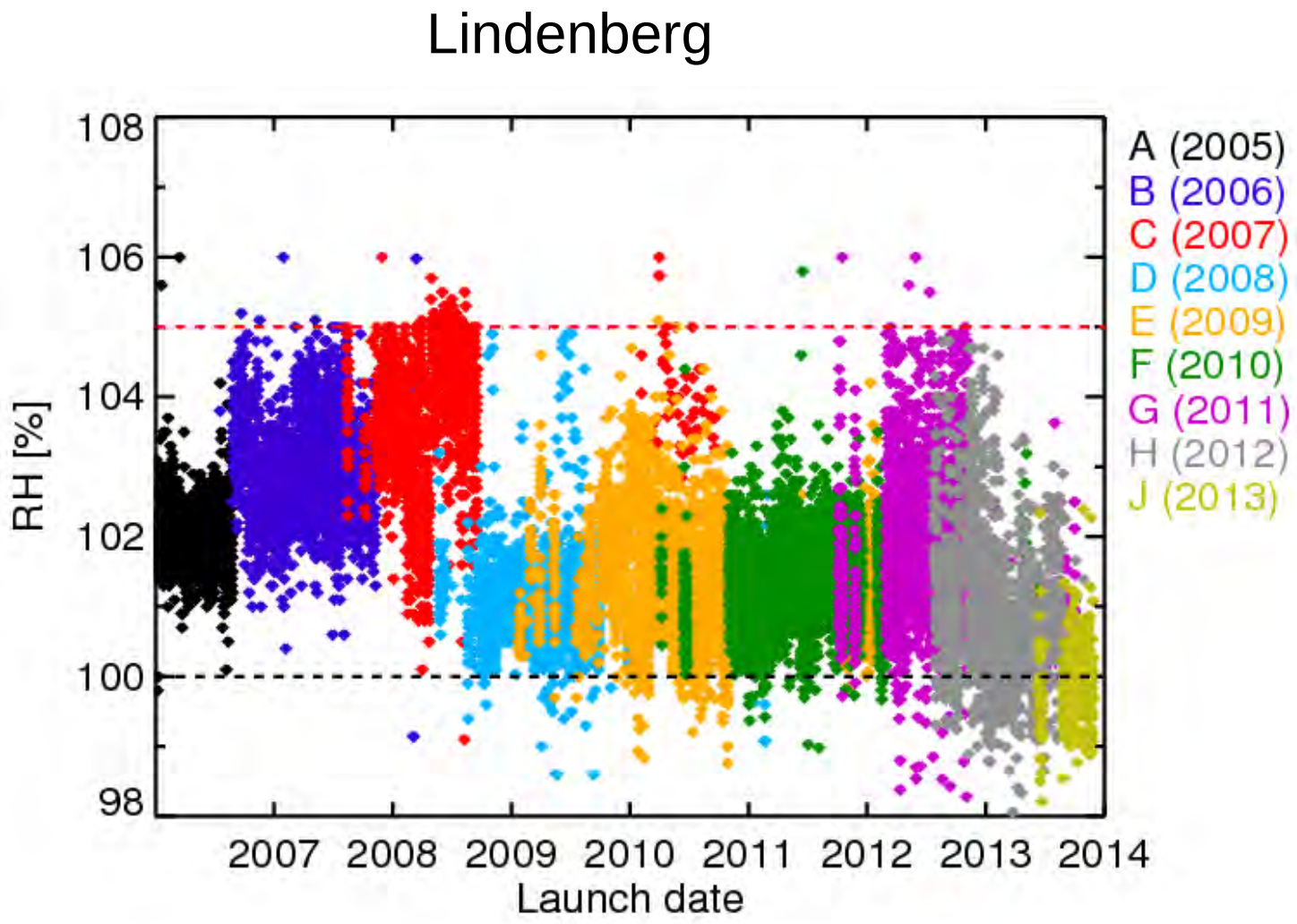
Degradation of desiccant introduces systematic error



Ground check in SHC

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

- Traceability
- 4% change over ~8 years
- SHC readings enter uncertainty budget
- Future version: use SHC to scale profile



RH: Dry bias

Heating of humidity sensor

$$RH_c = RH_m \frac{p_s(T + f\Delta T)}{p_s(T)}$$

- ΔT: radiation correction of T-sensor
- f: enhancement factor [6, 13] (laboratory experiments)

Uncertainties: ΔT, f

RH: calibration error

Temperature-dependent dry bias (-30, -70°C)

Based on RS92 - CFH comparison

Max at 7% at -60°C (similar to Voemel2007)

Uncertainty: comparable to correction

RH: time-lag

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

Relevant below -40°C, τ = 10s (τ > 100s at T= -80°C)

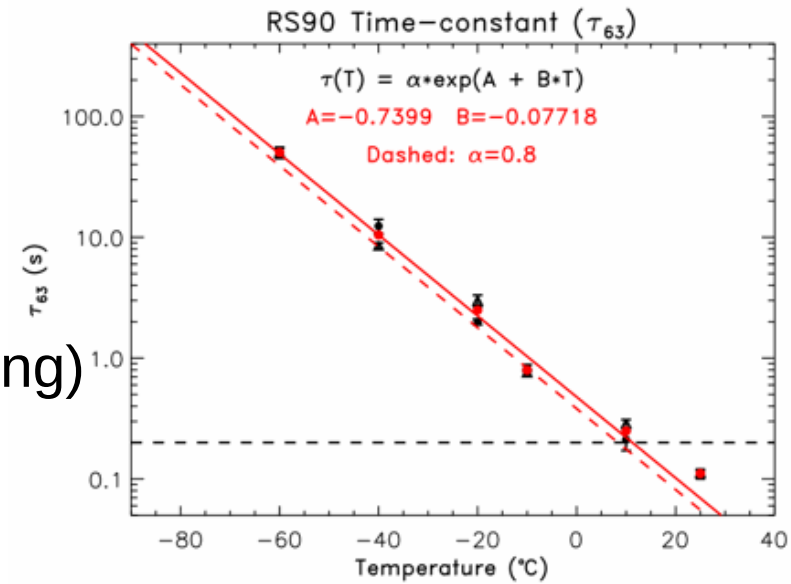
Flattens features in humidity profile

$$RH_i^{a^*} = RH_i^m + \sum_{j=0}^{i-1} (RH_i^m - RH_j^{a^*}) \exp\left(\frac{t_j - t_i}{\tau_i}\right)$$

Correction:

- numeric inversion of low-pass filter
- enhances structures & noise (a-posteriori filtering)

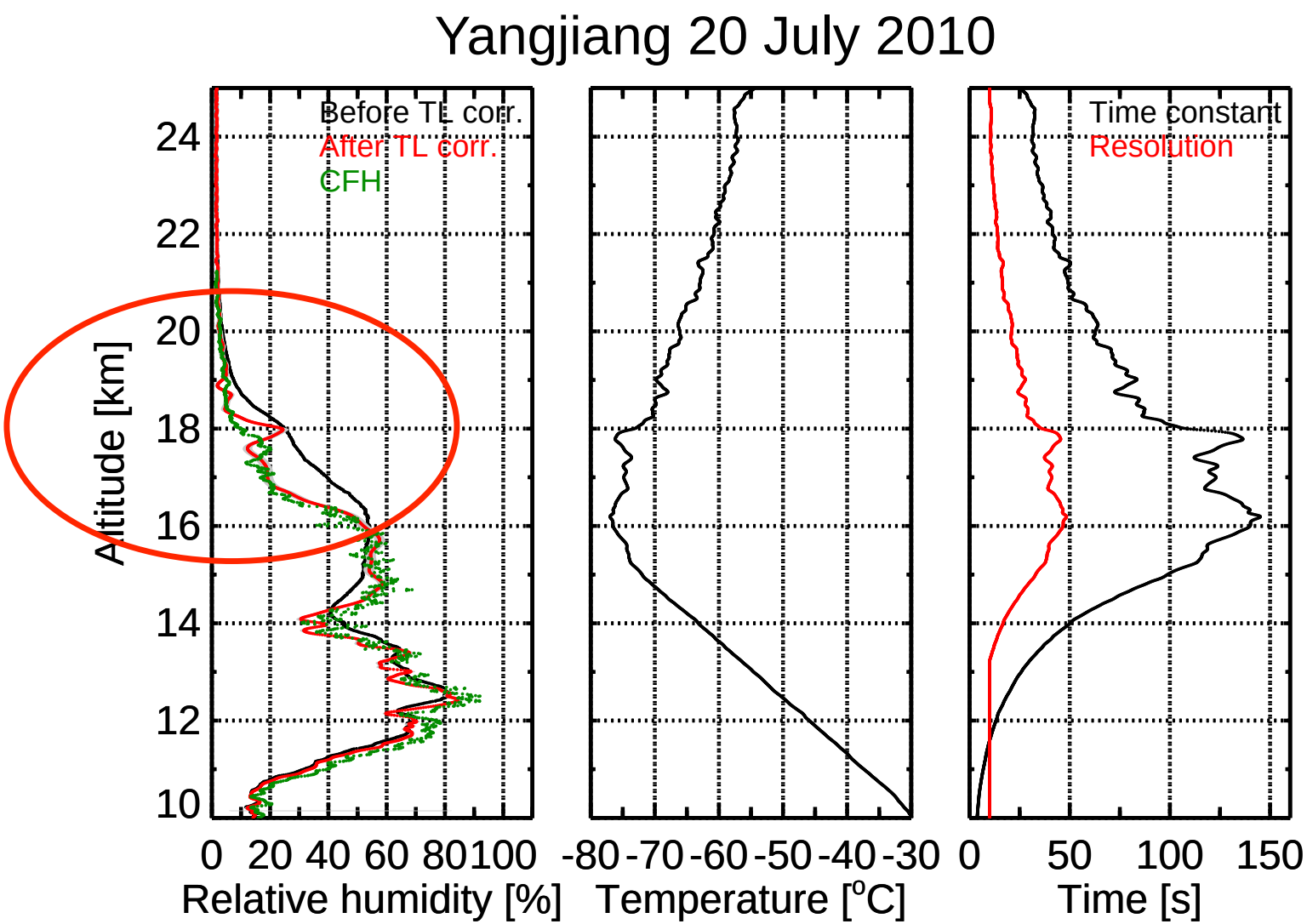
Uncertainties: time constant, statistical noise



http://milo-scientific.com/prof/corr_method.php

RH: time-lag

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

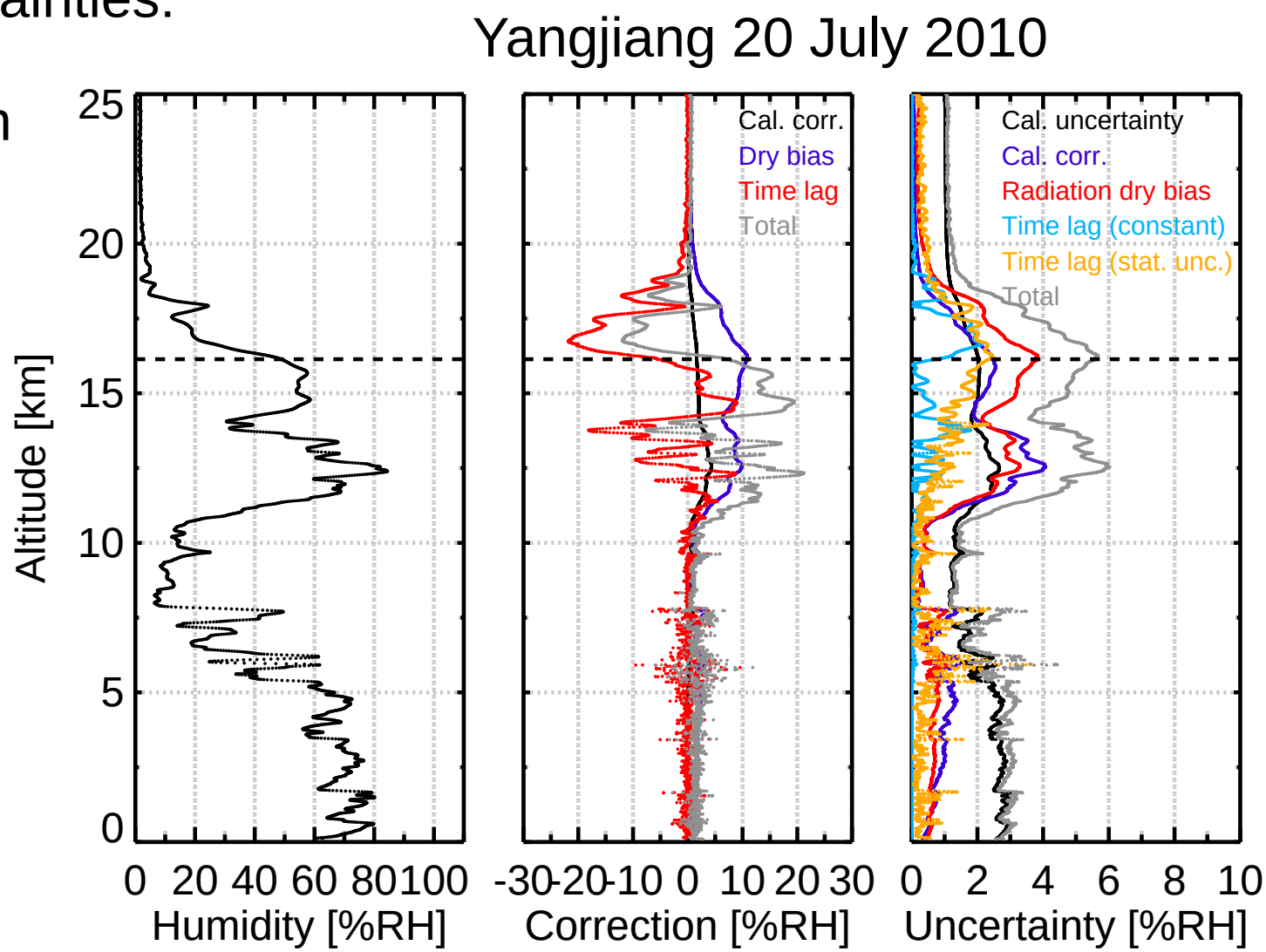


RH: corrections & uncertainties

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

Dominant uncertainties:

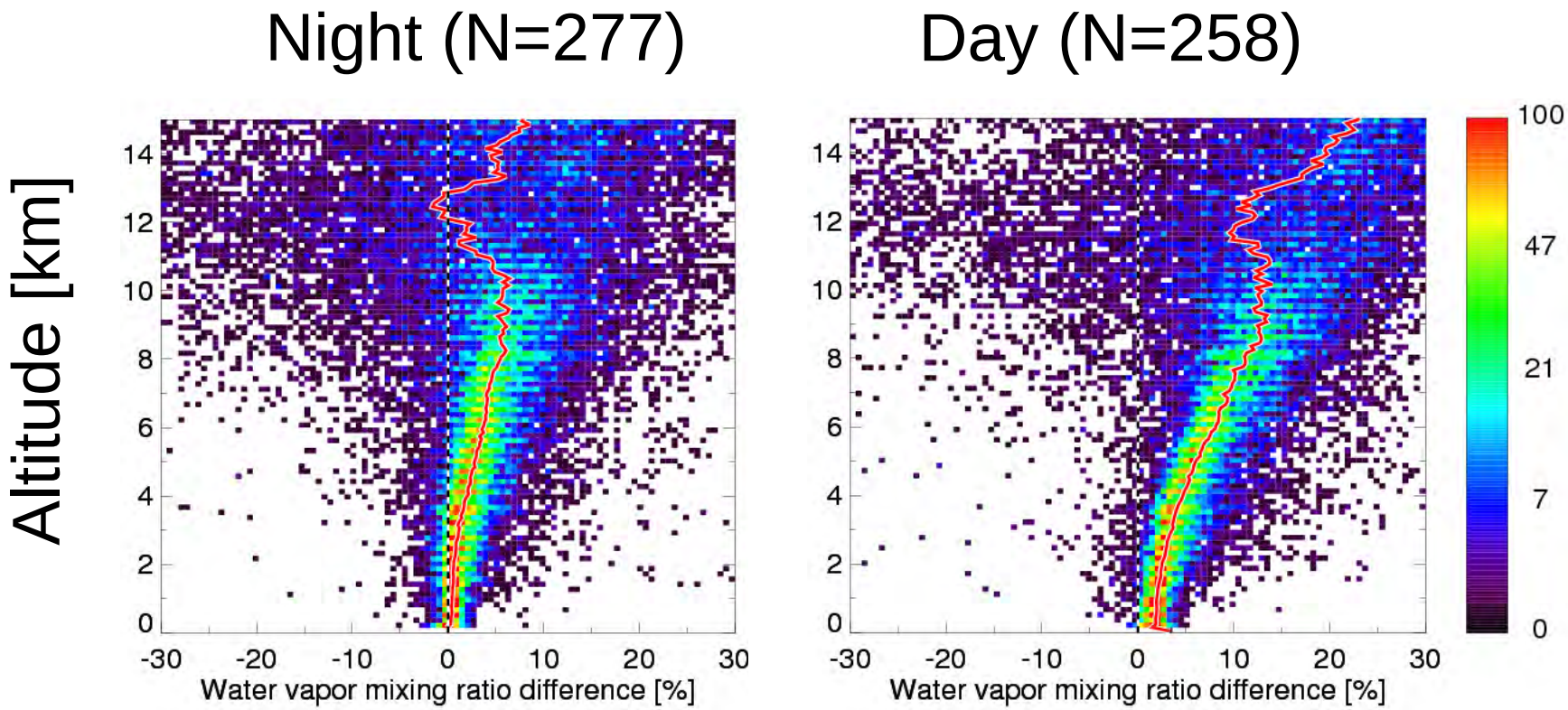
- Calibration
- Cal. correction
- Dry bias



RH: GRUAN - Vaisala

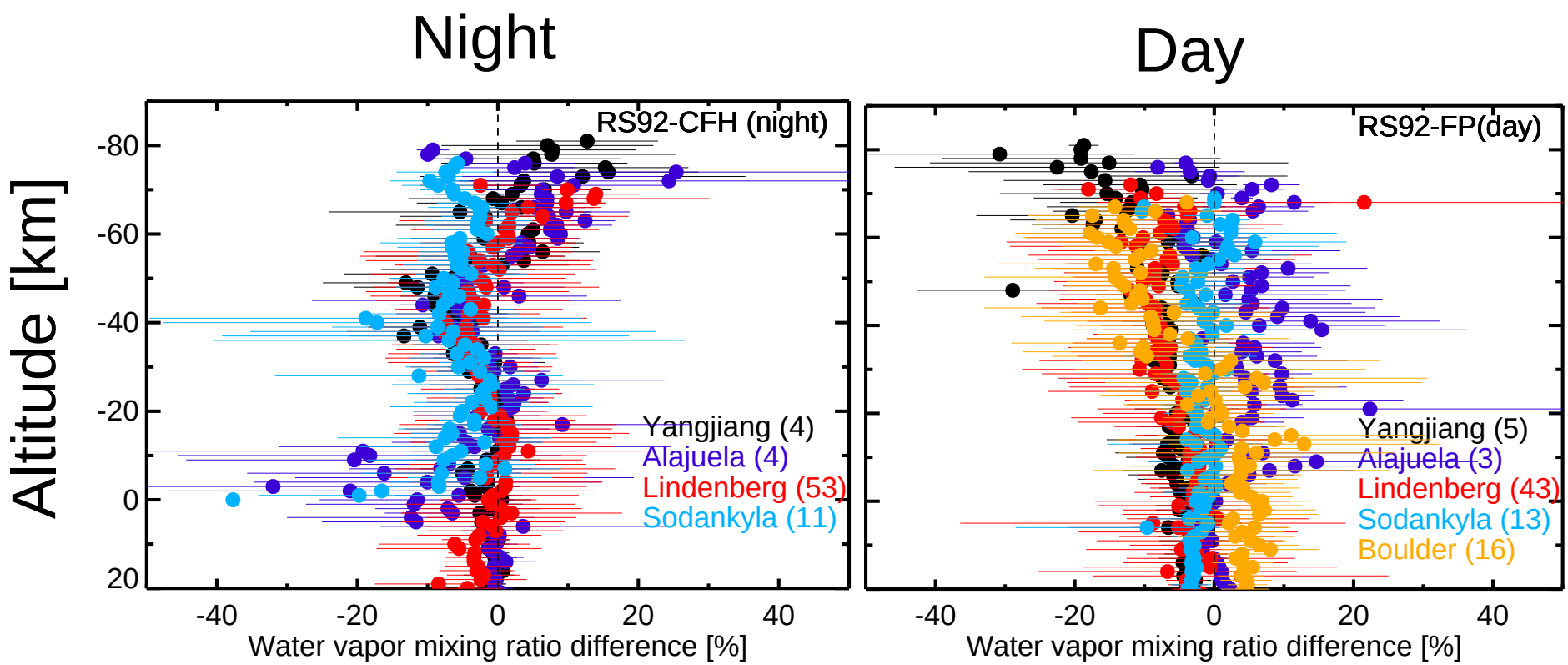
Deutscher Wetterdienst
Wetter und Klima aus einer Hand

- Calibration correction: ~5%
- Dry bias: ~10%



Comparison GRUAN RS92 – Frost point hygrometer

Deutscher Wetterdienst
Wetter und Klima aus einer Hand



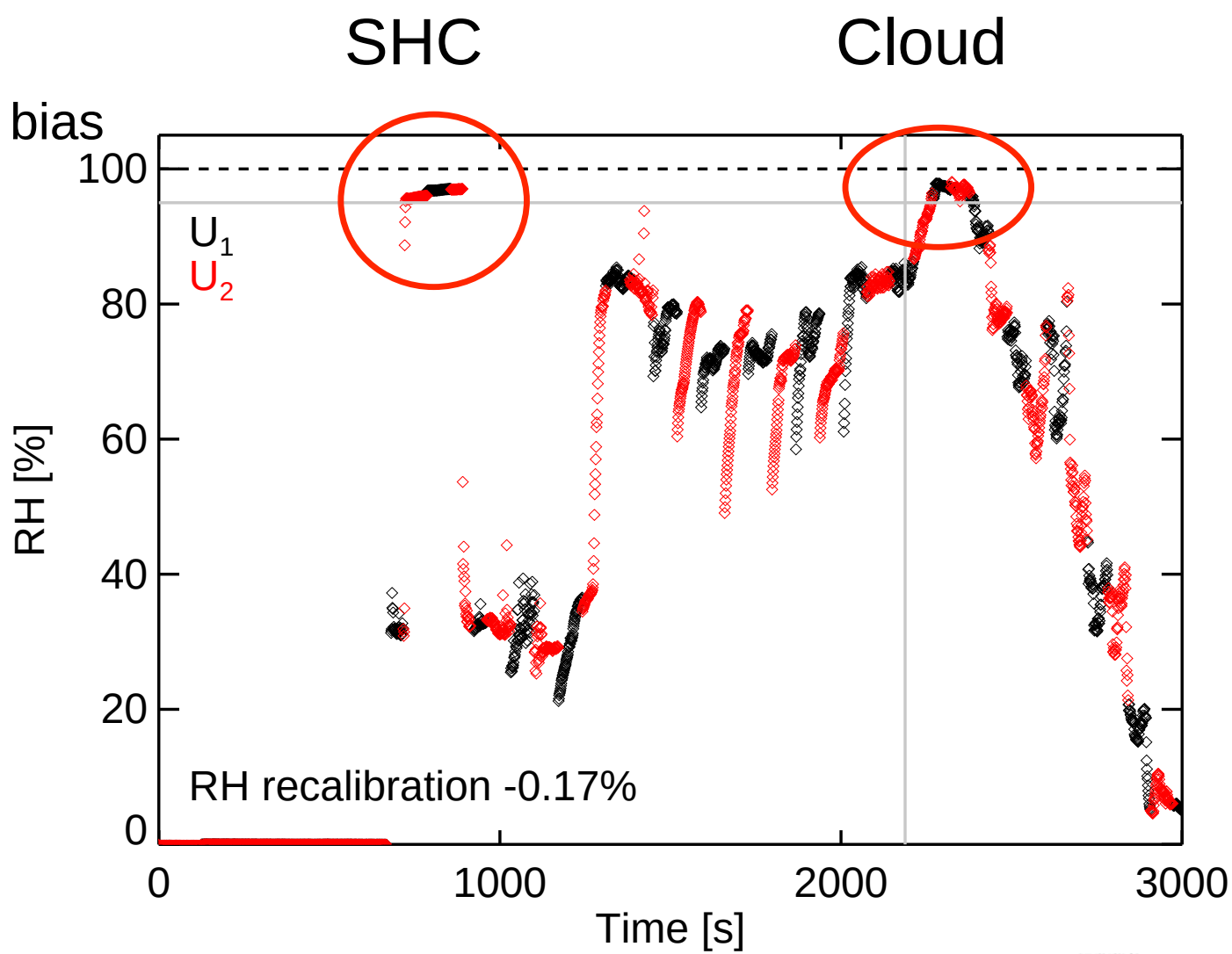
Radiosonde preparation

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

Analysis of SHC data

Skip reconditioning: 1-5% bias

Operational procedure!



Recommendations for reference soundings

- Traceability. Manufacturer-independent ground check (SHC)
- Measurement redundancy to determine systematic errors. (intercomparison)
- Ascent speed 5-7 m/s (radiation error)
- Operational procedure for radiosonde preparation
- Multi-instrument rigs: scattered radiation from styrofoam housing (radiation error)
- Unwinder length >30m, temperature spikes.

➔ **Standardized method to determine radiation temperature error?**

Coming soon…

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

Manuscript prepared for Atmos. Meas. Tech.
with version 5.0 of the LaTeX class copernicus.cls.
Date: 6 March 2014

Reference Quality Upper-Air Measurements: GRUAN data processing for the Vaisala RS92 radiosonde

Ruud J. Dirksen[1], Michael Sommer[1], Franz J. Immler[1,2], Dale F. Hurst[3,4], Rigel Kivi[5], and Holger Vömel[1]

[1]Deutscher Wetterdienst, Meteorologisches Observatorium Lindenberg, Richard Aßmann Observatorium, Am Observatorium 12, 15848, Lindenberg/Tauche, Germany.
[2]Now at: European Commission, Brussels, Belgium
[3]Global Monitoring Division, NOAA Earth System Research Laboratory, Boulder, CO, USA
[4]Cooperative Institute for Research in Environmental Sciences, University of Colorado, Boulder, CO, USA.
[5]Finnish Meteorological Institute, Sodankylä, Finland

Correspondence to: Ruud Dirksen
Ruud.Dirksen@dwd.de

Abstract. The GCOS Reference Upper Air Network (GRUAN) data processing for the Vaisala RS92 radiosonde was developed to meet the criteria for reference measurements. These criteria stipulate the collection of metadata, the use of well-documented correction algorithms, and estimates of the measurement uncertainty. An important and novel aspect of the GRUAN processing is that the uncertainty estimates are vertically resolved. This paper describes the algorithms that are applied in version 2 of the GRUAN processing to correct for systematic errors in radiosonde measurements

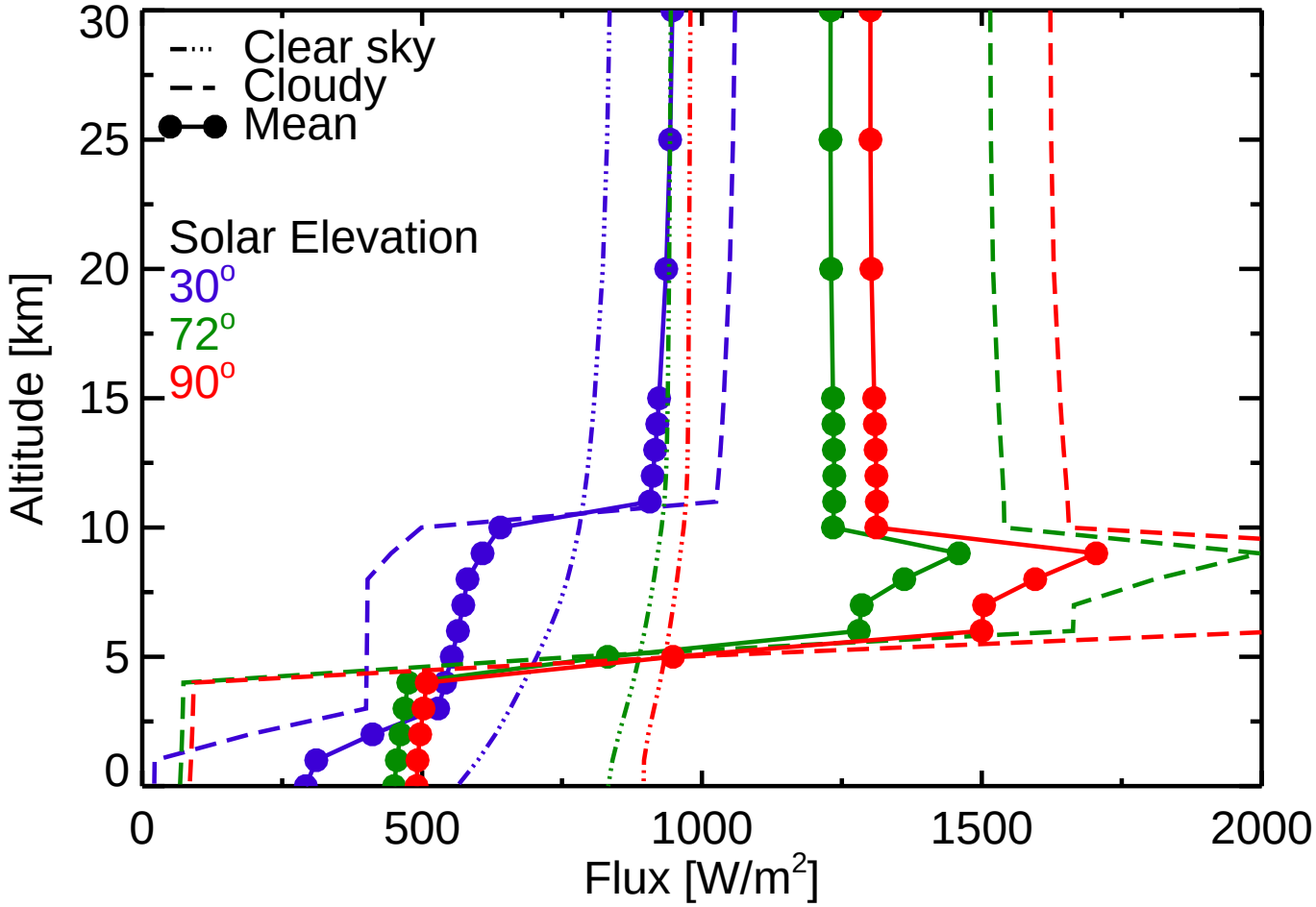
Radiative transfer simulations

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

Streamer model

Clear sky & cloudy

Mid-lat atmosphere



Dual RS92, nighttime data