Can we get one or more GCOS Reference Upper Air Network sites in Antarctica?

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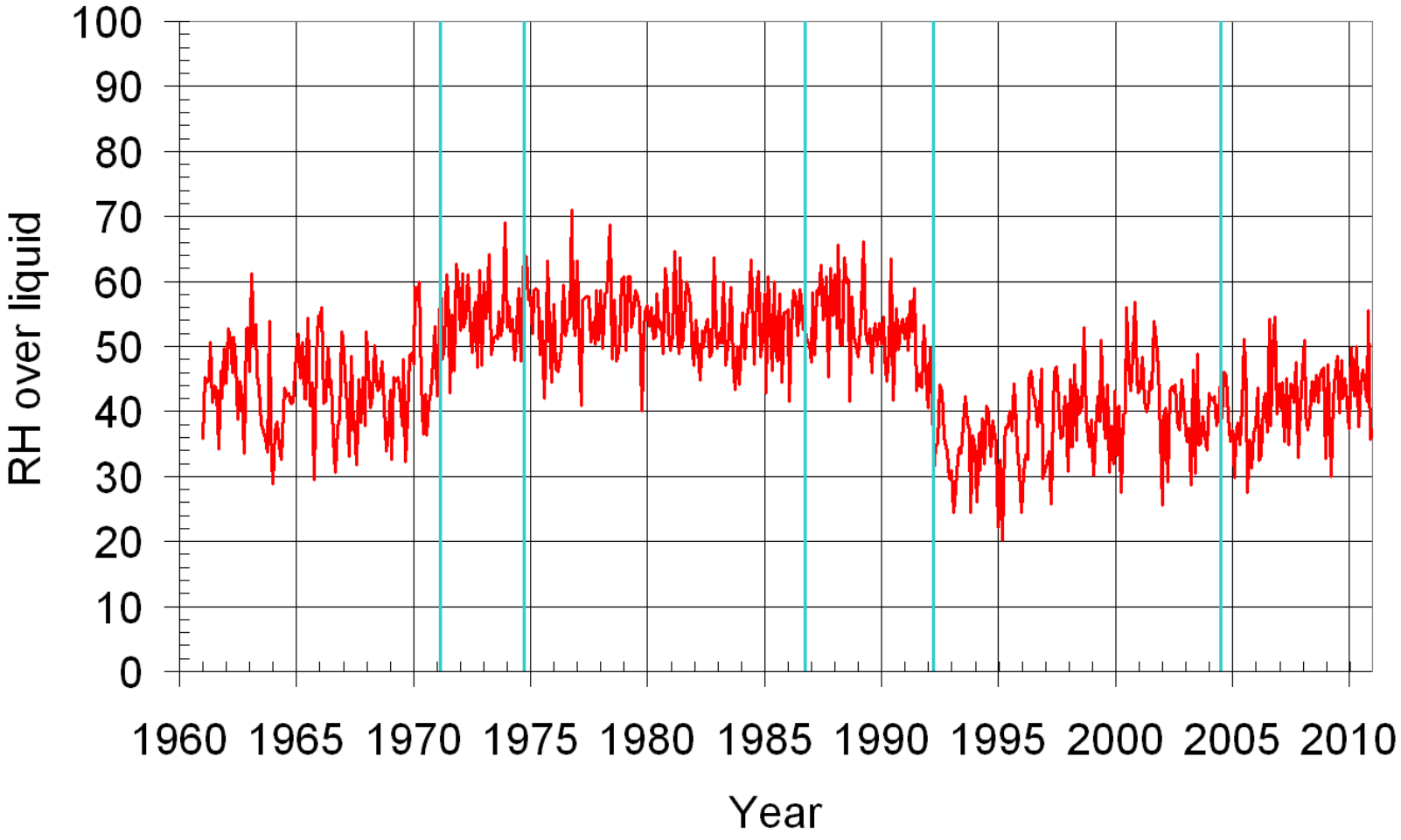
10th Antarctic Meteorological Observation, Modelling, and Forecasting Workshop

17th June 2015

Water vapor trends in the troposphere?

e.g.: Lindenberg 8km (0:00 UT)



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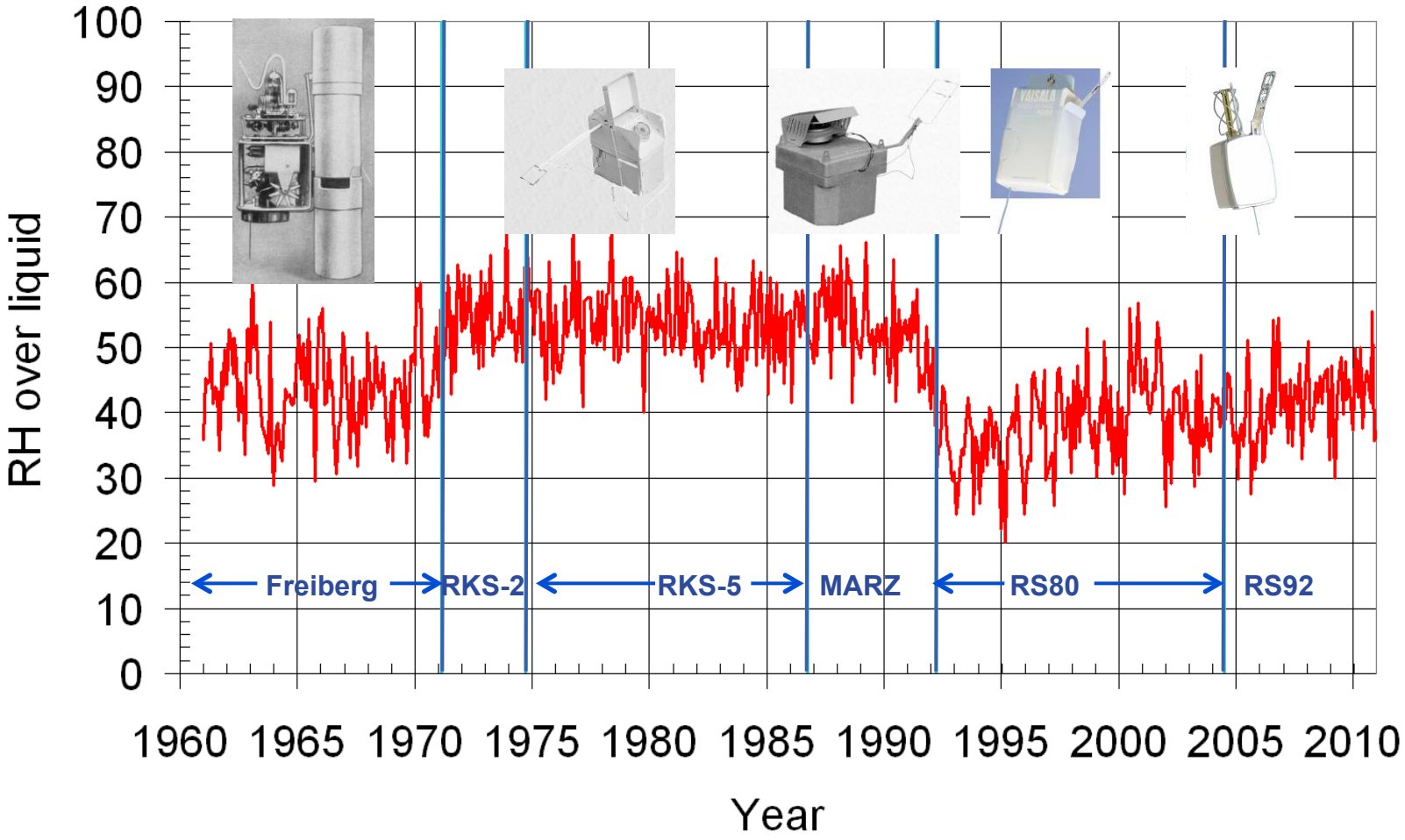


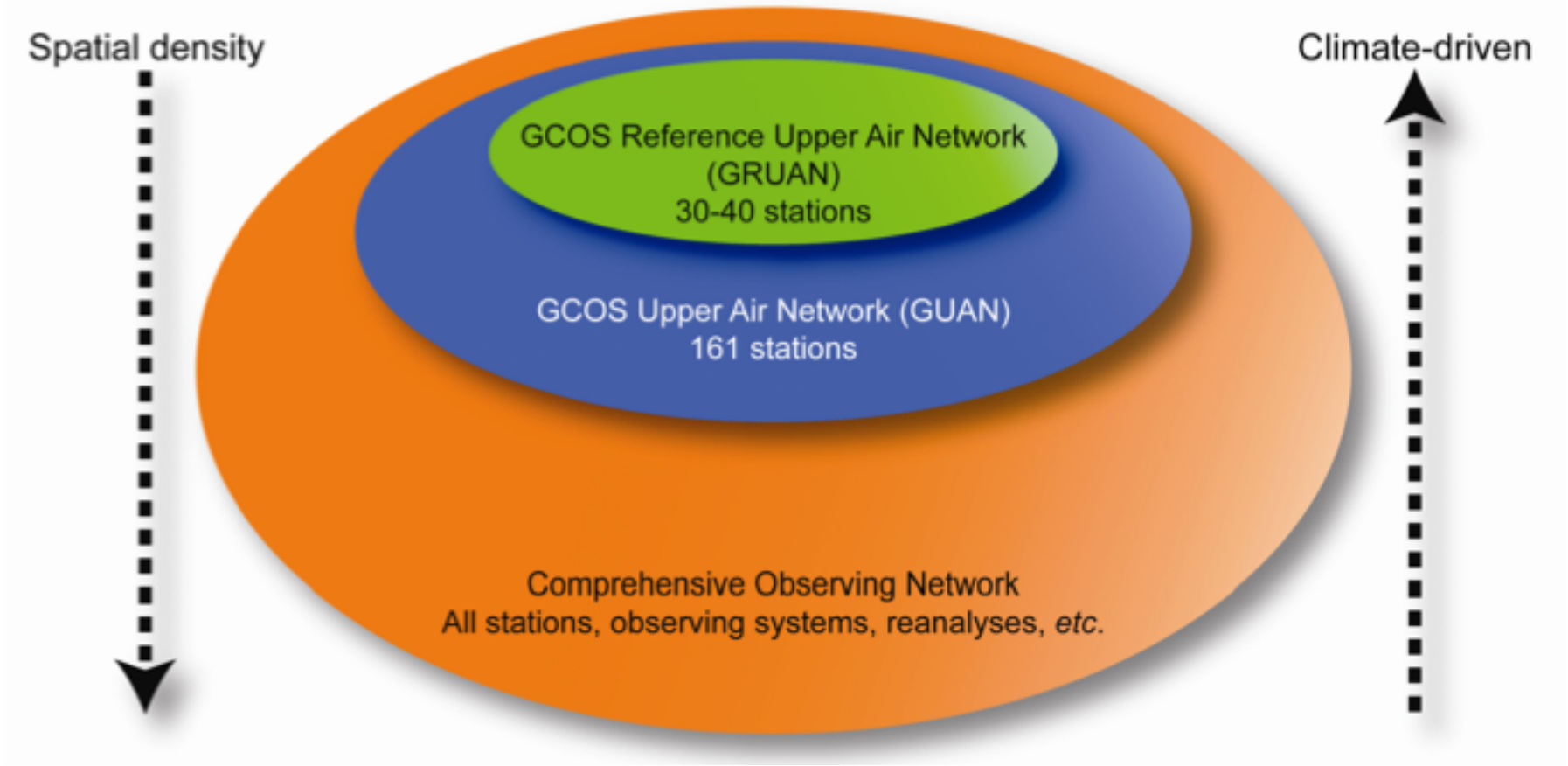
GCOS Reference Upper Air Network

- GRUAN is a response to the need of WMO and the Global Climate Observing System for improved monitoring of upper air climate as called for in the first GCOS Implementation Plan
- Ground based network for reference upper air observations for climate under GCOS and integrated into WIGOS
- Currently 21 active sites (7 certified), with aim to expand to 30 to 40 sites worldwide

GCOS Reference Upper Air Network

See **www.gruan.org**

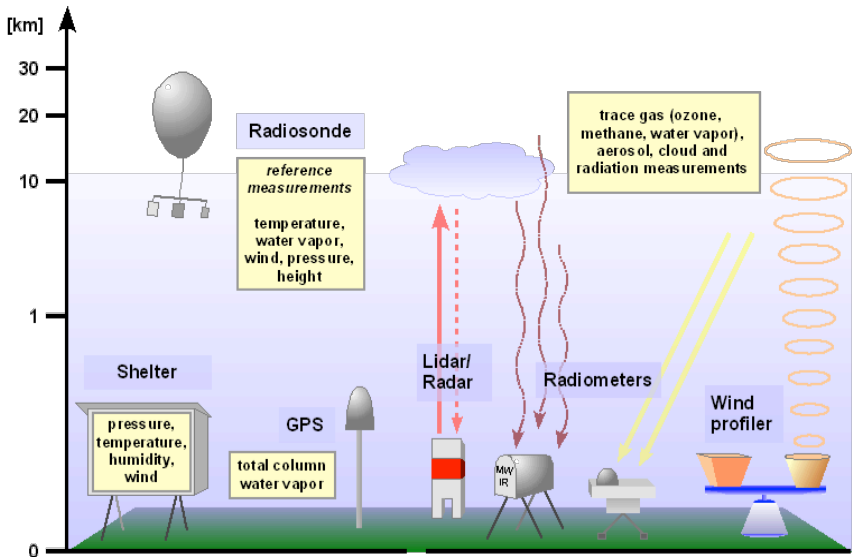
GRUAN's relationship to existing observational networks



Seidel et al., 2009

GRUAN goals

- Maintain consistent observations over decades
- Validate satellite systems
- Understand atmospheric processes
- Numerical weather prediction
- Deliberate measurement redundancy
- Standardization and traceability
- Quality management and managed change



Priority 1: Water vapor, temperature, (pressure and wind)

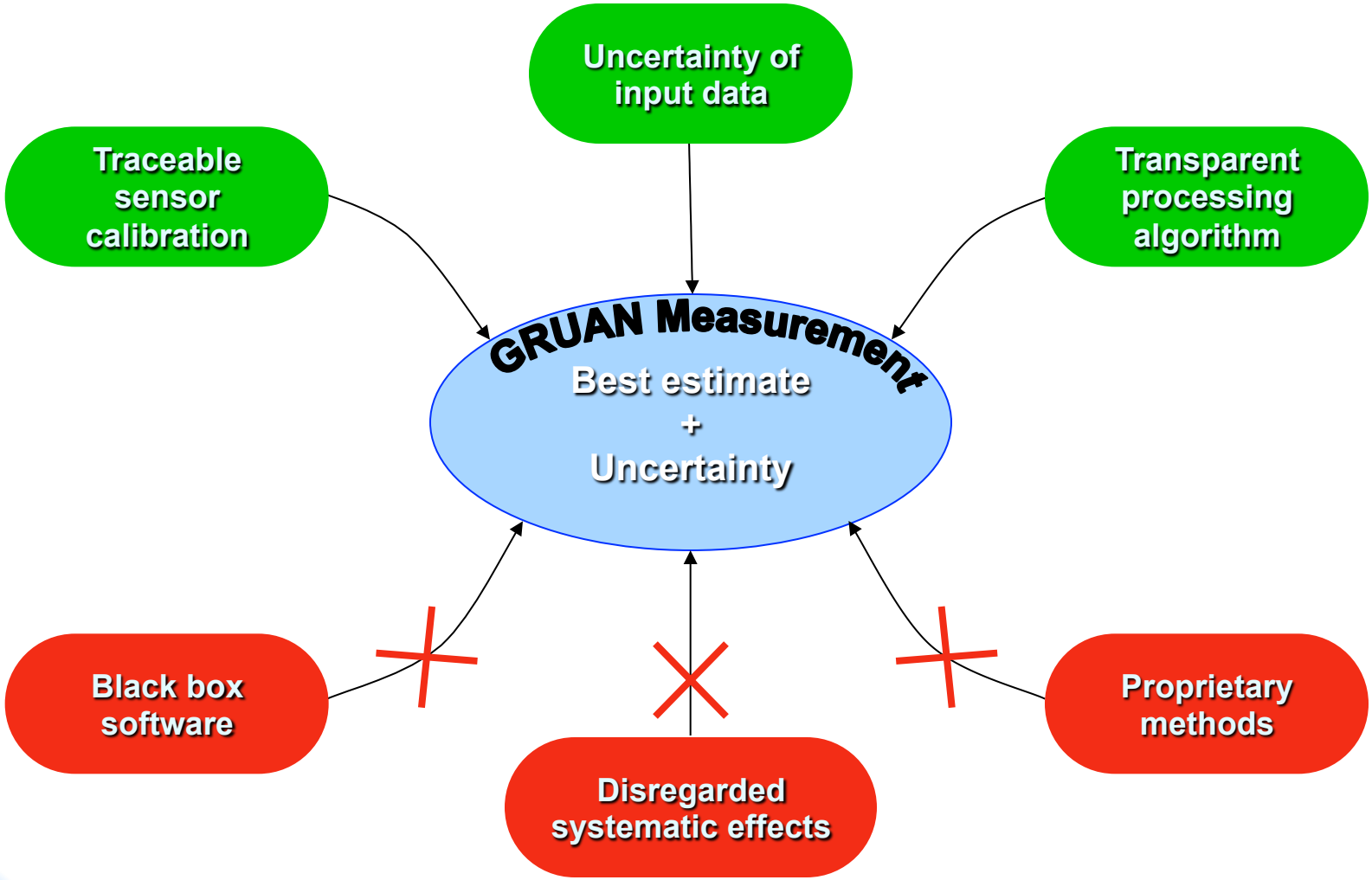
Priority 2: Ozone, …

Definition of “Reference Observation”

A GRUAN reference observation:

- ✓ Is traceable to an SI unit or an accepted standard
- ✓ Provides a comprehensive uncertainty analysis
- ✓ Maintains all raw data
- ✓ Includes complete meta data description
- ✓ Is documented in accessible literature
- ✓ Is validated (e.g. by intercomparison or redundant observations)

Establishing reference quality



Example GRUAN product – RS92

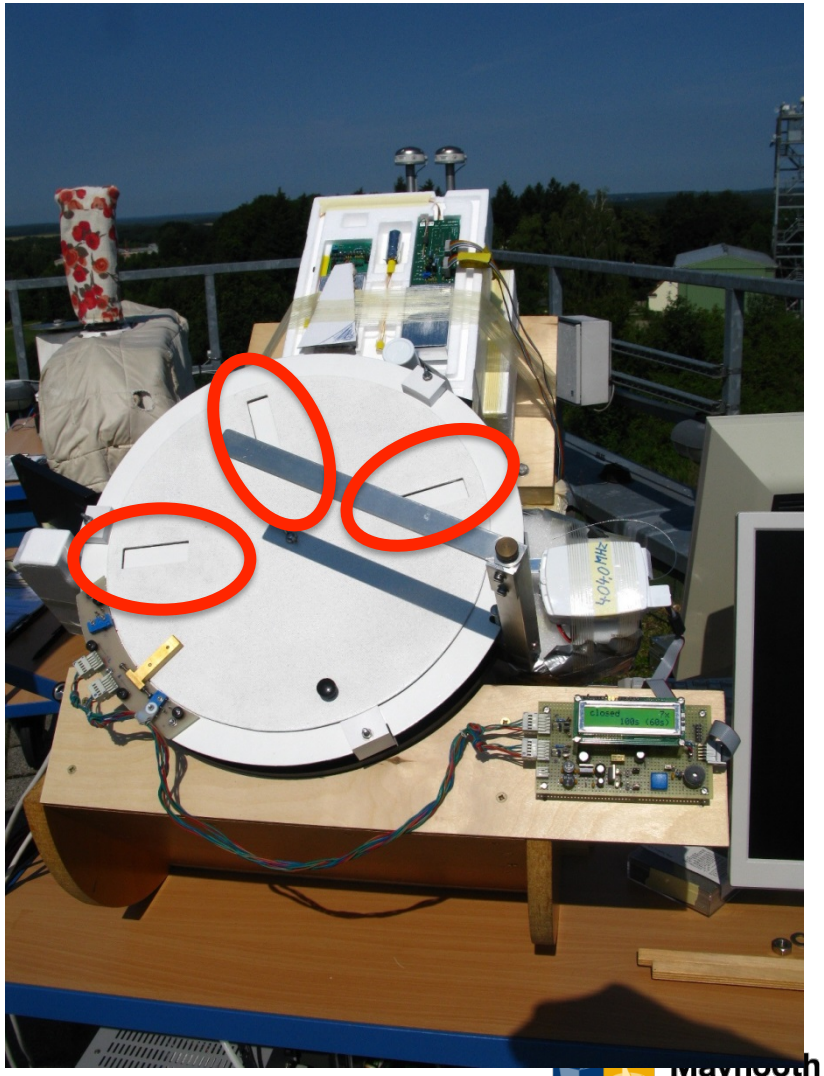
- The RS92 sonde model is the production sonde used by many sites around the world
- Vaisala provides raw (unprocessed) measurement data
- GRUAN Lead Centre and colleagues have undertaken an end-to-end processing understanding and quantifying uncertainty in each step.
- Data and metadata are captured in consistent manner
- See Dirksen et al. AMT, 2014

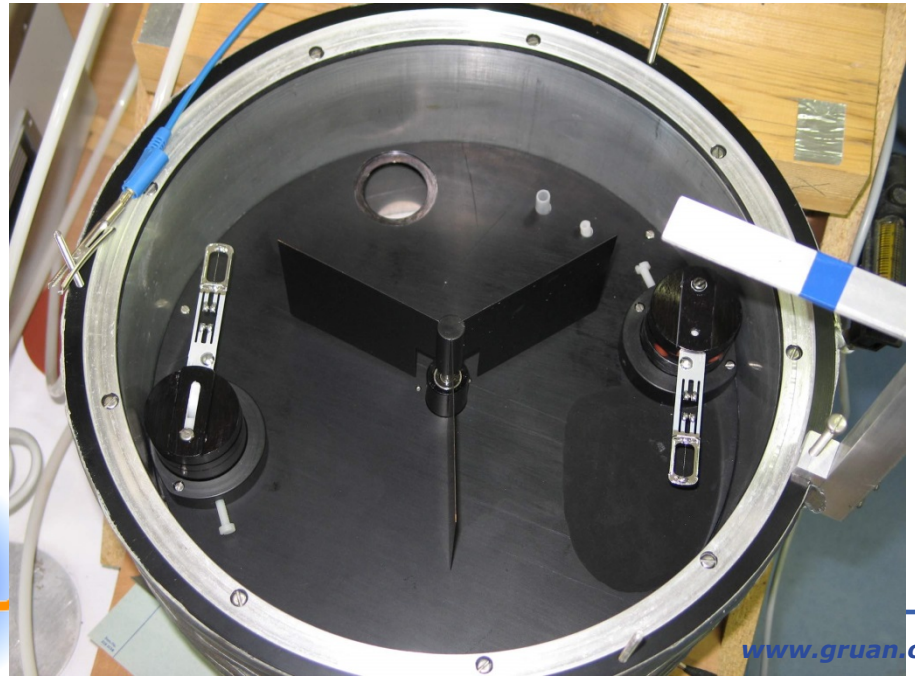
Radiation error: Laboratory experiments

Shadow RS92 records background temperature & ambient pressure

Simultaneous testing of 3 radiosondes

p=[3 hPa , ambient]





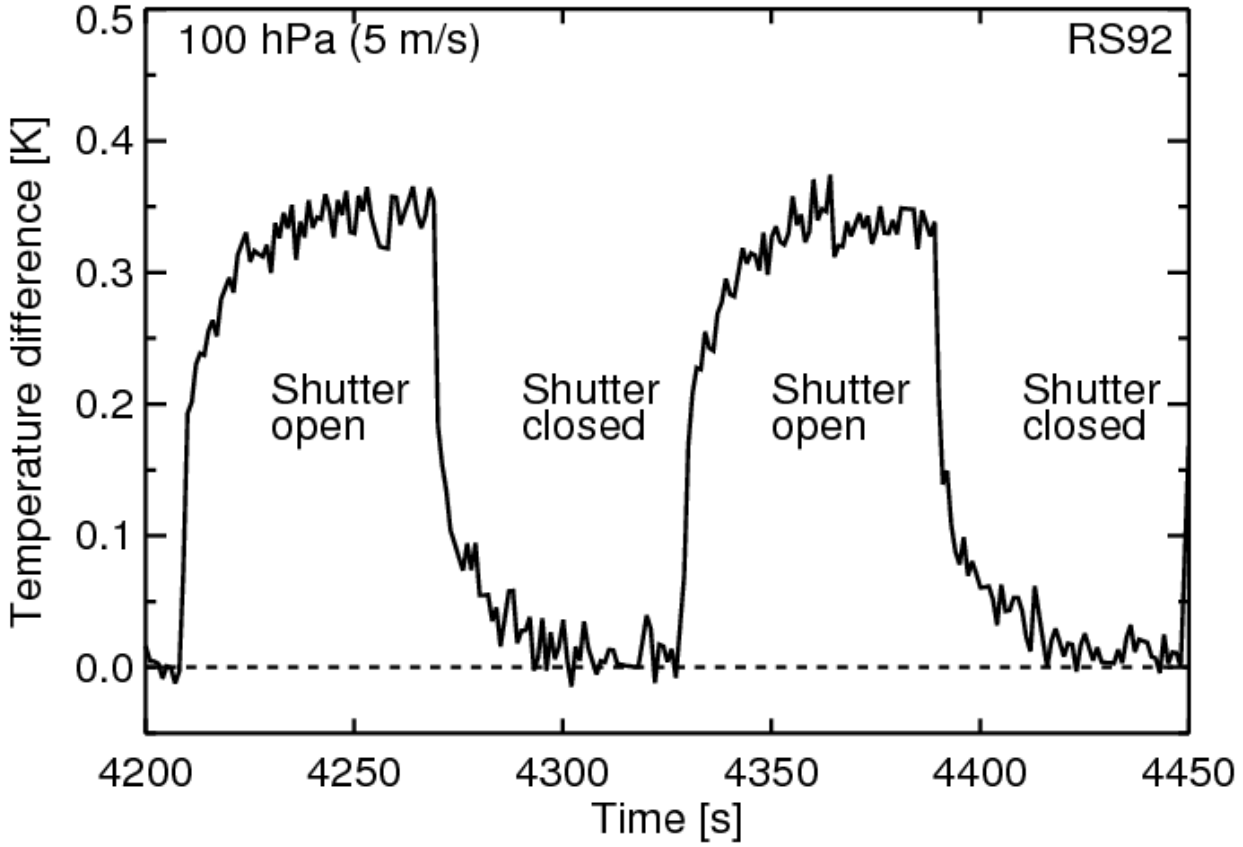
Radiation error: Laboratory experiments

Shadow RS92 records background temperatur

Simultaneo

p=[3 hPa ,

Difference illuminated – background radiosonde



Maynooth University
National University of Ireland Maynooth

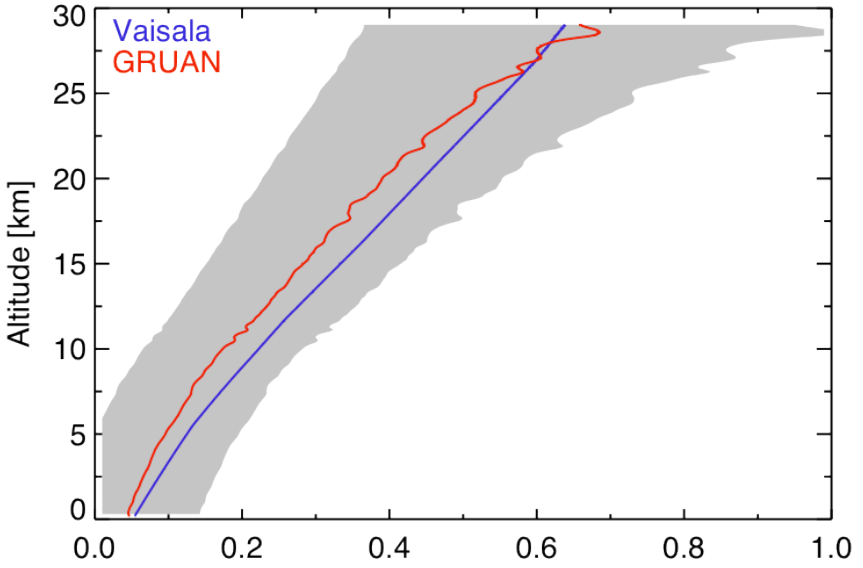
T-correction profile

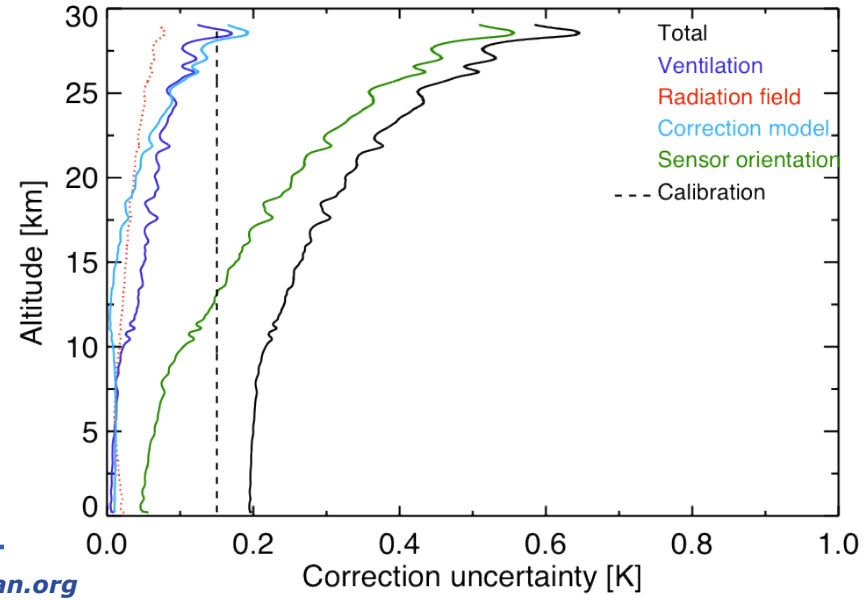
In processing: average of Vaisala and GRUAN correction

- **Update in version 3**

Sources of measurement uncertainty:

- **Sensor orientation**
- **Ventilation**
- **Unknown radiation field (albedo)**
- **Lab measurements of the radiative heating**
- **Ground check**
- **Calibration**



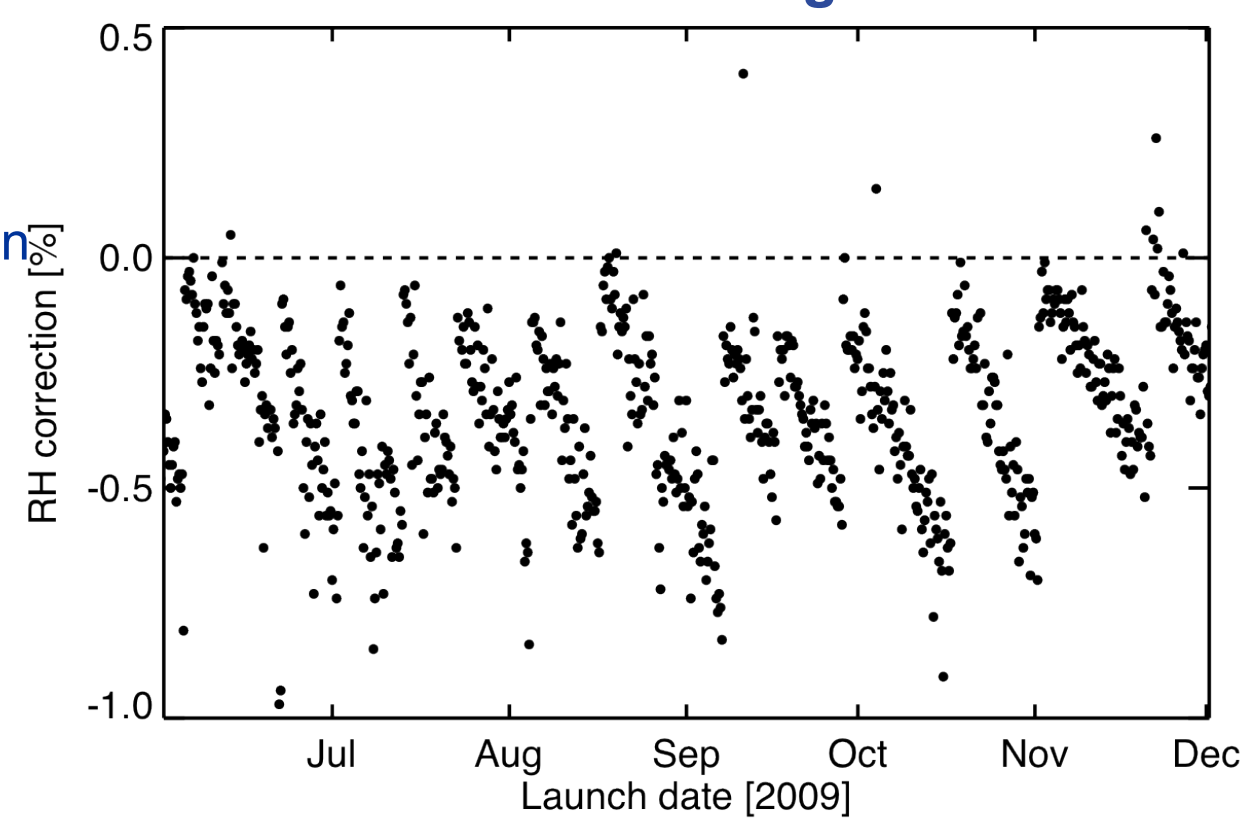


Humidity

Undo RH recalibration

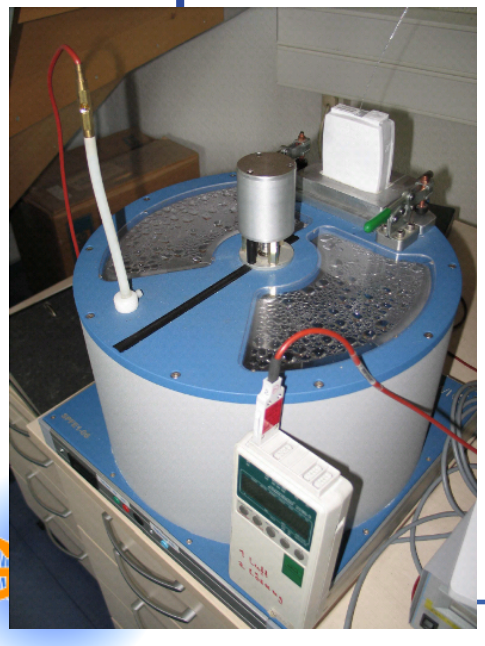
Errors

- T-dependent calibration
- Dry bias
- Time lag

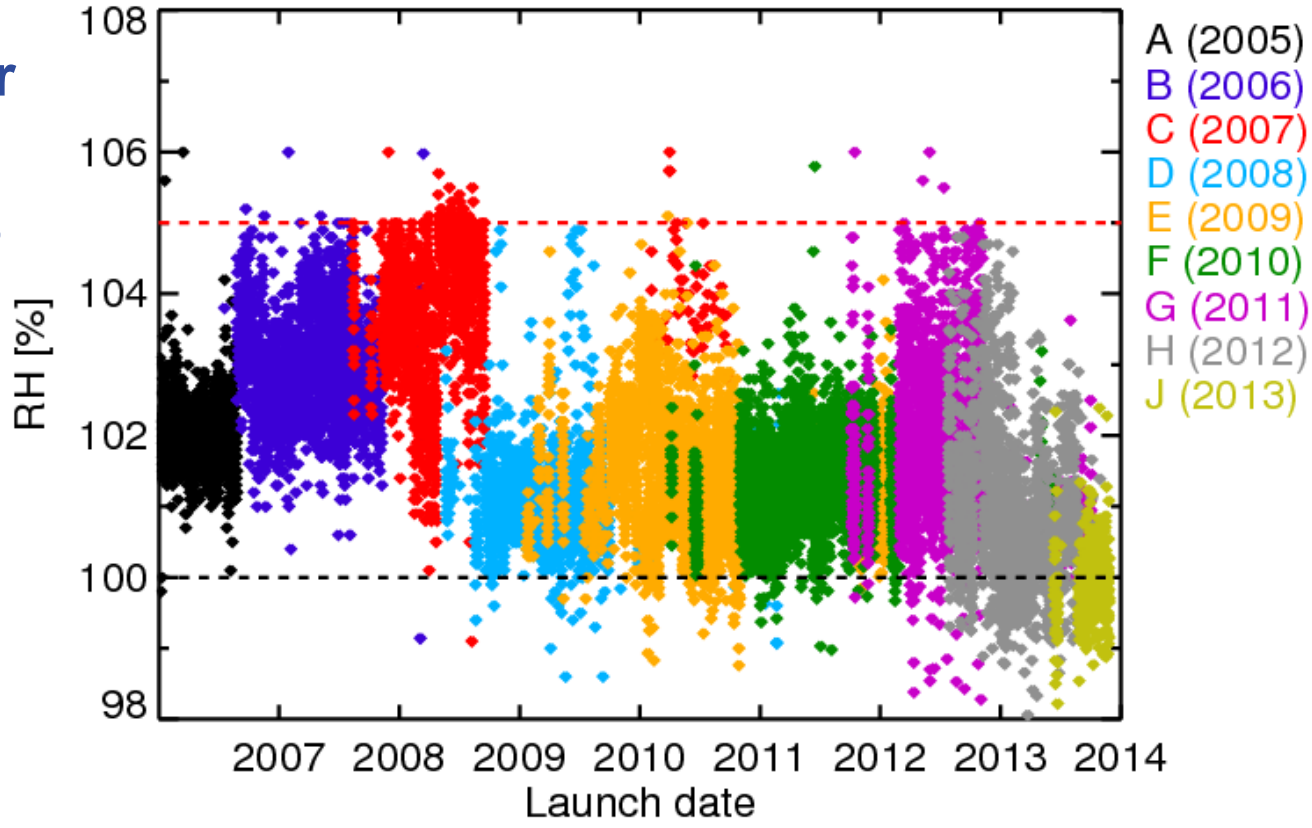


Ground check in SHC

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



Lindenberg



RH: Dry biases

Heating of humidity sensor

- ΔT: radiation correction of T-sensor $RH_c = RH_m \frac{p_s(T + f\Delta T)}{p_s(T)}$
- f: enhancement factor [6, 13] (laboratory experiments)

Uncertainties: ΔT, f

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

Based on RS92 - CFH comparison

Max at 7% at -60°C (similar to Voemel, 2007)

Uncertainty: comparable to correction

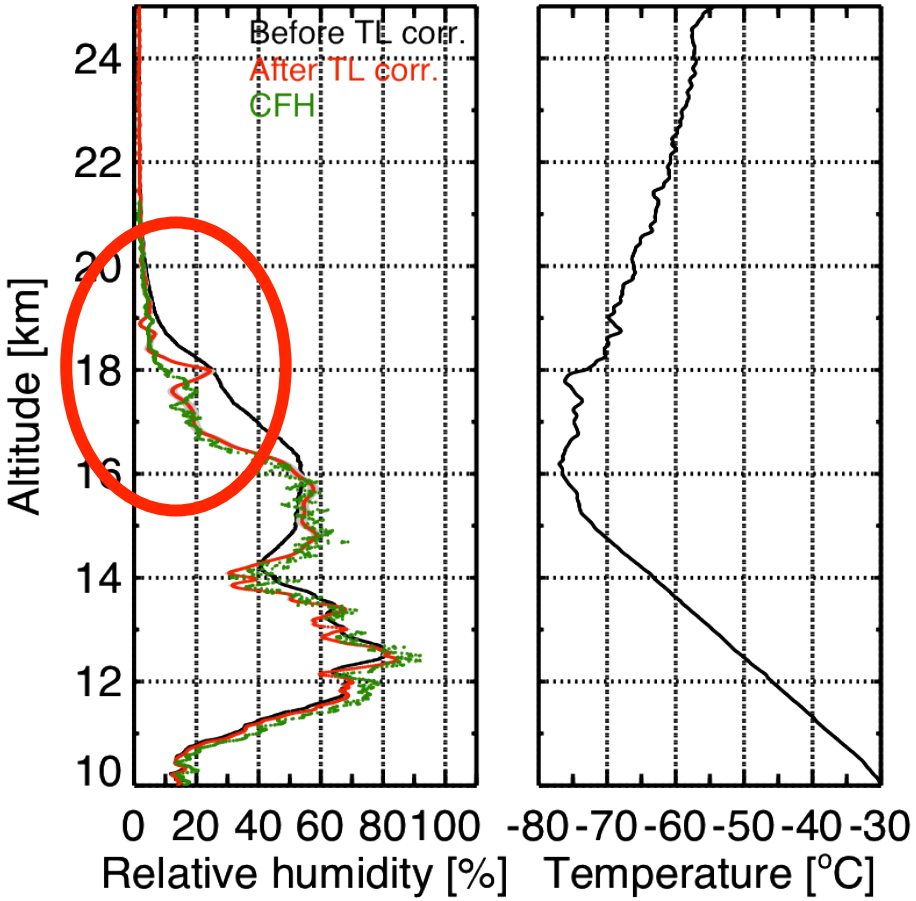
RH: time-lag

Relevant below -40°C,
τ = 20s (τ > 100s @ -80°C)
Flattens features in humidity profile

Correction:
numeric inversion of low-pass filter. Enhances structures & noise (a-posteriori filtering)

Uncertainties: time constant, statistical noise

Yangjiang 20 July 2010

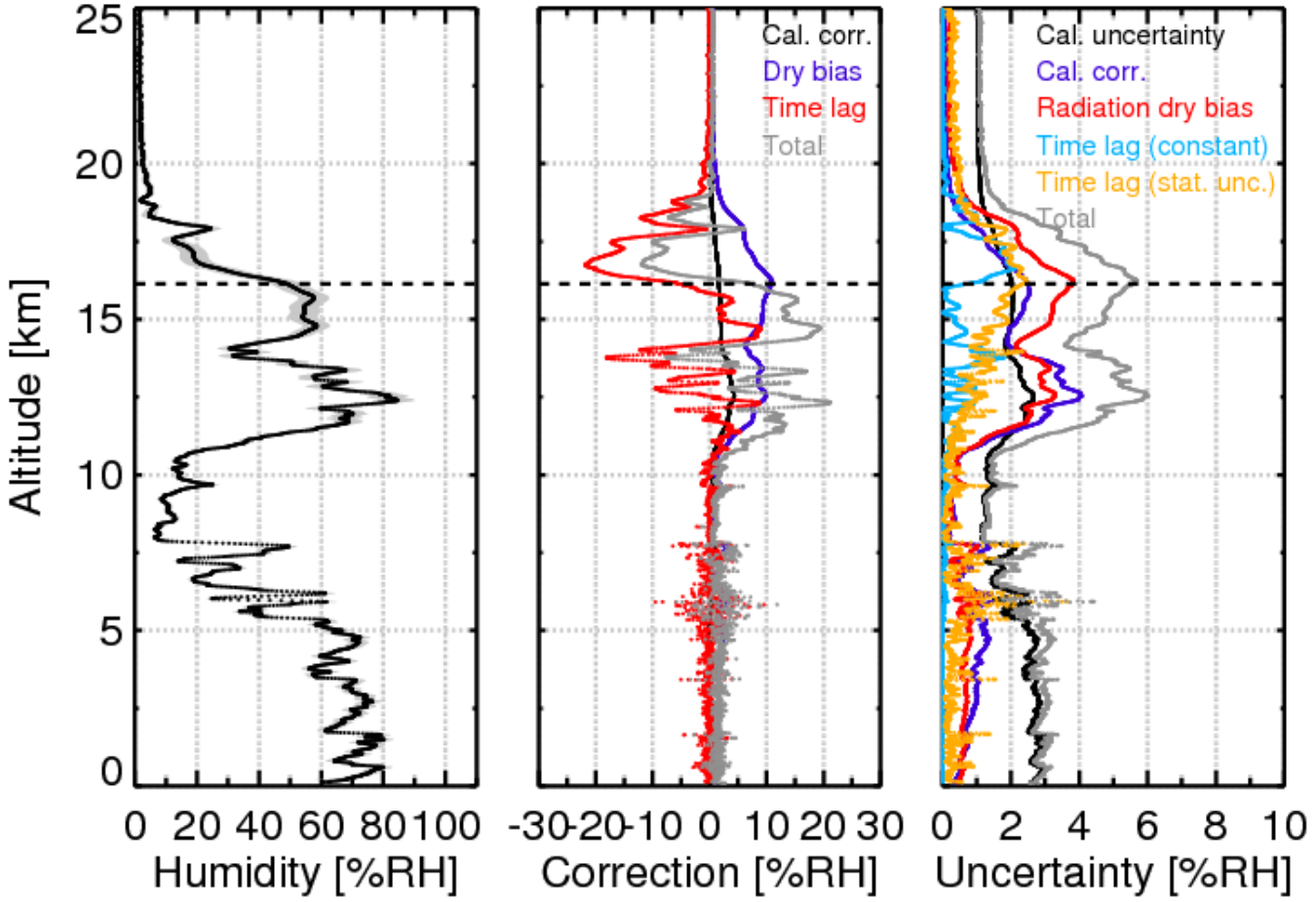


RH: corrections & uncertainties

Dominant uncertainties:

- **Calibration**
- **Cal. correction**
- **Dry bias**

Yangjiang 20 July 2010



Consistency for perfectly co-located measures

- **Two well defined and understood measurements should be consistent:**

$$|m_1 - m_2| < k\sqrt{u_1^2 + u_2^2}$$

  - ✓ **No meaningful consistency analysis possible without uncertainties**
  - ✓ **if m_2 has no uncertainties use $u_2 = 0$ or some design specification**

$\lvert m_1 - m_2 \rvert < k\sqrt{u_1^2 + u_2^2}$	TRUE	FALSE	significance level
k=1	consistent	suspicious	32%
k=2	in agreement	significantly different	4.5%
k=3	-	inconsistent	0.27%

Accounting for mis-match

Co-location / co-incidence matters and inflates the expected difference

- Determine the variability (σ) of a variable (m) in time and space from measurements or models
- Two observations on different platforms are consistent if

$$|m_1 - m_2| < k\sqrt{\sigma^2 + u_1^2 + u_2^2}$$

✓ This test is only meaningful, i.e. observations are co-located or co-incident if:

$$\sigma < \sqrt{u_1^2 + u_2^2}$$

Management of Change

- Change management is mandatory
- A new system, software, or procedure must be evaluated prior to implementation
- Systematic and random errors must be quantified for the new system
- Redundant observations verify the new system (overlap)
- Use transfer functions on old data where required

GRUAN achievements

- GRUAN data product for Vaisala RS92 radiosonde
- Other radiosonde products are being developed (Modem M10, Meisei RS11-G, Meteolabor SRS34, Frost point hygrometer)
- Other products & data streams being developed:
  - GNSS total water vapor column
  - Lidar (T, U)
  - μ-wave radiometer (T, U)
  - FTS (various trace gases)
- Archive with ~30,000 GRUAN-processed radiosounding profiles
- > 20 GRUAN-related publications

GRUAN and Antarctic research

- One or more GRUAN sites in Antarctica would provide metrologically traceable measurements of the column with uncertainty estimates
  - Providing a constraint to analyses and reanalyses
  - Helping process understanding
  - Providing long-term well-understood records
  - Helping to validate satellite program measurements
- Membership of GRUAN is not overly onerous
- Membership brings benefits arising from support of Lead Centre, Working Group, Task Teams and other sites

Minimum GRUAN site requirements

- Once weekly production sonde
- Once a month research sonde capable of measuring water vapour through the Lower Stratosphere
- GNSS-PW measurements or a similar capability
  - Monumentation issues may preclude GNSS-PW in parts of Antarctica
- A representative aims to attend the annual Implementation and Coordination Meetings (held at / near a site)

In a nutshell

- GRUAN is about…
- Being a network
  - Gaining & sharing knowledge (task teams etc.)
  - Interaction with data users and other high quality observing sites worldwide (ICMs)
- Growing international recognition of GRUAN, potentially attractive for (national) funding agency

Questions