# Impact of Greenhouse Gases: Measuring temperature change

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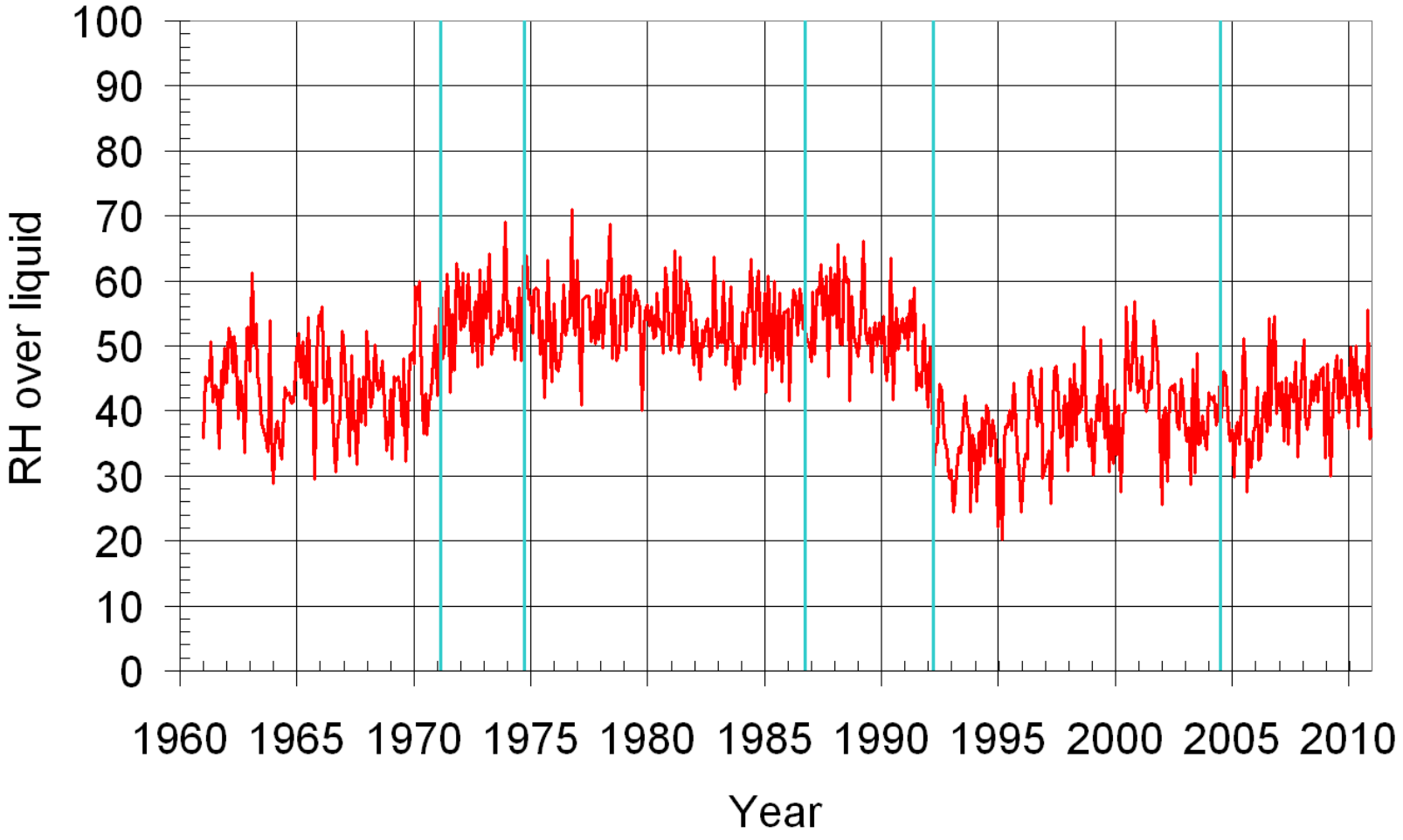
# Water vapor trends in the troposphere?

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



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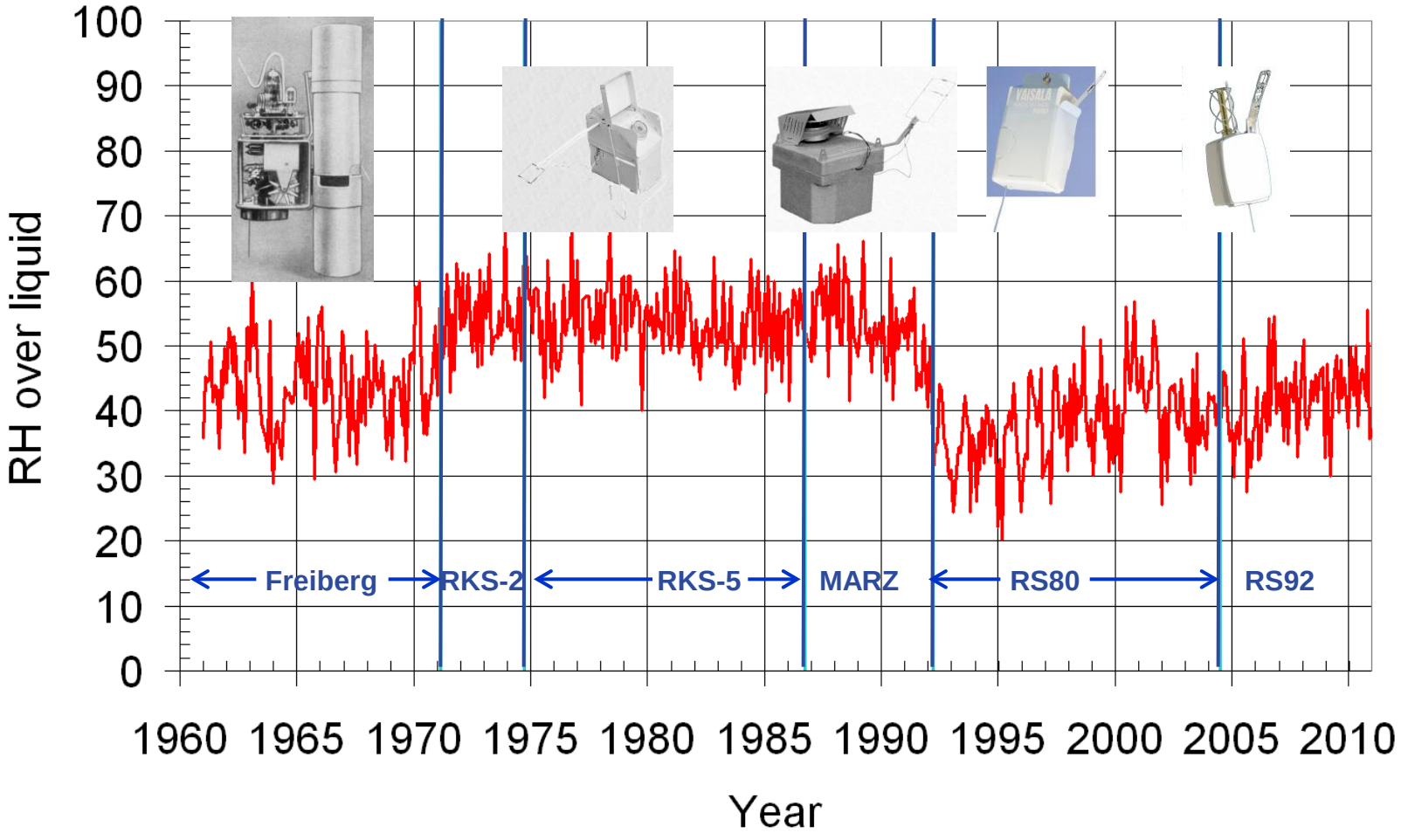
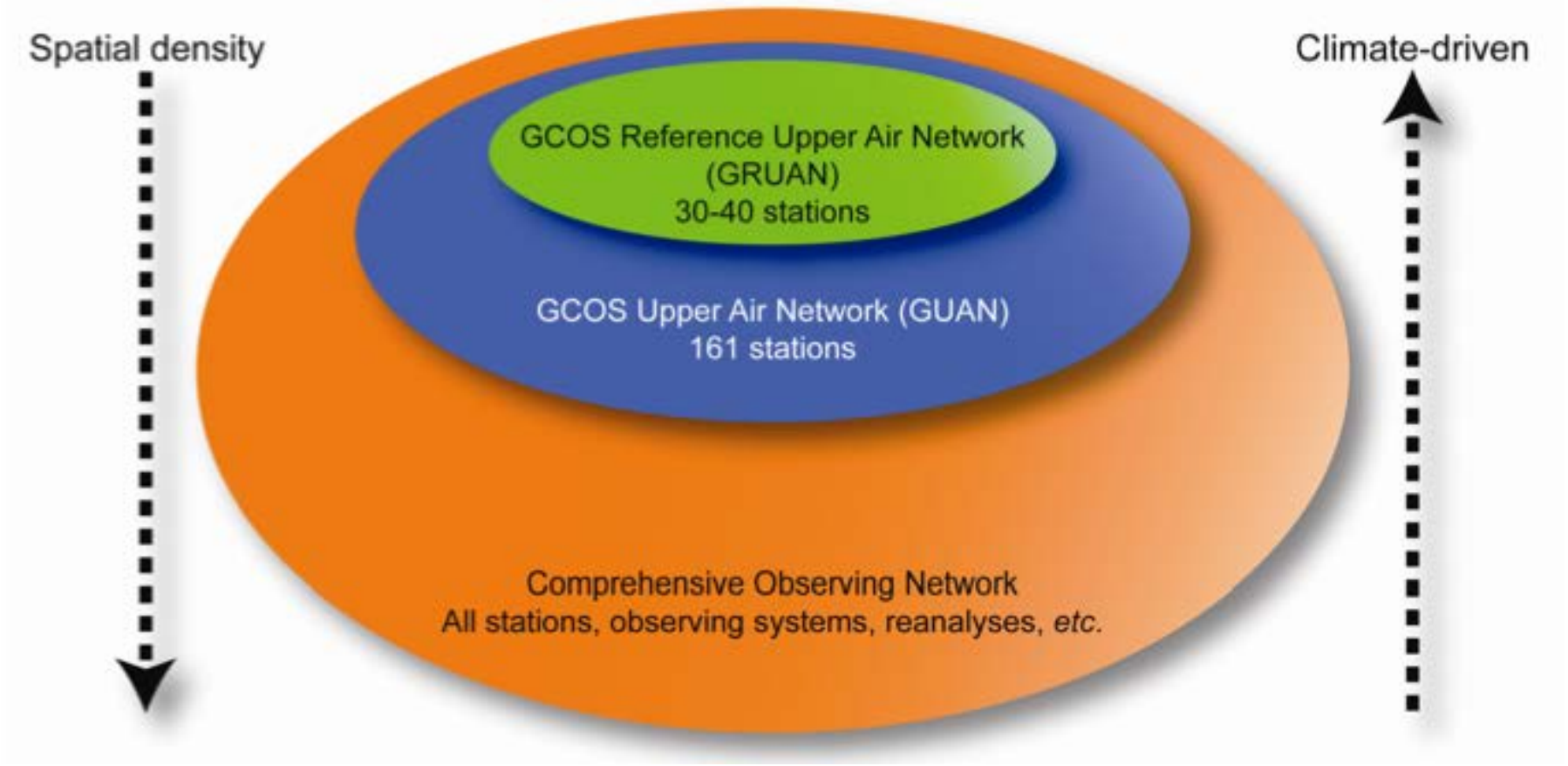


# GCOS Reference Upper Air Network


See **www.gruan.org**

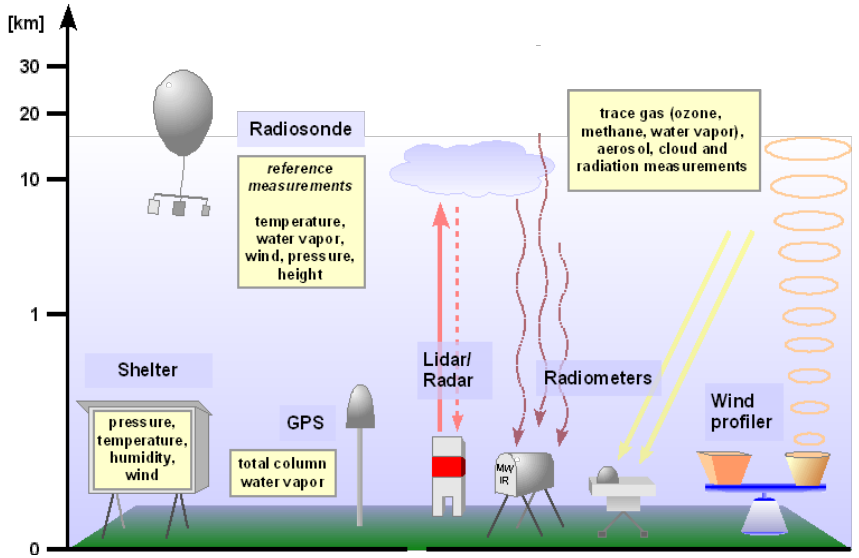
# GRUAN's relationship to existing observational networks




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)

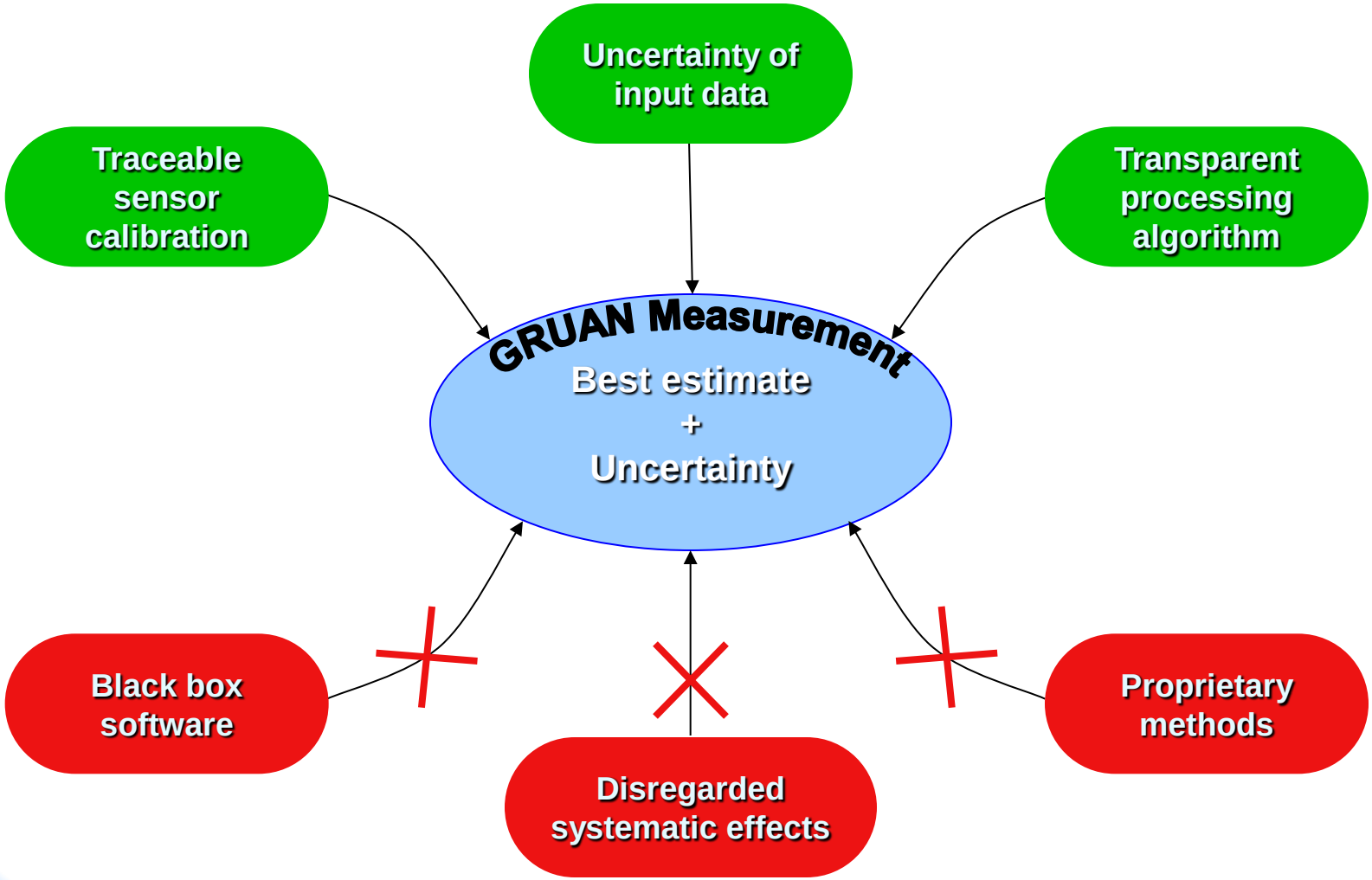
Priority 2: Ozone, …

# 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

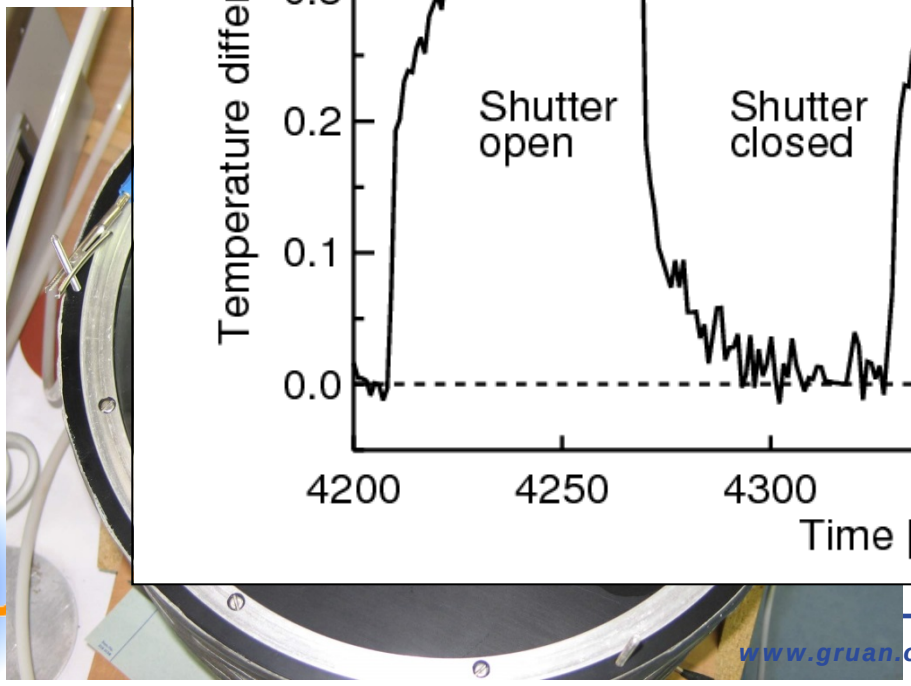
- The RS92 sonde model is the production sonde used by many sites around the world
- Vaisala provides raw (unprocessed) measurement data
- GRUAN Lead Centre and colleagues have undertaken an end-to-end processing understanding and quantifying uncertainty in each step. Following slides just a subset for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

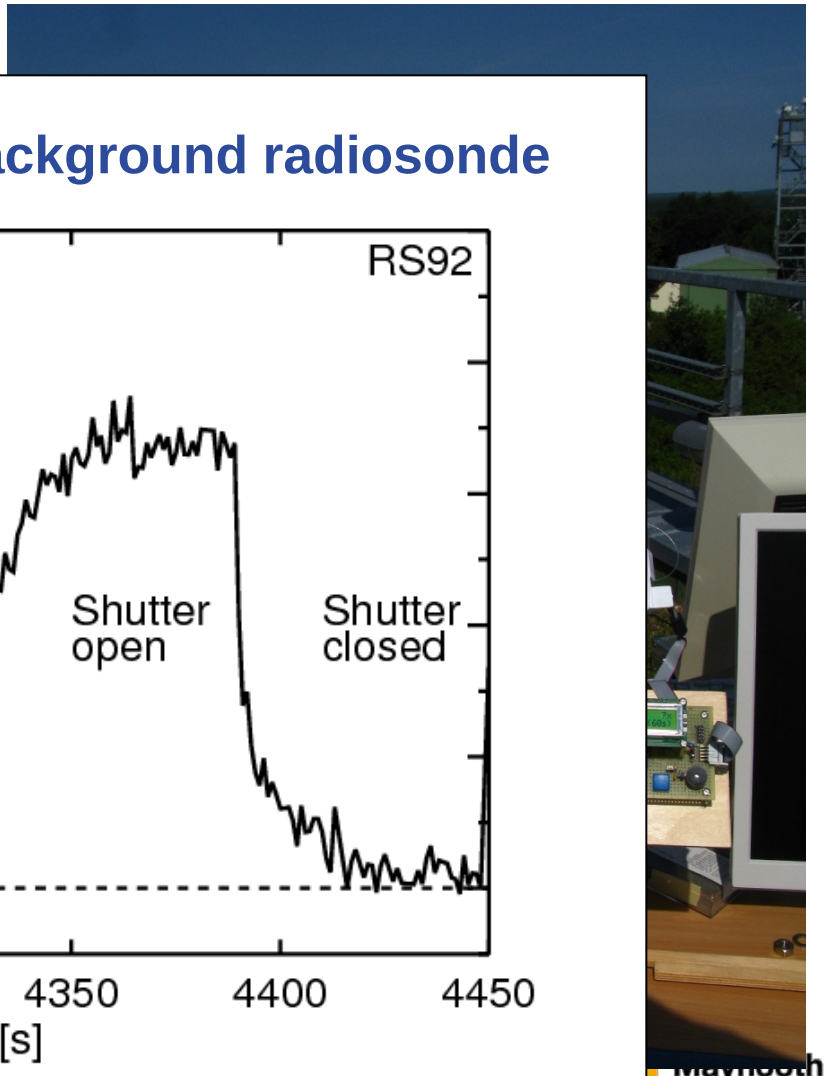
# Radiation error: Laboratory experiments

**Shadow RS92 records background temperatur**

**Simultaneo**

**p=[3 hPa ,**



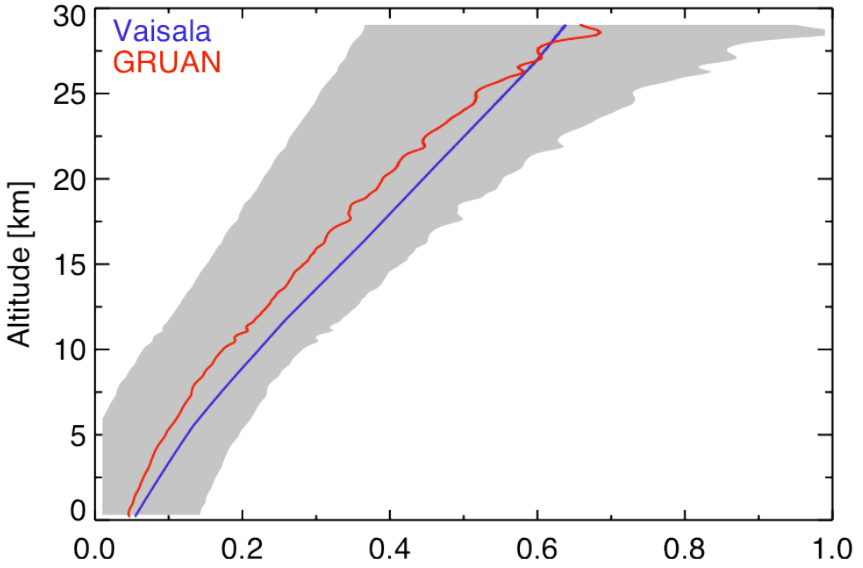


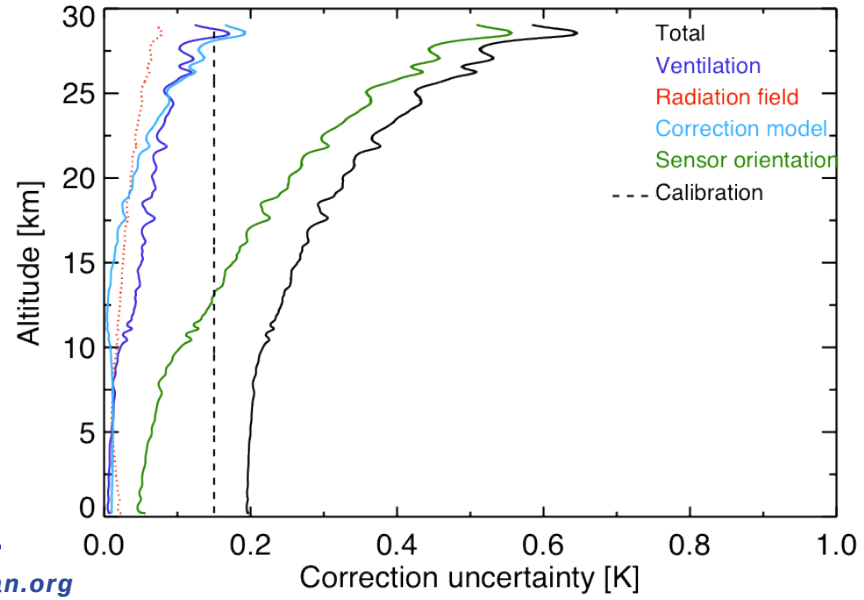
## Difference illuminated – background radiosonde

# T-correction profile

**Sources of measurement uncertainty:**

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



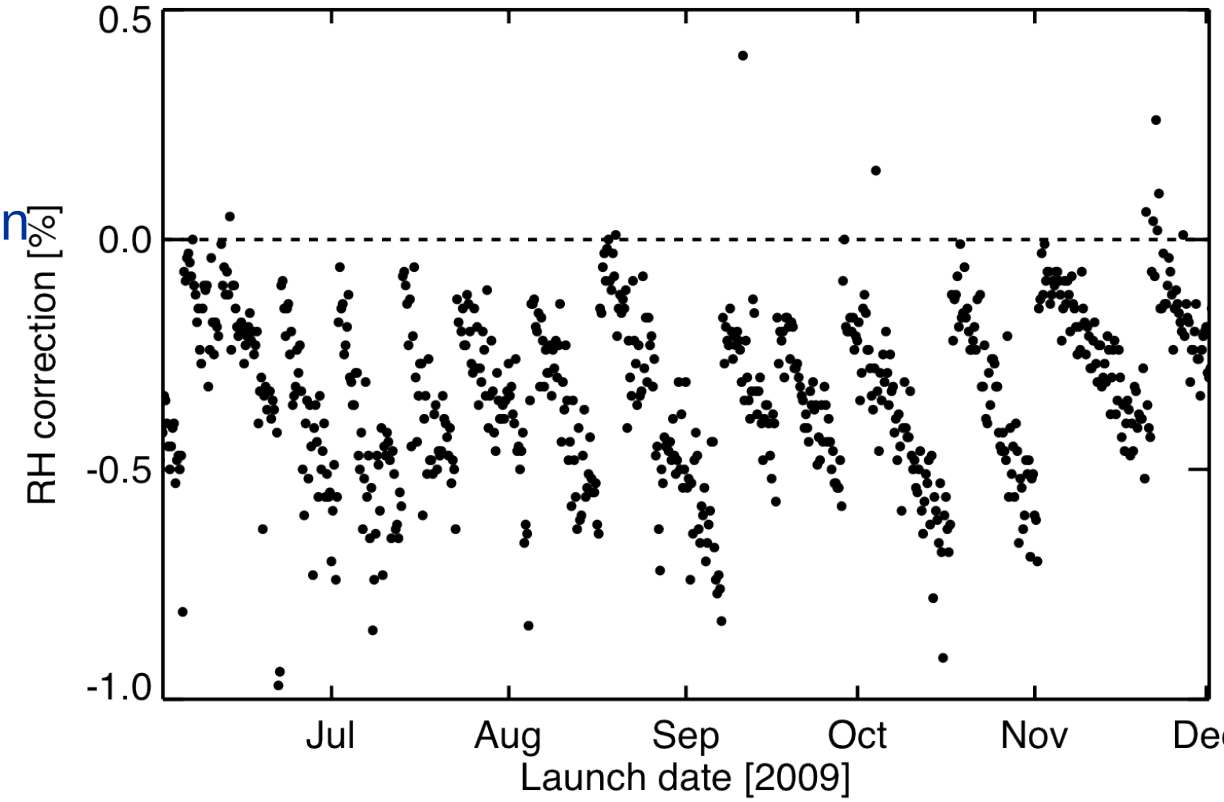
# Humidity

Undo RH recalibration

Errors

- T-dependent calibration
- Dry bias
- Time lag

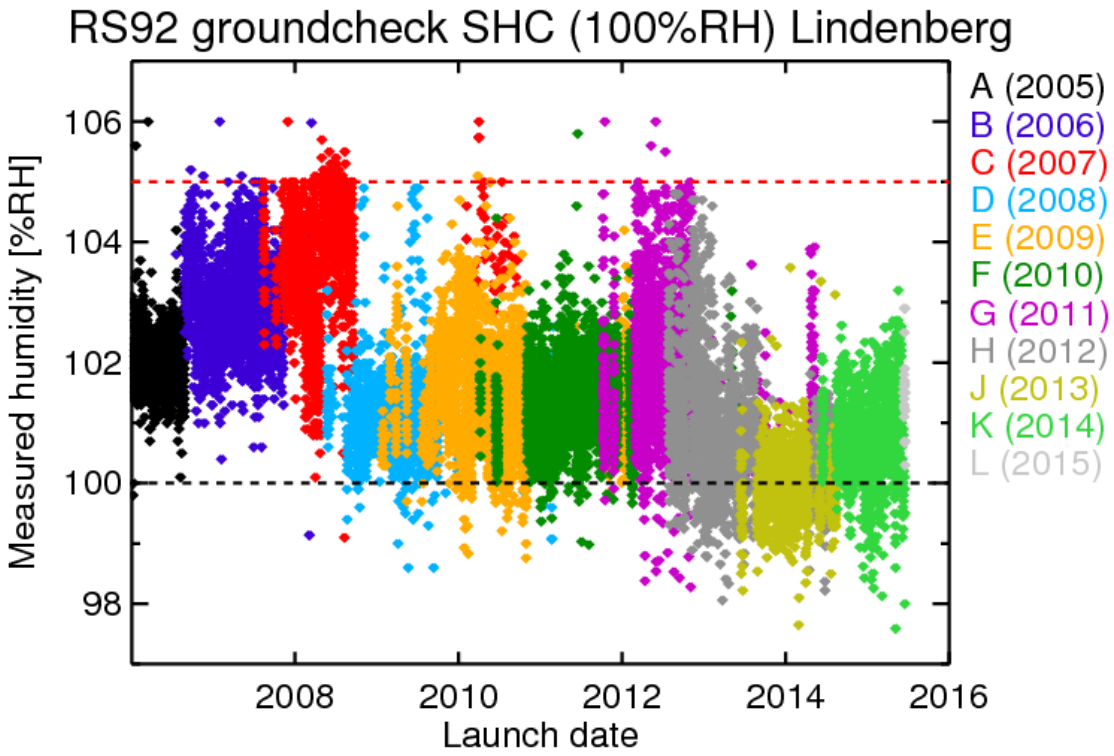
## Lindenberg



# Ground check in SHC

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

## Lindenberg



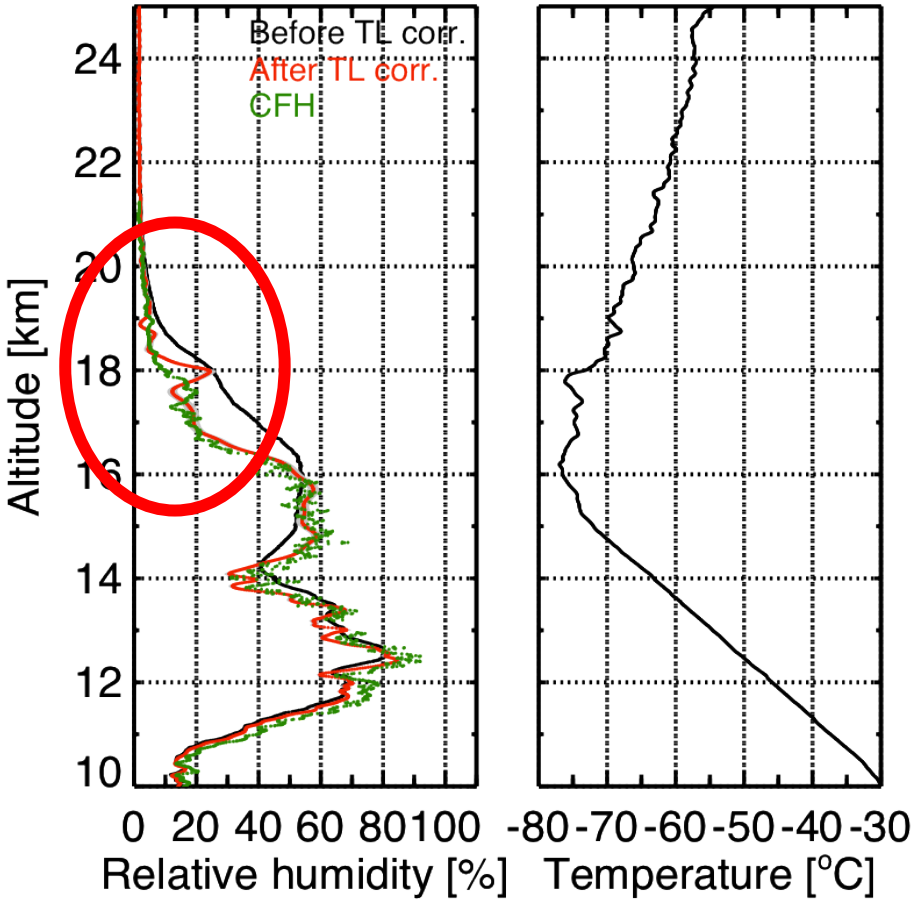
# RH: time-lag

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

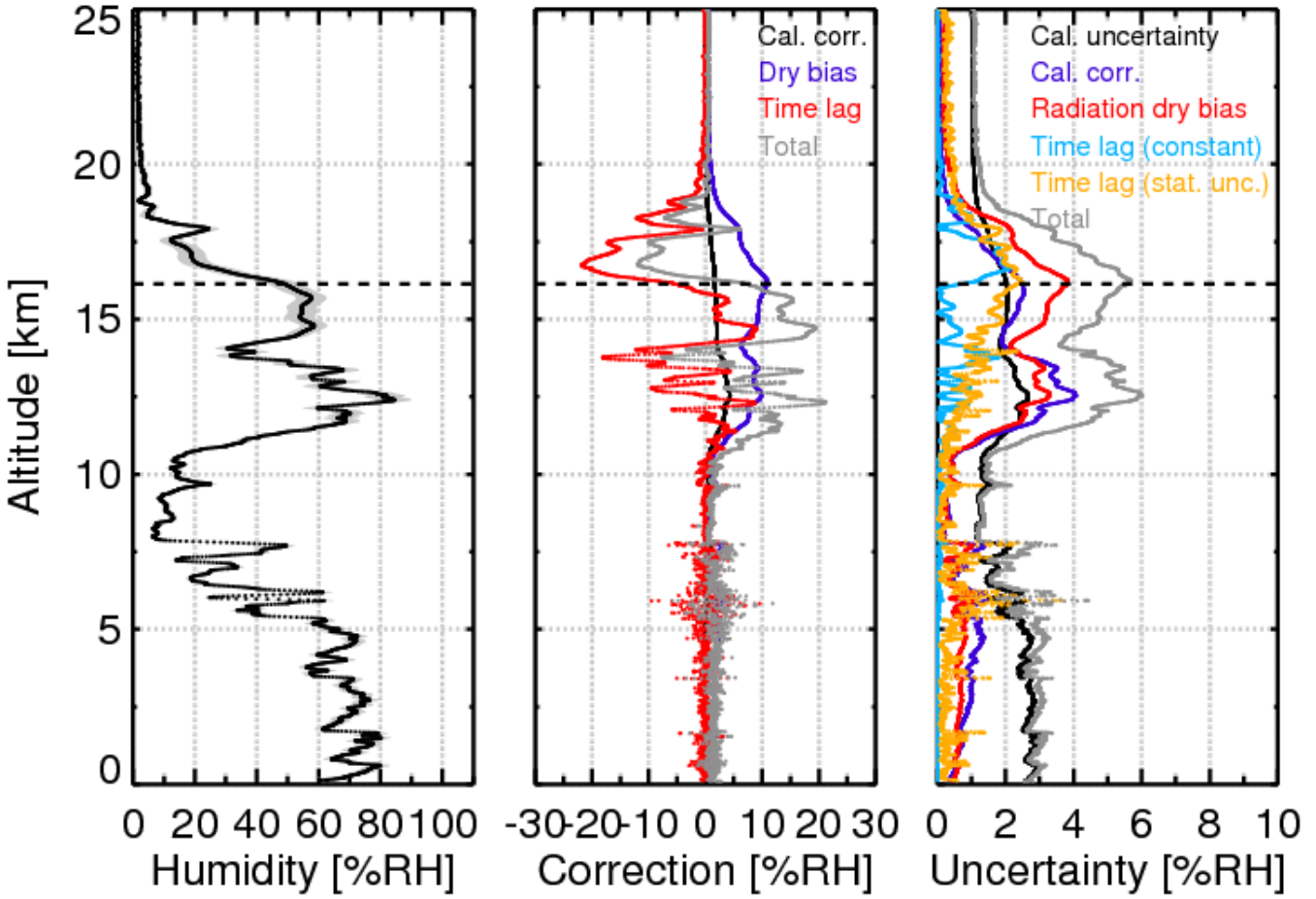


# RH: corrections & uncertainties

**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 ($\sigma$) of a variable (m) in time and space from measurements or models
- Two observations on different platforms are consistent if

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

✓ 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 metrology community

- GRUAN has at its heart metrological best practices
- To be sustainable requires a sustained engagement between climate, operational and metrological communities
- There are plenty of opportunities to get involved
- There are many potential projects if funding can be secured
- Please contact the Lead Centre - gruan.lc@dwd.de with any ideas / suggestions

# Questions