The GCOS Reference Upper Air Network: The path forward

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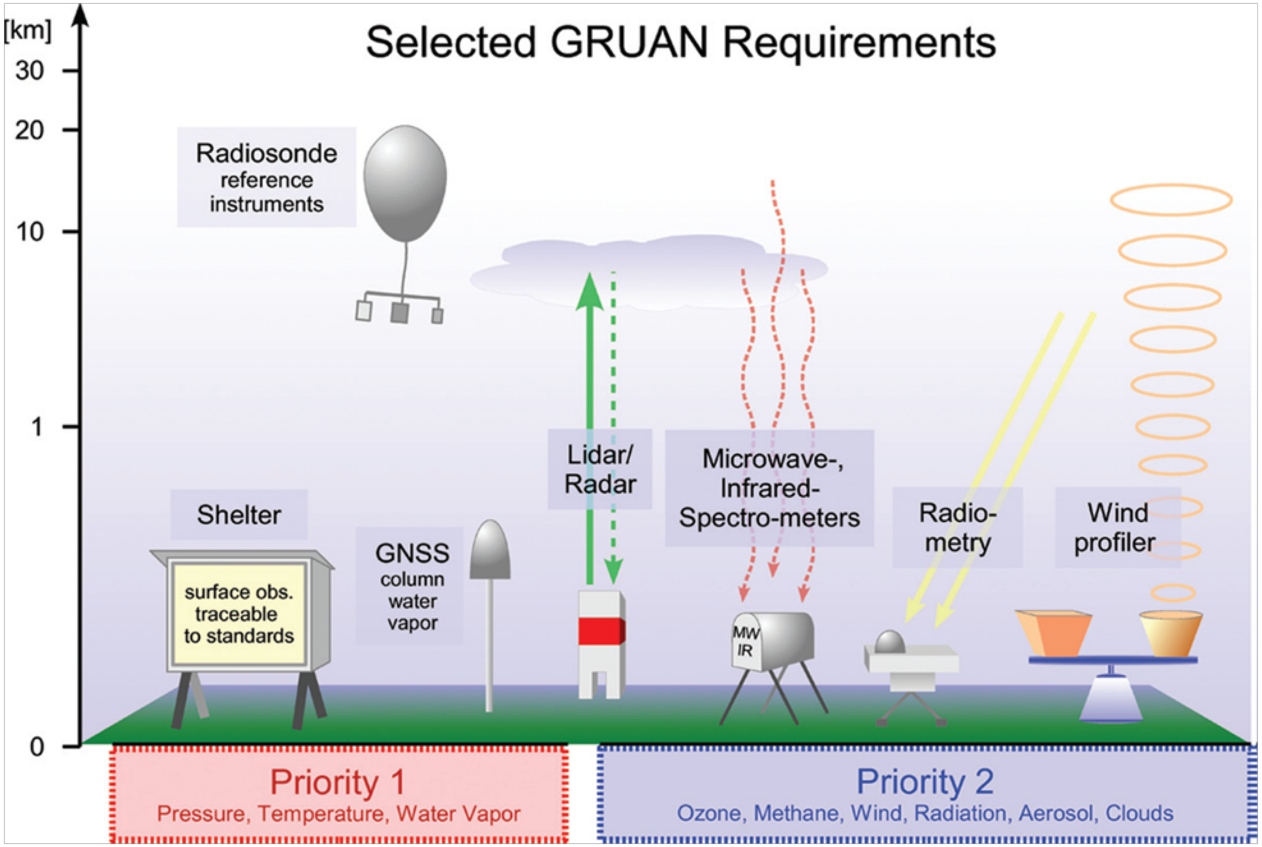
GRUAN Mandate

The GCOS Reference Upper-Air Network is required to:

1. **Provide long-term high quality climate records**
2. **Constrain and calibrate data from more spatially-comprehensive global observing systems (including satellites and current radiosonde networks)**
3. **Fully characterize the properties of the atmospheric column**

Measured quantities



- **Focus on priority 1: Pressure, temperature, water vapor**
- **Focus on upper troposphere and stratosphere**
- **Focus on reference observations for climate research**

Initial Network

GCOS Reference Upper-Air Network

To be expanded to about 30 to 40 stations worldwide

Temperature and water vapor

Accuracy requirements:

- **Water vapor:** **2%**
- **Temperature:** **0.1K (troposphere)**
  0.2K (stratosphere)

Long term stability:

- **Water vapor:** **1%**
- **Temperature:** **0.05K**

Requirements are not a realistic assessment of current capabilities.

They are the goal

Reference radiosonde: Current status

Research instruments:

- **Water vapor: CFH uncertainty ~4% - 9% (mixing ratio)**
- **Temperature: ATM uncertainty ~0.3K**

Reference radiosonde: Current status

Research instruments:

- **Water vapor: CFH uncertainty ~4% - 9% (mixing ratio)**
- **Temperature: ATM uncertainty ~0.3K**

Reference radiosonde:

What is a reference measurement?

A reference measurement gives:

- **the best estimate for the quantity to be measured**
- **the best estimate for the level of confidence for this measurement (i.e. uncertainty)**

The measurement uncertainty is a property of the measurement

What is a reference measurement?

To be a reference

GRUAN observations must include

the measurement uncertainty

Sources of uncertainty

- **Sensor calibration:**
  Accuracy of calibration reference
  Accuracy of calibration model

- **Sensor integration:**
  Integration into radiosonde
  Telemetry limitations

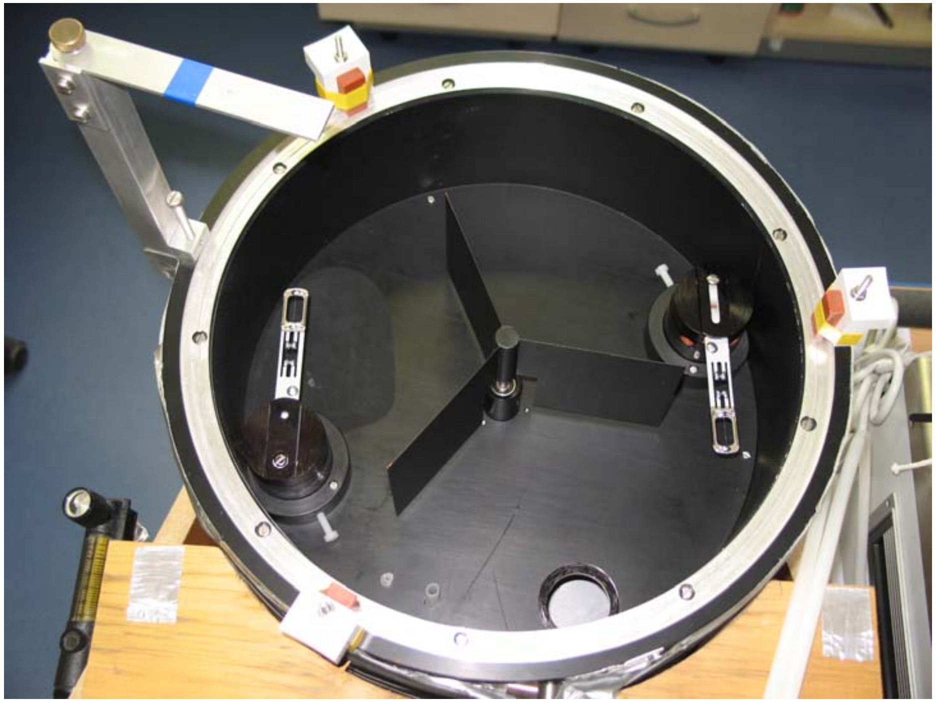
- **Sensor characterization:**
  Time lag variation of polymer sensor
  Controller stability of frostpoint hygrometer
  Production variability

- **External influences:**
  Radiation error
  Balloon contamination
  Sensor icing

Sources of uncertainty Example: Humidity

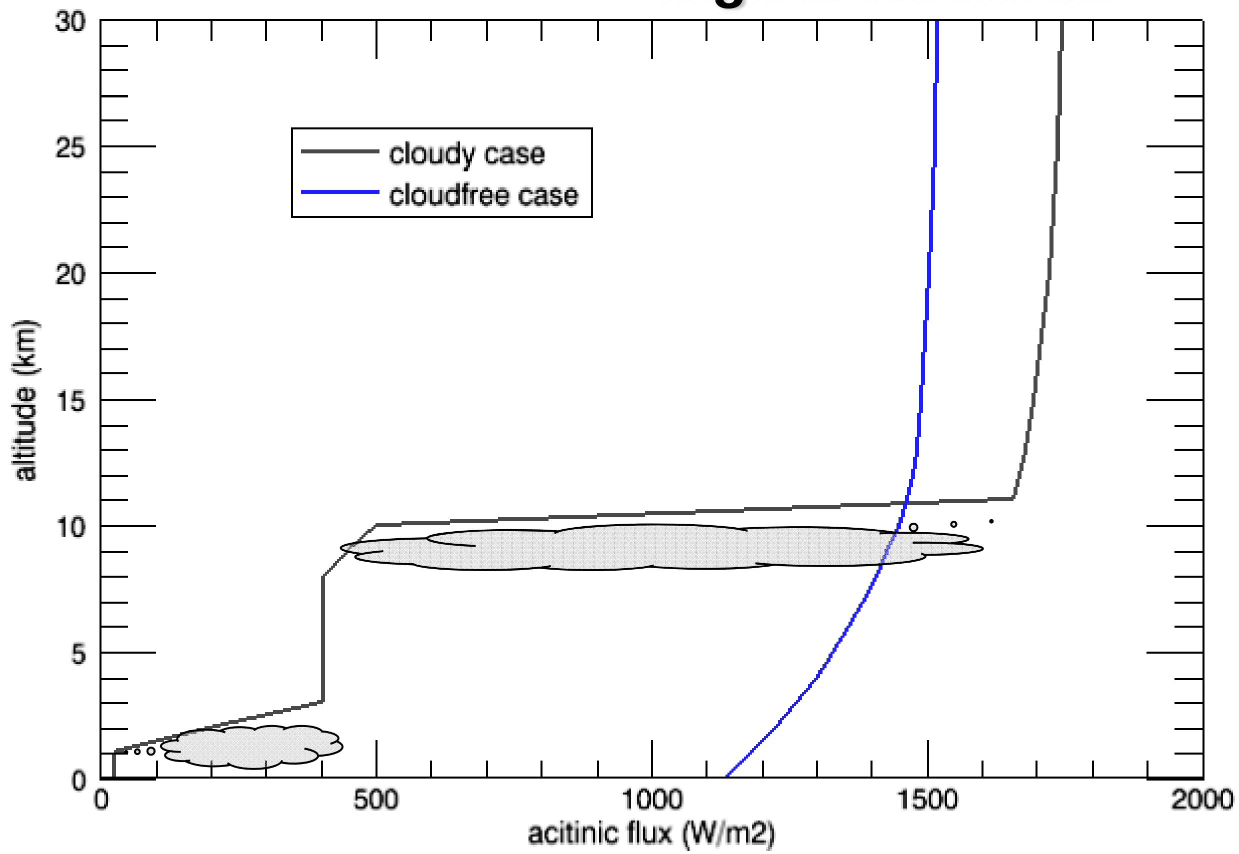
	Vaisala RS92 daytime
• **Sensor calibration:**	
Accuracy of calibration reference	small
Accuracy of calibration model	small
• **Sensor integration:**	
Integration into radiosonde	< 4% RH
Telemetry limitations	1% (default setting)
• **Sensor characterization:**	
Time lag variation of polymer sensor	< 10%
Controller stability of frostpoint hygrometer	
Production variability	2%
• **External influences:**	
Radiation error	< 40 % (rel. error)
Balloon contamination	? (troposphere)
Sensor icing	?

Temperature and humidity: Radiation effect

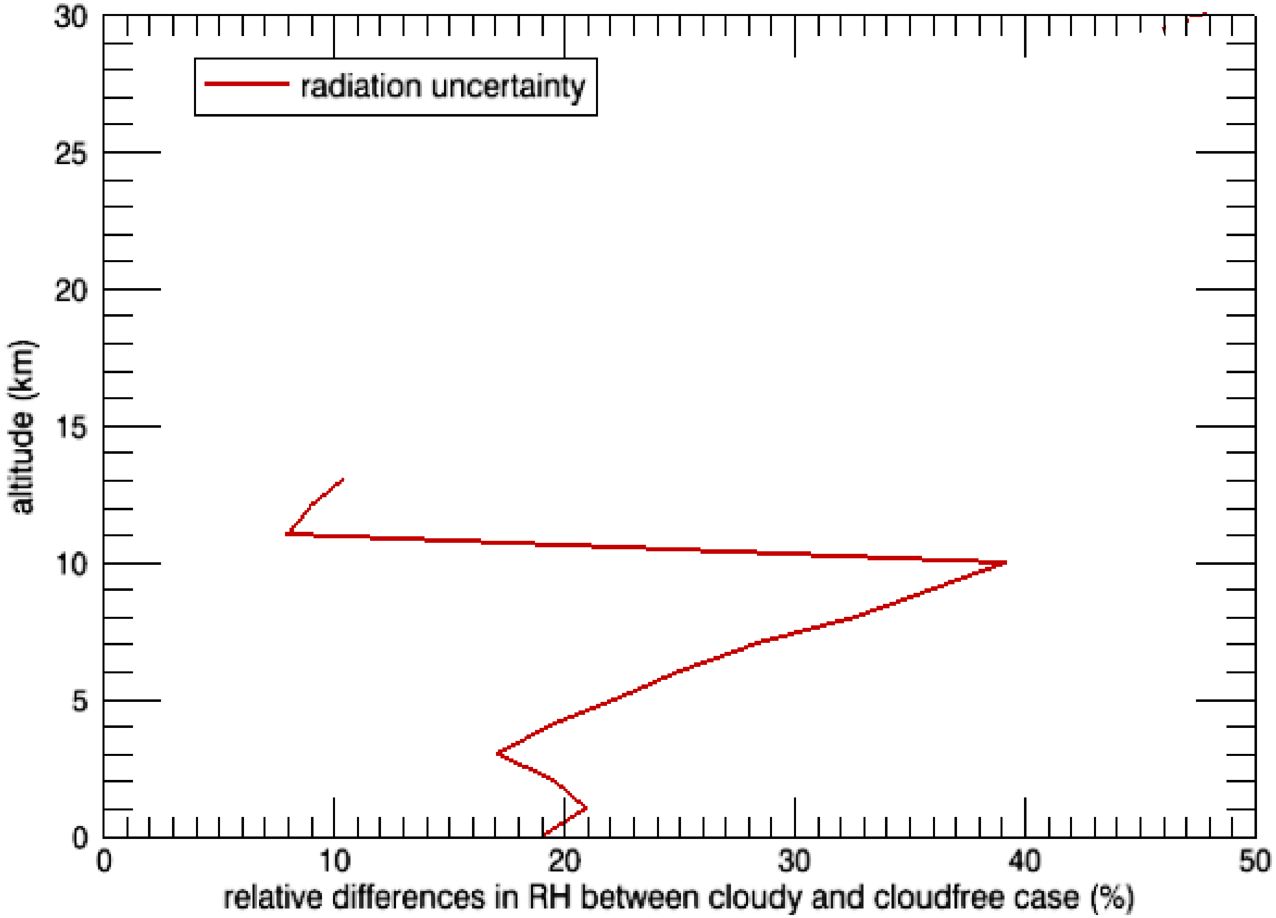


Temperature: Radiation effect

Actinic flux example: - Lindenberg (LUAMI)
- low level stratus
- high level cirrus



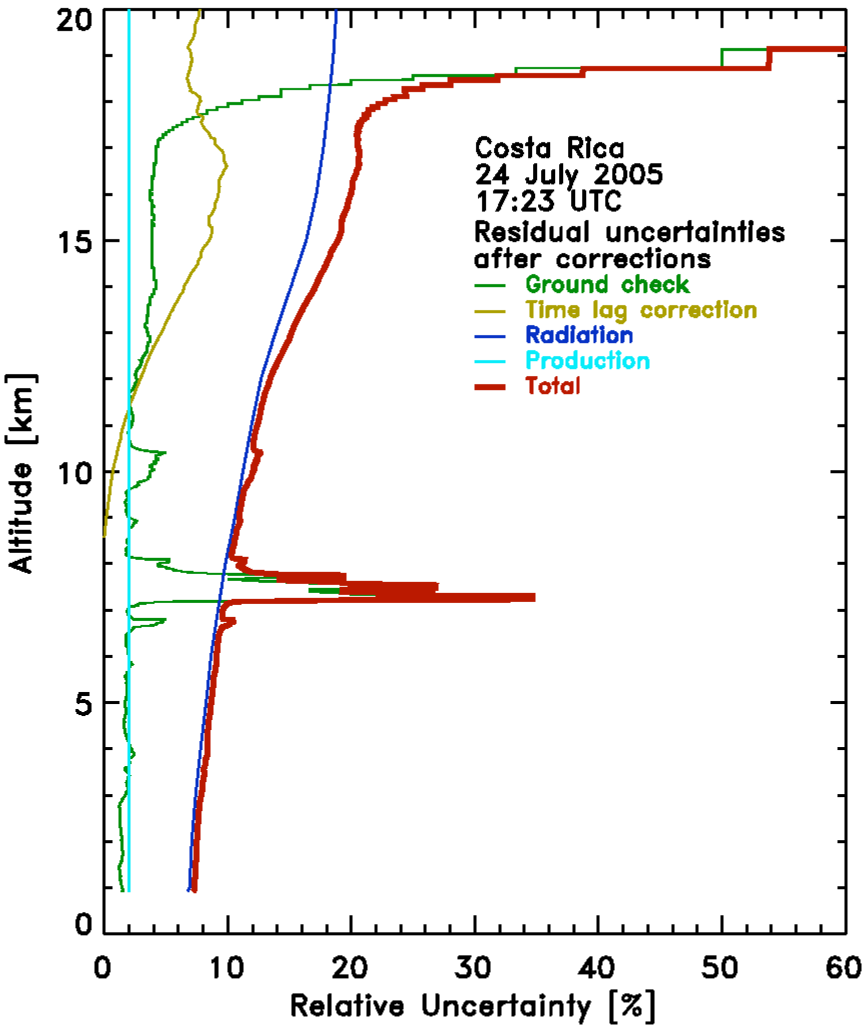
Humidity uncertainty



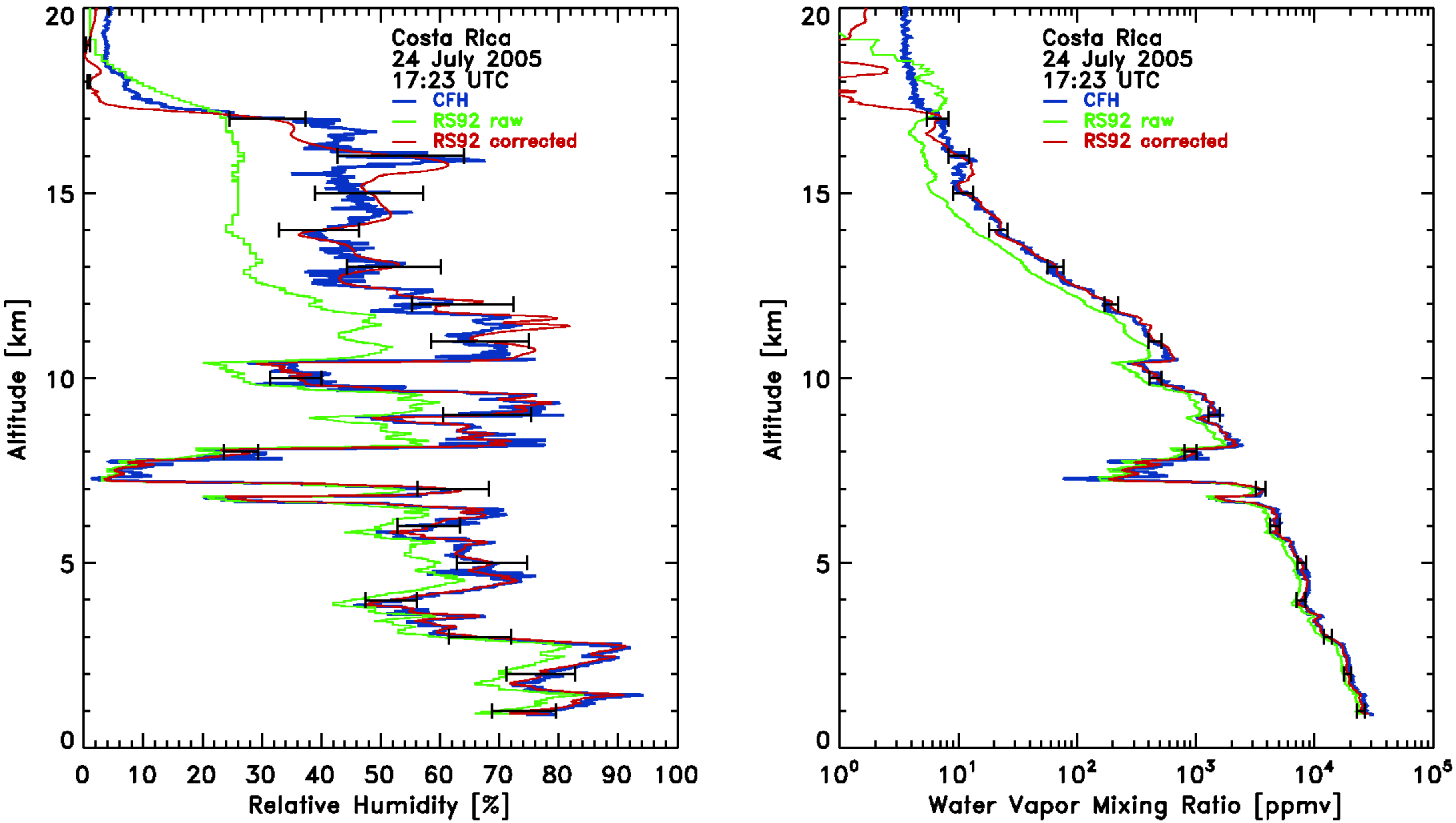
Example Humidity:
Combined uncertainties daytime

Uncertainties considered:

- **Ground check:** +/- 0.5% absolute
- **Integer resolution:** +/- 0.5% absolute
- **Radiation correction:** < 20% relative
- **Time lag correction:** < 10% relative
- **Production variability:** < 4% relative



Example Humidity: daytime
Corrected profile with uncertainties



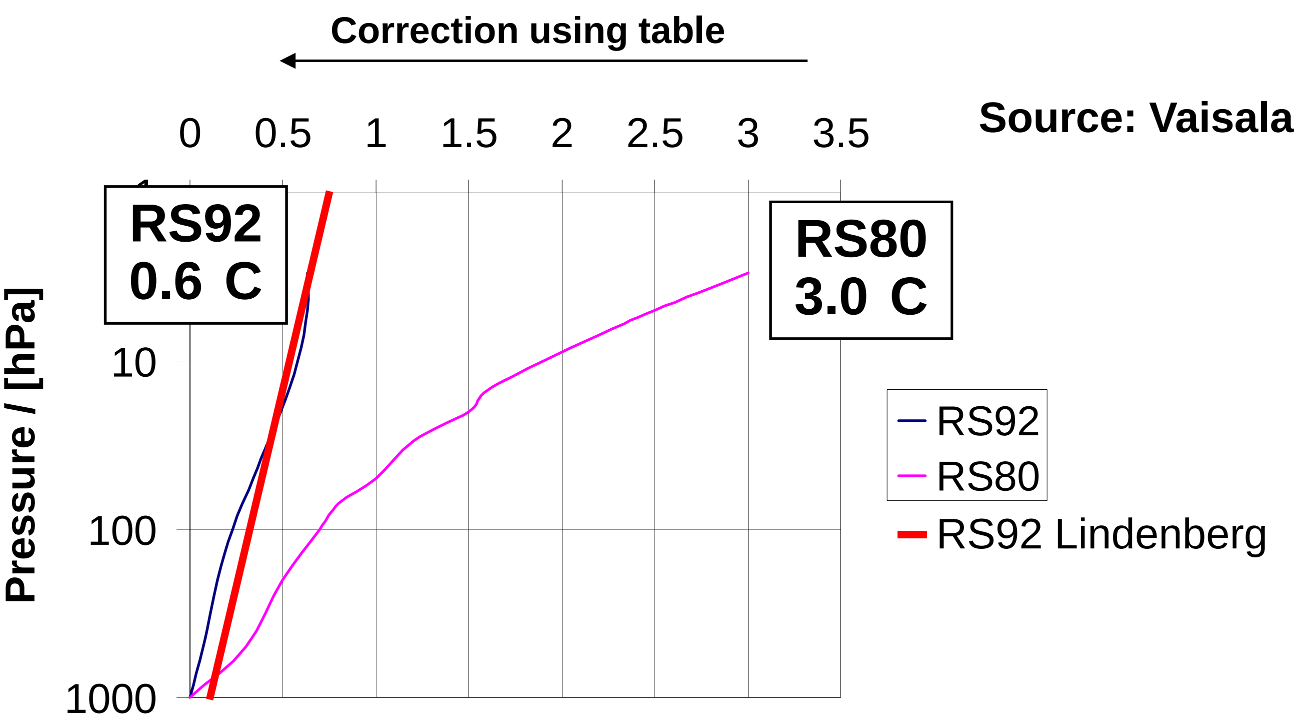
Questions?

GRUAN data: Generalization

Application of vertical uncertainty profile:

- **Metric for sensor comparison**
- **Quantification of vertical range of sensor output**
- **Quantification of 'Reference' instrument**
- **Identification of need for improvement**
- **Tool to manage sensor change**

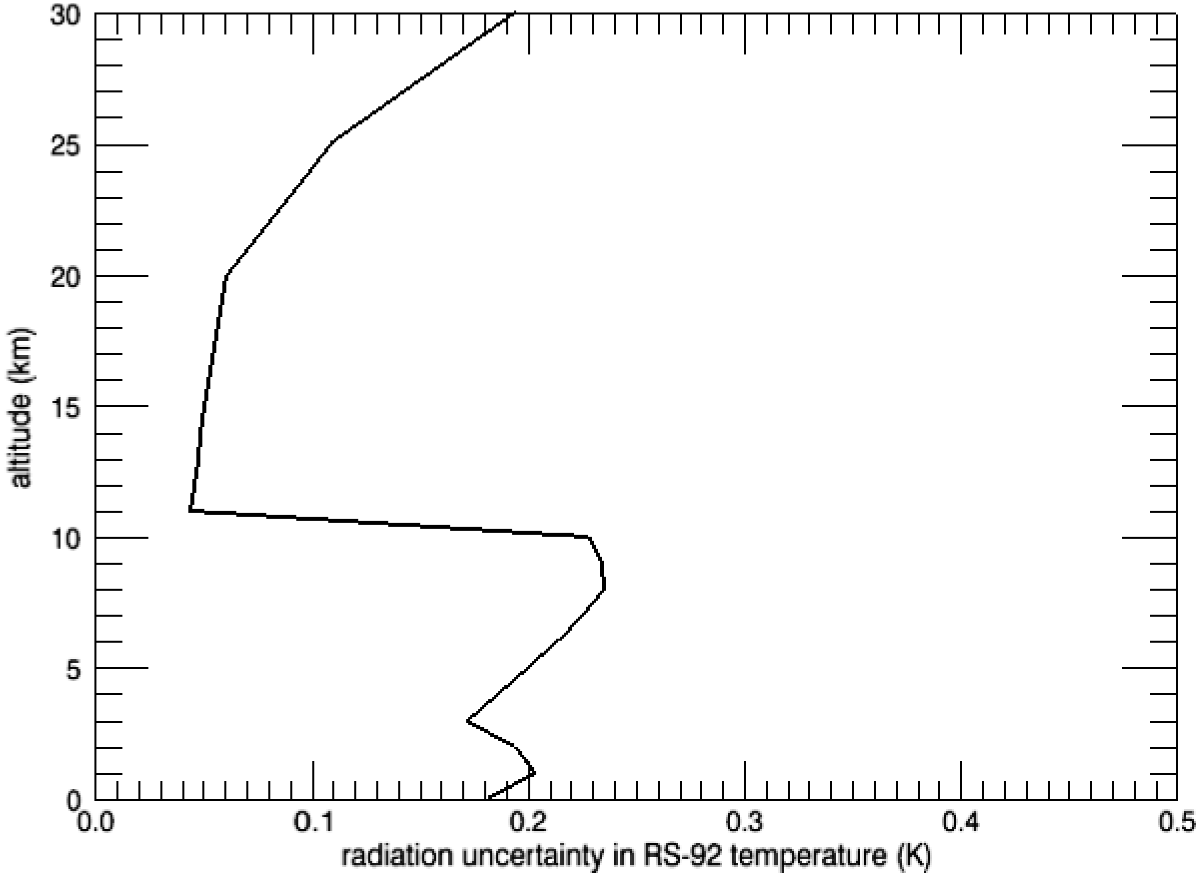
Temperature: Radiation effect



Lindenberg assumptions: On average 50% of maximum insolation
Ventilation independent
No clouds
Downward direct, downward and upward diffuse radiation
Radiative streamer model for radiation field

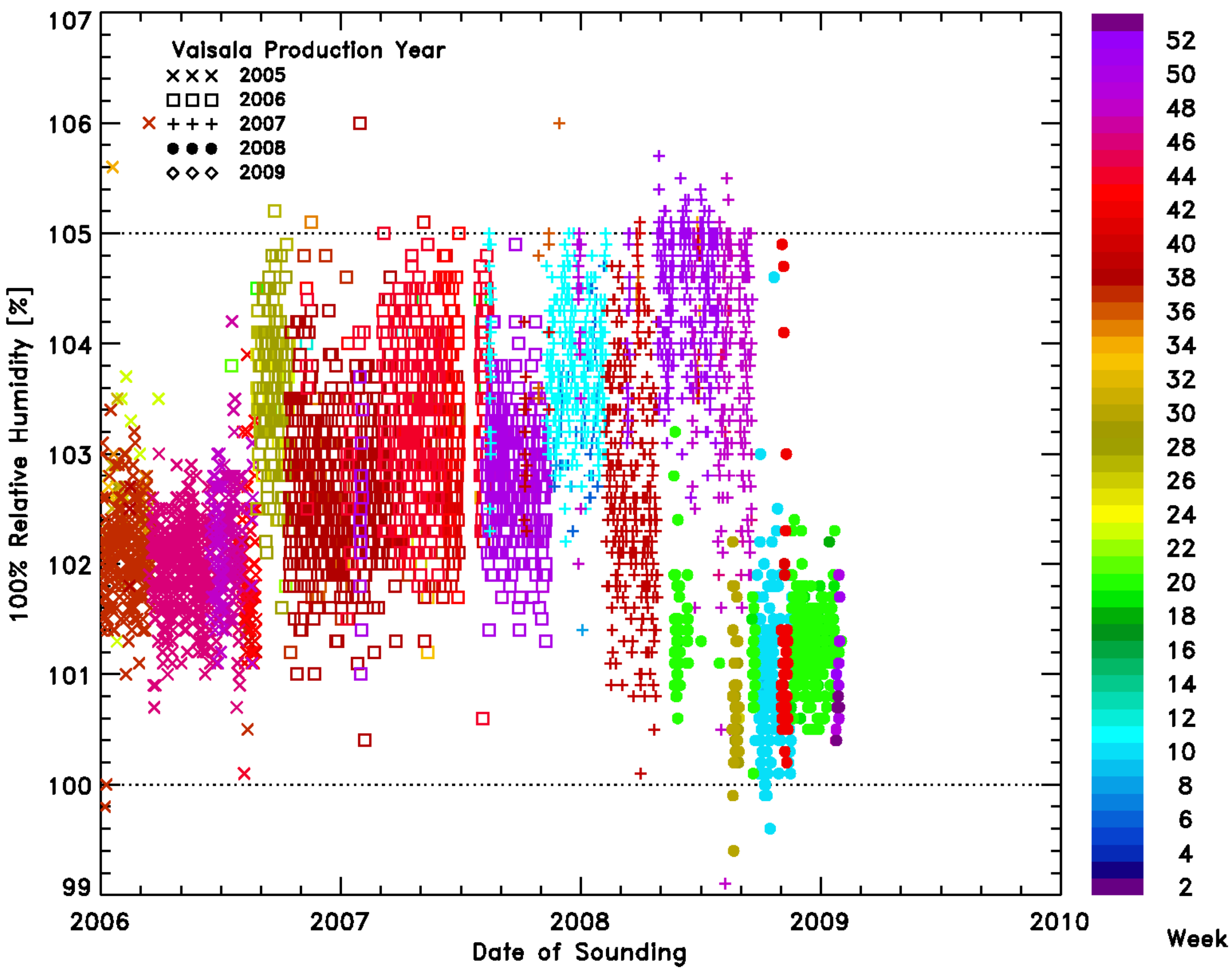
Temperature uncertainty

Remaining uncertainty after radiation correction (Lindenberg correction, Vaisala RS92 only)



Example Humidity: Ground check 100%

100% check



Sources of uncertainty
Example : Temperature

	Vaisala RS92 daytime
Sensor calibration:	
Accuracy of calibration reference	0.01K (est.)
Accuracy of calibration model	0.01K (est.)
Sensor integration:	
Integration into radiosonde	? *
Telemetry limitations	-
Sensor characterization:	
Time lag variation of polymer sensor	
Controller stability of frostpoint hygrometer	
Production variability	
External influences:	
Radiation error	0.2 K * (strat.)
Balloon contamination	?
Sensor icing	>1.0K (temporarily)

(* after correction is applied)

GRUAN as reference

Distinguish between sources of uncertainty that:

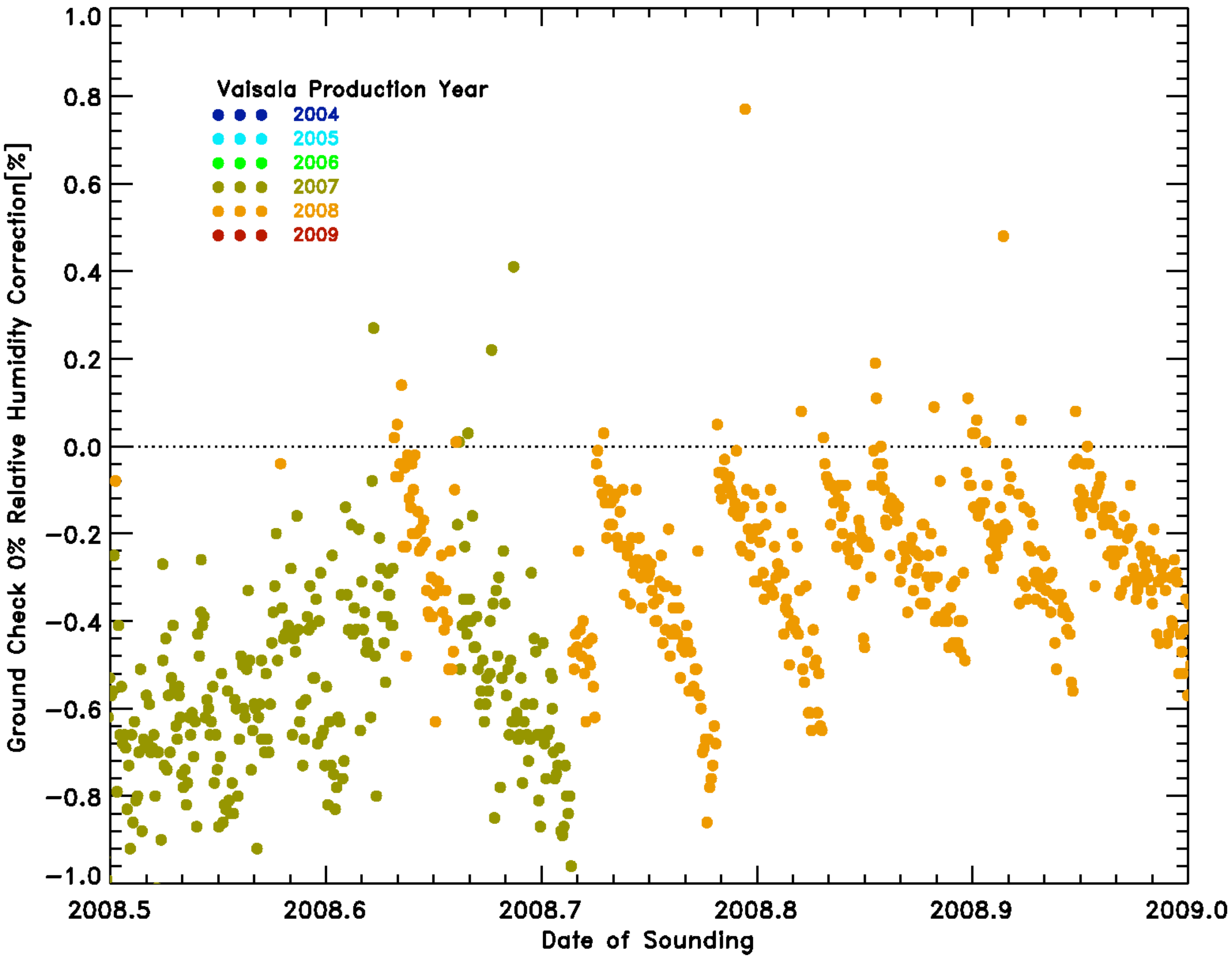
- **Can be quantified**
  ➔ **quantify uncertainty**

- **Can be corrected**
  ➔ **quantify remaining uncertainty after correction**

- **Can not be quantified nor corrected**
  ➔ **flag as questionable**

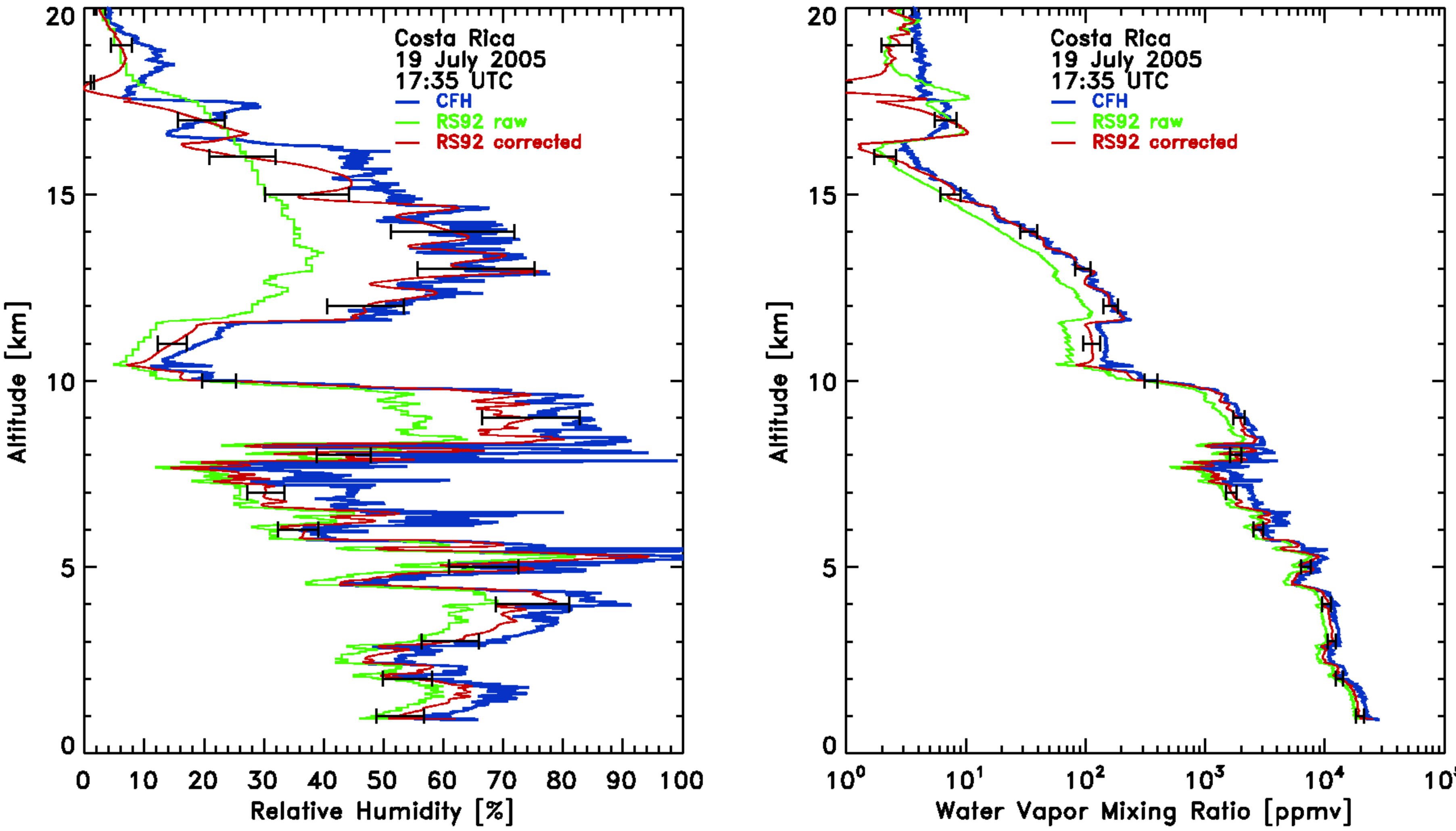
Example Humidity: Ground check 0%

0% check

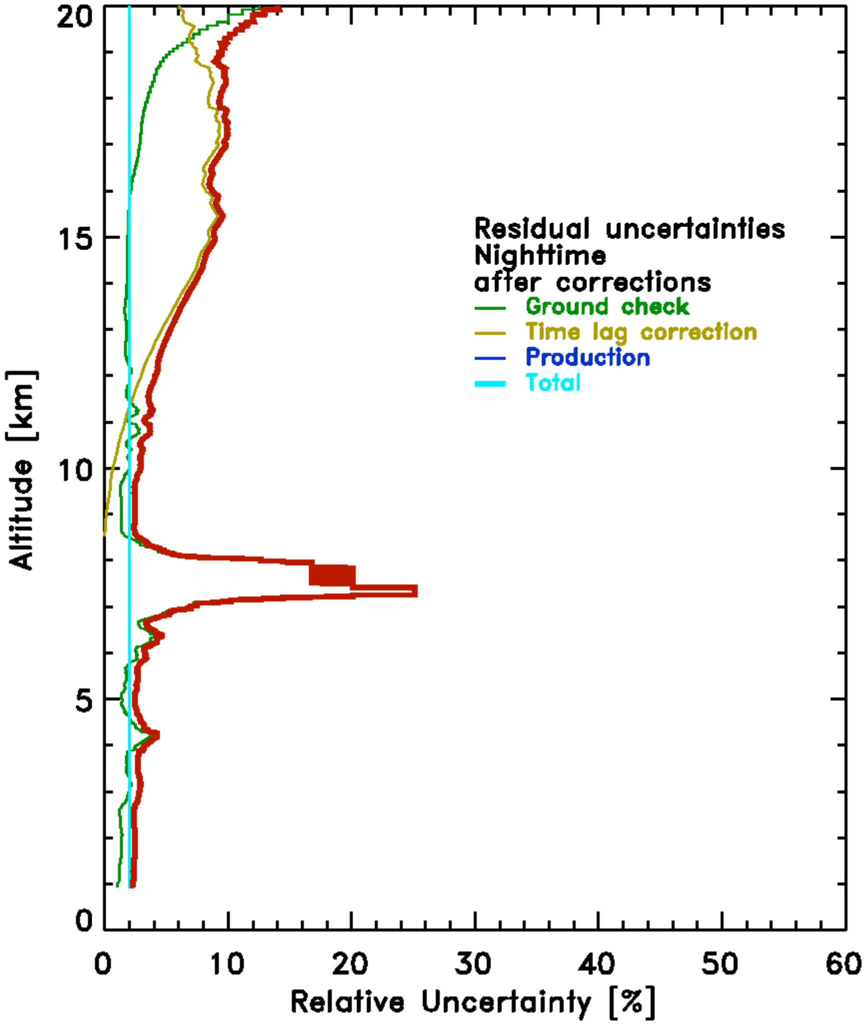


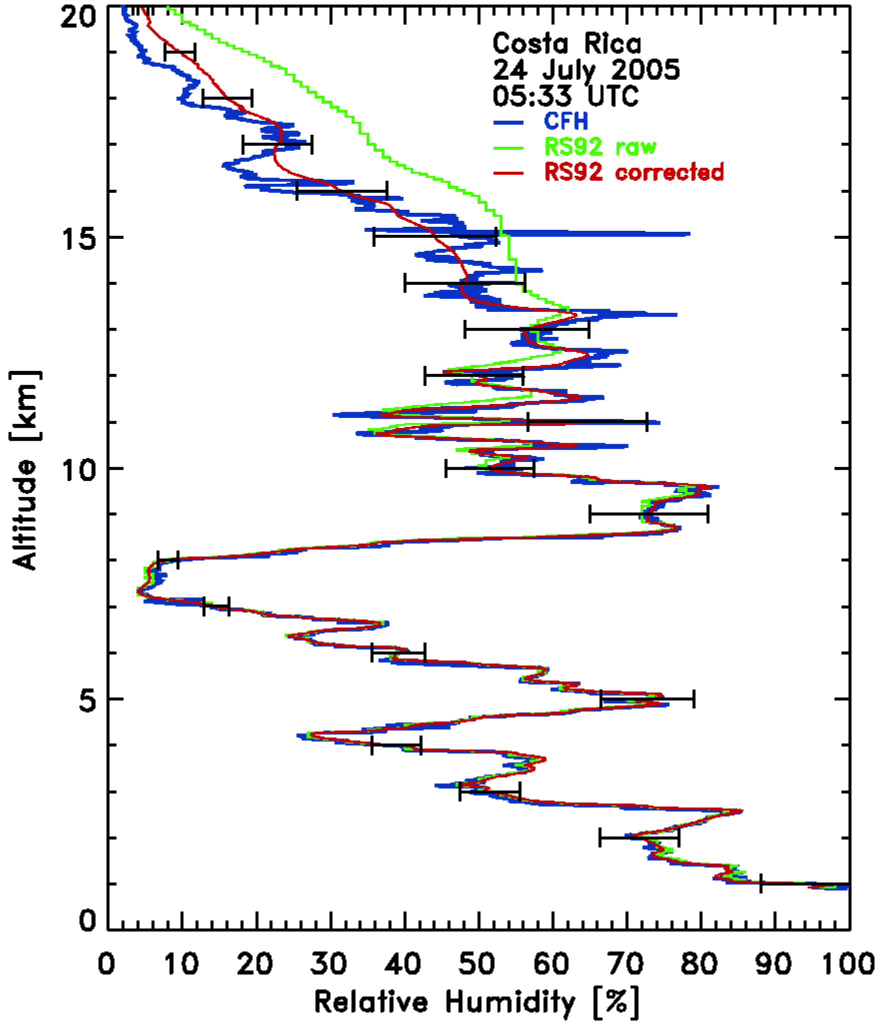
GRUAN

Example Humidity: daytime
Corrected profile with uncertainties

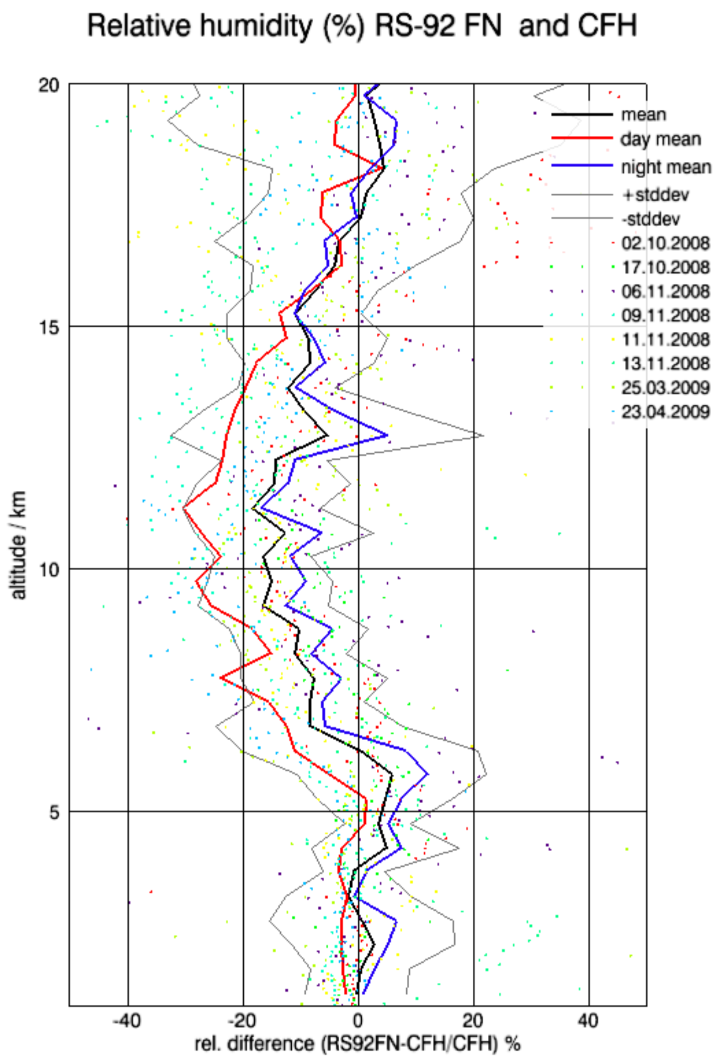


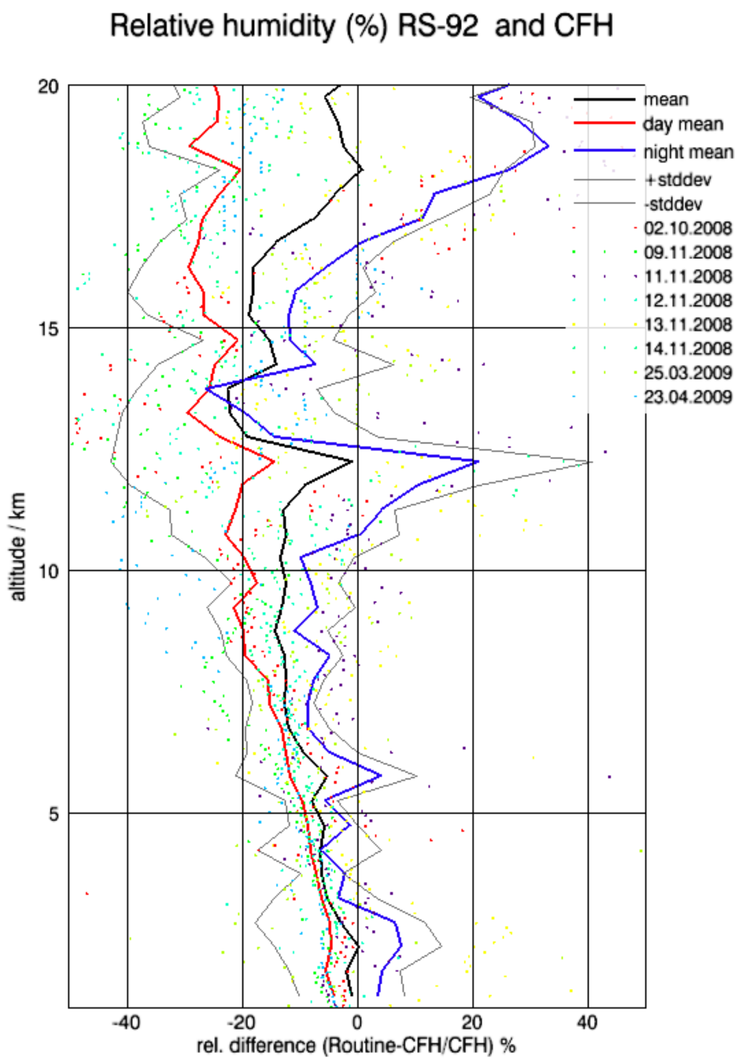
Example Humidity: nighttime
Corrected profile with uncertainties



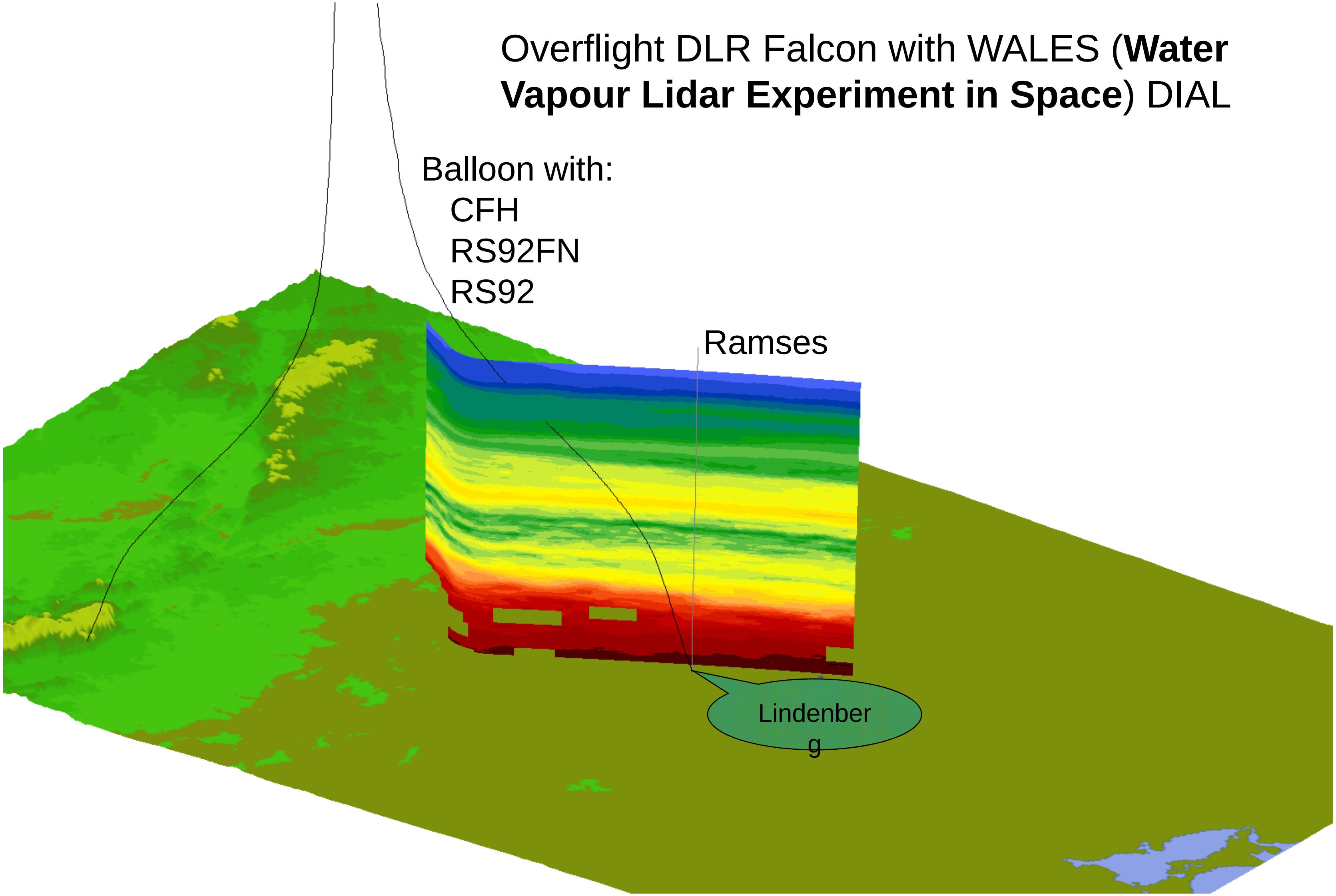


Example Humidity: nighttime
Ensemble comparison

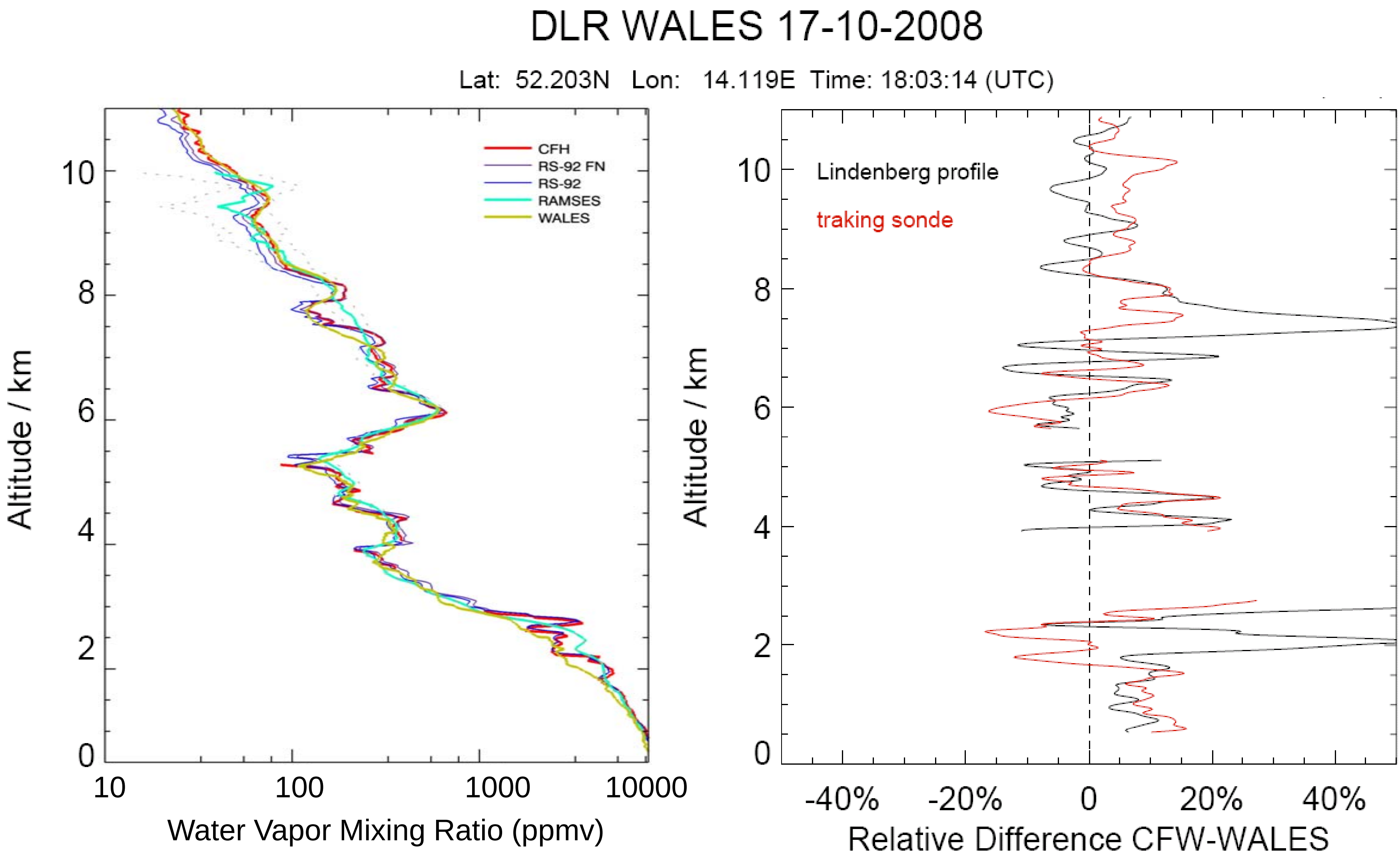




Example Humidity: nighttime
In situ comparison with remote sensing



Example Humidity: nighttime
In situ comparison with remote sensing



Overview

- GRUAN basics (focus on water vapor and temperature)
- How do we define reference observations
- How do we make reference observations
- How do we test reference observations