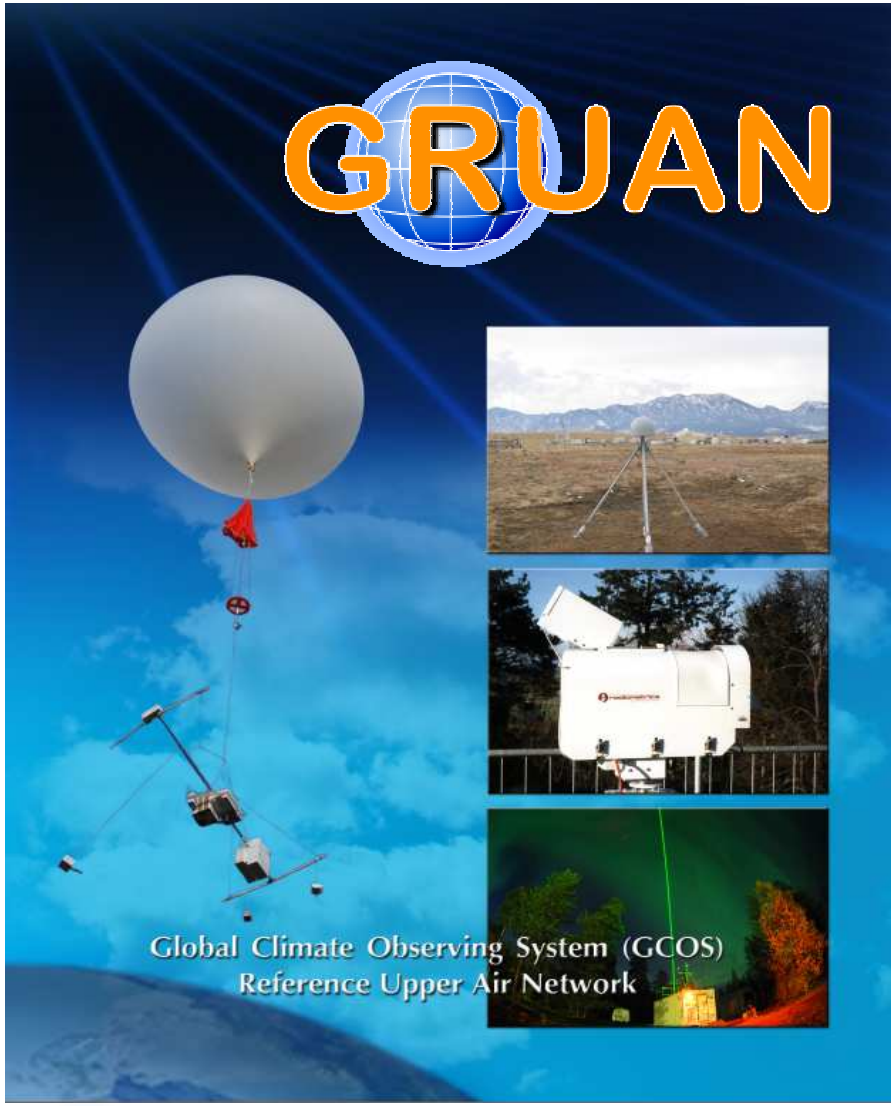
GCOS Reference Upper Air Network

Deutscher Wetterdienst
Wetter und Klima aus einer Hand



Report
GRUAN Lead Center

Holger Vömel,

Franz Immler, Michael Sommer

Head GRUAN lead center

Meteorological Observatory Lindenberg

DWD

The GCOS Reference Upper-Air Network is tasked to:

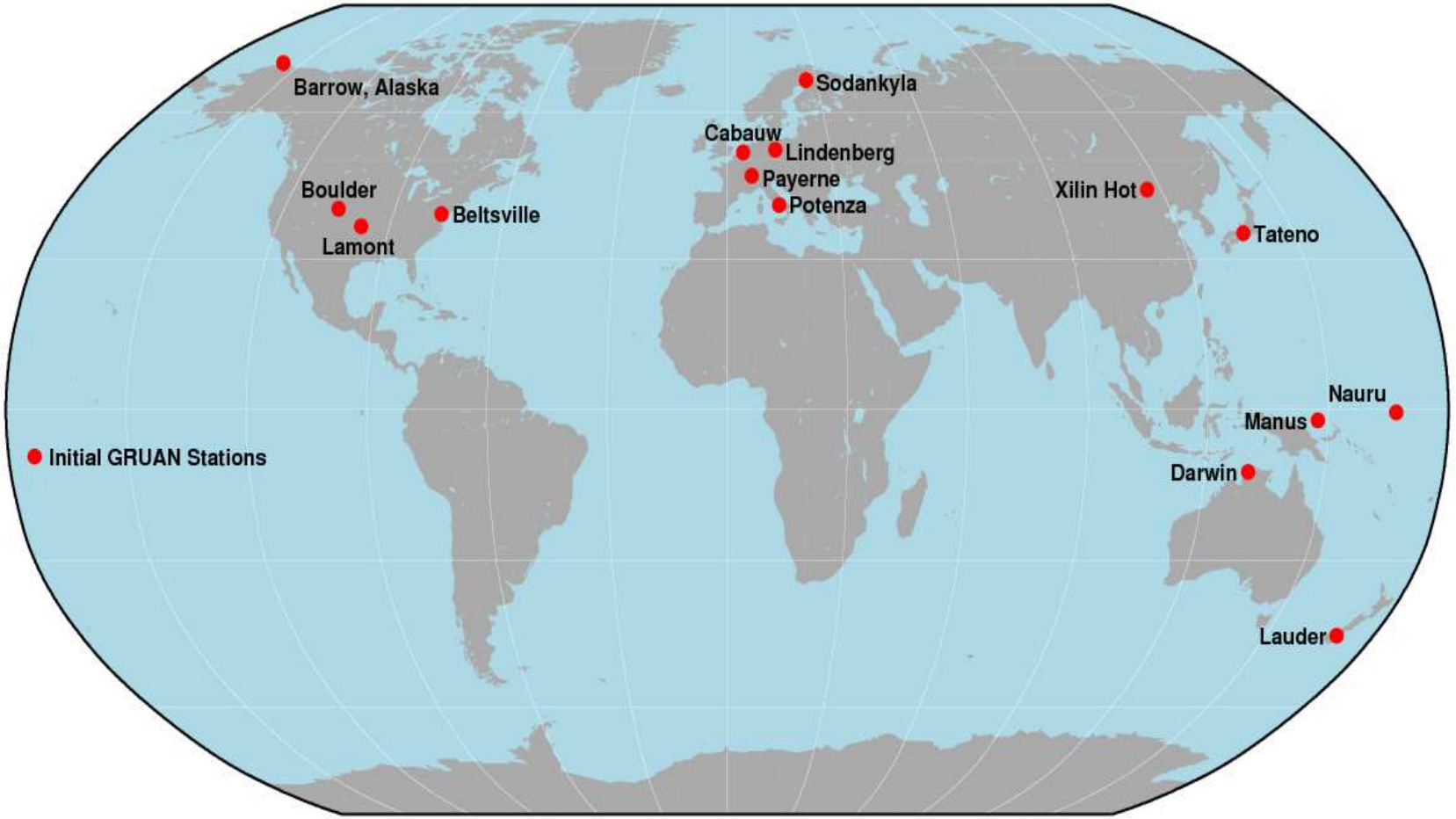
Deutscher Wetterdienst
Wetter und Klima aus einer Hand

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

See WWW.GRUAN.ORG for more detail

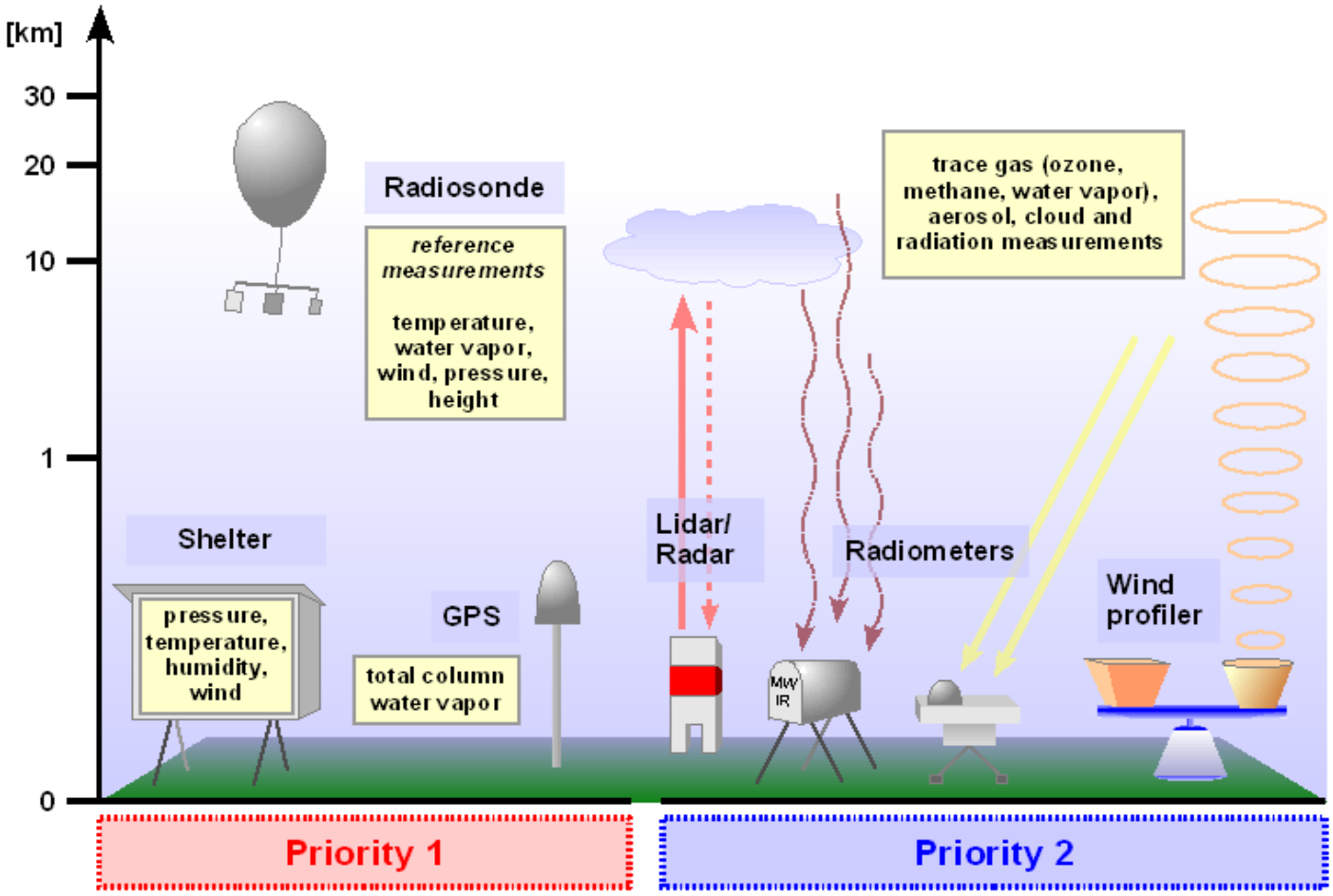
Initial GRUAN stations

Deutscher Wetterdienst
Wetter und Klima aus einer Hand



Select GRUAN requirements

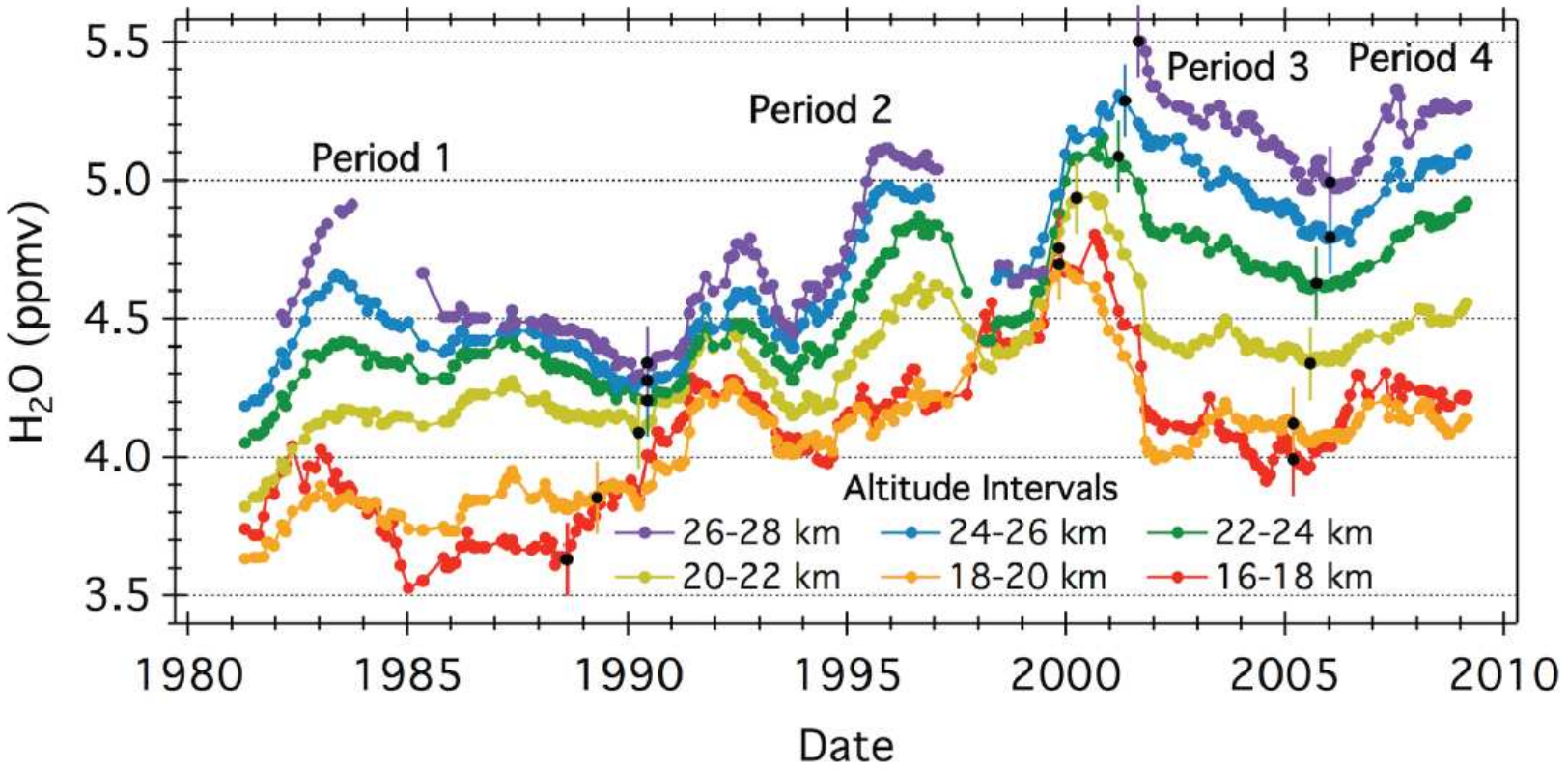
Deutscher Wetterdienst
Wetter und Klima aus einer Hand



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

GRUAN Lead Centre

Stratospheric water vapor over Boulder

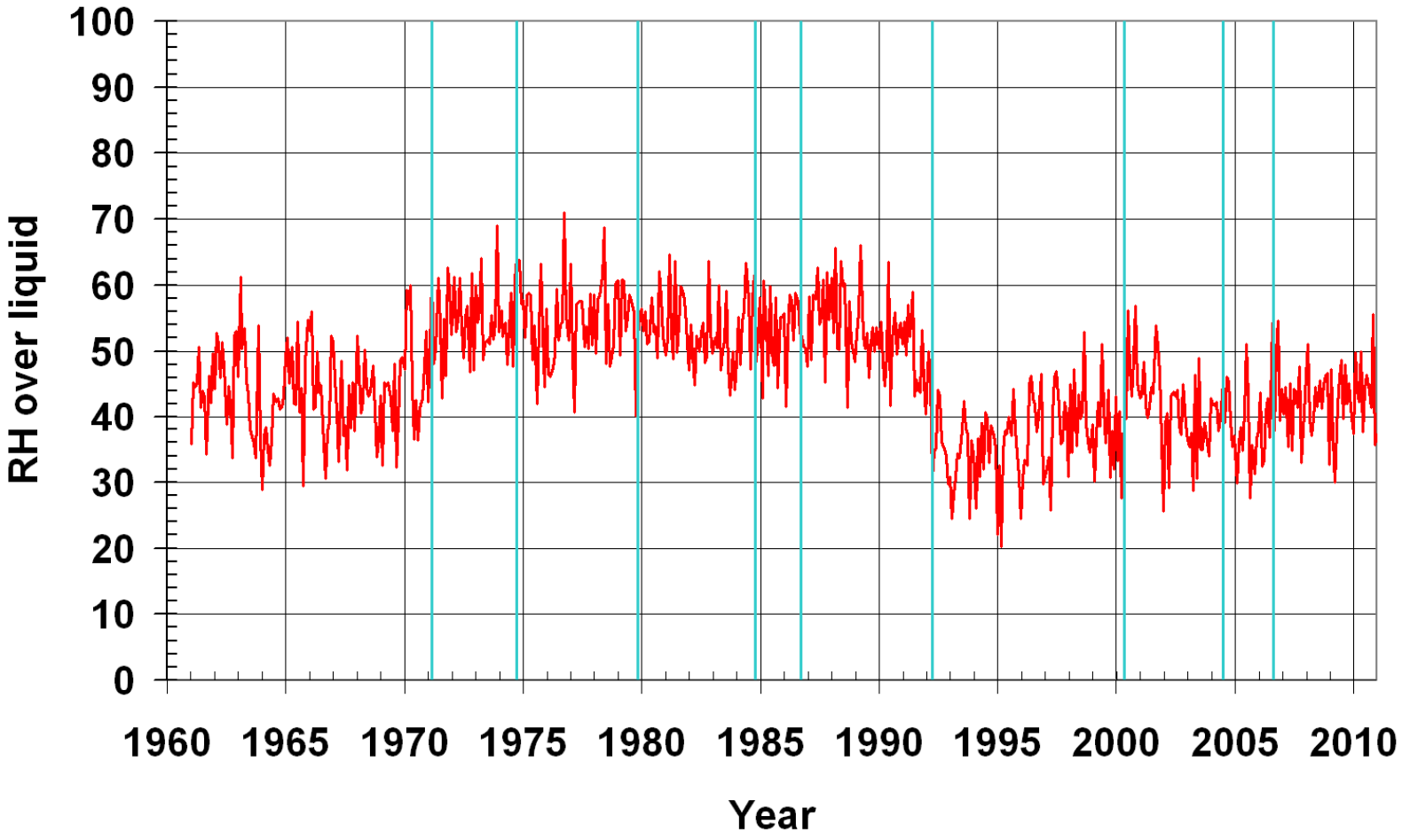


From Hurst et al. JGR, 2011

Water vapor trends in upper troposphere?

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

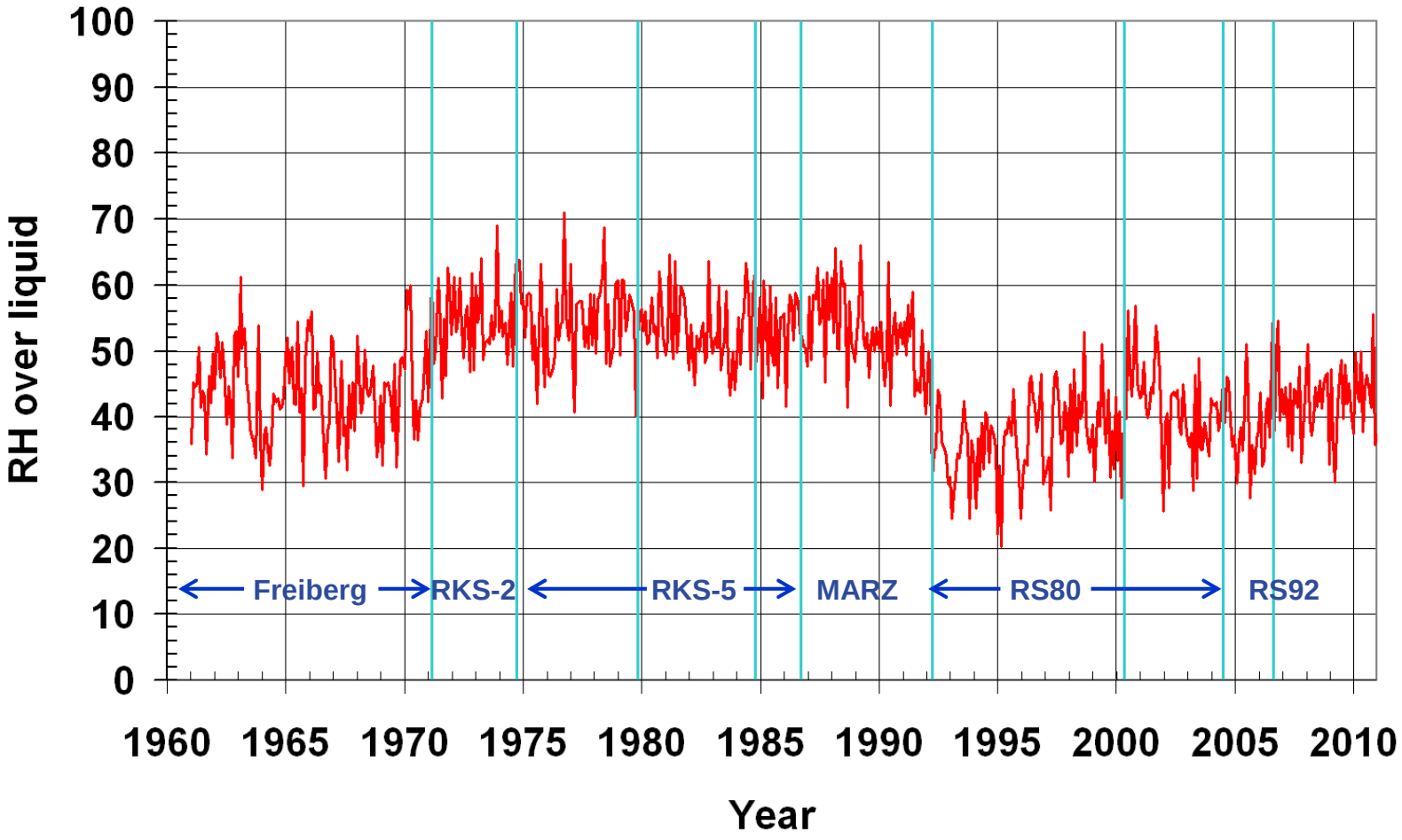
e.g.: Lindenberg 8km (0:00 UT)



Water vapor trends in upper troposphere?

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

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



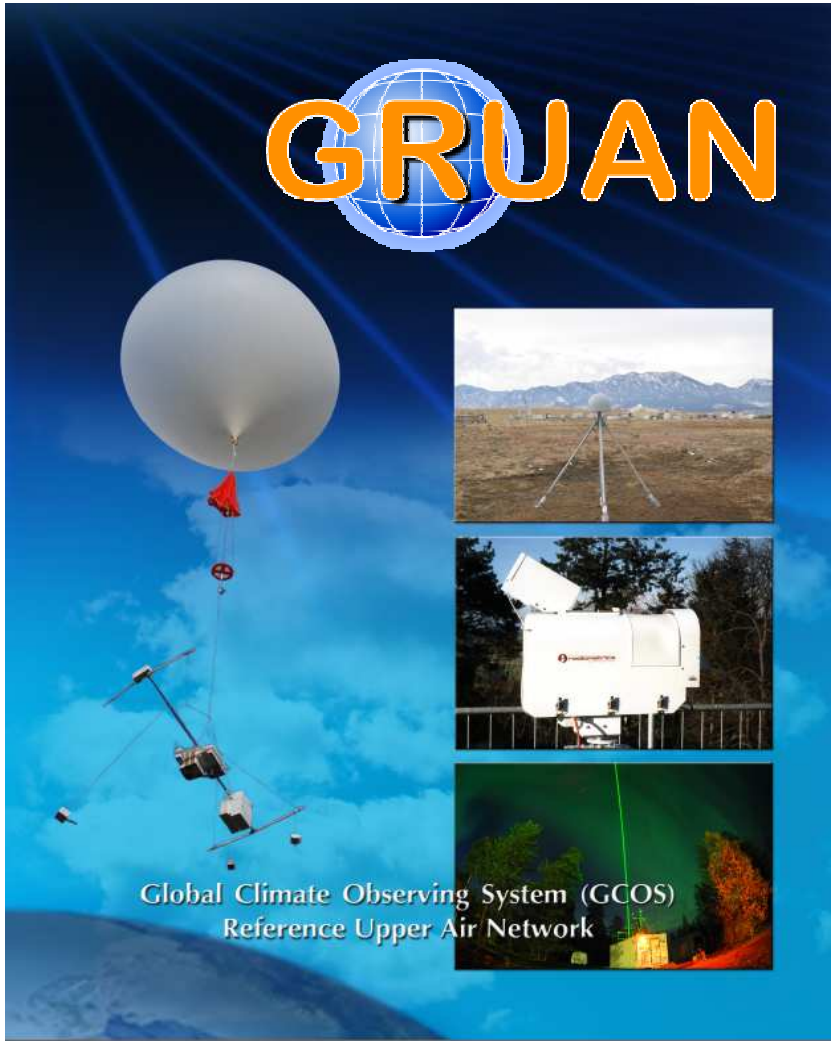
Water vapor trends in upper troposphere?

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

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

- No trend estimate possible: Trend signals caused by instrumental change
- Observations have been done for numerical weather prediction, not for long term climate
- Instrumental change has not been managed
- Instrumental uncertainties and biases have not been well characterized or documented
- Meta data are incomplete

- These deficiencies are some of the motivators to establish the GCOS Reference Upper Air Network (GRUAN)



Focus on *reference* observations

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

A GRUAN reference observation:

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

Establishing Uncertainty

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

GUM concept:

- The "true value" of a physical quantity is no longer used
- Error is replaced by uncertainty
- A measurement = a range of values
  - generally expressed by $m \pm u$
  - m is corrected for systematic effects
  - u is (random) uncertainty

References:

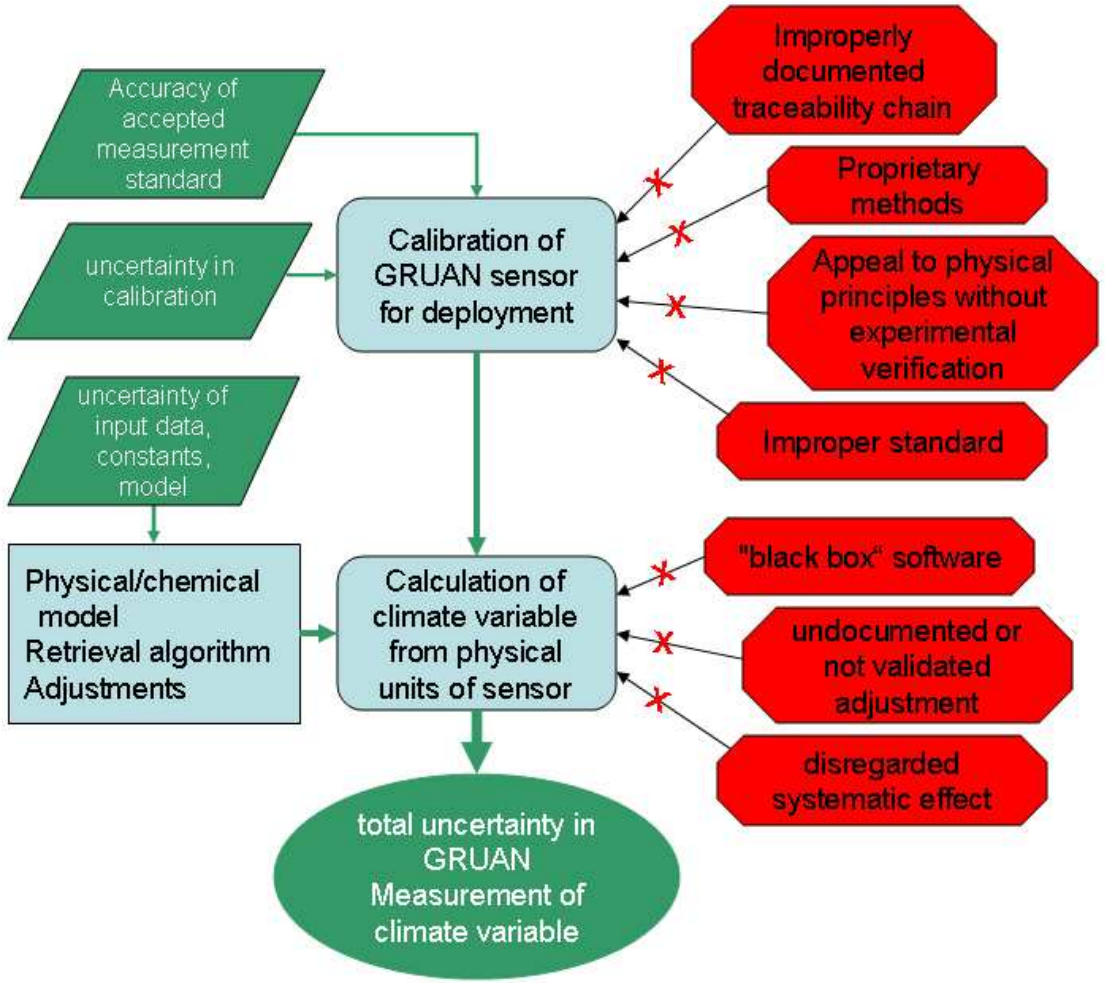
Guide to the expression of uncertainty in measurement (GUM, 1980)

Guide to Meteorological Instruments and Methods of Observation, WMO 2006, (CIMO Guide)

Reference Quality Upper-Air Measurements: Guidance for developing GRUAN data products, Immler et al. (2010), Atmos. Meas. Techn.

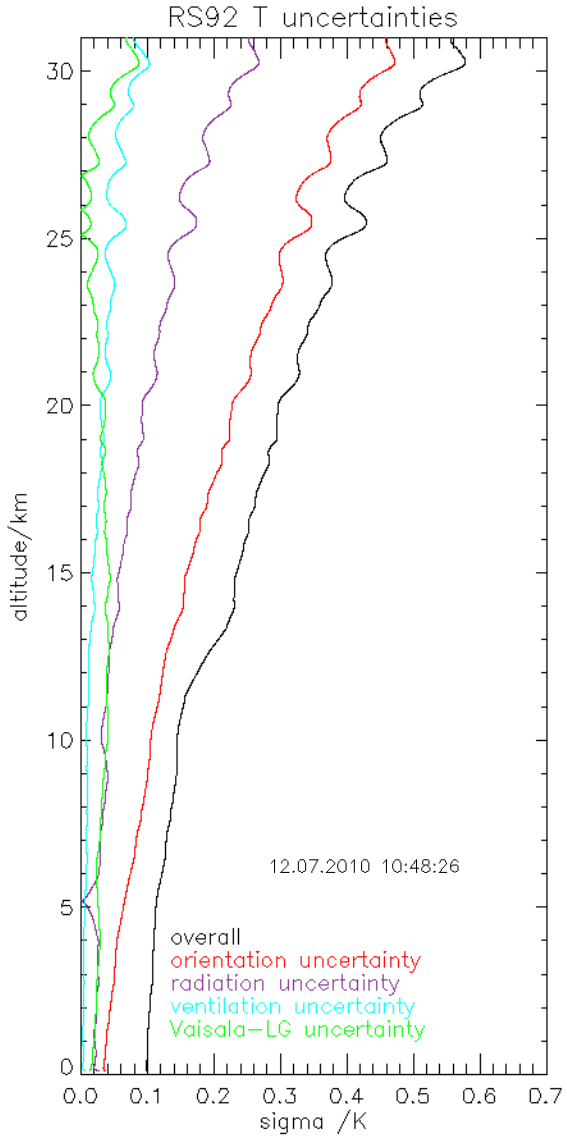
Establishing reference quality

Deutscher Wetterdienst
Wetter und Klima aus einer Hand



Uncertainty example: Daytime temperature Vaisala RS92

Deutscher Wetterdienst
Wetter und Klima aus einer Hand



GRUAN Lead Centre

Validation: Redundancy and Consistency

- Redundant observations are needed to test uncertainty estimates and consistency of measurements:

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

  - ✓ No meaningful consistency analysis possible without uncertainties
  - ✓ if m_2 has no uncertainties use $u_2 = 0$ (“agreement within errorbars”)

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

Redundant observations

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

Use uncertainty formalism to make use of redundant observations:

- Redundant observations continuously validate the understanding of instrumental performance
- Redundant observations in intensive campaigns place GRUAN observations in larger context
- Redundant observations maintain homogeneity across the network
- Identifies deficiencies in order to improve the measurements (instrumental upgrade, reprocessing)

Issues affecting long term trends

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

Use uncertainty formalism to improve long term trends:

- Identify, which sources of measurement uncertainty are systematic (calibration, radiation errors, …), and which are random (noise, production variability …)
- Develop and verify tools to identify and adjust systematic biases
- Maintain raw data and document every step in the data collection and processing chain

Managed change

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

Use uncertainty formalism to manage change:

- Determine instrumental uncertainties and biases of new system
- Remove systematic biases in new instrument and quantify random uncertainty
- Verify uncertainty estimate of new instrument in simultaneous (dual) observations

Summary

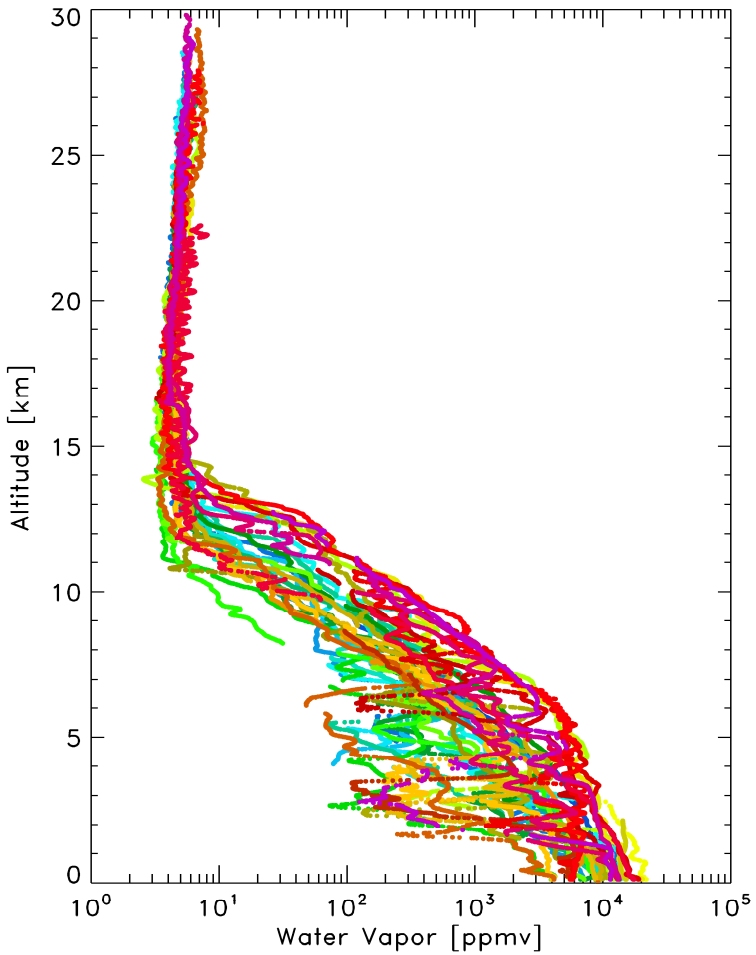
Deutscher Wetterdienst
Wetter und Klima aus einer Hand

- GRUAN is a completely new approach to long term observations of upper air essential climate variables
- GRUAN requires a new data processing and data storage approach
- Focus on priority 1 variables to start: Water vapor and temperature
- Focus on *reference* observation:
  - ✓ quantified uncertainties
  - ✓ traceable
  - ✓ well documented
- Understand the uncertainties:
  - ✓ analyze sources
  - ✓ synthesize best estimate
  - ✓ verify in redundant observations

Extras

Water vapor over Lindenberg from CFH launches

Deutscher Wetterdienst
Wetter und Klima aus einer Hand



Stratosphere

Upper Troposphere

Lower Troposphere

GRUAN Lead Centre

Consistency in a finite atmospheric region

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

Co-location / co-incidence:

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

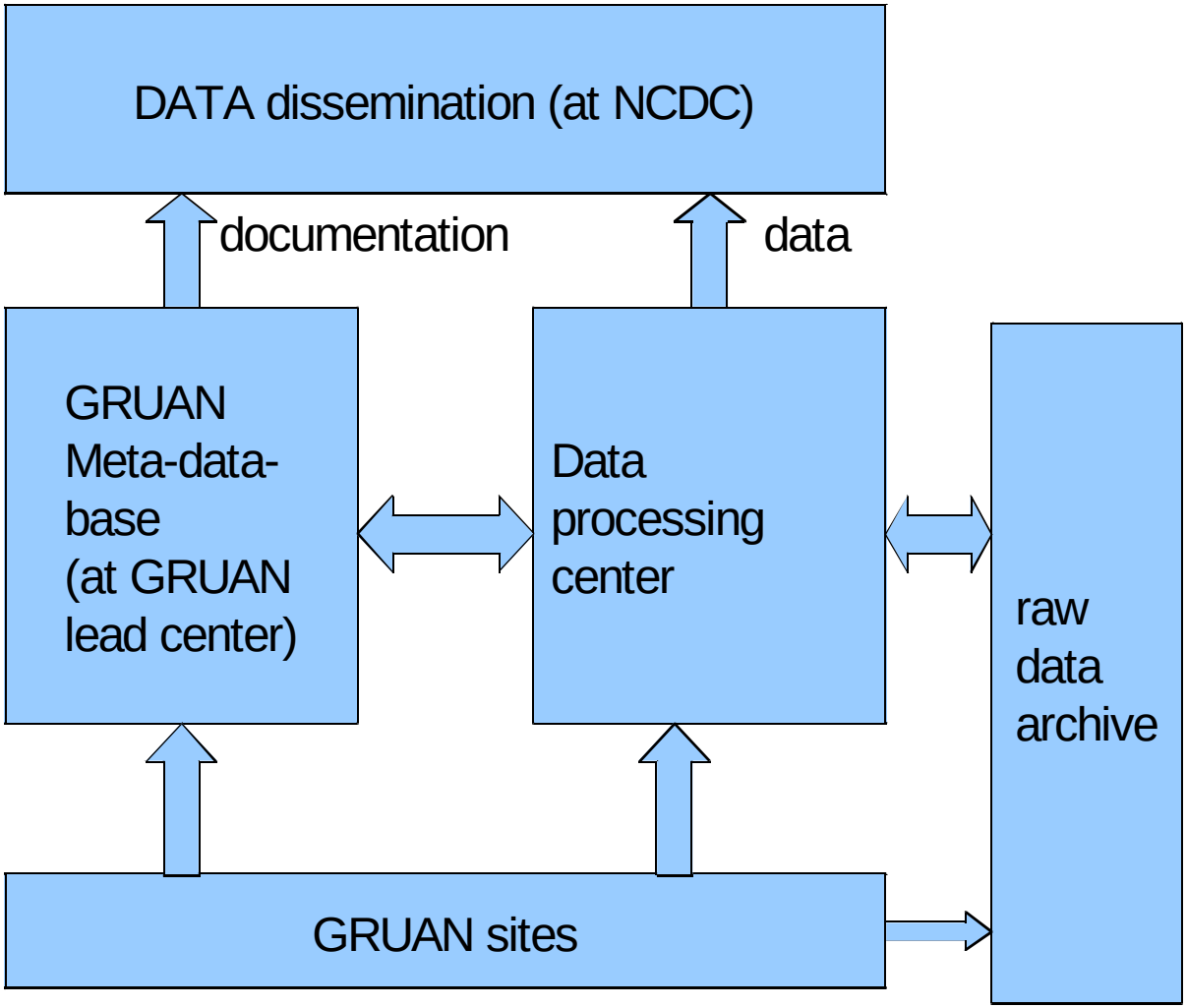
$$\left|m_1 - m_2\right| < k\sqrt{\sigma^2 + u_1^2 + u_2^2}$$

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

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

Distributed data processing

Deutscher Wetterdienst
Wetter und Klima aus einer Hand



Principles of GRUAN data management

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

- Archiving of raw data (at site or lead center) is mandatory
- All relevent meta-data is collected and stored in a meta-data base (at the lead centre)
- For each measuring system just one data processing center
- Version control of data products. Algorithms need to be traceable and well documented.
- Data levels for archiving:
  - ✓ level 0: raw data
  - ✓ level 1: raw data in unified data format (pref. NetCDF)
  - ✓ level 2: processed data product → dissemination (NCDC)

What is GRUAN?

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

- GCOS Reference Upper Air Network
- Network for ground-based reference observations for climate in the free atmosphere in the frame of GCOS
- Initially 15 stations, envisaged to be a network of 30-40 sites across the globe