

GCOS Reference Upper-Air Network (GRUAN): The current status and future plans

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GRUAN is a reference network

GCOS Reference Upper-Air Network



As of September 2026, GRUAN comprises of 35 sites, 16 of which have been GRUAN certified.

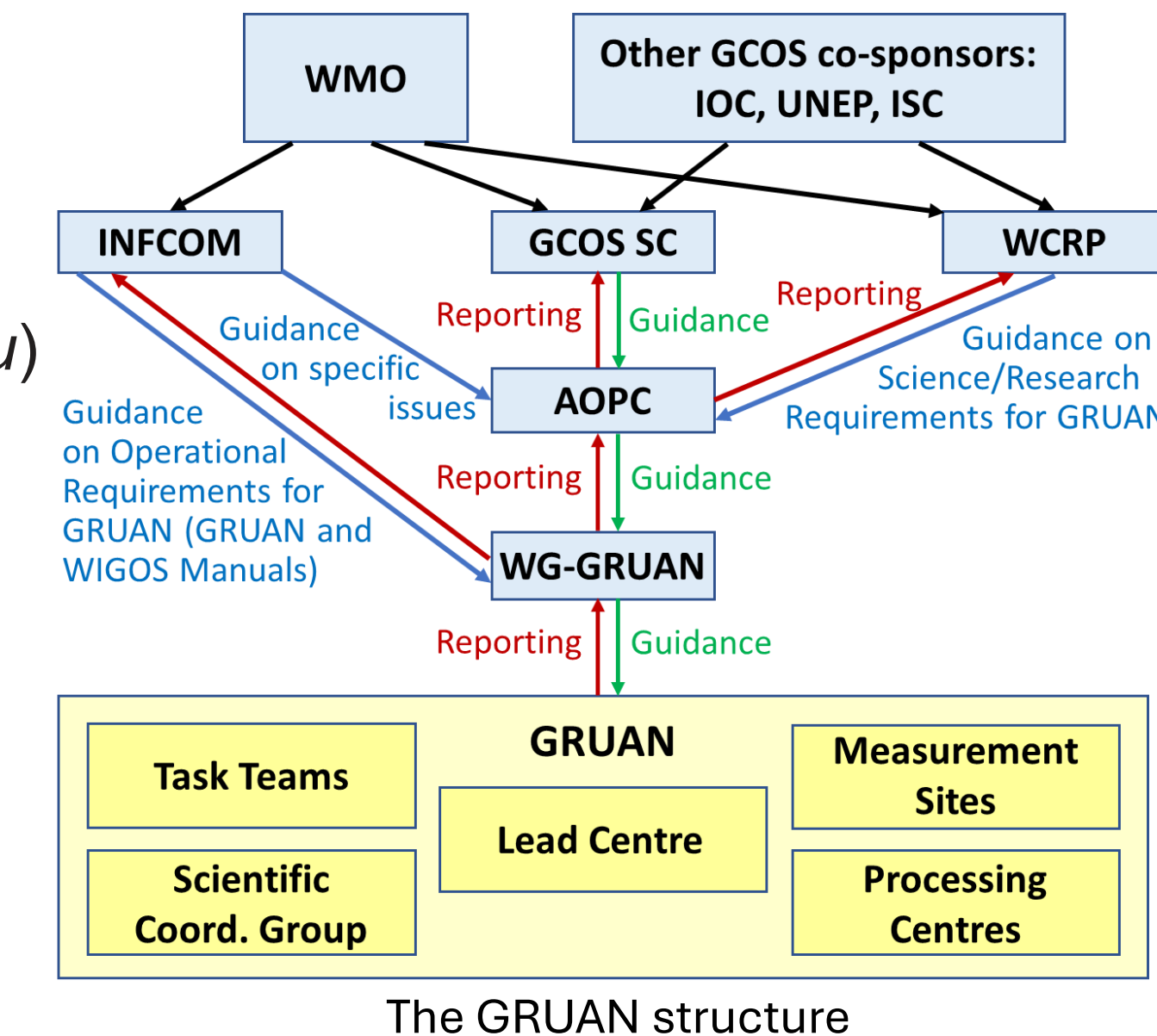
GRUAN: Global Climate Observing System (GCOS) Reference Upper Air Network.

- Ground based network for reference upper air observations for climate monitoring.
- Aim: 30 - 40 sites worldwide in representative climate regions
- Target ECVs: Temperature, water vapor, pressure, wind, and more

- Goals:
 - Maintain consistent observations over decades
 - Standardization and traceability
 - Provide best possible measurement + uncertainty (u)
 - (u for evaluating measurement consistency)
 - Deliberate measurement redundancy
 - Quality management and managed change
 - Validation of satellite systems

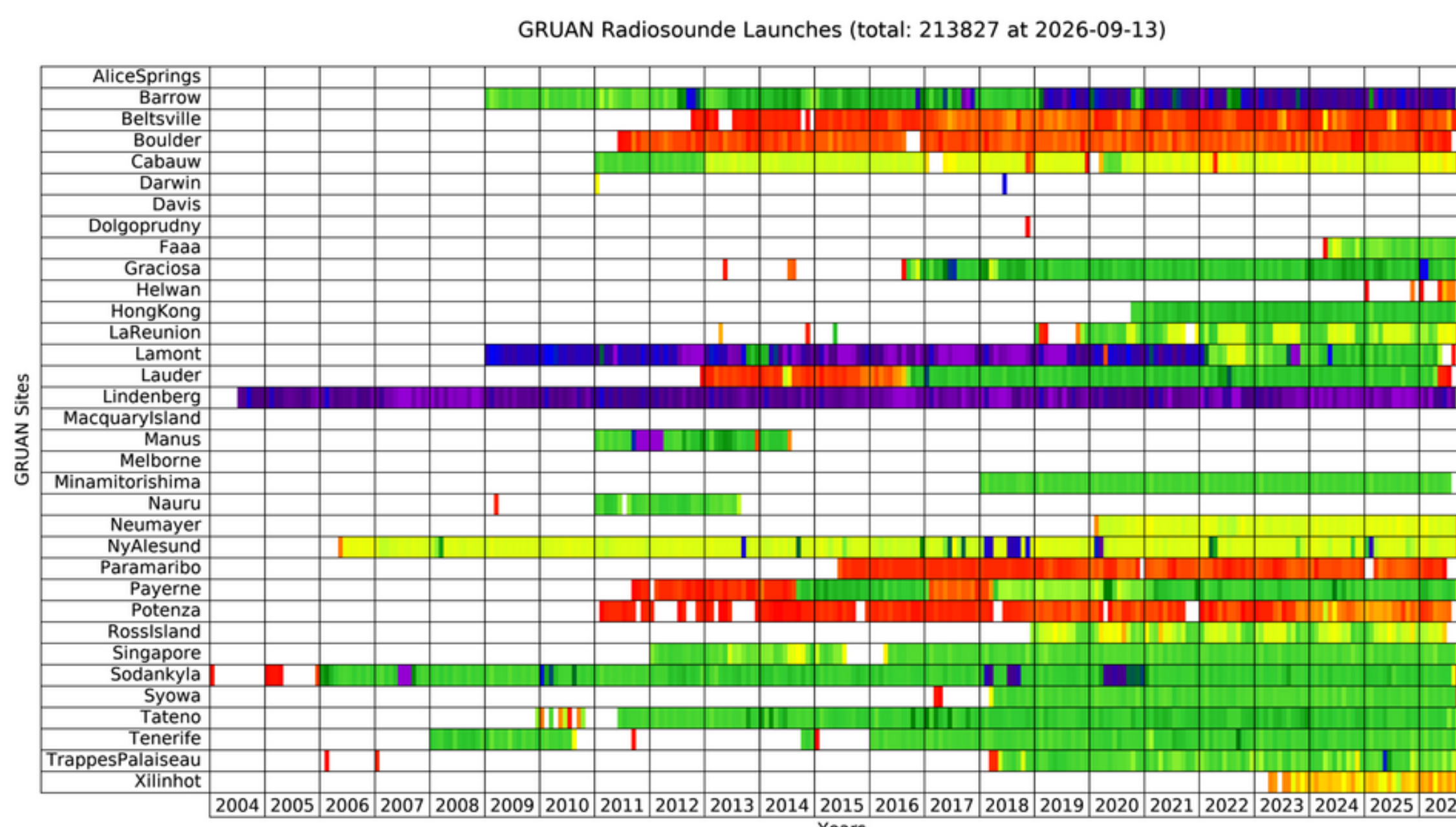
- Certification of sites and data products
 - Centralized data processing

- Cooperations: e.g. NDACC, GAW, GUAN

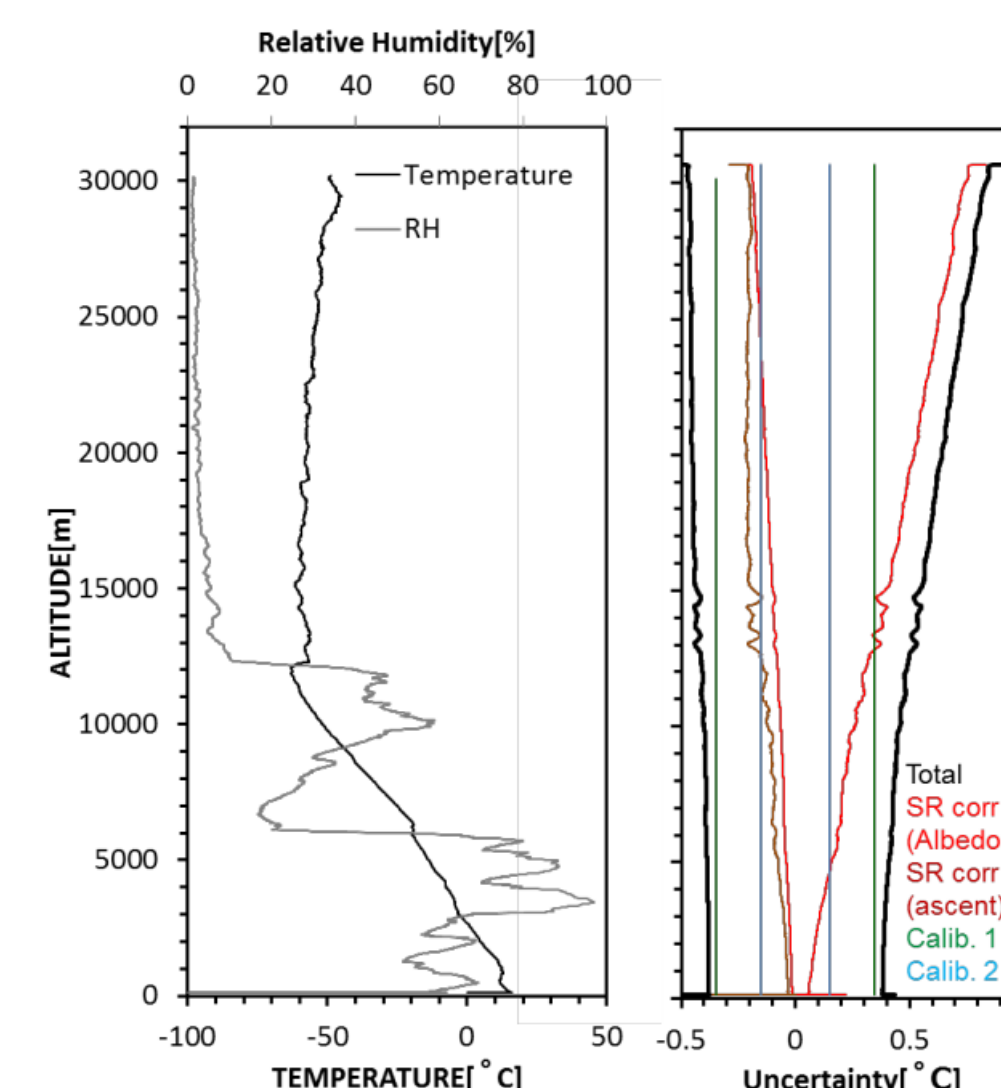


GRUAN data products (GDPs)

- A GRUAN data product (GDP) is a set of measurements from a given instrument system that have been undertaken in a sufficiently similar manner across all contributing sites to be intercomparable.
- Measurements are taken in such a manner as to be traceable to SI or community accepted standards with fully quantified uncertainty budgets.
- The data are collected using a tool that captures not only all of the data but also all relevant metadata that may be required in subsequent reprocessing.
- Processing is undertaken for each data type at a dedicated processing centre where uncertainty estimates are quantified and added and flags are appended providing additional information on data quality.



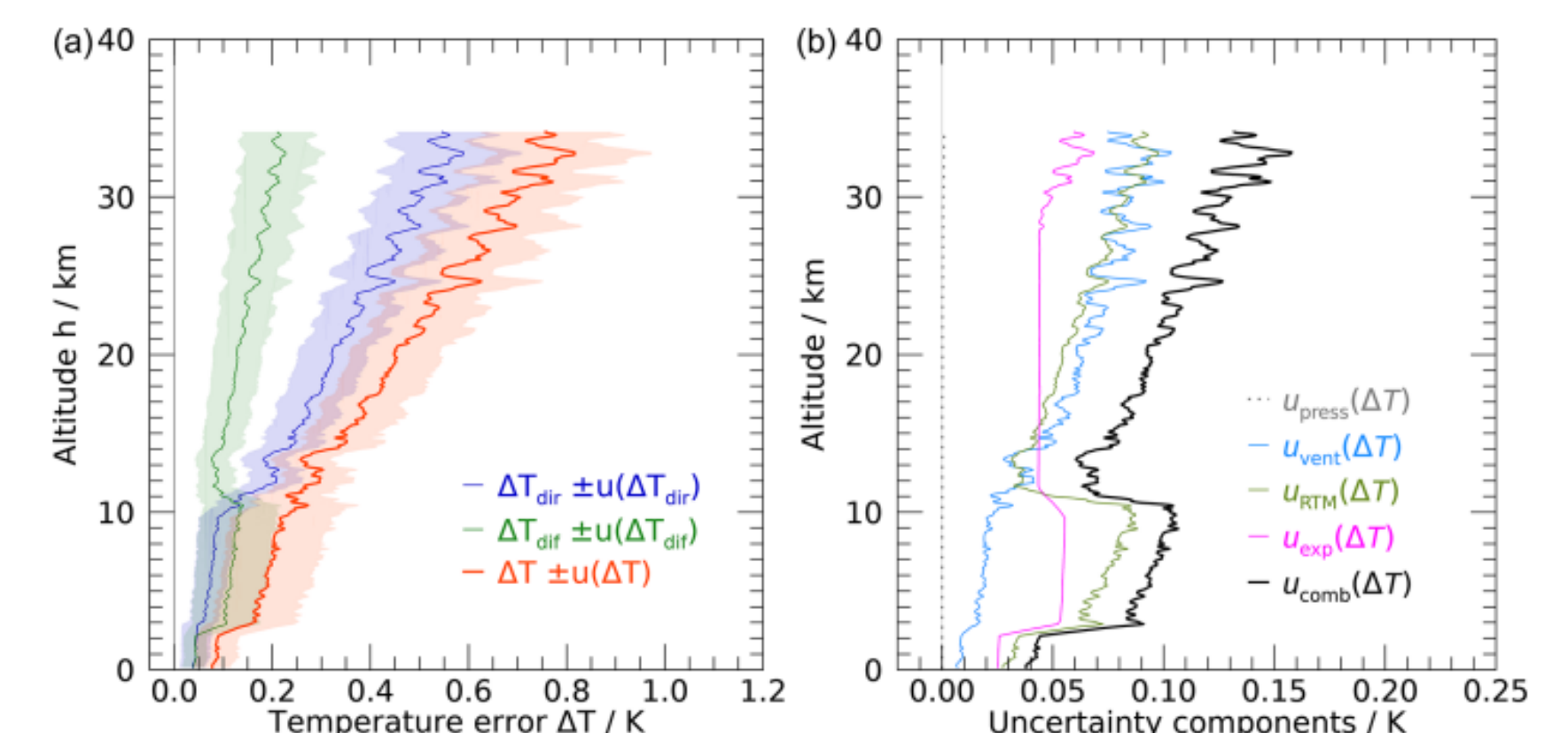
- A comprehensive volume of measurement data has been collected by GRUAN since 2008 (including some historical data). The archive includes raw data and related meta-data.
- For the Vaisala RS41 & RS92 and the Meisei IMS-100 & RS-11G radiosondes, GRUAN Data Products (GDPs) have been fully implemented and certified.
- Other GDPs are in certification process or under development:
 - Other radiosonde types: Modem M10, Huayuntijanyi GTH3, Graw DFM-09/DFM-17
 - GNSS PW, frostpoint hygrometers (CFH, NOAA FPH, SKYDEW), ECC ozonesondes, lidars, microwave radiometers, etc.



Example of the temperature uncertainty profile for the RS-11G radiosonde launched at 14:00 LT on 7 October 2014 at Lindenberg (52.21°N, 14.12°E), Germany.

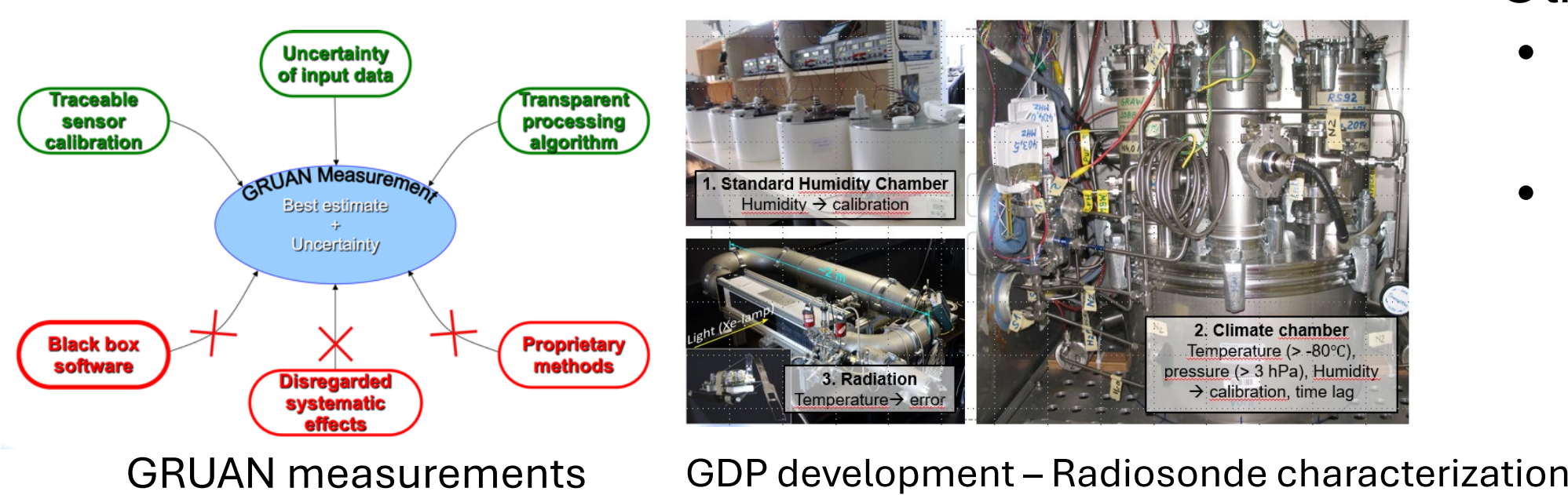
(Left) Profiles of temperature and RH.

(Right) Uncertainty of temperature measurement ($k=2$). Calib. 1 corresponds to the thermistor calibration error, while Calib. 2 corresponds to the component of variability in the calibration chamber



Vaisala RS41 GDP:

- Example for the estimated solar radiation error of temperature measurements (Lindenberg, 11 June 2020, 12:00 UTC). Red: overall bias; blue: component from direct radiation; green: component from diffuse radiation; shaded areas indicate uncertainties ($k=1$).
- Uncertainty components ($k=1$) associated with pressure, ventilation speed, radiation model, and laboratory experiments.

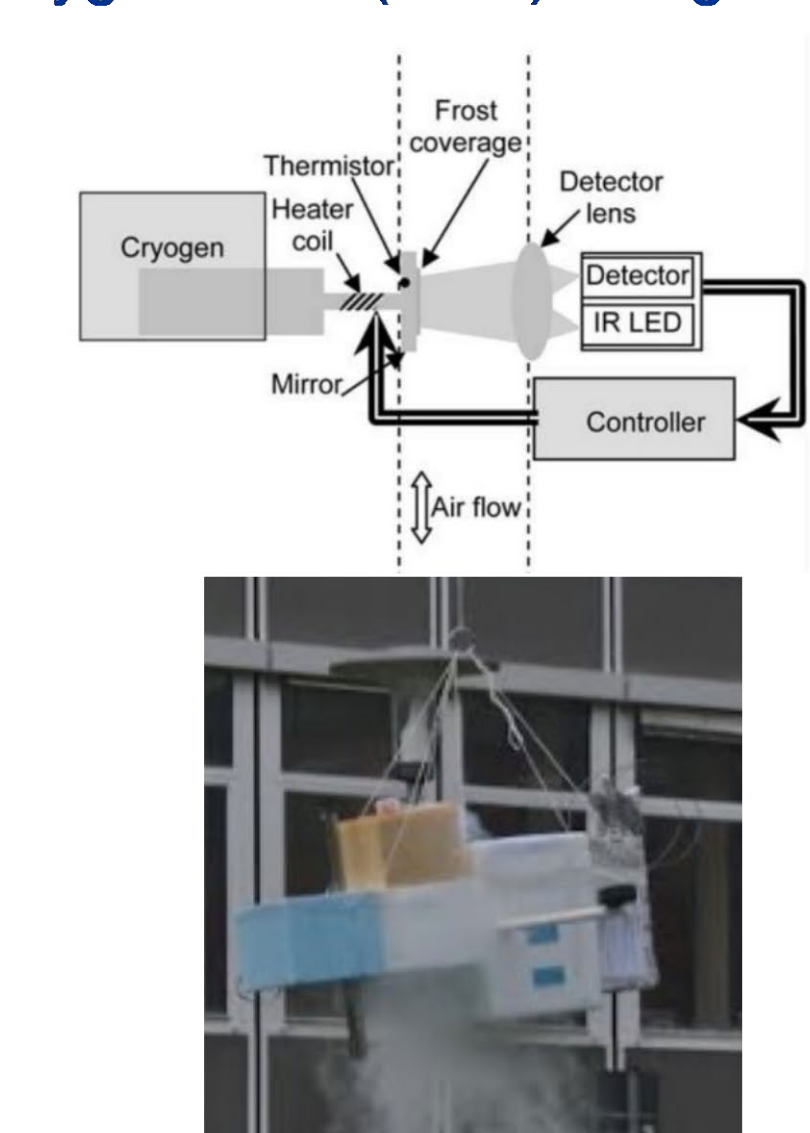


Research and science: Some recent developments

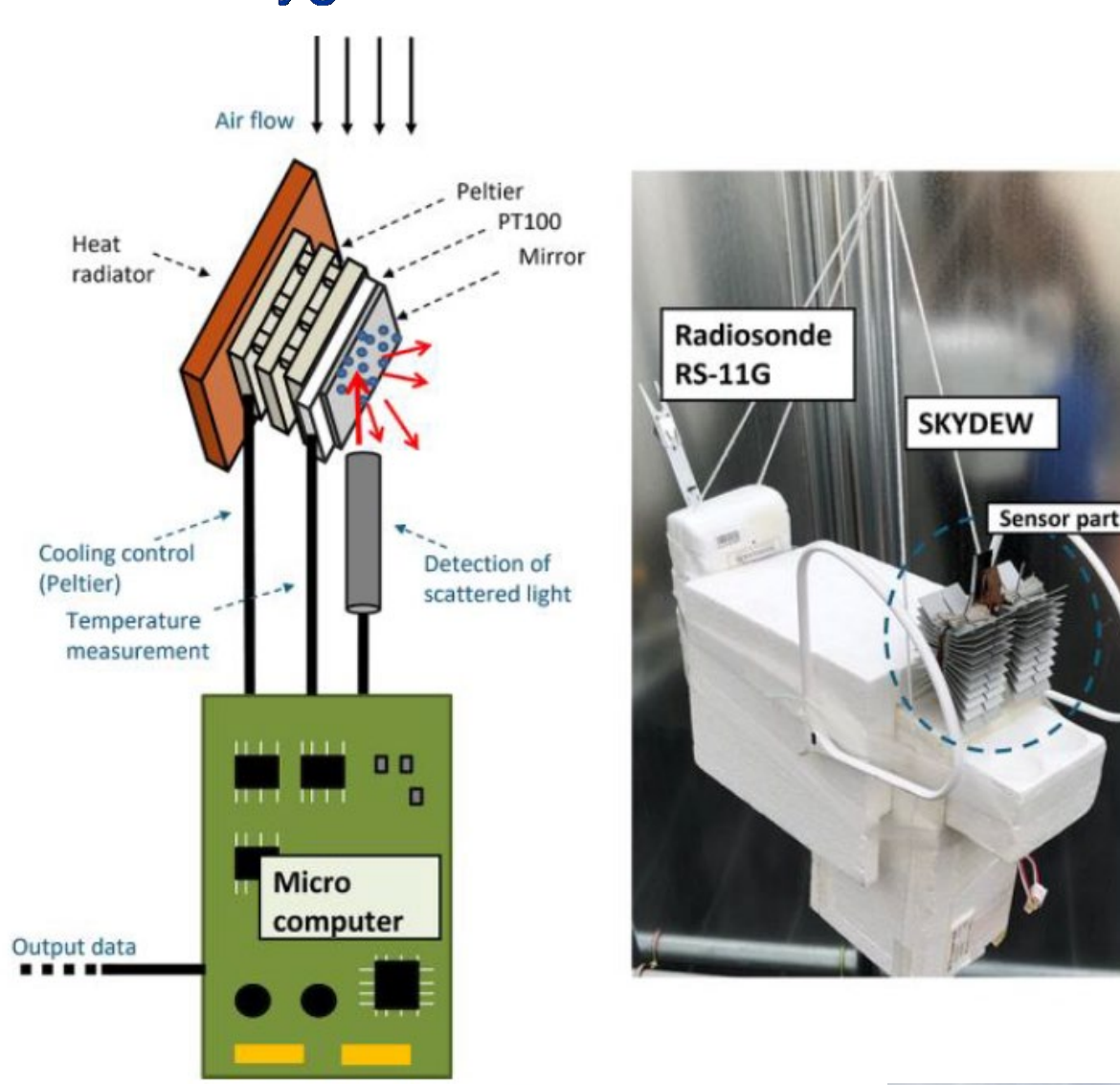
Stratospheric Water Vapour:

- Stratospheric water vapour contributes to both climate and ozone layer
- Stratospheric water vapour is determined mainly by cold-trap processes at the tropical tropopause, transport through the Brewer-Dobson circulation, and oxidation of methane
- Large increasing trends were observed at least up to around 2010
- Balloon-borne cryogenic frost-point hygrometers (such as CFH and NOAA FPH) are key instruments to measure stratospheric water vapour and to validate measurements from various satellite instruments
- Following the restrictions in several countries on the use of specific cryogen material (R-23), GRUAN has been testing/applying alternative methods to operate chilled mirror instruments, including alternate coolants (e.g. LN2: liquid nitrogen) for CFH and a new hygrometer SKYDEW (Sugidachi et al., AMT, 2025) using a Peltier electric cooler.

Cryogenic frostpoint hygrometer (CFH) using LN2

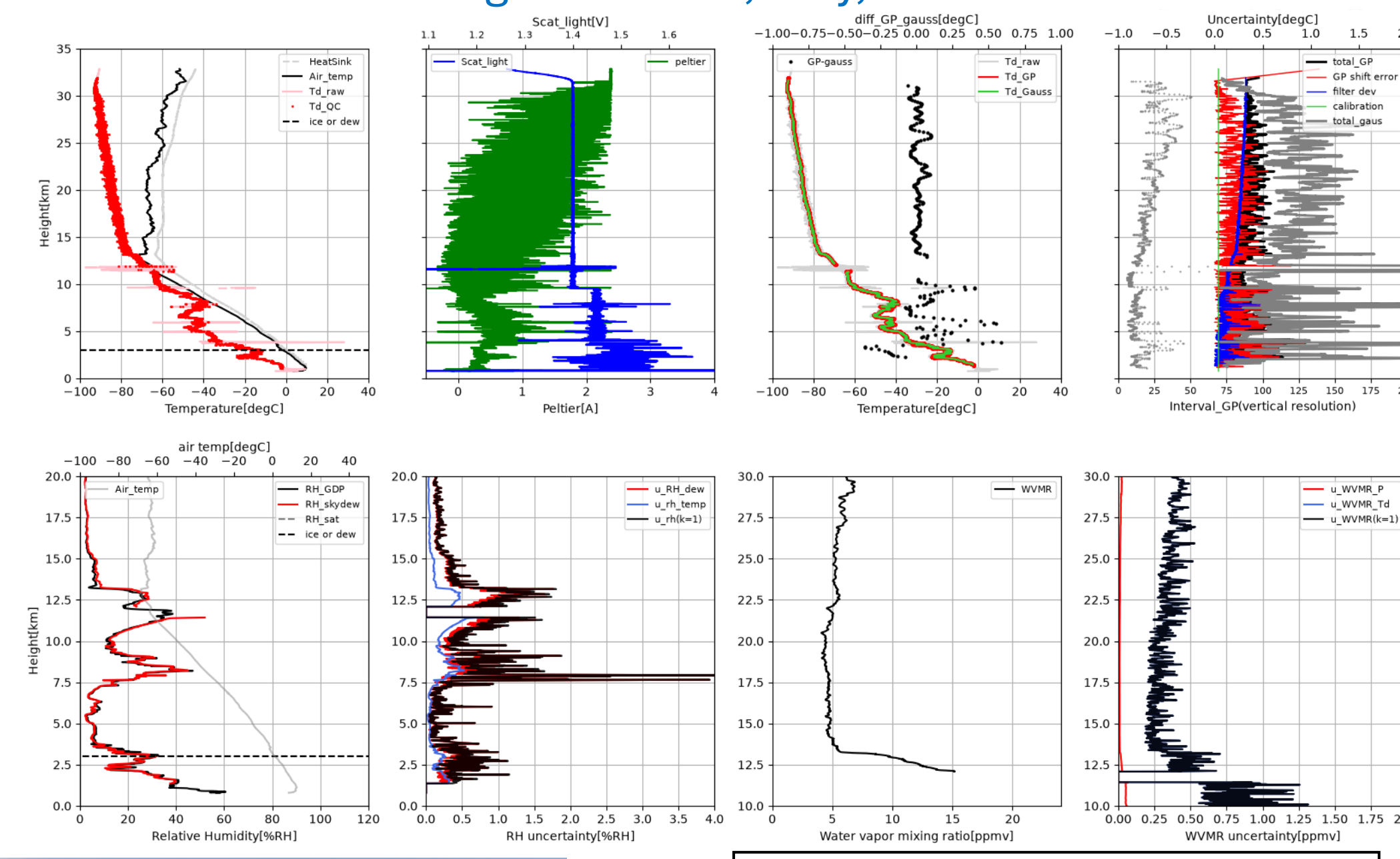


Peltier-based chilled-mirror hygrometer "SKYDEW"



SKYDEW: Sugidachi et al., AMT, 2025

A SKYDEW sounding at Potenza, Italy, on 10 December 2025



The Principal Investigator of Potenza station:
Dr. Marco Rosoldi

Justification for High Balloon Ascent:

- It is sometimes very important to have a peer-reviewed literature to justify additional cost for regular "high" balloon ascent.
- Fujiwara et al. (AMT, 2025) assessed and illustrated the benefits of high-altitude attainment of balloon-borne radiosonde soundings, up to and beyond 10 hPa level compared to, for example, 30 hPa, at operational and GRUAN sites.
- The paper discusses
 - technical challenges and the possible solutions for balloon soundings at these higher altitudes.
- Then, the paper assesses the role of high-ascent radiosonde measurements in
 - climate monitoring and various process studies
 - contributions to satellite calibration and validation
 - impacts on numerical weather prediction systems.
- Conclusions:
 - The analysis shows that the extra costs and technical challenges involved in consistent attainment of high ascents are more than outweighed by the benefits for a broad variety of real-time and delayed-mode applications.
 - Consistent attainment of high ascents should therefore be pursued across the GRUAN network and the broader observational network.



GRUAN home page



Group photo from the 16th GRUAN Implementation and Coordination Meeting (ICM-16) Tenerife, Spain November 2025

Next meeting (ICM-17)
Xilinhot, Inner-Mongolia (China)
21 - 25 June 2027
Hosted by China Meteorological Administration (CMA)



GRUAN Data Product