GRUAN

GCOS Reference
Upper-Air Network

Attendees at the 6th Implementation-Coordination Meeting held 10-14 March 2014 near the GRUAN site of Howard University at Beltsville, Maryland, USA

http://www.gruan.org

Authors & Editors:
Greg Bodeker, Ruud Dirksen, Anna Mikalsen, Emma Scarlet, Peter Thorne

Release Preparation:
Michael Sommer

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Front Cover Photos

Taken at 26 km altitude. Provided by Dale Hurst at NOAA Earth System Research Laboratory.	Radiosonde launch in Ny-Ålesund. Provided by Marion Maturilli.
Tateno Station. Provided by Nobuhiko Kizu, Japan Meteorological Agency.	
Radiosonde launch at Ny-Ålesund. Taken by Alfred Wegener Institute.	Bursting balloon. Provided by GRUAN Lead Centre.

Radiosonde launch from LAPBIAT campaign at Sodankylä, Finland

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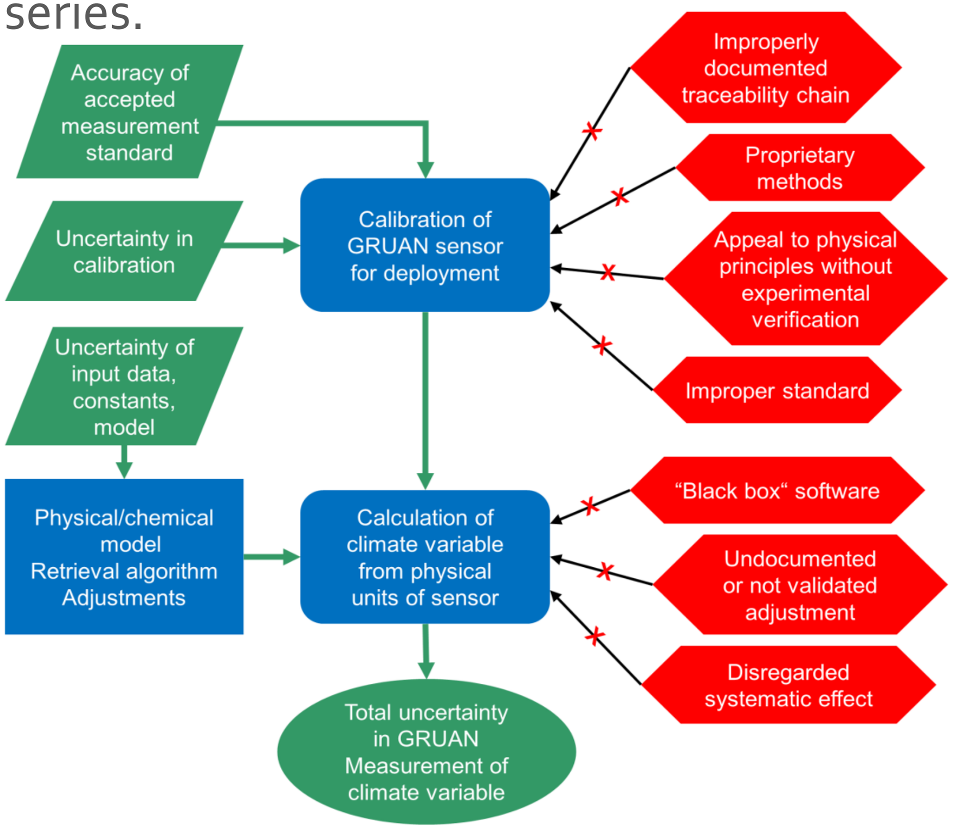
The Global Climate Observing System (GCOS) Reference Upper-Air Network (GRUAN) is an international reference observing network, designed to fill an important gap in the current global observing system. GRUAN measurements will provide long-term, high-quality climate data records from the surface, through the troposphere, and into the stratosphere. These will be used to determine trends, constrain and calibrate data from more spatially-comprehensive observing systems (including satellites and current radiosonde networks), and provide appropriate data for studying atmospheric processes. GRUAN is envisaged as a global network of eventually 30-40 sites that, to the extent possible, builds on existing observational networks and capabilities.

What Does Reference Quality Mean?

A GRUAN reference observation:

- Is traceable to a SI unit or an internationally accepted standard
- Provides comprehensive uncertainty analysis;
- Is documented in accessible literature
- Is validated (e.g. by inter-comparison with complementary measurement systems)
- Includes complete metadata description

Establishing consistency between measurements from different complementary systems provides a means of continuously evaluating the quality of the observations which is also key for the management of system changes. Laboratory studies and field intercomparisons are important to minimise the impact of systematic biases on long-term observations and are essential to the process of establishing reference quality measurement series.



Schematic for establishing reference quality. Reference data must be traceable to an accepted standard. The red boxes contain components jeopardising traceability. The procedure establishing traceability and determining the total uncertainty budget must be transparent and reproducible.

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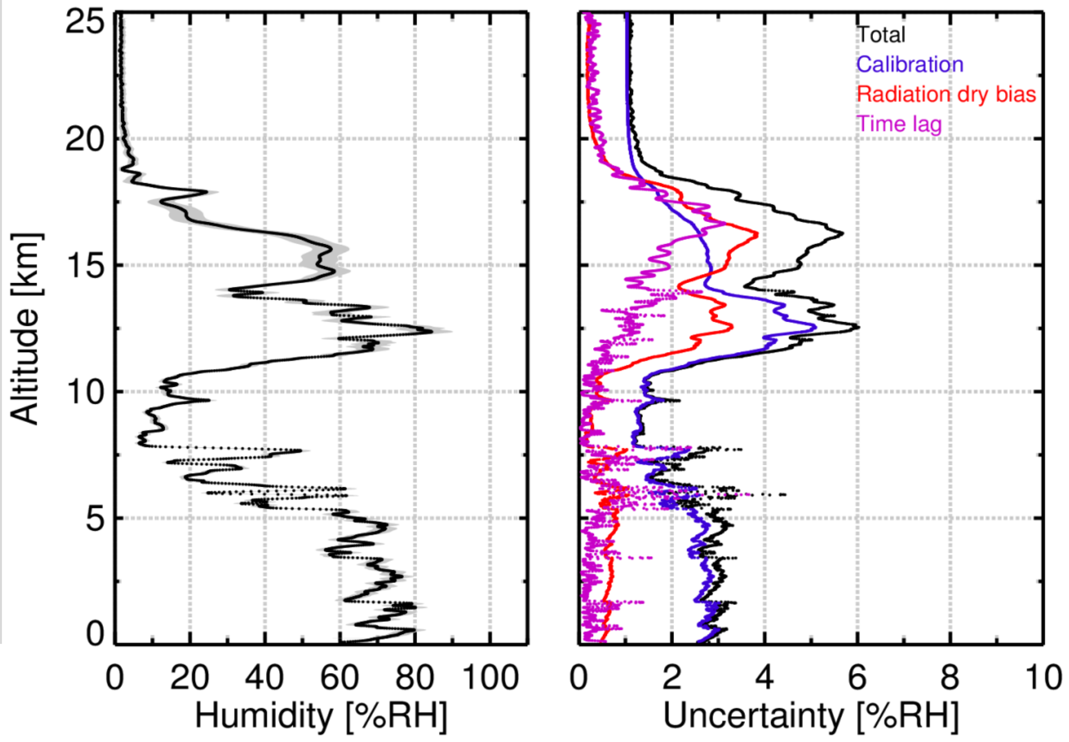
Example of Reference Quality

GRUAN processing of radiosonde data corrects the measured profiles for known errors and biases. The correction algorithms are based on effects previously reported in literature and on sensor characterisation using laboratory experiments. The correction algorithms provide the best possible estimate of the associated measurement uncertainty. The vertically resolved measurement uncertainty is included in the data product.



Example of the uncertainty estimates associated with various GRUAN corrections for the humidity profile measured by the Vaisala RS92 radiosonde. Left plot: GRUAN-processed humidity profiles (black trace) and the estimated measurement uncertainty (grey band). Right plot: the vertically resolved measurement uncertainty (black trace) and the contributions to the total uncertainty by various error sources.

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GRUAN data processing:

- Corrects for all known errors and biases
- Is based on sensor characterisation from laboratory studies and field intercomparisons
- Provides best estimate of the – vertically resolved – measurement uncertainty

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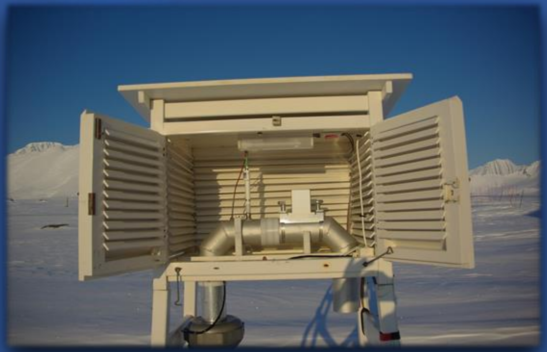

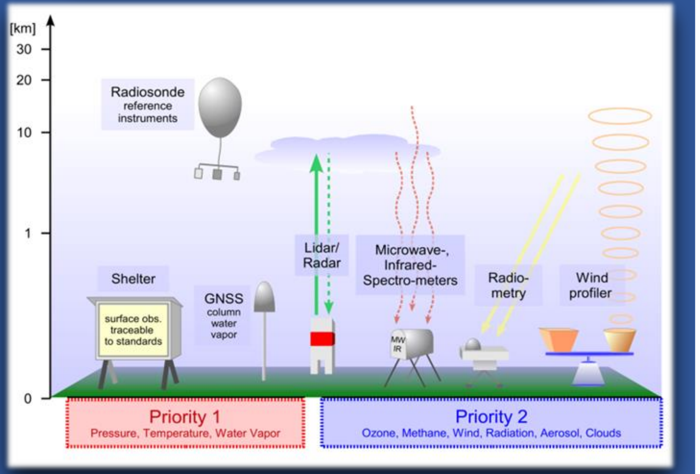

Idealised pictorial representation of the typical suite of GRUAN measurements.

The GRUAN Measurement Strategy Aims to:

- Maintain measurements over several decades to accurately quantify trends
- Provide data to validate and calibrate measurements from observing systems that are more spatially extensive, such as satellite systems and the global radiosonde network, leading to improved satellite data products
- Fully characterise the properties of the atmospheric column
- Measure essential climate variables using a number of different but complementary techniques to validate derived measurement uncertainties
- Characterise observational biases and estimate measurement uncertainties
- Describe measurements using extended metadata and comprehensive documentation of the observing technique
- Ensure long-term stability of measurement series by managing instrument changes, thus improving the overall upper-air observing network
- Tie measurements to SI units or internationally accepted standards
- Ensure that potential gaps in satellite programmes do not invalidate the long-term climate data record
- Further our understanding of climate variability and change

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Scientific Imperatives Include:

- Characterisation of changes in essential climate variables, in particular temperature, humidity, and wind
- Understanding the climatology and variability of humidity, particularly in the region around the tropopause since this is where changes have their largest effect on climate sensitivity
- Understanding changes in the hydrological cycle
- Understanding and monitoring tropopause characteristics
- Understanding the vertical profile of temperature trends
- Bringing closure to the Earth's radiation budget and balance
- Understanding climate processes and improving climate models

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Global Positioning System instrument measuring total column water vapour at Boulder, Colorado, USA

Windprofiler at Lindenberg, Germany

LIDAR at Sodankylä, Finland

WHY DO WE NEED GRUAN?

Understanding our changing climate, and the underlying causes of these changes, requires an understanding not just of changes at the surface of the Earth but throughout the atmospheric column. Furthermore, high-quality measurements are needed to separate the climate change signal from natural variability.

Example: Water Vapour

Water vapour is the most important greenhouse gas as it is responsible for about 60% of the natural greenhouse effect. There are vigorous discussions within the research community regarding whether stratospheric humidity has changed and whether any further change is expected to influence the Earth’s energy budget. At the same time, water vapour measurements, particularly around the tropopause, are afflicted with high measurement uncertainties. Even key mechanisms controlling humidity in this region are not fully understood, leading in turn to significant deficiencies in the pre-dictive skill of global climate models. Currently, satellites and research-quality instruments on aircraft and balloon platforms are the main sources of humidity measurements around the tropopause. Differences between these measurement systems have been difficult to reconcile.

Example: Temperatures

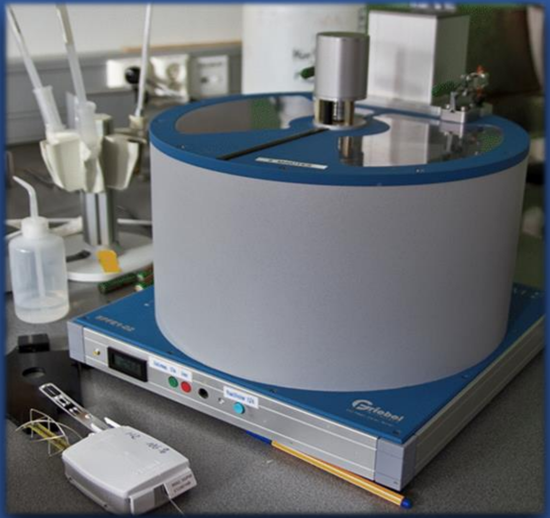
Existing records of upper-air temperatures are insufficient to meet the growing range of needs for studying climate. They greatly lack continuity, homogeneity and representativeness of data, because past measurements were seldom intended for climate research, but mainly for short-term weather forecasting. It is likely that similar problems will persist in the future. Therefore, a way of separating climate change signals from the inevitable non-climatic effects, caused by measurement biases, instrument instabilities and network inhomogeneities, is essential.

Radiosonde launch at Ny-Ålesund, Norway

Similar concerns exist for all other relevant upper-air essential climate variables. Since the early 1990s, the climate research community has been calling for a ground-based reference observing system for measuring changes in upper-air climate.

GRUAN Sites

Microwave radiometer at Lindenberg, Germany



Humidity chamber for pre-launch testing of radiosondes at Ny-Ålesund, Norway

The distribution of GRUAN sites as (as of May 2015). Sites with certified RS92 radiosonde programs are shown in red while sites in the process of being certified, or awaiting certification, are shown in blue.

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GRUAN Milestones

- Establishment of a GRUAN Lead Centre at the Lindenberg Meteorological Observatory (Germany), supported by Deutscher Wetterdienst
- Identification of candidate GRUAN sites
- Implementation Plan published to define a roadmap to implementation
- Task Teams established on Radiosondes, GNSS-Precipitable Water, Measurement schedules and associated site requirements, Ancillary measurements, and Site representation
- Designation of GRUAN as a pilot project for the WMO Integrated Global Observing System (WIGOS)
- Participation in WMO intercomparison of radiosondes
- Publication of formal GRUAN operating procedures, documented in the GRUAN *Manual* and *Guide*, including formal site assessment and certification
- Dissemination of the first GRUAN data product via NOAA/NCDC, http://www.gruan.org/data
- Development of criteria to guide the design and expansion of GRUAN

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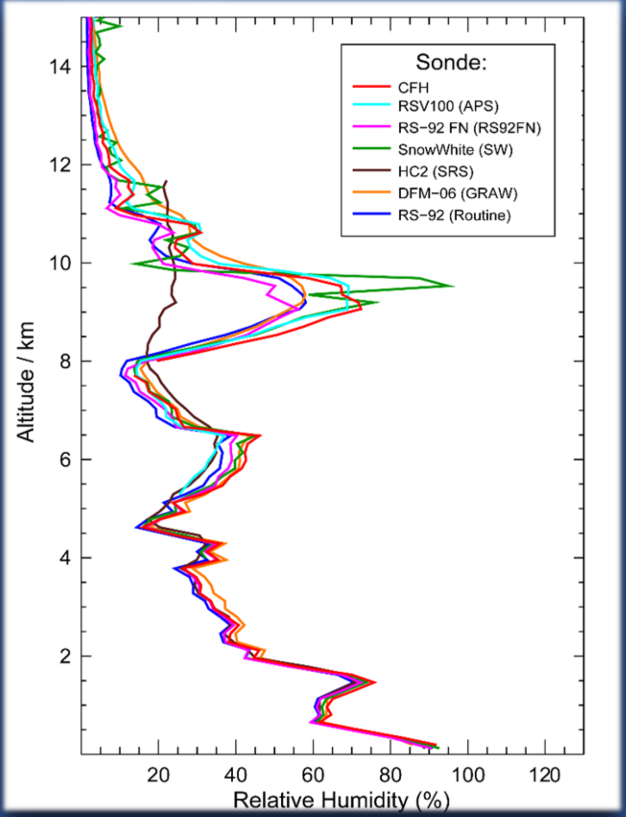
Balloon lifting several radiosondes as part of a regular intercomparison at Lindenberg, Germany.

Examples of Knowledge Transfer Leading to Improvements Beyond GRUAN Include:

- Developing GRUAN data products for radiosonde models used at GRUAN sites has improved understanding of instrument performance.
- GRUAN measurements provided reference observations for a WMO radiosonde intercomparison (Yangjiang, China) where for the first time radiosonde biases – not merely differences – could be assessed.
- GRUAN experience from performance tracking is helping the wider upper-air observing network to address long-standing network management and monitoring concerns.
- GRUAN planning efforts are contributing to discussions regarding the future composition and operation of the wider upper-air observing network (GRUAN-RP-4).
- GRUAN has provided expert input into deliberations on the future of GUAN.



Humidity profiles from radiosonde types measured during the LUAMI campaign 2008, illustrating the uncertainty of measurements in the upper troposphere region.

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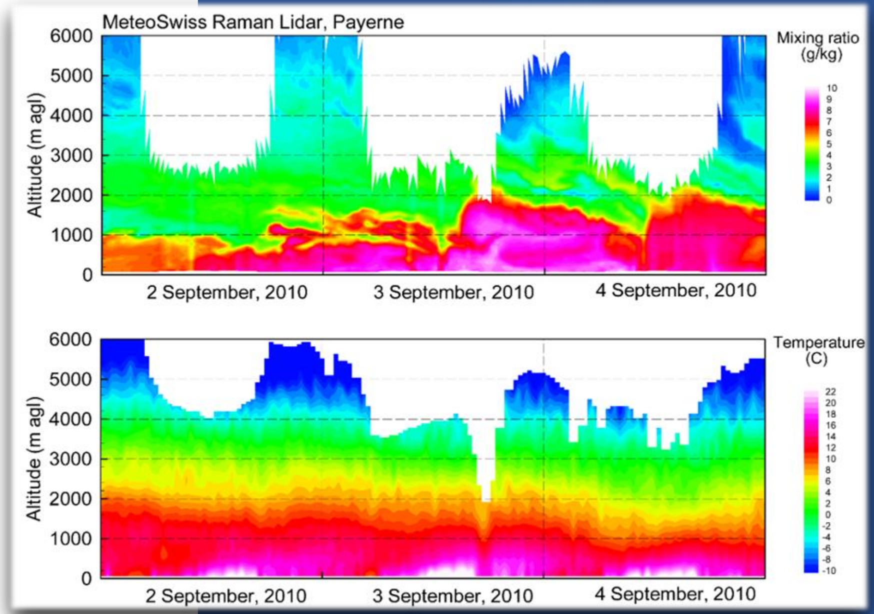
Supporting the Evolution of GRUAN

- Expertise and knowledge that has been developed within GRUAN is not a conserved quantity and new sites benefit from access to this pool. For a marginal additional investment to meet the requirements of GRUAN, the quality of the measurements at new sites can be significantly improved.
- GRUAN sites are needed in the tropics and southern hemisphere, particularly in South America and Africa. National Meteorological Services and sites interested in joining GRUAN should contact the Lead Centre.
- Instrument experts are invited to contribute to the development, assessment and improvement of GRUAN data streams and to contribute to the work of the GRUAN task teams. Sites are invited to perform measurement intercomparisons to better understand instrument biases and measuring system characteristics.
- Ongoing scientific research is needed to underpin GRUAN operations, including scientific analyses of GRUAN data. Scientists interested in contributing should contact the GRUAN Lead Centre.



Three days of continuous temperature (in test mode) and water vapour profiles measured with Raman LIDAR at Payerne, Switzerland, in September 2010.

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Many GRUAN scientists participate in coordinated international programs and collaborate with colleagues internationally. Identifying, nurturing and maintaining these connections has been a GRUAN priority, and participating as a pilot project in the WMO Integrated Global Observing System (WIGOS) programme reinforced this effort.

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Partners

- National contributors (fundamental to success of the enterprise) currently: CMA, CNR, DOE/ACRF, DWD, FMI, Howard University, JMA, JPL, KNMI, MeteoFrance, MeteoSwiss, NIWA, NOAA, NCAR
- Existing observational networks (NDACC, ARM, GAW, BSRN, GUAN, GSN, ACTRIS, AERLINET, AERONET)
- The Global Space-based Inter-calibration System (GSICS) and the "Sustained, Coordinated Processing of Environmental Satellite Data for Climate Monitoring" (SCOPE-CM) Initiative
- The climate science community
- The metrology community who provides guidance to GRUAN on how to ensure that measurements are traceable to international standards and that best practices are adhered to.
- WMO; its Commission for Instruments and Methods of Observations (CIMO); Commission on Climatology (CCI); Commission for Basic Systems (CBS); The World Climate Research Programme (WCRP)

WIGOS
WMO Integrated Global Observing System

GCOS
GLOBAL CLIMATE OBSERVING SYSTEM

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Yangjiang Observatory, China

GCOS / WCRP Atmospheric Observation Panel for Climate - Working Group on GRUAN

Greg Bodeker, Co-Chair
Bodeker Scientific
Alexandra, New Zealand

email: greg@bodekerscientific.com

Peter Thorne, Co-Chair
National University of Ireland
Maynooth, Ireland

email: peter@peter-thorne.net

Contact

GRUAN Lead Centre

Lindenberg Meteorological Observatory
German Meteorological Service (DWD)
Am Observatorium 12
D-15848 Tauche OT Lindenberg
GERMANY

phone: +49 69 8062 5820
fax: +49 69 8062 5710
email: gruan.lc@dwd.de