The GCOS Reference Upper-Air Network (GRUAN) and its Relevance to the Radio Occultation Community

Jordis Tradowsky[1,2,3,4], Greg Bodeker[1], Peter Thorne[5], Ruud Dirksen[6]

[1]Bodeker Scientific, New Zealand
[2]National Institute of Water and Atmospheric Research, New Zealand
[3]Freie Universität Berlin, Germany
[4]ROM SAF
[5]Maynooth University, Ireland
[6]Deutscher Wetterdienst, Germany

OPAC-IROWG, 13th September 2016

Overview

Motivation

- Cooperation between the RO and GRUAN community valuable for both communities
- 3G workshop in Geneva GRUAN-GSICS-GNSS-RO [WMO, 2014], goals:
  - better connect GRUAN with satellite community
  - compare methods for uncertainty estimation, cal/val
  - discuss how to better serve climate/meteorological application
  - discuss future observing system design
- RO measurements, as well as GRUAN data products, are known to be of reference quality
- Comparison of entirely independent measurement techniques can reveal biases and uncertainties in measurements/retrieval

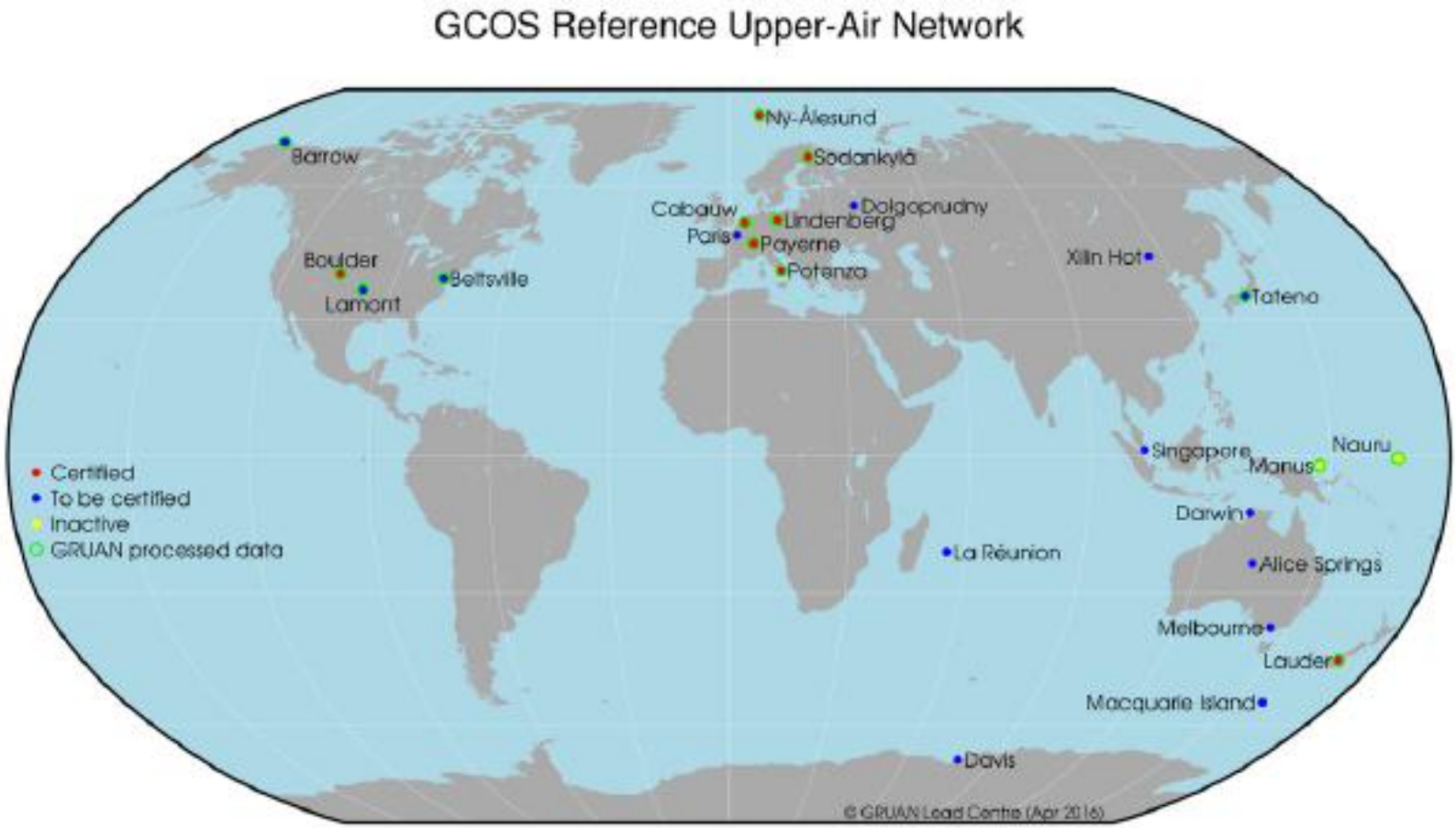
GRUAN - Global Climate Observing System (GCOS) Reference Upper-Air Network

GRUAN was established to fill the need for long-term measurements suitable to detect changes in the climate system

- International ground-based reference observing network
- Provides high-quality ground-based measurements of ECVs[1] in upper-air
- While satellite measurements of ECVs are very valuable, many instruments need to be calibrated
  $\rightarrow$ Operational ground-based networks often do not offer suitable quality and homogeneity for validation

[1] Essential Climate Variables

The GRUAN Network



Currently 24 stations, intended to be 30-40!

Focus of GRUAN

- Provide long-term stable measurements $\rightarrow$ managing change in instruments
- Measurements traceable to SI unit or internationally accepted standard
- Redundant measurements with various instruments essential for validation of the measurement and its uncertainty

GRUAN aims to provide data products suitable to detect climate change!

Reference quality within GRUAN

[Immler et al., 2010]
"Reference within GRUAN means that, at a minimum,

1. the observed profiles are tied to a **traceable standard** at one point (e.g., by an extended, manufacturer-independent ground check of a radiosonde),
2. that the **uncertainty** of the measurement (including corrections) is determined, and
3. that the entire measurement procedure and set of processing algorithms are properly **documented and accessible**."

How to reach the goals of GRUAN

- Collect a rich set of meta data, which, if needed, allows the reprocessing of measurements
- Perform high-quality measurements over long time scales
- Tests in laboratory to estimate biases
- Eliminate causes of bias where possible
- Estimation and propagation of uncertainty
- ... hard work

GRUAN stations

- GRUAN stations are well equipped research facilities
  $\rightarrow$ Measurements of the same ECV[2] available from different instruments
- Redundant measurements are useful for detection of biases and estimation/validation of uncertainties

Typical instrumentation:

- Radiosonde, ozonesonde, frost point hygrometer
- GNSS precipitable water vapour
- Lidar
- Microwave radiometer
- Automatic weather station

[2] essential climate variable

Sonde in Lauder

GRUAN Data Products

- GRUAN data products must include an estimation of the uncertainty on each datum
- Metadata are included in the GRUAN data product
- Documented in the peer-reviewed literature

Atmos. Meas. Tech., 7, 4463–4490, 2014
www.atmos-meas-tech.net/7/4463/2014/
doi:10.5194/amt-7-4463-2014
© Author(s) 2014. CC Attribution 3.0 License.

Atmospheric Measurement Techniques
Open Access

Reference quality upper-air measurements: GRUAN data processing for the Vaisala RS92 radiosonde

R. J. Dirksen[1], M. Sommer[1], F. J. Immler[1,*], D. F. Hurst[2,3], R. Kivi[4], and H. Vömel[1]

Availability of GRUAN data products
Free of charge!

Currently available GDPs[3]:

- RS92 version 002 [Dirksen et al., 2014]
- Beta version of Meisei RS11-G

GDPs in development:

- Radiosondes: RS92 v003, RS41, Modem M10, MeteoLabor
- GNSS precipitable water vapour
- Microwave radiometer
- Lidar
- Ozonesonde
- (Cryogenic) frost point hygrometer

[3] GRUAN Data Products

Example: Radiosonde change management

Currently many GRUAN stations change from the Vaisala RS92 radiosonde to the Vaisala RS41

- A small bias between instruments might exist
- Most GRUAN site (and some non-GRUAN sites) do parallel launches
  $\rightarrow$ Lauder uses parallel launches for one year
- A coordinated program to analyse the results from parallel launches is planned
- Analysis will also include laboratory based measurements
- Investigating potential of using interlaced measurements

GRUAN and RO community

RO and GRUAN data can complement each other!

- RO best in upper troposphere/lower stratosphere, GRUAN very valuable also in lower levels
- Comparing GRUAN and RO enables us to study the quality of RO retrievals and GRUAN bias corrections
- In a perfect world the measurements made with different techniques agree within their uncertainties
- RO technique offers the possibility to be SI traceable. A traceable uncertainty estimate on each datum is desirable!

Example: Comparing the GRUAN RS92 product with RO profiles

As part of the ROM SAF Visiting Scientist Project 31 we intend to:

- Compare RS92 GDP departures with bending angle departures propagated into dry temperature space as described in [Tradowsky, 2015]
  $\rightarrow$ see Chris Burrows presentation later today!
- Use the GRUAN data to estimate how low in the atmosphere we can use the RS[4] bias corrections calculated in [Tradowsky, 2015]

[4] Radiosonde

Example: Comparing the GRUAN RS92 product with RO profiles

- [Ladstädter et al., 2015] found a warm bias in RS92 GDP at the highest pressure levels
- Estimate the warm bias in RS92 GDP from profiles available in 2014/2015 $\rightarrow$ 8003 temperature profiles
- The results of this study will become available as ROM SAF Visiting Scientist Report 31 at:

  `http://www.romsaf.org/visiting_scientist.php`

Available RS92 profiles 2014/15

Station	Station ID	Profiles
Barrow (BAR)	70027	**931**
Beltsville (BEL)		4
Boulder (BOU)	72471	60
Cabauw (CAB)	06260 (De Bilt)	**494**
Lauder (LAU)	93817	78
Lindenberg (LIN)	10393	**2726**
Manus (MAN)		40
Ny Alesund	01004	**745**
Payerne (PAY)	06610	48
Potenza (POT)		49
La Reunion (REU)		19
Lamont (SGP)	74646	**1862**
Sodankyla (SOD)	02836	**837**
Tateno (TAT)	47646	110

Site Atmospheric State Best Estimates[6]

- Use all available measurements of an ECV[5] to best estimate the state of the ECV above the site
- Better temporal and vertical resolution than with individual instruments
- Uncertainty estimate included on each datum
- Currently I am working on a temperature SASBE for the GRUAN site in Lauder including
  - Radiosondes launched in Lauder
  - Radiosondes launched in Invercargill
  - Automatic weather station
- Possibly RO profiles can be included in a later data product
- SASBEs can be used for satellite/model validation

[5] Essential Climate Variable

[6] This project is funded by the German Academic Exchange Service

Summary

- GRUAN is providing a growing amount of measurements/data products
- Ongoing exchange between GRUAN and RO community valuable
- Do not hesitate to contact the GRUAN Lead Centre, the co-chairs or myself if you got any question!

References

Dirksen, R. J., Sommer, M., Immler, F. J., Hurst, D. F., Kivi, R., and Vömel, H. (2014).
Reference quality upper-air measurements: GRUAN data processing for the Vaisala RS92 radiosonde.
Atmos. Meas. Tech., 7:4463–4490.

Immler, F. J., Dykema, J., Gardiner, T., Whiteman, D. N., Thorne, P. W., and Vömel, H. (2010).
Reference Quality Upper-Air Measurements: guidance for developing GRUAN data products.
Atmos. Meas. Tech., 3:1217–1231.

Ladstädter, F., Steiner, A. K., Schwärz, M., and Kirchengast, G. (2015).
Climate intercomparison of GPS radio occultation, RS90/92 radiosondes and GRUAN from 2002-2013.
Atmos. Meas. Tech., 8:1819–1834.

Tradowsky, J. S. (2015).
Characterisation of radiosonde temperature biases and errors using radio occultation measurements.
ROM SAF Visiting Scientist report 26, Radio Occultation Meteorology Satellite Application Facility.
available at `http://www.romsaf.org/visiting_scientist.php#y2015`.

WMO (2014).
WMO INTEGRATED GLOBAL OBSERVING SYSTEM (WIGOS); GRUAN-GSICS-GNSSRO WIGOS Workshop on Upper-Air Observing System Integration and Application.

References

Interactive SASBE available at:

`http://sasbe.bodekerscientific.com/`

GRUAN video available at:

`https://www.youtube.com/watch?v=3y113Zz3y4U`

You can reach me at:

jordis@bodekerscientific.com

Thank you for your attention!