

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

Jordis Tradowsky^{1,2,3,4}, Greg Bodeker¹, Peter Thorne⁵,
Ruud Dirksen⁶

¹Bodeker Scientific, New Zealand

²National Institute of Water and Atmospheric Research, New Zealand

³Freie Universität Berlin, Germany

⁴ROM SAF

⁵Maynooth University, Ireland

⁶Deutscher Wetterdienst, Germany

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- 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 ECVs¹ in upper-air
- While satellite measurements of ECVs are very valuable, many instruments need to be calibrated
→ Operational ground-based networks often do not offer suitable quality and homogeneity for validation

¹Essential Climate Variables

The GRUAN Network



GCOS
Reference
Upper-Air
Network

GCOS Reference Upper-Air Network



Currently 24 stations, intended to be 30-40!

- Provide long-term stable measurements → 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!

[Immmler 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



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GRUAN RO
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SASBEs

Summary

- 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 are well equipped research facilities
→ Measurements of the same ECV² 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

²essential climate variable

Sonde in Lauder



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- 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/
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Atmospheric
Measurement
Techniques



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

R. J. Dirksen¹, M. Sommer¹, F. J. Immeler^{1,*}, D. F. Hurst^{2,3}, R. Kivi⁴, and H. Vömel¹

Availability of GRUAN data products

Free of charge!



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Currently available GDPs³:

- 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

³GRUAN Data Products

Example: Radiosonde change management



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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
→ 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

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



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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 [Tradosky, 2015]
→ see Chris Burrows presentation later today!
- Use the GRUAN data to estimate how low in the atmosphere we can use the RS⁴ bias corrections calculated in [Tradosky, 2015]

⁴Radiosonde

Example: Comparing the GRUAN RS92 product with RO profiles



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- [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 → 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

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 Estimates⁶



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- Use all available measurements of an ECV⁵ 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

⁵Essential Climate Variable

⁶This project is funded by the German Academic Exchange Service

- 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!



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.

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

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Thank you for your attention!

