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

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Overview



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Motivation



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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





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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

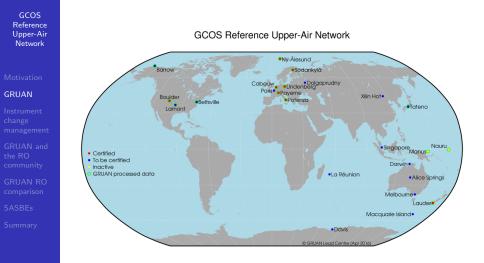
- International ground-based reference observing network
- Provides high-quality ground-based measurements of ECVs¹ in upper-air
- While satellite measurements of ECVs are very valuable, many instruments need to be calibrated
 → Operational ground-based networks often do not offer

suitable quality and homogeneity for validation

¹Essential Climate Variables

The GRUAN Network





Currently 24 stations, intended to be 30-40!

Focus of GRUAN



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- \bullet 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



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[Immler et al., 2010]

"Reference within GRUAN means that, at a minimum,

- the observed profiles are tied to a traceable standard at one point (e.g., by an extended, manufacturer-independent ground check of a radiosonde),
- that the uncertainty of the measurement (including corrections) is determined, and
- 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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- 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

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- 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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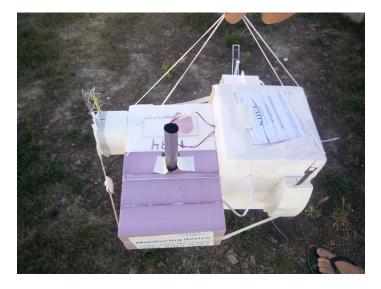
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GRUAN Data Products

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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/ doi:10.5194/amt-7-4463-2014 © Author(s) 2014. CC Attribution 3.0 License.



Atmospheric Measurement Atmospheric Provide At



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

R. J. Dirksen¹, M. Sommer¹, F. J. Immler^{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
 - \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

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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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Summary

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 RS⁴ bias corrections calculated in [Tradowsky, 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 \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



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| 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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Summary

- 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

⁶This project is funded by the German Academic Exchange Service

⁵Essential Climate Variable





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- 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



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 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.
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Interactive SASBE available at:

http://sasbe.bodekerscientific.com/

GRUAN video available at:

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

You can reach me at:

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Thank you for your attention!

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