The ongoing collaboration between GRUAN and the radio occultation community

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Overview

Why am I here?

- I am here to represent the GRUAN community.
- In 2014 the 3G workshop in Geneva was organised to improve the collaboration between GRUAN[1], GSICS[2] and GNSS-RO.
- Goals of this workshop included:
  - Better connect GRUAN with satellite community.
  - Compare methods for uncertainty estimation.
  - Discuss how to better serve climate/meteorological application.
- Over the years, this lead to an ongoing exchange between the communities. Some of you typically join the yearly GRUAN Implementation and Coordination Meeting and I am here for the third time.

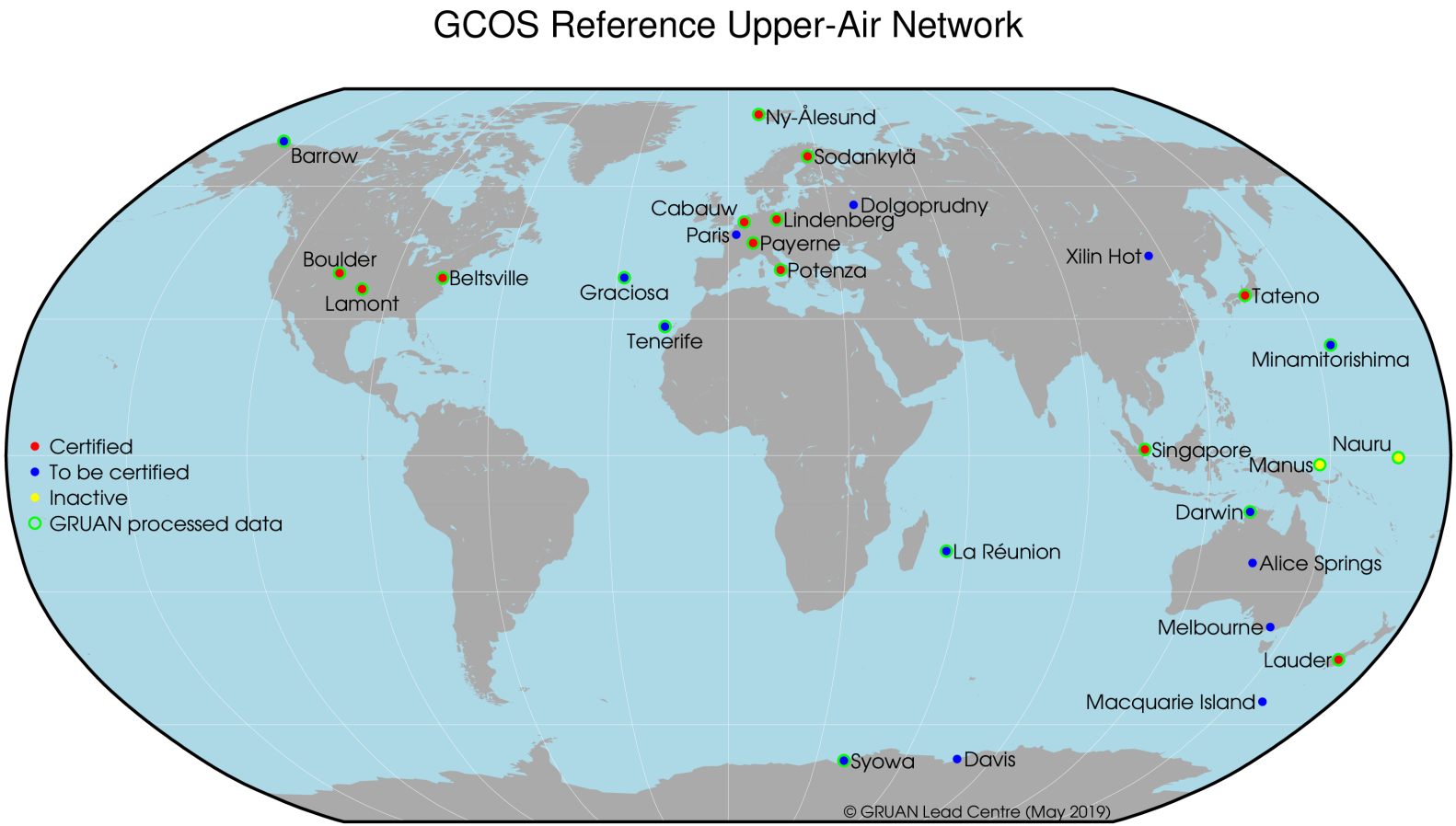
[1] GCOS Reference Upper-Air Network
[2] Global Space-based InterCalibration System

What is GRUAN?

GRUAN - Global Climate Observing System (GCOS) Reference Upper-Air Network (www.gruan.org)

- International ground-based reference observing network, currently 28 sites.
- GRUAN was established to fill the need for long-term measurements suitable to detect changes in the climate system.
- Measurements traceable to SI unit or internationally accepted standard.
- Currently, two radiosonde data product are available, one for the Vaisala RS92 and one for **Meisei RS11-G**.
- Data products for ground-based GNSS water vapour, microwave radiometer, lidar, frost point hygrometer etc. are under development $\rightarrow$ GRUAN is not only a radiosonde network.

Map of GRUAN sites



We now also have candidate sites in Barbados and Suriname!

Reference quality within GRUAN

Within a GRUAN data product, all known biases are corrected and an uncertainty estimate is given with every value.
Following 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**."

Ongoing collaborations and exchange between the communities

Why should we collaborate?

- RO and GRUAN data are of high-quality, but they rely on entirely independent measurement techniques.
- Thus, the comparison between GRUAN and RO can help to:
  - reveal problems in the retrieval,
  - reveal undetected biases, and
  - improve uncertainty estimates.

Ongoing collaborations and exchange between the communities

- GRAS occultation prediction developed by Axel → allows GRUAN sites to time their measurements for better colocations. → Could this be offered by other RO providers as well?
- Joe's work on estimating uncertainties based on comparison to GRUAN.
- Bomin Sun's and Tony Reale's work on RO and GRUAN comparison.
- Weihua Bai's comparison of FY-3 with GRUAN.
- Comparison of GRUAN data for the Vaisala RS92 sonde and the ROM SAF Climate Data Record for GRAS.

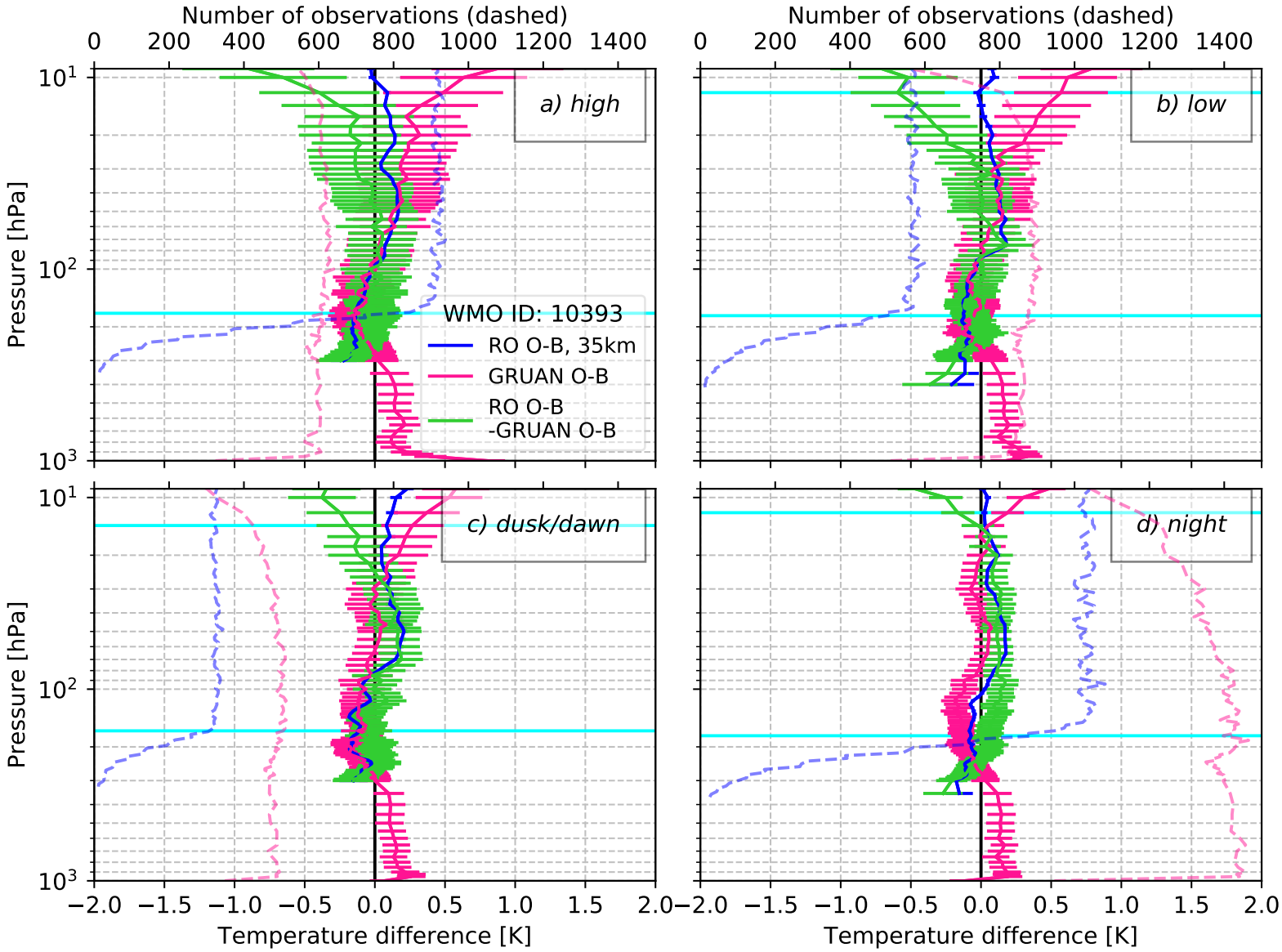
Comparison of GRUAN and ROM SAF CDR

- The comparison between GRUAN Vaisala RS92 and ROM SAF CDR for GRAS has been done for the years 2014-2016.
- A double differencing method using UK Met Office model background fields as transfer standard has been used to minimise effects caused by imperfect colocation.
- A tangent linear RO retrieval is used to propagate bending angle departures (with respect to model background fields) into dry temperature departures.
- A detailed description of the method can be found in Tradowsky et al. (2017).

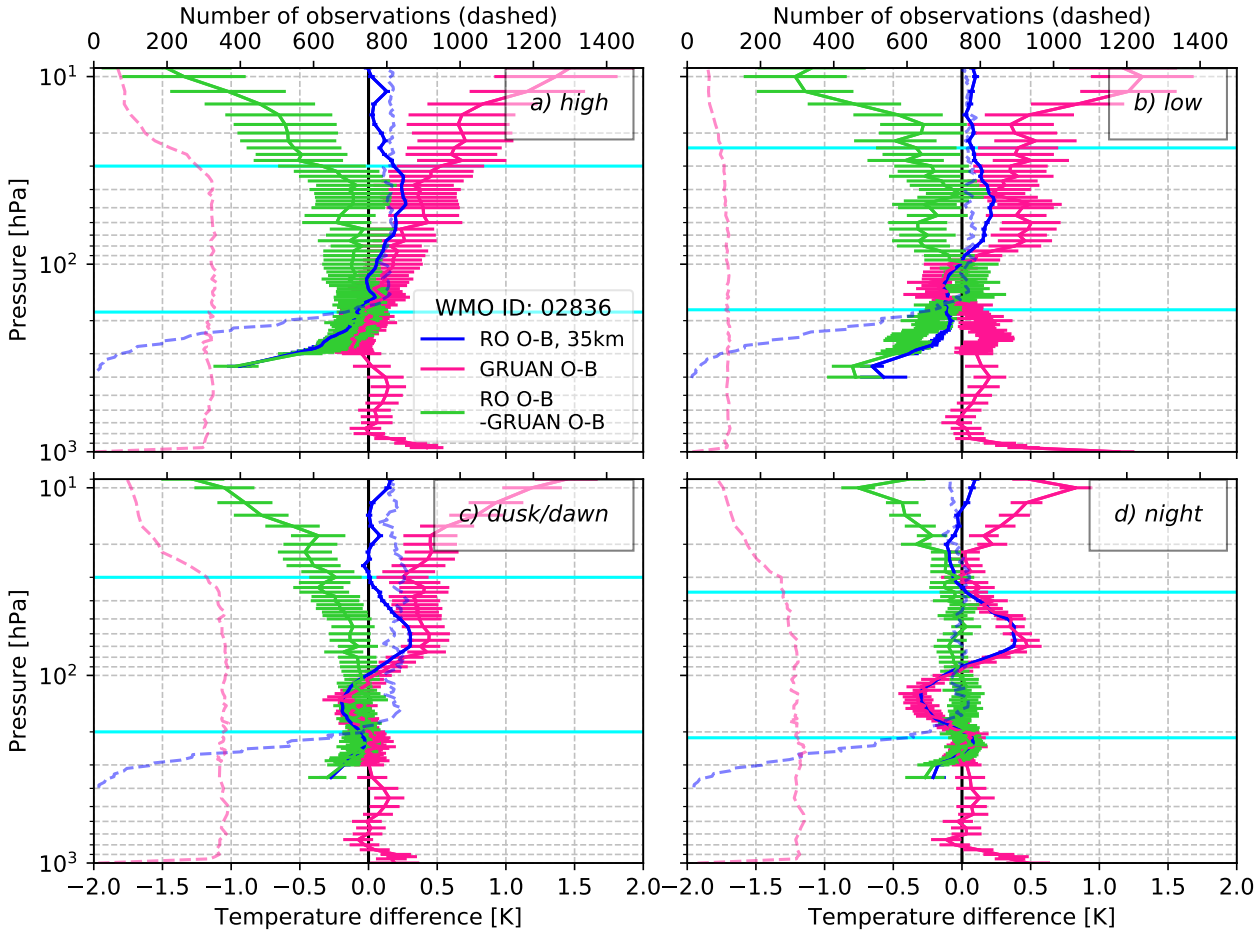
Uncertainties in the GRUAN - RO comparison

- The uncertainties given in the GRUAN data product are propagated into the mean GRUAN departures taking into account two distinct parts of the uncertainty budget, i.e
  - Uncorrelated uncertainties, which decrease with sample size N by $1/\sqrt{(N)}$.
  - Correlated uncertainties, which don't decrease with sample size.
- These uncertainties are propagated individually and are then combined.
- For RO, only the sampling uncertainty is taken into account which means the RO uncertainty will be underestimated. A separate investigation into structural uncertainties builds part of ROM SAF VS37, see Tradowsky (2019).

Comparison of GRUAN and ROM SAF CDR



Comparison of GRUAN and ROM SAF CDR



The comparison can also reveal model biases as can be seen strongest at night time.

Summary

GRUAN's value proposition to users:

- Data products for upper-air measurements from an increasing amount of instruments.
- Uncertainty estimates on every value!!! $\rightarrow$ Please make use of them, much effort goes into producing them.
- Reference-quality data including corrections of all known biases.
- Strict evaluation of suitability of sites.

And all of this is available for free!

References I

A GRUAN video can be found here: `https://www.gruan.org/documentation/public-outreach/`

Immler, F., Dykema, J., Gardiner, T., Whiteman, D., Thorne, P., and Vömel, H. (2010). Reference Quality Upper-Air Measurements: guidance for developing GRUAN data products. *Atmos. Meas. Tech.*, 3(5):1217–1231.

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Thank you for your attention!