The reason I am joining this conference

The GCOS Reference Upper-Air Network

GRUAN - RO comparison

Summary

Comparison of GRUAN profiles with radio occultation bending angles propagated into temperature space

Jordis Tradowsky[1,2,3], Chris Burrows[5], Sean Healy[5], John Eyre[4], Greg Bodeker[1]

[1]Bodeker Scientific
[2]National Institute of Water and Atmospheric Research (NZ)
[3]Freie Universität Berlin
[4]Met Office
[5]European Centre for Medium-Range Weather Forecasts

Study performed as EUMETSAT Radio Occultation Meteorology Satellite Application Facility Visiting Scientist project

jordis@bodekerscientific.com

Overview

1. The reason I am joining this conference
2. The GCOS Reference Upper-Air Network
3. GRUAN - RO comparison
4. Summary

Why am I here?

- I am here to represent the GRUAN community
- 3G workshop in Geneva GRUAN[1]-GSICS[2]-GNSS-RO [WMO, 2014], goals:
  - better connect GRUAN with satellite community
  - compare methods for uncertainty estimation
  - discuss how to better serve climate/meteorological application
- Greg Bodeker, current co-chair of GRUAN, values this cooperation

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

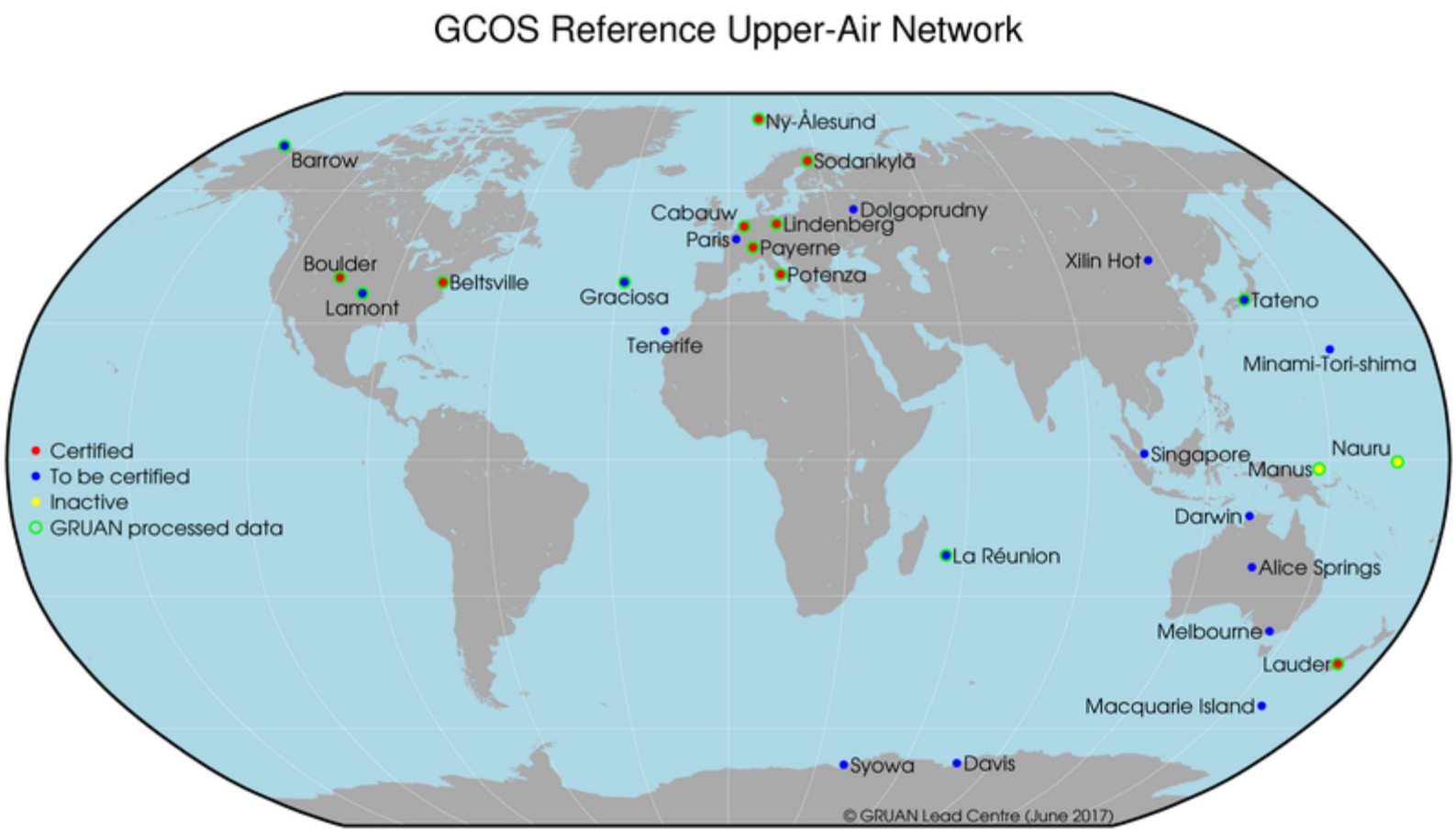
GRUAN

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

- International ground-based reference observing network, currently 28 stations
- Data products with SI-traceable uncertainty estimates
- Currently only radiosonde data product[3], others under development
- GRUAN was established to fill the need for long-term measurements suitable to detect changes in the climate system

[3] https://www.gruan.org/data/data-products/gdp/rs92-gdp-2/

Map of GRUAN sites



Recently published method

A New Method to Correct Radiosonde Temperature Biases Using Radio Occultation Data

JORDIS S. TRADOWSKY

Bodeker Scientific, Alexandra, New Zealand, and National Institute of Water and Atmospheric Research, Lauder, New Zealand, and Freie Universität Berlin, Berlin, Germany

CHRIS P. BURROWS

Met Office, Exeter, United Kingdom

SEAN B. HEALY

European Centre for Medium-Range Weather Forecasts, Reading, United Kingdom

JOHN R. EYRE

Met Office, Exeter, United Kingdom

- double differencing approach
- tangent linear RO retrieval
- RO null space
- structural uncertainty

Method to compare GRUAN radiosondes (RS) and RO

- Double differencing using Met Office NWP system as transfer medium

$$\overline{O_{RO} - O_{RS}} \simeq \overline{O_{RO} - B_{RO}} - \overline{O_{RS} - B_{RS}} \qquad (1)$$

  where O is the observation and B is the background
- Model bias constant over separation distance $\rightarrow$ distinctively smaller standard deviations than using direct differences between observations
- RO bending angles minus background departures are propagated into dry temperature space with a tangent linear retrieval [Tradowsky et al., 2017]
- Bending angle departures above 35km impact height are set to zero (upper cut-off) [Burrows and Healy, 2016] $\rightarrow$ no upper level initialization

Uncertainty estimation in the RO retrieval

- Sampling uncertainty (see [Tradowsky, 2015])
- Structural uncertainty in a tangent linear RO retrieval (see [Tradowsky et al., 2017])
  - Calculated from the spread of the departures for different cut-off impact heights in the RO retrieval
  - Individual for every upper-air site
- Comparison of global structural uncertainty is similar to the structural uncertainty in conventional RO retrievals (see [Ho et al., 2012, Steiner et al., 2013])

GRUAN - RO comparison

- Calculated GRUAN RS92 and RO departure statistics using data from 2014 and 2015
- Statistics calculated using all GRUAN sondes at one site and all COSMIC profiles within a 500 km circle
- GRUAN uncertainties propagated into the departure uncertainties
- RO combined sampling/structural uncertainties
- Consistency ($k = 2$) or agreement ($k = 1$) is tested based on [Immler et al., 2010]

$$|m_1 - m_2| < k\sqrt{u_1^2 + u_2^2} \tag{2}$$

m: measurement, k: coverage factor, u: uncertainty

GRUAN - RO comparison Lindenberg

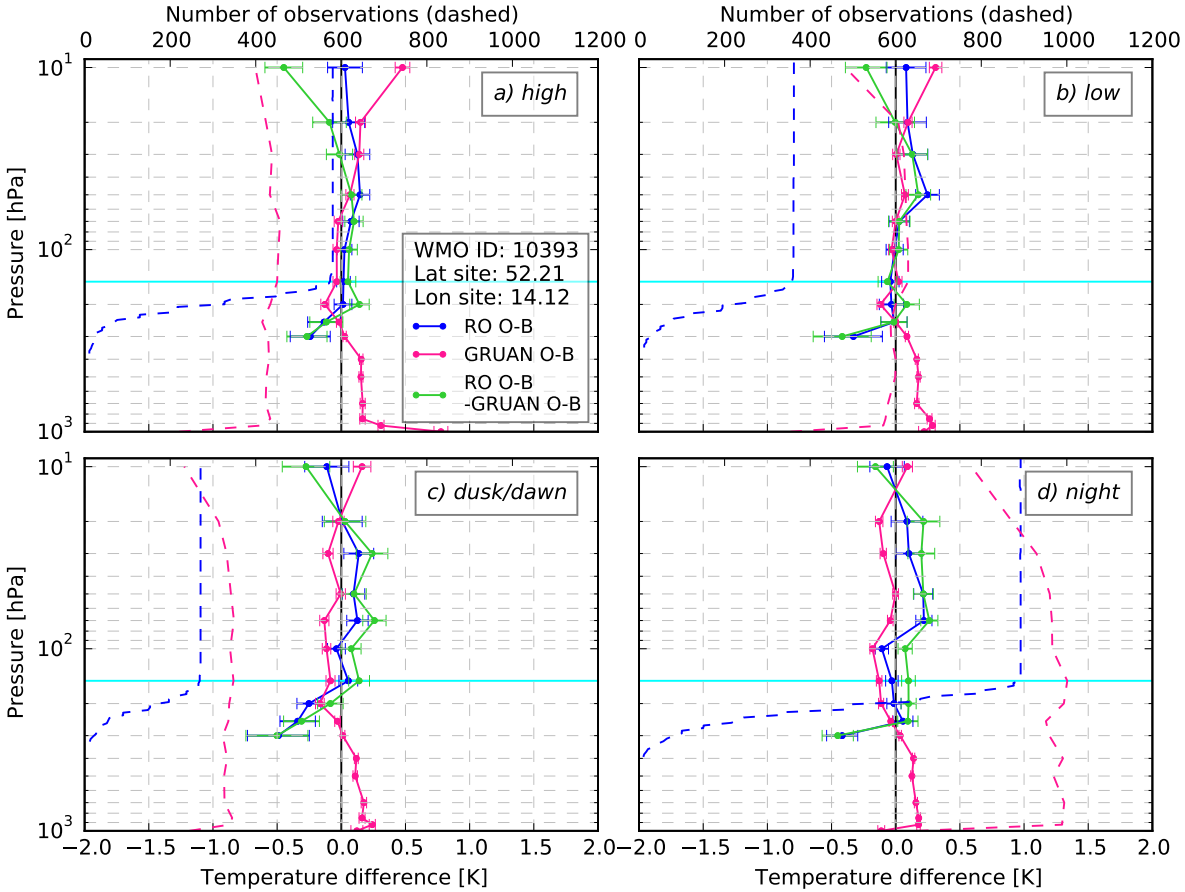


Figure 1: Mean RO Tdry departures (blue), mean GRUAN temperature departures (pink) and RO O-B minus GRUAN O-B (green) at the example site in Germany for different SEA ranges (a)-(d). The horizontal cyan line indicates the highest standard pressure level (lowest altitude) where at least 95% of the RO profiles are included. The RO error bars represent the structural uncertainty in addition to the sampling uncertainty, i.e. $uncertainty = SE + range/2$.

GRUAN - RO uncertainties Lindenberg

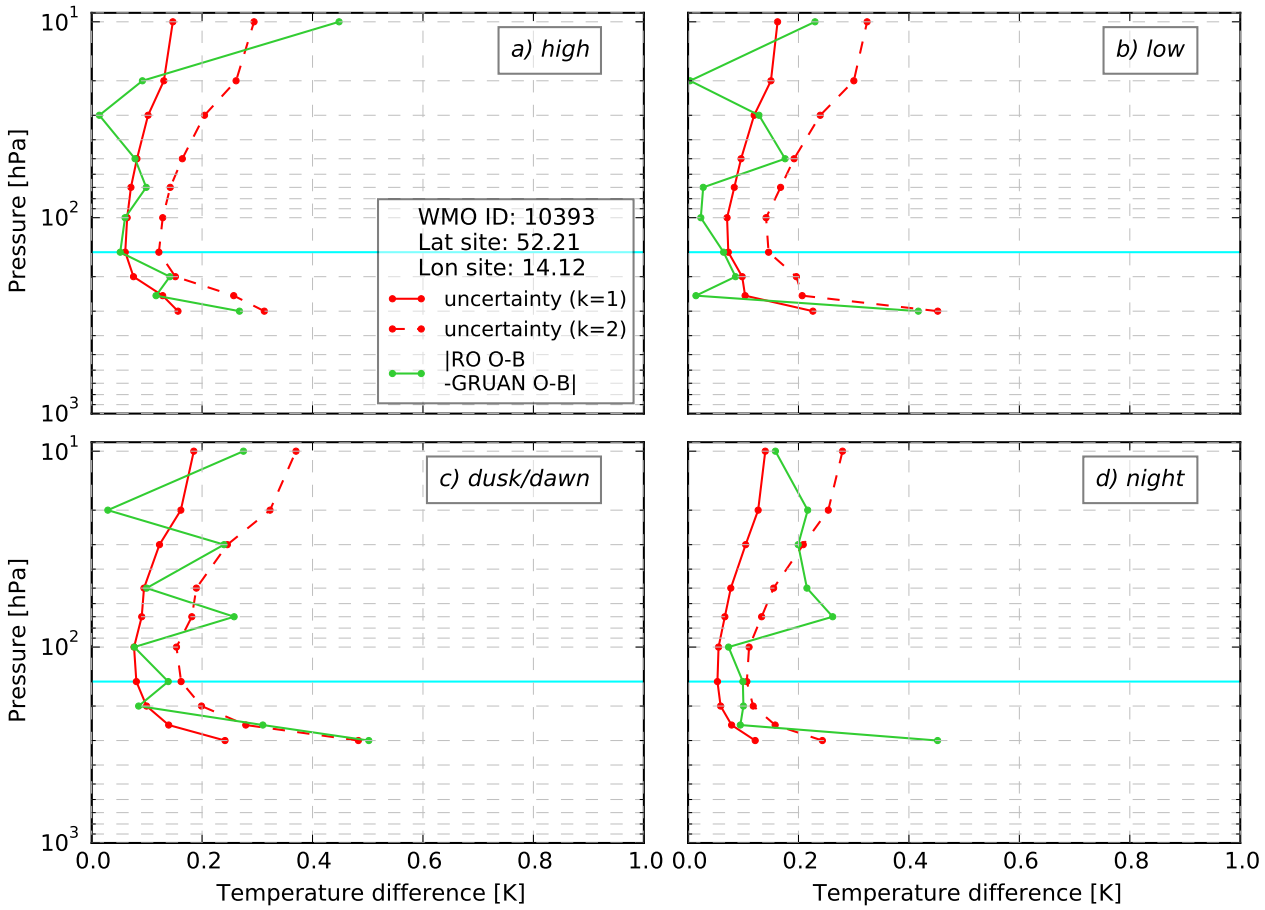


Figure 2: Uncertainty estimates for the difference between the RO minus GRUAN departures for $k = 1$ (red), and $k = 2$ (red dashed). Green: absolute temperatue difference between RO and GRUAn departures.

GRUAN - RO comparison Sodankylä

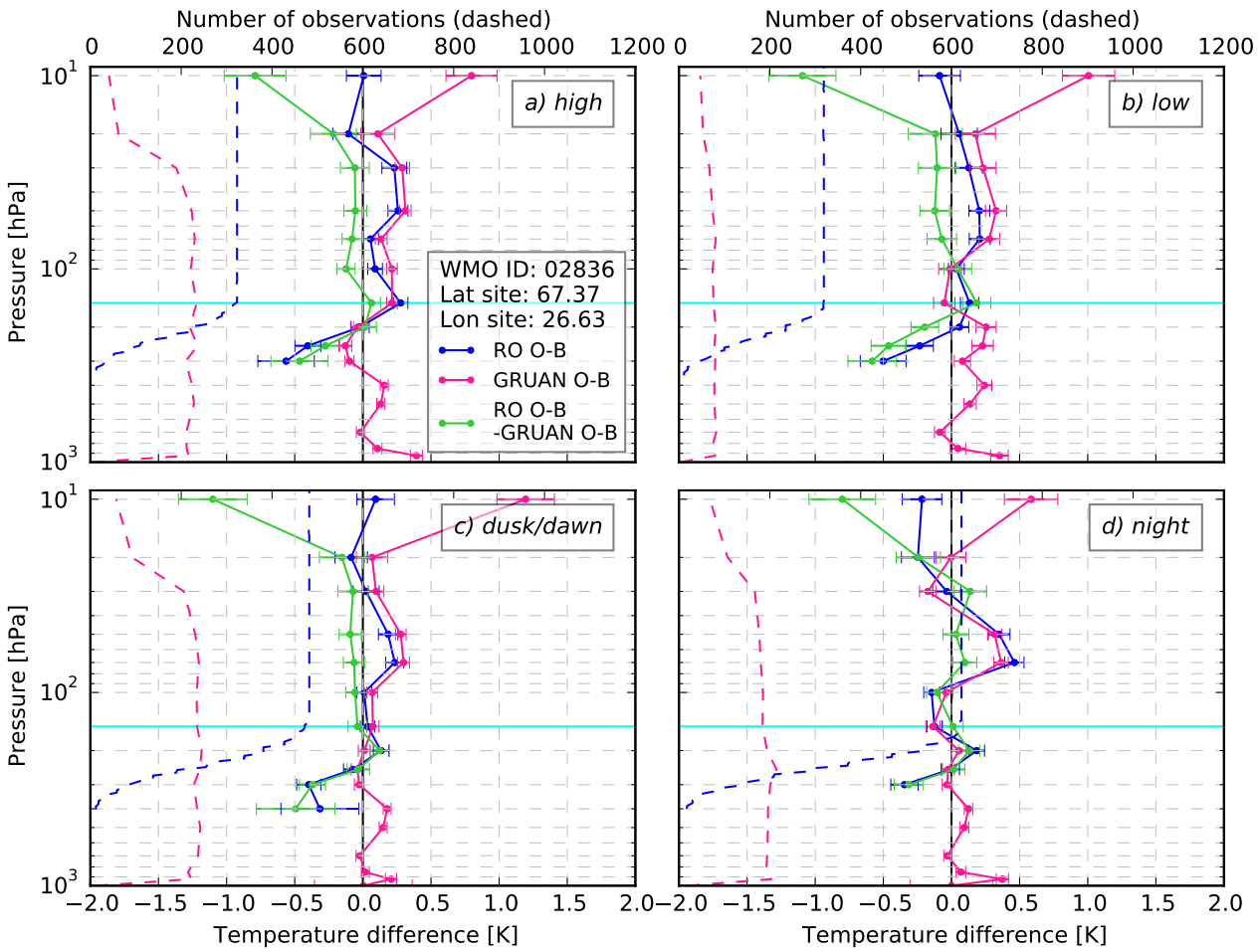


Figure 3: As Fig.1, but for the GRUAN site Sodankylä.

GRUAN - RO uncertainties Sodankylä

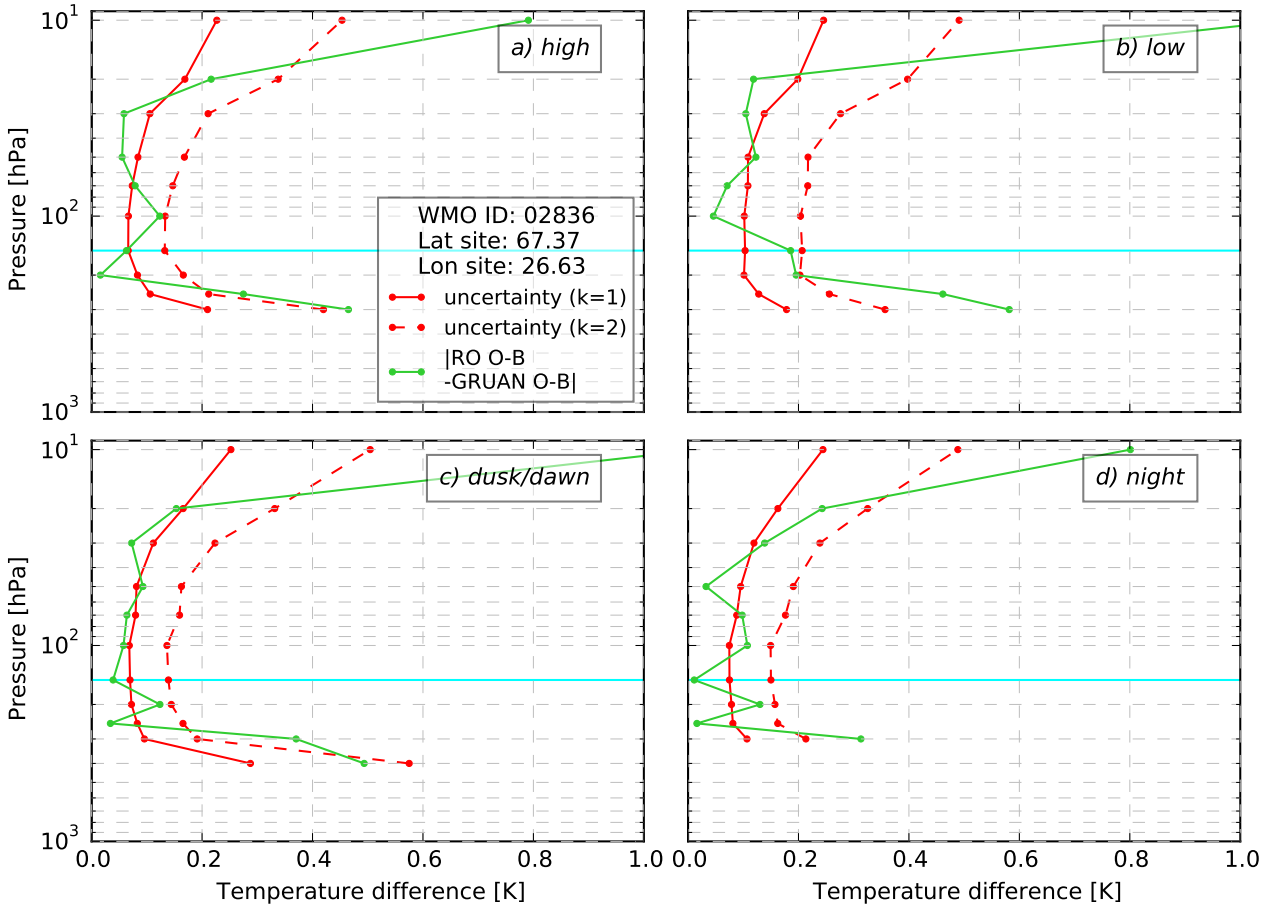


Figure 4: As Fig 2, but for Sodankylä.

Summary

- Comparison between entirely independent measurement techniques can reveal biases in the measurements and problems in the retrieval
- GRUAN and RO consistence or agreement at many levels
- Possibly a warm bias in the GRUAN RS92 version 2 data product
- The ongoing cooperation between GRUAN and RO communities is valuable (Axel, Ben, Bomin, Florian, Greg and others)
- I will aim to join the next IROWG meeting (this depends on funding and we are currently fighting to get money for Greg's co-chair role)

References I

Burrows, C. P. and Healy, S. B. (2016).
Sensitivity of radio occultation-based dry temperature retrievals to upper-level information and its relevance to radiosonde bias corrections.
Forecasting Research Technical Report 615, Met Office.
Available at http://www.metoffice.gov.uk/binaries/content/assets/mohippo/pdf/library/frtr_615_2016_2p.pdf.

Ho, S.-P., Hunt, D., Steiner, A. K., Mannucci, A. J., Kirchengast, G., Gleisner, H., Heise, S., von Engeln, A., Marquardt, C., Sokolovskiy, S., Schreiner, W., Scherrlin-Pirscher, B., Ao, C., Wickert, J., Syndergaard, S., Lauritsen, K. B., Leroy, S. S., Kursinski, E. R., Kuo, Y.-H., Foelsche, U., Schmidt, T., and Gorbunov, M. (2012).
Reproducibility of GPS radio occultation data for climate monitoring: Profile-to-profile inter-comparison of CHAMP climate records 2002 to 2008 from six data centers.
J. Geophys. Res., 117.

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(5):1217–1231.

Steiner, A. K., Hunt, D., Ho, S.-P., Kirchengast, G., Mannucci, A. J., Scherllin-Pirscher, B., Gleisner, H., von Engeln, A., Schmidt, T., Ao, C., Leroy, S. S., Kursinski, E. R., Foelsche, U., Gorbunov, M., Heise, S., Kuo, Y.-H., Lauritsen, K. B., Marquardt, C., Rocken, C., Schreiner, W., Sokolovskiy, S., Syndergaard, S., and Wickert, J. (2013).
Quantification of structural uncertainty in climate data records from gps radio occultation.
Atmospheric Chemistry and Physics, 13(3):1469–1484.

References II

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/Publications/reports/romsaf_vs26_rep_v12.pdf.

Tradowsky, J. S., Burrows, C. P., Healy, S. B., and Eyre, J. R. (2017).
A new method to correct radiosonde temperature biases using radio occultation data.
Journal of Applied Meteorology and Climatology, 56(6):1643–1661.

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

Thank you for your attention!