An Update from the International Radio Occultation Working Group Meeting 2016

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Overview

1. Motivation
2. Radio Occultation
3. GRUAN and the RO community
4. Sub-groups
5. RO uncertainty estimation
6. Summary
Motivation

- GRUAN-GSICS\(^1\)-GNSS-RO\(^2\)(3G) workshop in Geneva [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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\(^1\)Global Space-based Intercalibration System
\(^2\)Global Navigation Satellite System Radio Occultation
The Radio Occultation Method

- Signal transmitted by GNSS satellite (here GPS) is received by a low-earth orbit (LEO) satellite

Phase shift $\rightarrow$ bending angle $\rightarrow$ refractivity $\rightarrow$ (dry) temperature

Figure credit: [Syndergaard, 1999]
GRUAN and RO community

RO and GRUAN data can complement each other!

- RO highest accuracy 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
OPAC - Occultations for Probing Atmosphere and Climate

IROWG - International Radio Occultation Working Group Meeting

- Joined OPAC-6 IROWG-5 meeting was held in Austria in September 2016

- I participated to represent the GRUAN community and gave the presentation
  ‘The GCOS Reference Upper-Air Network (GRUAN) and its Relevance to the Radio Occultation Community’
  [Tradowsky et al., 2016]
Focus of the OPAC-IROWG Meeting

- Occultation methodology
- RO in meteorology, numerical weather prediction
- RO in climate monitoring and research
- RO in ionospheric science
- Future missions
IROWG Sub-group Meetings

- Climate
- Numerical Weather Forecast
- Ionosphere and Space Weather
Climate Sub-group

Members e.g.: Chi Ao, Andrea Steiner, Ben Santer, Johannes Nielsen, myself...

The sub-group was working on recommendations for:

1. Coordination Group for Meteorological Satellites
   - Ensure long-term availability of data with global coverage, regular reprocessing for RO climate records

2. Recommendations to satellite operators and data providers
   - Document processing chain, increase effort on uncertainty estimation, gridded data products with uncertainties

3. Recommendations within IROWG
   - Develop RO as climate monitoring system (SCOPE-CM³), continue participation in wider scientific community

³Sustained and coordinated processing of Environmental Satellite data for Climate Monitoring
Uncertainty estimation in RO retrievals 1

- RO does not offer a direct measurement of essential climate variables
- The phase shift is measured and the bending angle can be calculated
- In the conventional RO retrieval the noisy bending angles are merged with a smooth bending angle profile above approximately 40 km → climatology
- The choice of smoothing algorithm and climatology influences the retrieval at all levels → structural uncertainty
• Comparison of retrievals from different processing centres used to estimate this structural uncertainty [Ho et al., 2012, Steiner et al., 2013]

• Chris Burrows, Sean Healy, John Eyre and I presented a tangent linear retrieval algorithm which allows to estimate the structural uncertainty in the retrieval directly [Tradowsky et al., 2017]

• The Wegener Center in Graz is working on a Reference Occultation Processing System which includes uncertainty propagation

• Jacob Schwarz et al.: Integrating uncertainty propagation in GNSS radio occultation retrieval: From bending angle to dry-air atmospheric profiles [Schwarz et al., 2017]
Summary

- Valuable to keep an ongoing exchange between RO and GRUAN communities. Thank you Axel, Rob, Joe and others for being here!

- I will present a GRUAN-RO comparison in a separate talk

- I am looking forward to represent GRUAN at the next IROWG meeting during September 2017

- Please keep me up to date about your projects involving GRUAN and RO
References

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.

Integrating uncertainty propagation in gnss radio occultation retrieval: From bending angle to dry-air atmospheric profiles.

Quantification of structural uncertainty in climate data records from gps radio occultation.

Retrieval Analysis and Methodologies in Atmospheric Limb Sounding Using the GNSS Radio Occultation Technique.
Danish Meteorological Institute Scientific Report 99-6, Danish Meteorological Institute.
The GCOS Reference Upper-Air Network (GRUAN) and its Relevance to the Radio Occultation Community.
Conference presentation.

A new method to correct radiosonde temperature biases using radio occultation data.

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!