CGMS

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Prepared by IROWG
Agenda Item: WGII/3

UPDATE FROM THE INTERNATIONAL RADIO OCCULTATION WORKING GROUP

Prepared by IROWG[1] (www.irowg.org)

Executive Summary

The IROWG community has not met since CGMS-49. Therefore, we re-state the four key recommendations previously presented at CGMS-49, endorsed by the IROWG community at IROWG-8 (virtual conference, hosted by NOAA and UCAR), April 7-13, 2021.

The four key recommendations carried forward from IROWG-8 are:

- IROWG reaffirms that all providers of RO observations should classify these as essential in the sense of WMO Resolution 40. IROWG stresses the importance of free, timely and unrestricted access in real-time to essential RO data, and free and unrestricted access to archived raw data (including auxiliary data).

- IROWG continues to recommend that WMO and CGMS should coordinate any GNSS-RO data purchases. Specifically, we suggest convening a meeting of all agencies considering procuring these data, in order to discuss if, how and when the current 20,000 daily target will be met with global and full local time coverage.

- IROWG recommends that CGMS encourages technology and retrieval developments for improving planetary boundary layer profiling from GNSS-RO and their utilization in NWP data assimilation – and the further exploration of RO-derived water vapor as a climate variable.

- Per CGMS priority HLPP 1.1.4 (optimized system for atmospheric and ionospheric RO observations), IROWG recommends that CGMS encourages on-going and future GNSS-RO and non-RO missions, including commercial providers of RO observations, to incorporate a complete set of ionospheric measurements.

The CGMS-49 working paper from IROWG-8 is available at http://irowg.org/workshops/irowg-8/. All given workshop presentations can be found at https://cpaess.ucar.edu/meetings/2021/irowg-8.

The next IROWG-9 workshop will be held on September 8-14, 2022 in Seggauberg, Austria. It will be combined with the 7th Workshop on “Occultations for Probing Atmosphere and Climate”.

Action/Recommendation proposed: CGMS is invited to take note and comment.

[1] International Radio Occultation Working Group, represented by the rapporteur Anthony Mannucci and the co-chairs Ulrich Foelsche, Sean Healy, and Hui Shao (co-chair elect). Affiliations are listed at the end of this document.

1 INTRODUCTION

The IROWG community has not met since IROWG-8 in April 2021, and therefore we simply carry forward the four key recommendations previously presented at CGMS-49. Consequently, this report will be brief.

Sean Healy is stepping back as IROWG co-chair; an election process for a new co-chair was therefore initiated, and Dr. Hui Shao (Joint Center for Satellite Data Assimilation) was elected by the community. The formal handover will happen at the upcoming IROWG meeting in September 2022 (see below).

The structure of this report is as follows: Section 2 gives a brief overview of the organization of the upcoming IROWG-9 workshop. Section 3 summarizes the main recommendations from the IROWG-8 workshop in 2021 – including some remarks related to recent developments, and Section 4 concludes the main section of the report. The status of actions and recommendations is covered in the Appendix.

2 PROPOSED IROWG-9 SETUP

The next IROWG workshop (IROWG-9) will be held on September 8-14 2022 in Seggauberg, Austria, in conjunction with the OPAC-7 meeting (Occultations for Probing Atmosphere and Climate).

https://opacirowg2022.uni-graz.at/en/

It will be a full workshop, including presentations, posters and sub-group discussions. The presentations/posters and the sub-groups will be organized according to the following specific topics, namely:

- Numerical Weather Prediction (NWP);
- Climate;
- Receiver Technology and Innovative Occultation Techniques;
- Space Weather.

IROWG-9 participants will be asked to summarize relevant activities within the scope of the sub-group in dedicated sub-group meetings and express recommendations which could either be relevant to CGMS, to the GNSS (Global Navigation Satellite System, e.g. GPS) RO community, to providers of RO data, or within the IROWG. Recommendations will be discussed in the open plenary. Furthermore, the sub-groups will assess the status of the relevant CGMS actions.

3 MAIN RECOMMENDATIONS FROM IROWG-8

3.1 IROWG reaffirms that all providers of RO observations should classify these as essential in the sense of WMO Resolution 40. IROWG stresses the importance of free, timely and unrestricted access in real-time to essential RO data, and free and unrestricted access to archived raw data (including auxiliary data).

This is important for NWP, Climate and Space Weather. For applications in climate science it is particularly important that all information necessary for independent processing towards climate data products is freely available. Data latency is particularly important for Space Weather applications (requirement of 30 minutes (median), with a goal of 15 minutes).

3.2 IROWG continues to recommend that WMO and CGMS should coordinate any GNSS-RO data purchases. Specifically, we suggest convening a meeting of all agencies considering procuring these data in order to discuss if, how and when the current 20,000 target will be met with global and full local time coverage.

It is likely that commercial data will need to be purchased, with a world license for near-real-time data, to meet the current target of 20,000 globally available occultations per day.

IROWG notes that commercial data are of operational quality and have been used successfully by several agencies, as demonstrated by the successful operational assimilation by the ECMWF, UK Met Office, and USAF of over 7000 daily, near real-time Spire Level 2 RO BUFR profiles over more than four months in 2020. The daily target of 20,000 – although possible within 2021 with the inclusion of commercial data – will be difficult to achieve without sharing the data. These data should be evenly distributed in local time and latitude.

Climate requirements should be taken into consideration when purchasing commercial data, and the potential climate quality of commercial data needs to be assessed.

A world license has numerous benefits, including avoiding data duplication, sharing of experience with data sets among different centres, fairness among countries, and reducing the timeline toward implementation.

IROWG will provide links to current real time statistics on the number of assimilated GNSS-RO data in various systems, and their performance.

3.3 IROWG recommends that CGMS encourages technology and retrieval developments for improving planetary boundary layer profiling from GNSS-RO and their utilization in NWP data assimilation – and the further exploration of RO-derived water vapor as a climate variable.

GNSS-RO can provide very high vertical resolution, all-weather, thermodynamic profiling of the planetary boundary layer (PBL) that is difficult to achieve from any other remote sensing technique. The unique contribution from GNSS-RO for spaceborne PBL profiling of temperature and water vapor as well as PBL height has been recognized in the U.S. 2017–2027 Decadal Survey for Earth Science and Applications from Space.

Atmospheric radio-refractivity is heavily dependent on water vapor. GNSS-RO data in the lower troposphere therefore contain a lot of water vapor information, which has so far only been partly exploited.

3.4 Per CGMS priority HLPP 1.1.4 (optimized system for atmospheric and ionospheric RO observations), IROWG recommends that CGMS encourages on-going and future GNSS RO and non-RO missions, including potential commercial providers of RO observations, to incorporate a complete set of ionospheric measurements.

- across all negative elevation angles as defined in the LEO local level frame from orbit altitude down to near the Earth's limb to allow for ionospheric profiling (for RO missions)
- across all positive elevation angles in the zenith direction for ionospheric/plasmaspheric sensing
- dual frequency signal amplitudes or SNRs, pseudoranges, phases, slant TECs, amplitude and phase scintillation indices
- with the maximum sampling rate allowed by the receiver (at least for all the time intervals for which the level of ionospheric scintillation is significant).

IROWG endorses the merit of ionospheric upgrades to EPS being implemented for ionospheric data, as done in the Metop-A End-of-Life test. In addition, the sub-group acknowledges that the Sentinel-6 hardware is capable of acquiring ionospheric observations in addition to the atmospheric RO, and endorses plans for implementing ionospheric capabilities via software upgrade to the Sentinel-6 receiver.

Current Status and Recent Developments

The main recommendations from IROWG-8 are still valid.

Related to Recommendation (3.2):

> IROWG acknowledges that such coordination has already started, however, further coordination would be beneficial to allow for optimal data use by the global community.

Purchasers of RO data for NWP should document their access to raw data, so that such purchased data can be used reliably in climate applications, where traceability of the measurements to fundamental units (e.g. definition of the second) is essential. For climate, appropriate documentation and meta-data needs to be available with the provision of raw data.

Recent world events and ongoing conflicts have increased the use of GNSS radio jammers in various theatres. The RO community has begun to document the resulting degradation on RO measurements from radio frequency interference. It will be to the benefit of CGMS to acquire information on these developments and monitor their impacts to the observing system.

4 CONCLUSIONS

The “GPS” RO technique is now a true “GNSS” RO technique, where signals from all GNSS constellations are being exploited.

GNSS-RO data demonstrate a high impact in NWP. This impact clearly increases with the number of high-quality profiles – without any sign of “saturation”.

GNSS-RO climate data advance climate change monitoring and contributed to the IPCC assessment report #6.

GNSS-RO data with high spatial and temporal resolution allow for unprecedented studies of atmospheric and ionospheric phenomena.

A better penetration into the lowest kilometres allows for studying the planetary boundary layer – including tropospheric water vapor.

Overall, the aim of the community is to ensure the long-term continuity of the GNSS-RO measurements, and to maximize the number of high-quality GNSS-RO observations, providing good spatial and local time coverage, which can be freely exchanged. Specifically, the researchers need access to the raw data, not just retrieved products. The provision and funding of long-term archiving of both the raw GNSS-RO data and all the meta-data are essential for climate studies, for reanalyses, and for any reprocessing activities. The researchers also need access to information about the instrument’s performance. Overall, it is important that multiple centers have all the information required for them to process and re-process GNSS-RO from both government-sponsored and commercial missions. Therefore, there is strong support for a “backbone” of agency-funded GNSS-RO missions with long-term commitment.

Commercial GNSS-RO missions have reached operational quality (at least in the UTLS), and could help to close the identified gaps in geographic and local-time coverage – provided that they are made available for the scientific community.

5 APPENDIX

Status of CGMS Actions/Recommendations relevant to IROWG

There is one open action (for data providers) related to IROWG.

A48.02: Data providers to document data processing QC processes (including a month of QC statistics, e.g. rejection percentage at each QC step) and space sampling information and provide to IROWG.

- IROWG notes that this is a CGMS recommendation to data providers.
- IROWG suggests that the relevant agencies send representatives to the next IROWG meeting so that detailed information on quality control methods and statistics used by the different agencies can be discussed, leading to their improved documentation.
- The need for this has been recognised, and members of the community will take steps to document their procedures.
- Certain WG members (from EUMETSAT, Spire and NOAA-NESDIS) agreed to provide information on QC numbers in the next IROWG meeting.

This action was also discussed during the latest Intersessional meeting, and there was agreement that this action should be closed during CGMS-50 – WGII and a new action should be formulated.

Affiliations

Anthony Mannucci is with the Jet Propulsion Laboratory, California Institute of Technology. Sean Healy is with the European Center for Medium Range Weather Forecasts. Ulrich Foelsche is with the University of Graz, Austria. Hui Shao is with the Joint Center for Satellite Data Assimilation.