IROWG update on recommendations and activities

Presented to CGMS-51 WGII session, agenda item 3

Co-Chairs: Hui Shao (JCSDA)
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Rapporteur: Tony Mannucci (NASA/JPL)

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Overview

- IROWG status
- IROWG-9 Meeting
- IROWG-9 Highlights
- IROWG-9 main recommendations
- Action item review

IROWG Status

- Dr. **Sean Healy** has stepped back as IROWG co-chair. His dedication and support over many years are much appreciated by the IROWG community!

- Dr. **Hui Shao** (UCAR/Joint Center for Satellite Data Assimilation) was elected by the IROWG community. The formal handover happened at IROWG-9 meeting in September 2022.

IROWG-9 Meeting

8 – 14 September 2022, **Seggau Castle**, Leibnitz near Graz, **Austria**

Together with the 7th **International Workshop on Occultations for Probing Atmosphere and Climate** (OPAC).

Celebrating **20 years of OPAC**.

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

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IROWG-9 Meeting

- First in-person IROWG meeting since the pandemic
- More than 100 scientists, including representatives from all the major RO processing centers, space agencies, weather prediction centers, commercial data providers, and the research community
- 81 oral presentations, three opening talks, one keynote talk, and 21 posters
- Four working subgroup meetings: Numerical Weather Prediction (NWP); Climate; Receiver Technology and Innovative Occultation Techniques; Space Weather
- Dedicated specialist meetings: BUFR format revision; level 0 data format definition; and future radio occultation operator development.

Full workshop minutes and CGMS working paper from IROWG-9 are available at http://irowg.org/workshops/irowg-9/

Workshop presentations can be found at https://opacirowg2022.uni-graz.at/en/

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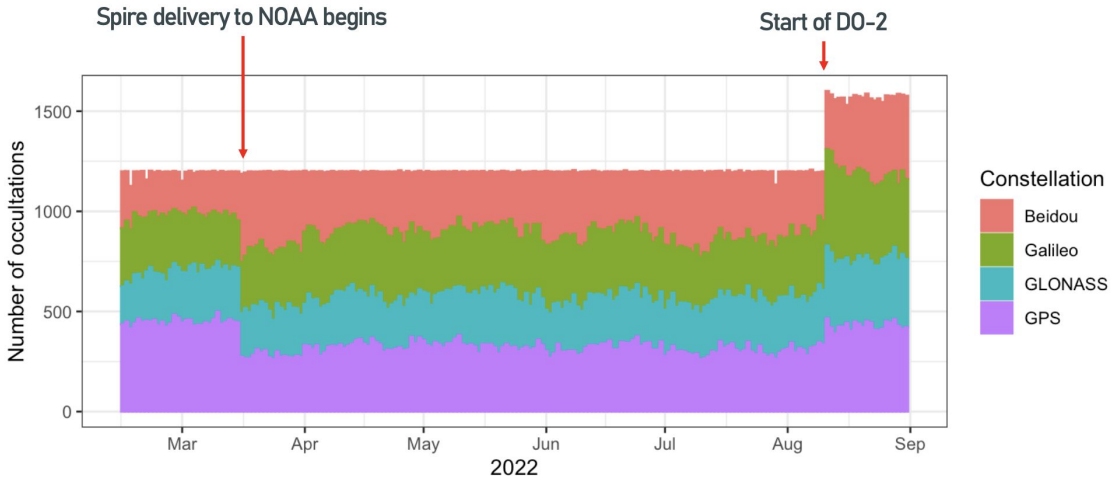
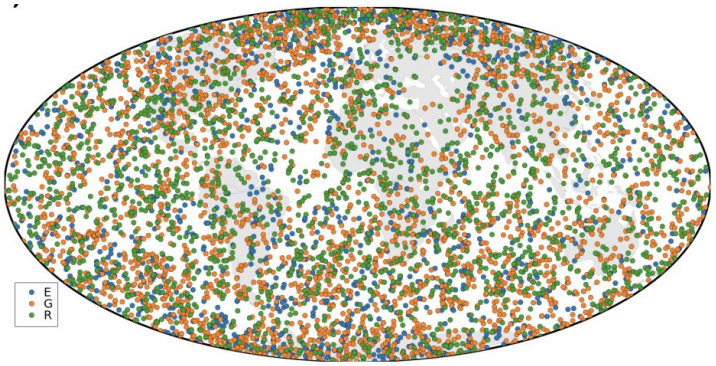
IROWG-9 Science Highlights

The "GPS" RO Technique is now a true "GNSS" RO Technique, where **signals from all GNSS constellations** are being exploited.



Number of occultations during DO-1/2 by GNSS constellations for EUMETSAT commercial purchase

Christian Marquardt (EUMETSAT)



UCAR processing GPS, GLONASS, and Galileo occultations (color coded) since NOAA commercial order (DO)-3

Maggie Sleziak-Sallee (UCAR)

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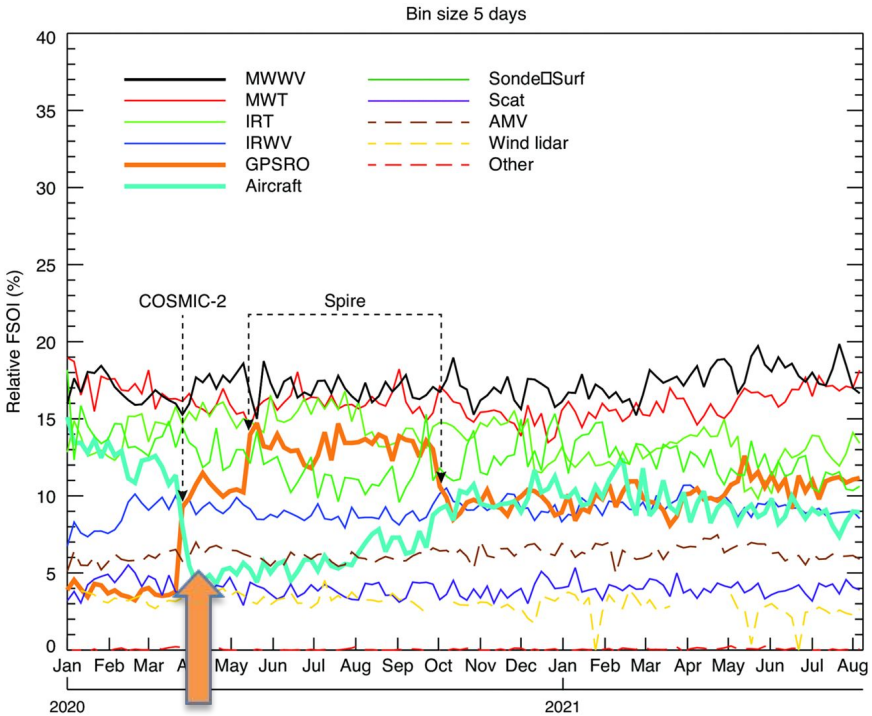
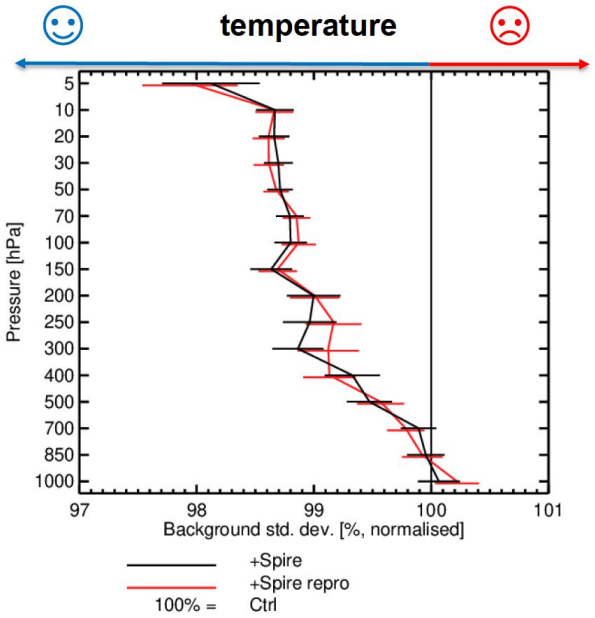
IROWG-9 Science Highlights

IROWG acknowledges and encourages the continuation of

- The efforts at NOAA and ECMWF for commercial purchase with global license, providing open data access to the global NWP community.
- Coordination and cooperation from the commercial providers to successfully incorporate their data effectively



Impact increases with # of RO profiles (S. Healy, ECMWF)



Improved analysis: fit to observations after assimiliating 11,000 Spire occultations per day

(Lonitz, Healy, Marquardt, IROWG-9, 9/2022)

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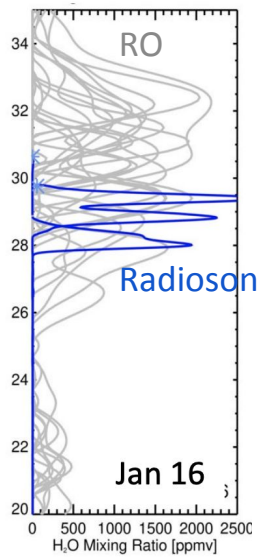
IROWG-9 Science Highlights

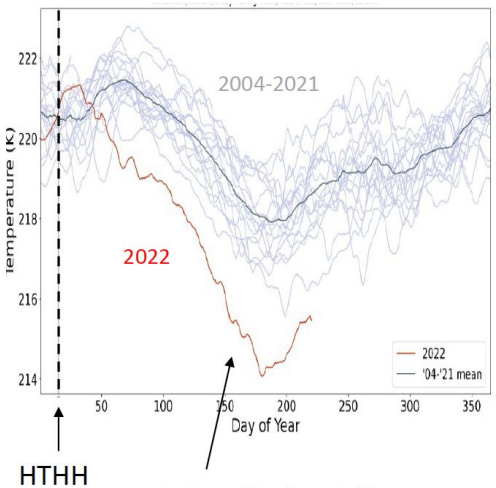
Use of GNSS RO for climate studies due to availability of observation archive (including low level data) - the need for backbone missions to provide stable, long-term, SI-traceable and reliable GNSS-RO observations

Radio occultation can detect >1000 ppmv of stratospheric H2O from Hunga Tonga-Hunga Ha'apai (HTHH) eruption on 15/1/2022.
Large H_2O anomalies persist in the stratosphere, leading to large-scale cooling (William Randel, NCAR/UCAR/COSMIC)

Water vapor from RO over Australia

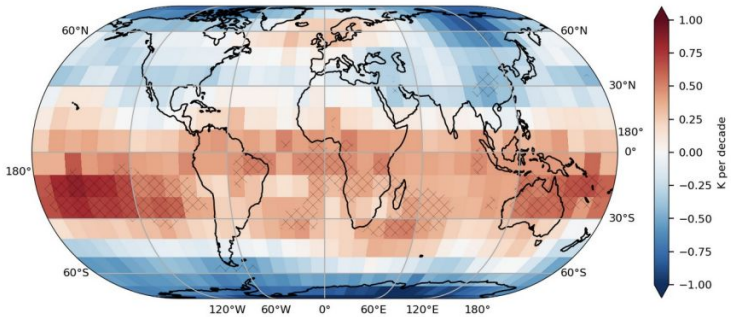


Temps at 10-50° S 26 km

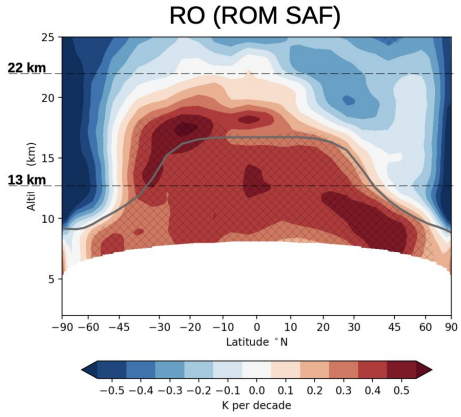


GNSS RO (2002-2021) providing a detailed view on the thermal structure of **temperature trends** in Earth's atmosphere (Florian Ladstadter, Wegener Center)

RO@18 km



RO (ROM SAF)



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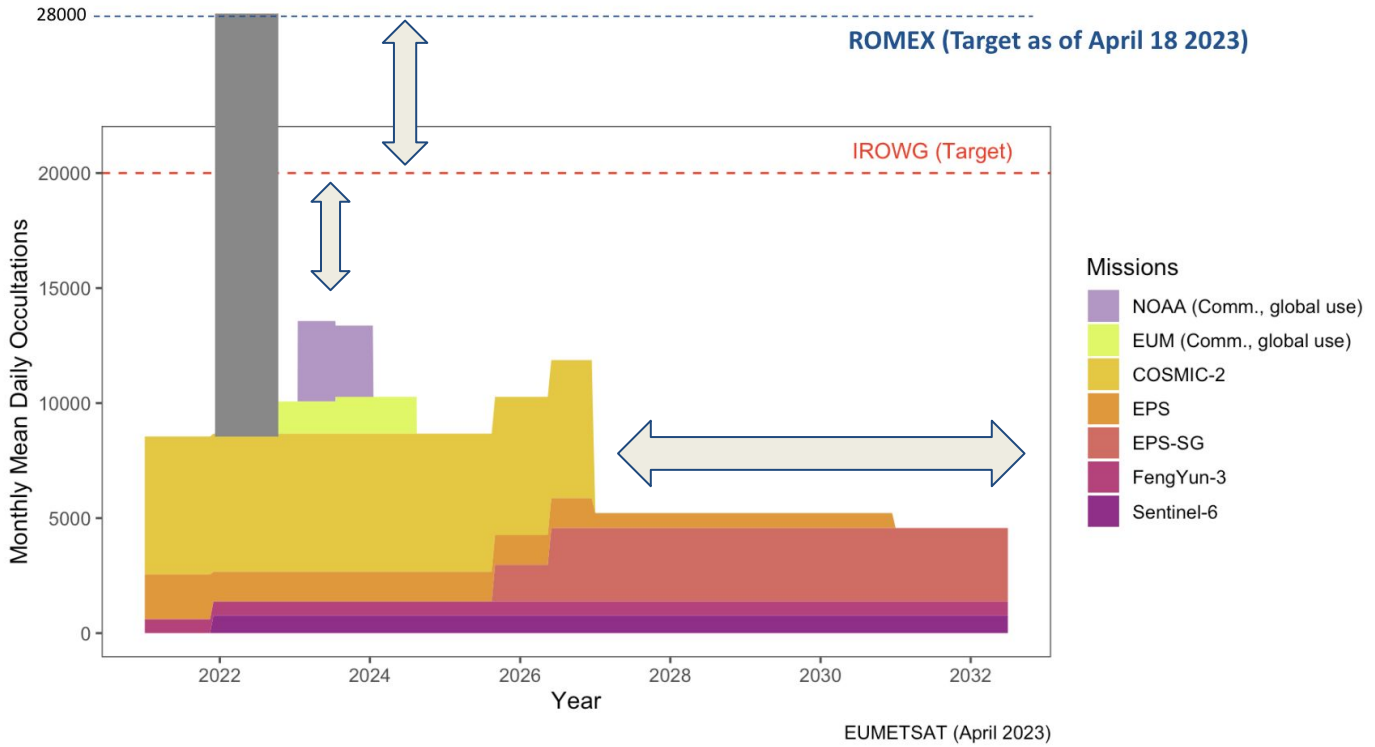
IROWG-9 Science Highlights

Presentation and agreement to coordinate a Radio Occultation Model Experiment (ROMEX) among the IROWG community (next presentation) to help answer answer pressing technical and programmatic questions and help inform near- and long-term strategies for RO missions and acquisitions by all CGMS partners



EUMETSAT RO mission projection provided by Christian Marquardt (EUMETSAT)

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Main Recommendations IROWG-9 (1)

IROWG strongly supports an **open data policy** towards the purchase of commercial RO data and recommends that all agencies follow this model. IROWG stresses the importance of **free and unrestricted access** to essential RO data including **archived raw or low-level (level 0) data**.

IROWG recognizes the recent efforts and activities at EUMETSAT and NOAA for **global licensing** of their commercial data purchase and supports continuing efforts. The **free and open exchange** of data leads to the greatest improvements in forecast quality, due to the ability to rigorously compare processing methods and assimilation techniques when using a common base of shared data. IROWG encourages institutions to purchase **full datasets** (with all acquired observations and including low-level data) and to make these available to the global community.

Main Recommendations IROWG-9 (2)

IROWG recommends **operational** Global Navigation Satellite System RO missions for continuous global climate observations to be established and maintained as **a backbone** to ensure **continuity and long-term availability of climate quality RO**.

IROWG reaffirms our support for **publicly funded high-quality observations** and also acknowledges the contributions of commercial data providers, pending validation of their climate data quality, including complete long-term access by independent processing centres to the complete set of acquired data without any data removal due to pre-screening. The **backbone** missions can provide **stable**, **long-term**, **SI-traceable** and **reliable** observations. The expertise of publicly funded data-processing centres is invaluable in assessing and archiving commercial data provision. They also help to reduce the risk to the global observing system if one or more commercial providers were to go out of business, or if the market became dominated by a single player.

Main Recommendations IROWG-9 (3)

IROWG continues to support the previous recommendations that GNSS-RO data - with **at least 20,000 occultations per day** - are **globally distributed** and provide **full sampling of the diurnal cycle** (local time). This is important for NWP, climate, and space weather. IROWG also **recommends further investigation of the value of increased target observation quantities**, to provide a sound basis for future statements on the desirable number of observations and insights on satellite mission planning and coordination.

The **ROMEX experiment** was proposed to investigate operational NWP impact versus numbers of occultations, as an international collaboration between NWP centres and data providers (see next presentation).

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Main Recommendations IROWG-9 (4)

IROWG recognizes the importance of **space weather applications** of RO data. IROWG recommends that **RO and non-RO missions** that use **dual-frequency GNSS receivers for their orbit determination** needs should make available to the operational and research communities all necessary low-level (level 0) data and metadata required to produce **accurate overhead TEC data** from the GNSS receiver.

Overhead TEC data is a valuable space weather data type that is potentially available from a wide variety of orbiting platforms, including those that are not specifically purposed for space weather or radio occultation. Downloaded GNSS data and metadata should include, at a minimum, dual-frequency code and phase measurements, and, if possible: antenna phase centre variations, spacecraft attitude orientation, and solar array motion. The data should have sample intervals of 1 sec or higher and low latency if possible (goal of 15 minutes).

Main Recommendations IROWG-9 (5)

- IROWG encourages **technology and retrieval developments** for improving **planetary boundary layer profiling** from GNSS-RO and their **utilization in NWP** data assimilation as well as the further exploitation of RO-derived **water vapor**.

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. NWP centers are encouraged to investigate whether additional benefits can be extracted from RO measurements in the lower troposphere, with a particular thought on how signal-to-noise ratio affects this usefulness. 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.

Action Item Summary

There is no open action for IRWOG, however, there has been an 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.

  – This action was also discussed during the latest Intersessional meeting, and there was agreement that this **action should be closed**
  – Instead of this, IROWG proposes the following best practices:

IROWG recommends that data providers ensure that all information necessary for independent processing towards climate data products is freely available (following WMO Unified Data Policy Resolution 1), including long-term archiving of *all* measured and acquired data *without* filtering (i.e. including the data not passing quality control), starting with level 0 data, and public data access, thus assuring full climate traceability.

IROWG proposes that a good practice for data providers is to include information on instrument/software updates and full documentation of the processing chains that keep track of any introduced changes/updates (e.g., POD-induced uncertainties).

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QC: quality control

Summary

Recommendations from IROWG-9

- IROWG strongly supports an **open data policy** towards the purchase of commercial RO data and recommends that all agencies follow this model. IROWG stresses the importance of **free and unrestricted access** to essential RO data including archived raw or low-level (level 0) data
- IROWG recommends **operational** Global Navigation Satellite System (GNSS) RO missions for continuous global climate observations to be established and maintained as **a backbone** to ensure **continuity and long-term availability of climate quality RO**
- IROWG continues to support the previous recommendations that GNSS-RO data - with **at least 20,000 occultations** per day - are **globally distributed** and **provide full sampling of the diurnal cycle**. IROWG also recommends further **investigation of the value of increased target observation quantities**, to provide a sound basis for future statements on the desirable number of observations and insights on satellite mission planning and coordination
- IROWG recognizes the importance of **space weather applications** of RO data. IROWG recommends that **RO and non-RO missions that use dual-frequency GNSS receivers for their orbit determination** needs should make available to the operational and research communities all necessary low-level (level 0) data and metadata required to produce accurate **overhead TEC data from the GNSS receiver**
- IROWG encourages technology and retrieval developments for improving **planetary boundary layer profiling** from GNSS-RO and their utilization in NWP data assimilation as well as the further exploitation of RO-derived **water vapor**.

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