Outcomes and Recommendations from the IROWG-9 Workshop

Presented to CGMS-51 Plenary, agenda item 6

Co-Chairs: Ulrich Foelsche (University of Graz)
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With contributions from the ROMEX team and IROWG members

8 – 14 Sep.2022, Seggau Castle, Austria

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

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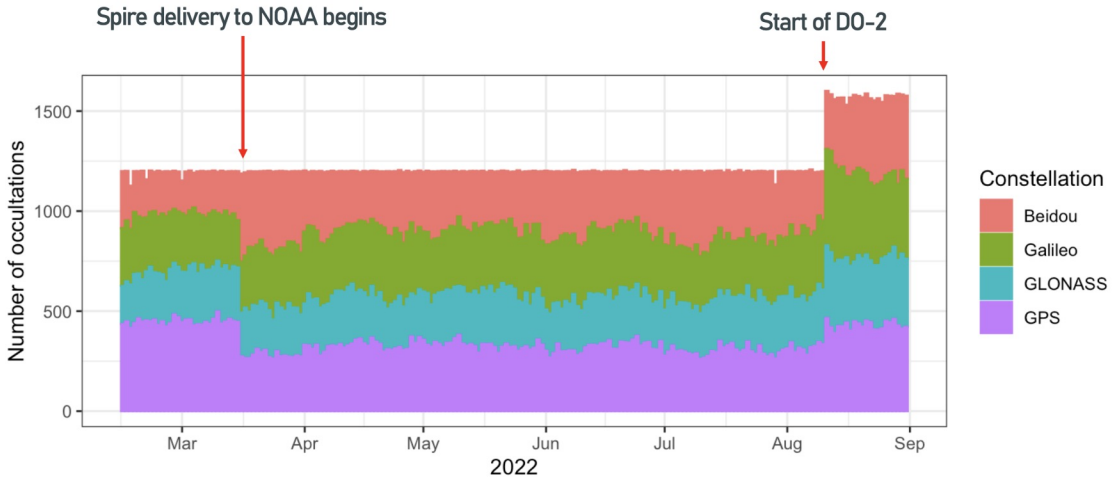
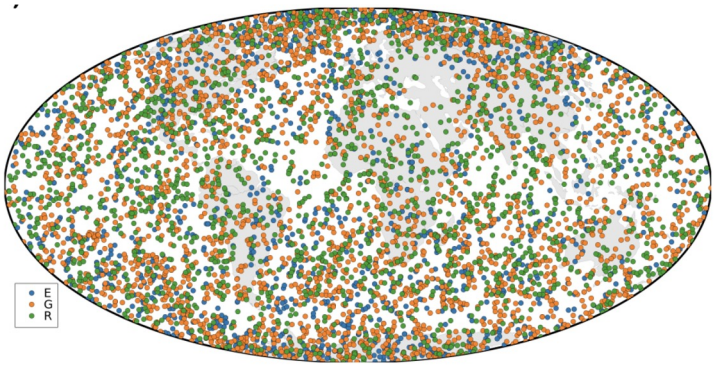
IROWG-9 Science Highlights

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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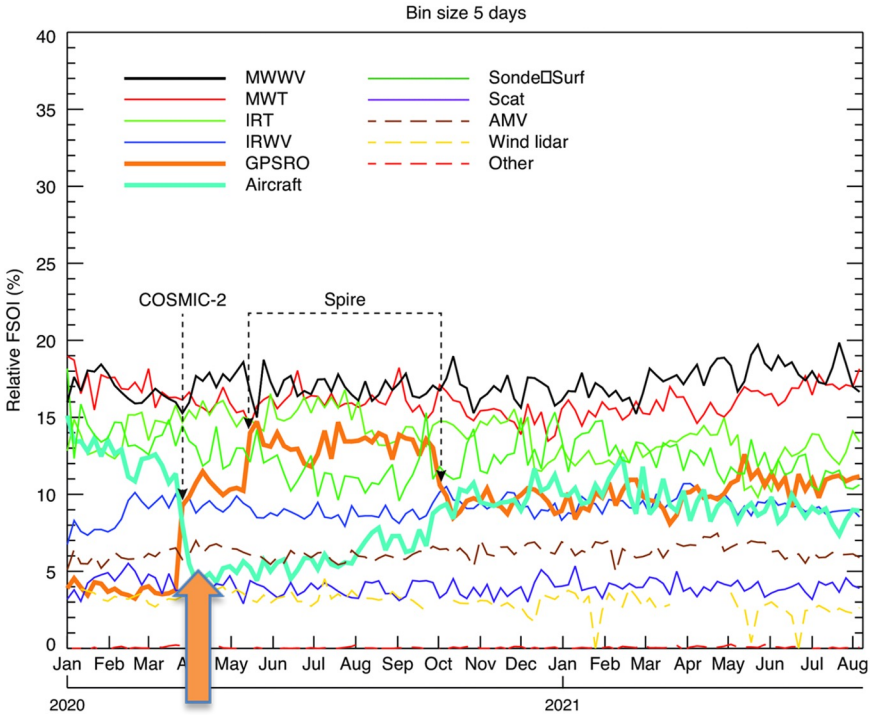
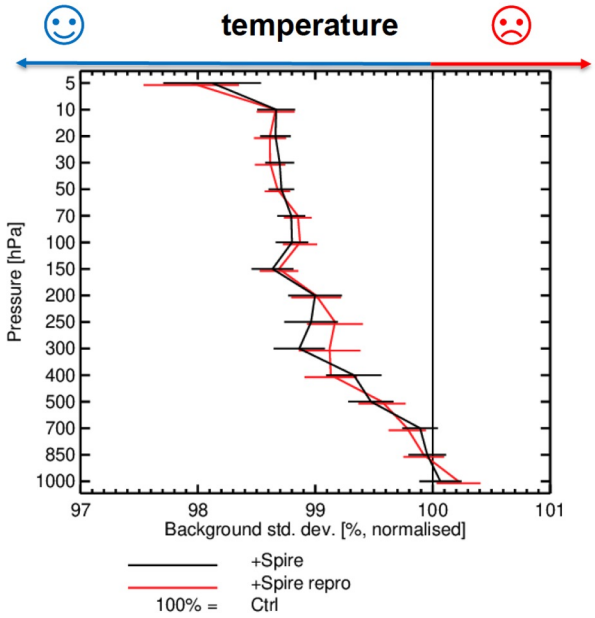
IROWG-9 Science Highlights

IROWG acknowledges and encourages the continuation of

- The efforts at NOAA and EUMETSAT for commercial purchase with global license, providing open data access to the global NWP community (NASA just joined this effort).
- 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 assimilating 11,000 Spire occultations per day

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

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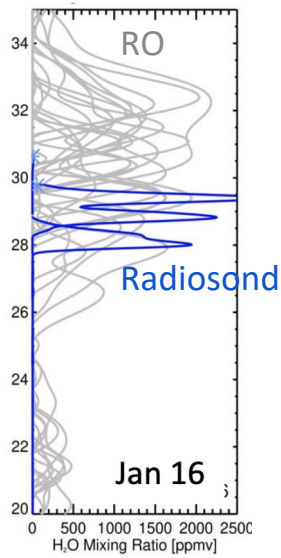
IROWG-9 Science Highlights

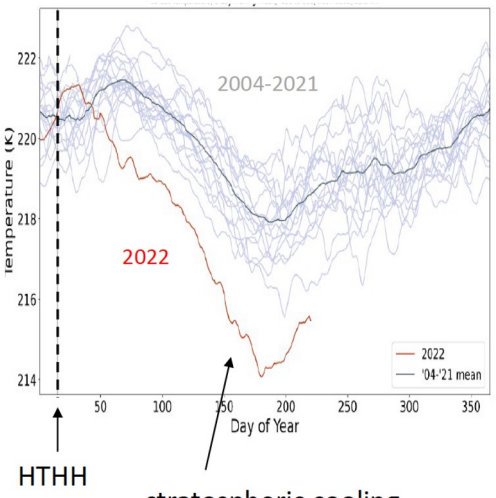
Use of GNSS RO for climate studies due to availability of observation archive (including low level data) - the need for **backbone missions** to provide stable, long-term, SI-traceable and reliable GNSS-RO observations

Radio occultation can detect >1000 ppmv of **stratospheric H_2O** 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

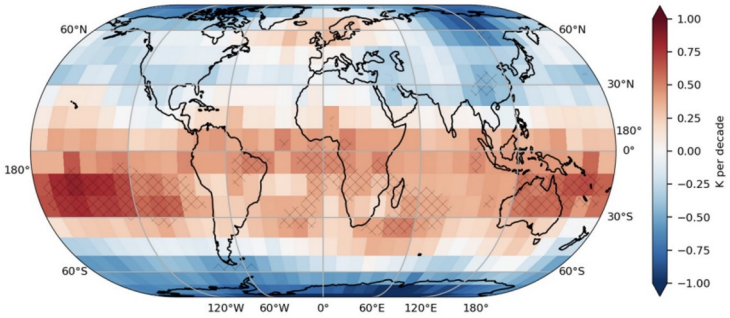


Temps at 10-50° S 26 km

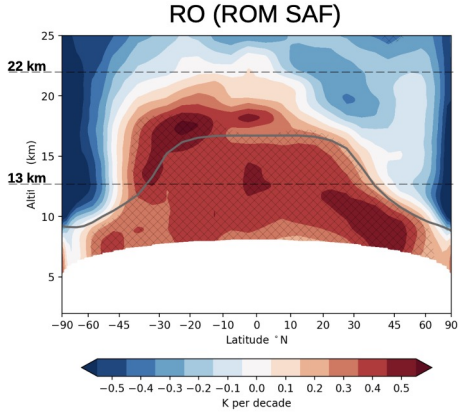


GNSS RO (2002-2021) providing a detailed view on the thermal structure of **temperature trends** in Earth's atmosphere (Florian Ladstädter, Wegener Center)

RO@18 km



RO (ROM SAF)



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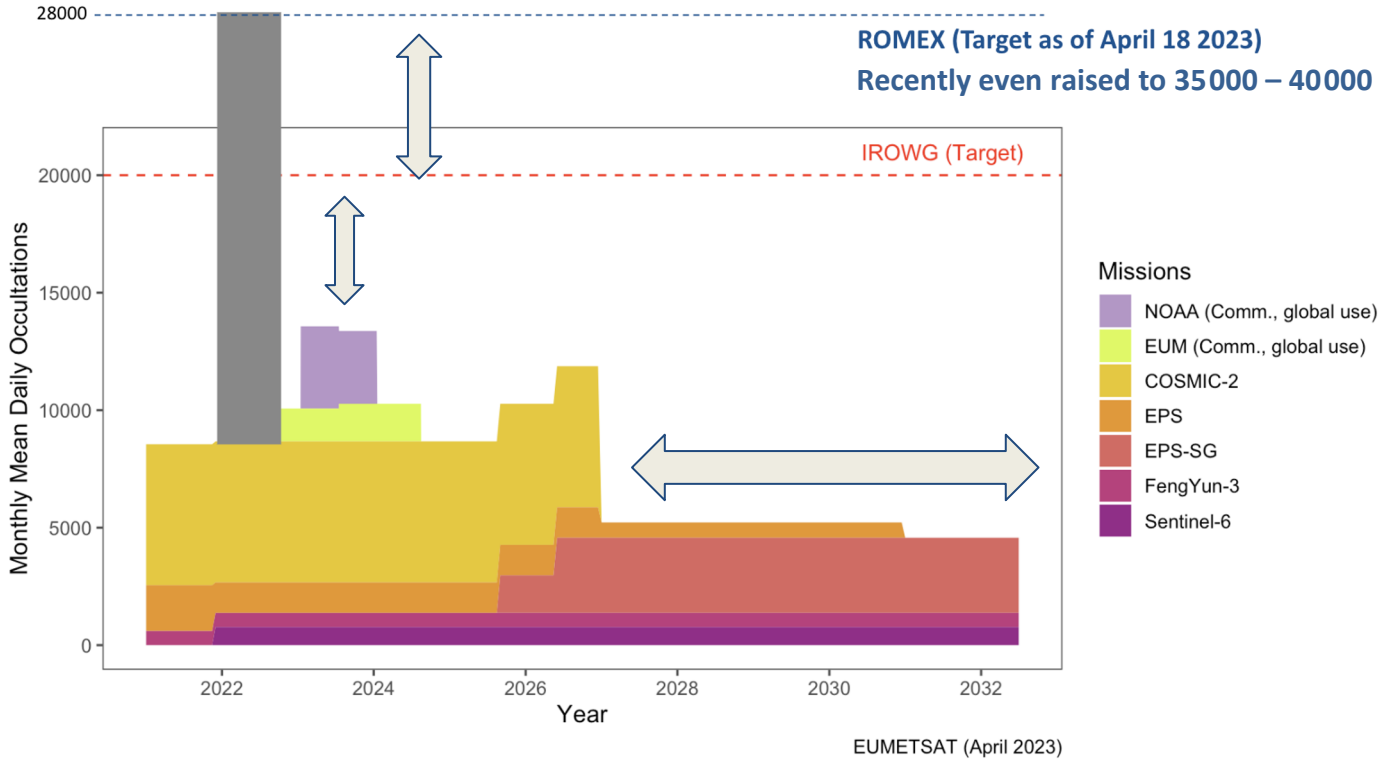
IROWG-9 Science Highlights

Presentation and agreement to coordinate a **Radio Occultation Model Experiment** (ROMEX) among the IROWG community to help 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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IROWG-9 Science Highlights - ROMEX

ROMEX seeks to quantify the **benefit of increasing the quantity of RO observations** using additional observations which were not available to weather centers for their real time operational systems. The IROWG community has gained approval from their respective institutions to perform **data assimilation experiments** with the additional RO measurements over the designated time period.

The effort concept, was first introduced Dr. Richard Anthes in May 2022, in **response to questions from by NOAA for input on future RO needs**. The resulted discussion led to a proposal for the Radio Occultation Modeling Experiment (ROMEX), which was endorsed by the IROWG in September, 2022 (IROWG-9).

The experiment results provide guidance to the CGMS partners to answer pressing technical and programmatic questions facing the numerical weather prediction (NWP) community. This will help inform near- and long-term strategies for RO missions and acquisitions by all CGMS partners.

The **initial data distribution within ROMEX** is expected to be in **July 2023**, followed by data quality assessment and NWP experiments in following months. Intermediate and final reports are expected to be presented in the upcoming **CGMS 52/WGII** meeting and at I**ROWG-10**, **Sept. 2024**.

Questions from/for the RO community

1) Data Quantity

How many RO profiles per day are needed?

Using the supplemental ROMEX data is there a fall-off or asymptote in the cost-benefit curve? With roughly 30 thousand profiles per day being collected today, the experiment can measure improvements up to that daily volume.

2) Geographic / Temporal Sampling

How should RO observations be distributed around the globe and in local time?

Should the tropics or other specific latitude regions receive relatively more focus? How important is local-time sampling to NWP and climate applications?

3) Data Quality

Are there systematic differences in the GNSS-RO sources and their processing algorithms?

What is the value of higher SNR? How to best exploit the various quality aspects, such as penetration depth? How can ROMEX help quantify the impact of the quality aspects to help CGMS partners form data requirements?

4) Make vs. Buy

How much can CGMS partners rely on commercial services to provide operational data?

Issues include total cost per observation, restrictions on data, robustness of system and long-term stability, level of transparency, and value of additional capabilities (e.g., space weather data and neutral atmosphere observations combined).

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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 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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