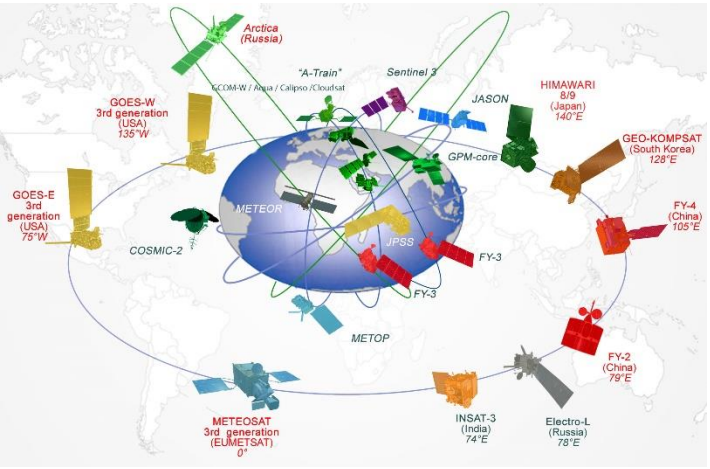

Outcome and Recommendations from the IROWG-8 Workshop

Presented to CGMS-49, WG II, agenda item 3

Co-Chairs: Ulrich Foelsche (University of Graz),
Sean Healy (ECMWF)
Rapporteur: Tony Mannucci (NASA/JPL)

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Overview

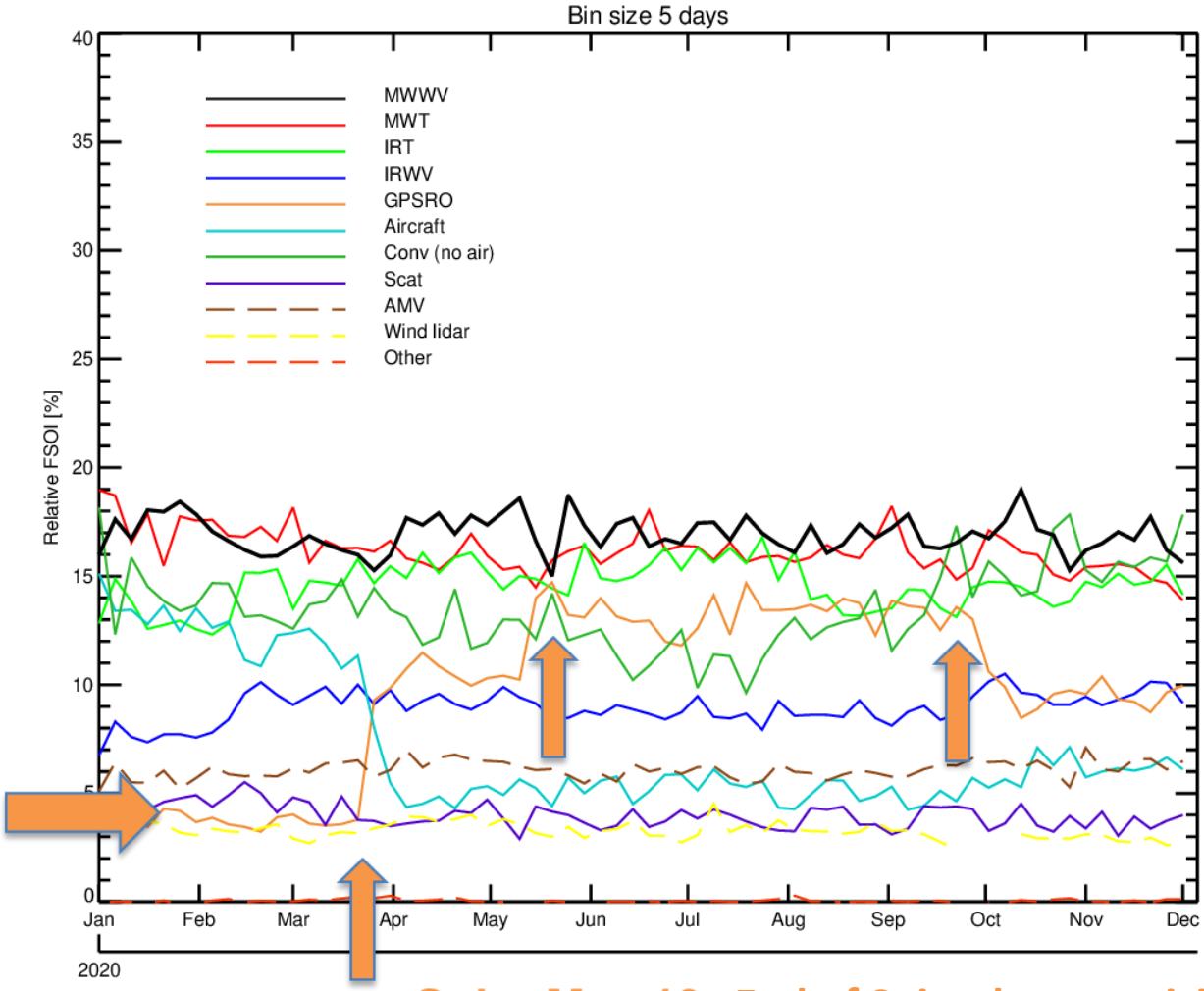
- IROWG-8 Workshop – Science Highlights
  - April 7-13, 2021, virtual, hosted by NOAA and UCAR
  - Workshop minutes and full recommendations will be available at: http://irowg.org/workshops/irowg-8/
  - Workshop presentations are available at https://cpaess.ucar.edu/meetings/2021/irowg-8
- Impact of RO data in NWP
- Future status of RO and impending gaps
- IROWG-8 main recommendations
- Action item review
- IROWG-9

IROWG-8 Science Highlights (1)

- The “GPS” RO Technique is now a true “GNSS” RO Technique, where **signals from all GNSS constellations** are being exploited.
- A **better penetration into the lowest kilometers** allows for studying the **planetary boundary layer** – including tropospheric **water vapor**.
- GNSS-RO data with **high spatial and temporal resolution** allow for unprecedented studies of **atmospheric** and **ionospheric** phenomena.

IROWG-8 Science Highlights (2)

- GNSS-RO data demonstrate a **high impact in NWP** – not only in the UTLS, but **also in the lower troposphere** (water vapor). This impact clearly increases with the number of high-quality profiles – without any sign of “saturation”.
- **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**.
- GNSS-RO climate data advance **climate change monitoring** and contribute to the **upcoming IPCC assessment report**.



Spire May 13

End of Spire data provision

COSMIC-2 March 25

Impact of RO data in NWP

Integrated measure of 24 hour forecast impact at ECMWF

Impact increases clearly with # of RO profiles, no saturation

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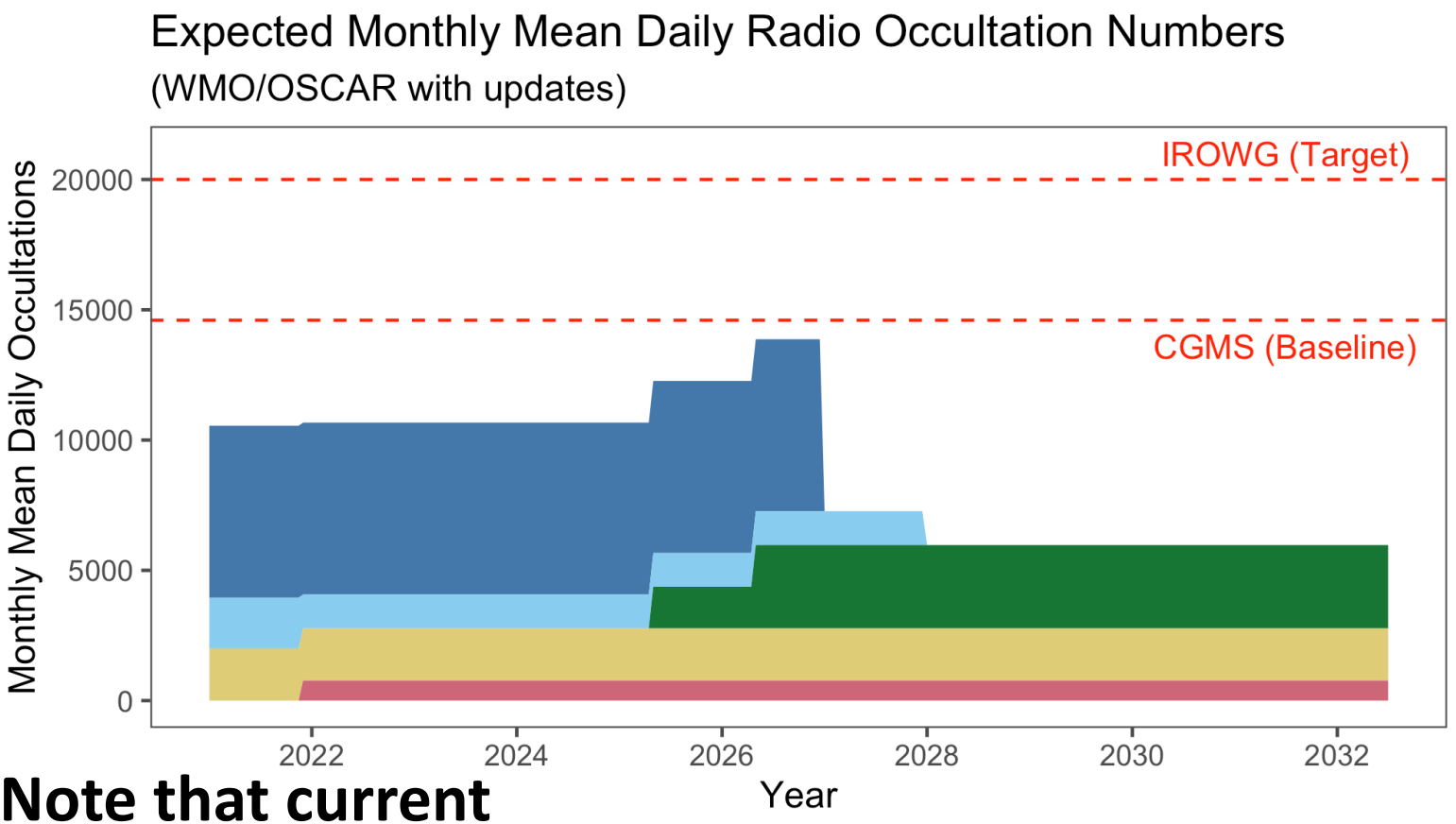
Figure courtesy of Sean Healy, ECMWF

Future Status of RO



EUMETSAT (April 2021)

Note that current actual numbers are smaller

- Predicted numbers based on WMO/OSCAR
- Only operational missions with secured funding
- Nominal (baseline) mission performance
- GNSS constellations nominal

And not only the numbers matter …

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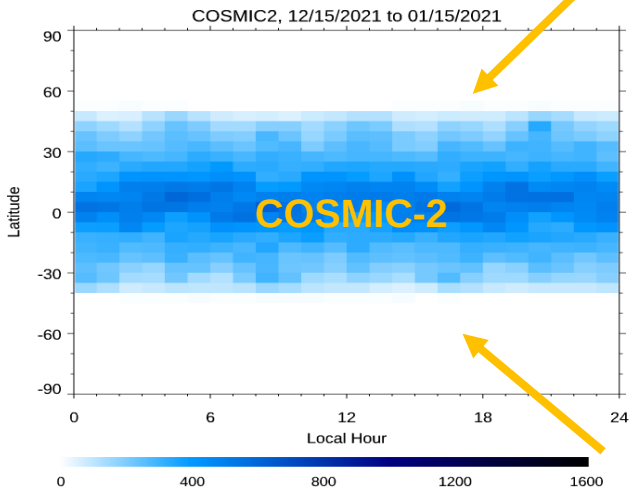
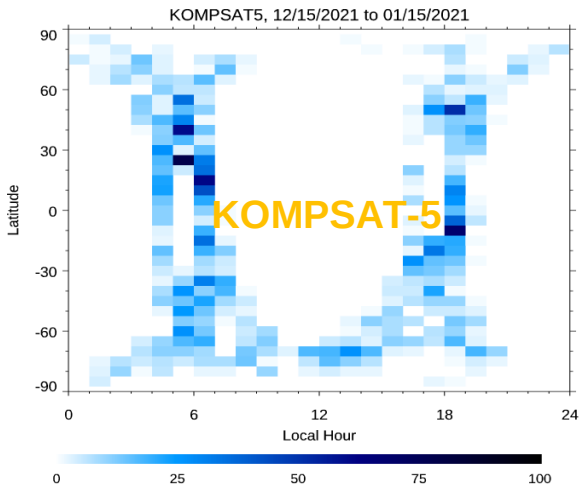
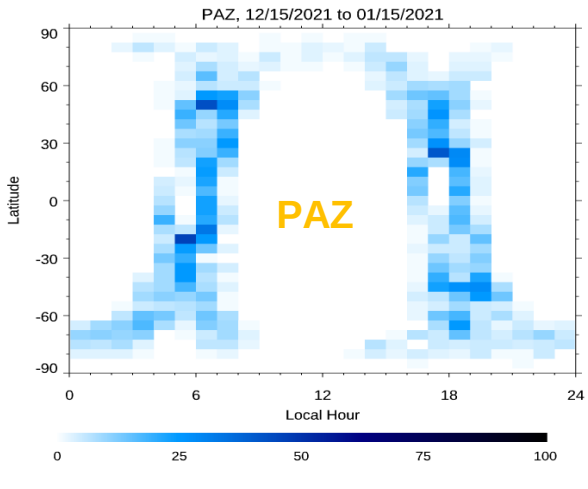
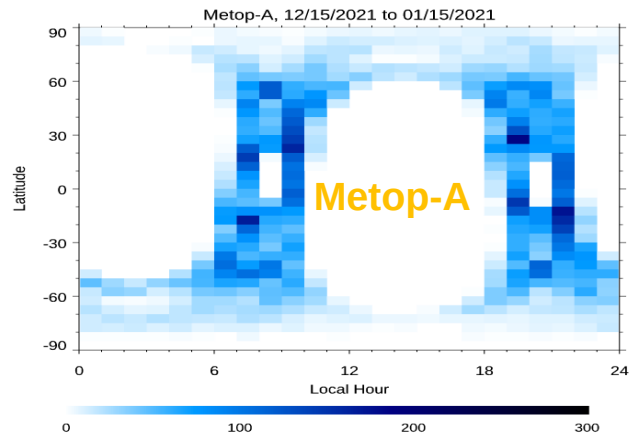
Figure courtesy of Christian Marquardt, EUMETSAT

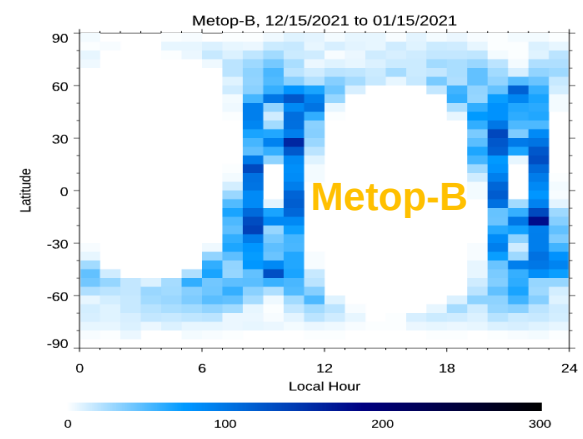
Geographic and Local Time Coverage

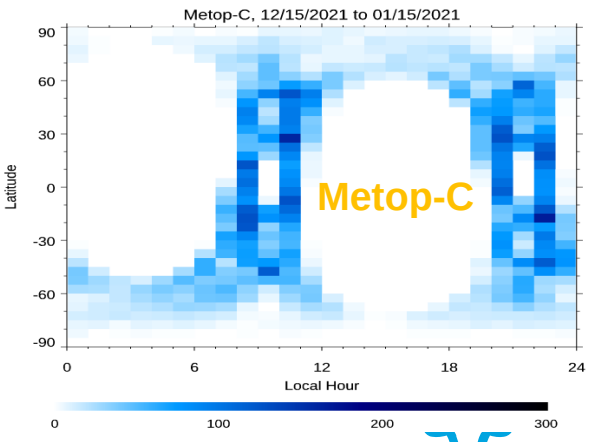












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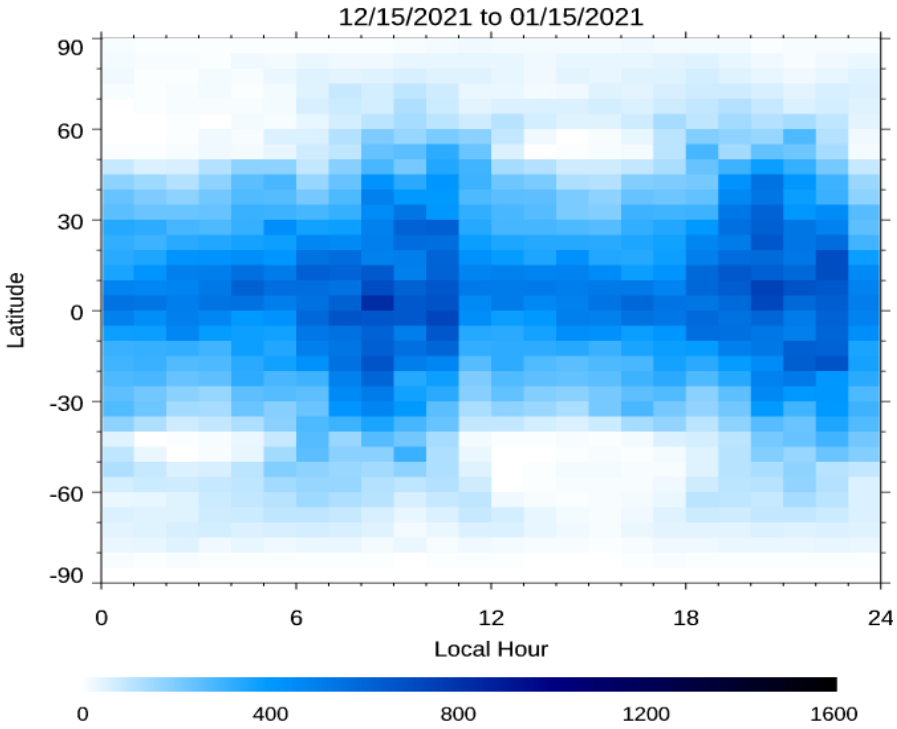
NOAA data, mid Dec 2020 – mid Jan 2021

Note different colorbar-ranges

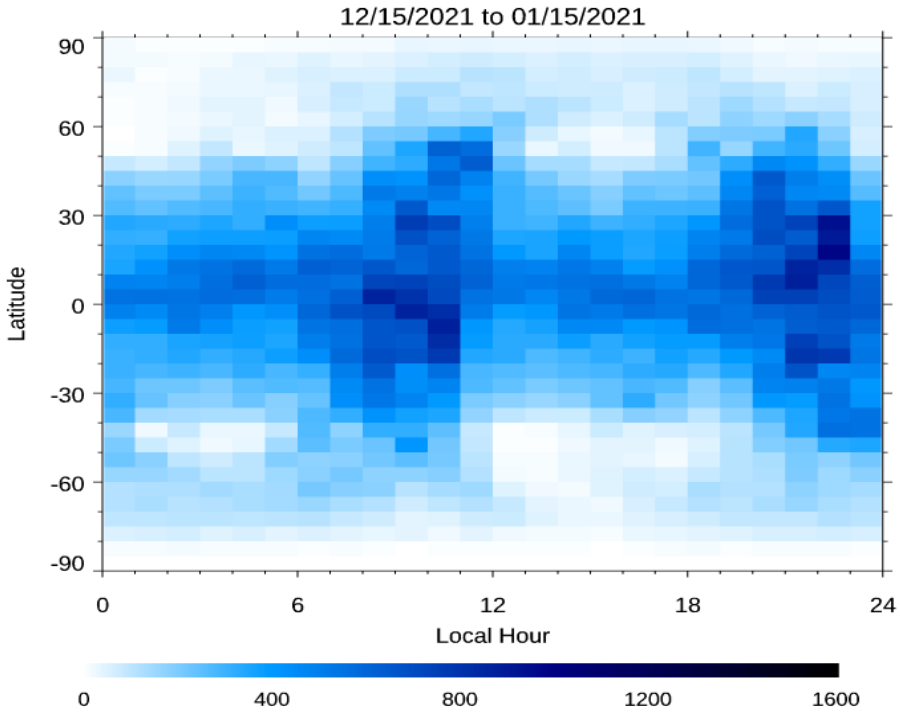
Figure courtesy of Ben Ho, NOAA

Geographic and Local Time Coverage



COSMIC-2 + 3 Metops + Kompsat-5 + PAZ

Note that this is **not** a good sampling of the diurnal cycle …



COSMIC-2 + 3 Metops + Kompsat-5 + PAZ + SPIRE + GeoOptics

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NOAA data, mid Dec 2020 – mid Jan 2021

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Figure courtesy of Ben Ho, NOAA

IROWG-8 Discussions (1)

- Radio Frequency Interference (RFI), e.g. through GPS jammers, has been identified as a major problem – receiver developers need to address this issue.
- All of the sub-groups recognized the importance of Level 0 (raw) data. It was stressed that raw data should be included in data purchase plans from commercial providers.
  Action within IROWG: A working group will be formed to develop an exchange format for raw data that is common to the different receiver types and that can be used for data exchange among users.
- Technology and retrievals for the PBL, and their utilization for NWP have been discussed:
  Action within IROWG: Form a working group on PBL – how best to extract profile information.

IROWG-8 Discussions (2)

- New RO data probe the lower troposphere better than before.
  Action within IROWG: Establish a task force for the lower troposphere. Explore RO-derived water vapor further as a climate variable.
- NWP and climate requirements are not exactly the same – care is needed when purchasing commercial data and climate requirements need to be considered.
- IROWG should verify that the WMO OSCAR database properly documents the abilities of current and future missions to obtain ionospheric data.
- Our main aim is to ***ensure long-term measurement continuity and maximise the number of high quality RO observations that can be freely exchanged***.

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Main Recommendations IROWG-8 (1)

(1) IROWG reaffirms that all providers of RO observations should classify these as **essential** in the sense of **WMO Res 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).

(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 daily target will be met with **global and full local time coverage**.

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Main Recommendations IROWG-8 (2)

(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**.

(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**.

Action Item Summary (1)

See working paper for details

- **A47.31:** CGMS baseline and RO: IROWG and 7th WMO Impact Workshop needs to validate the current baseline in terms of the coverage, number, quality and sampling of RO
  - IROWG notes that the current **CGMS baseline** (6000 occultations from low inclination orbits; 1000 occultations from drifting high inclination orbits; and 7600 occultations from sun-synchronous orbits) **does not necessarily reflect the IROWG recommendations regarding geographic and local time coverage**.
  - E.g., the requirement "7600 occultations from sun-synchronous orbits" (without further specification) **can** result in an adequate sampling of the diurnal cycle – or not (see below).
  - It is mandatory, that RO data are **globally distributed** and provide a **good sampling of the diurnal cycle**. This can be either achieved with a dedicated **constellation** with orbits that **drift sufficiently fast in local time** (typically in six orbit planes, including high-inclination orbits), or with **satellites in six or more sun-synchronous orbit planes**.

Action Item Summary (2)

- **A47.31:** CGMS baseline and RO: IROWG and 7th WMO Impact Workshop needs to validate the current baseline in terms of the coverage, number, quality and sampling of RO …. continued
  - The current (and near future) situation is unsatisfactory: Due to the cancellation of its polar component, **COSMIC-2 data are confined to latitudes below ~40°**. **Metop** as well as **Metop-SG** satellites are/will be limited to **one orbit plane**, and there is currently only one sun-synchronous satellite (FY-3D), which covers other local times than Metop(-SG). This leaves a **serious gap in local time coverage at mid and high latitudes** – **even more pronounced for ionospheric data**, which are not provided by the first generation of Metop satellites.
  - This situation can/will be **slightly improved** (but certainly **not mitigated**) by including RO data from the upcoming **FY-3E satellite with different equator-crossing time** and data from **Sentinel-6 in a drifting orbit**. Initial Sentinal-6 data look very promising, and will – ultimately – cover all local times, however, it takes almost two months to achieve this.

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Action Item Summary (3)

- **A47.31:** CGMS baseline and RO: IROWG and 7th WMO Impact Workshop needs to validate the current baseline in terms of the coverage, number, quality and sampling of RO …. continued
  - **Actual profile numbers tend to be smaller than the nominal ones**. Based on the nominal performance in the WMO OSCAR database, one would assume that the current operational RO missions would deliver at least 10 000 profiles per day (April 2021); however, the actual number of post-QC profiles that can be assimilated at ECMWF is less than 8000.
  - IROWG shares the concern, expressed in the recent WGIII risk assessment, that there is "**Continuity risk for the number and geographic distribution of radio occultations; especially in the low- to mid- latitudes**", since there is currently no plan for a successor of the COSMIC-2 mission.
  - The **baseline** is currently **not sufficient** to meet the **HLPP objective** (1.2) to advance the atmospheric Radio Occultation constellation, with the long-term goal of providing **20,000 occultations per day** on a sustained basis.

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Action Item Summary (4)

- **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**.

Welcome to IROWG-9 !

International Workshop on
Occultations for Probing Atmosphere and Climate
Seggau Castle, Leibnitz near Graz, Austria
8 – 14 September 2022

OPAC-IROWG 2022

Wegener Center
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Summary

- Recommendations from IROWG-8. They include:
  - IROWG reaffirms that all providers of RO observations should classify these as **essential** in the sense of **WMO Res 40**. IROWG stresses the importance of **free, timely and unrestricted access in real time to essential RO data**, and **archived raw 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
  - 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 potential commercial providers of RO observations, to incorporate a **complete set of ionospheric measurements**.
  - **IROWG-9**: September 8-14, 2022, Seggauberg, Austria

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