



# Overview

- IROWG-7 main recommendations
  - September 19-25, 2019, Elsinore, Denmark
  - Workshop minutes and full recommendations are available at: <http://irowg.org/workshops/irowg-7/>
- Impact of COSMIC-2 data in NWP
- Outline of IROWG-7 discussions relating to commercial options
- Action item review
- IROWG-8

# Main Recommendations IROWG-7

- IROWG encourages all providers of RO observations to classify these as **essential** in the sense of WMO Res 40. IROWG stresses the importance of **free and unrestricted access** to essential RO data **including archived raw data**.
- IROWG recommends that **WMO and CGMS should co-ordinate any GNSS-RO data purchases** to avoid duplication amongst agencies. **If purchased**, the commercial GNSS-RO data should be bought with a **world license**, so that the data – including raw data - are equally available to all agencies.
- IROWG recommends that GNSS-RO data - with at **least 20,000 occultations per day** - are **globally distributed** and provide good **sampling of the diurnal cycle**. This is important for NWP, Climate, and Space Weather.

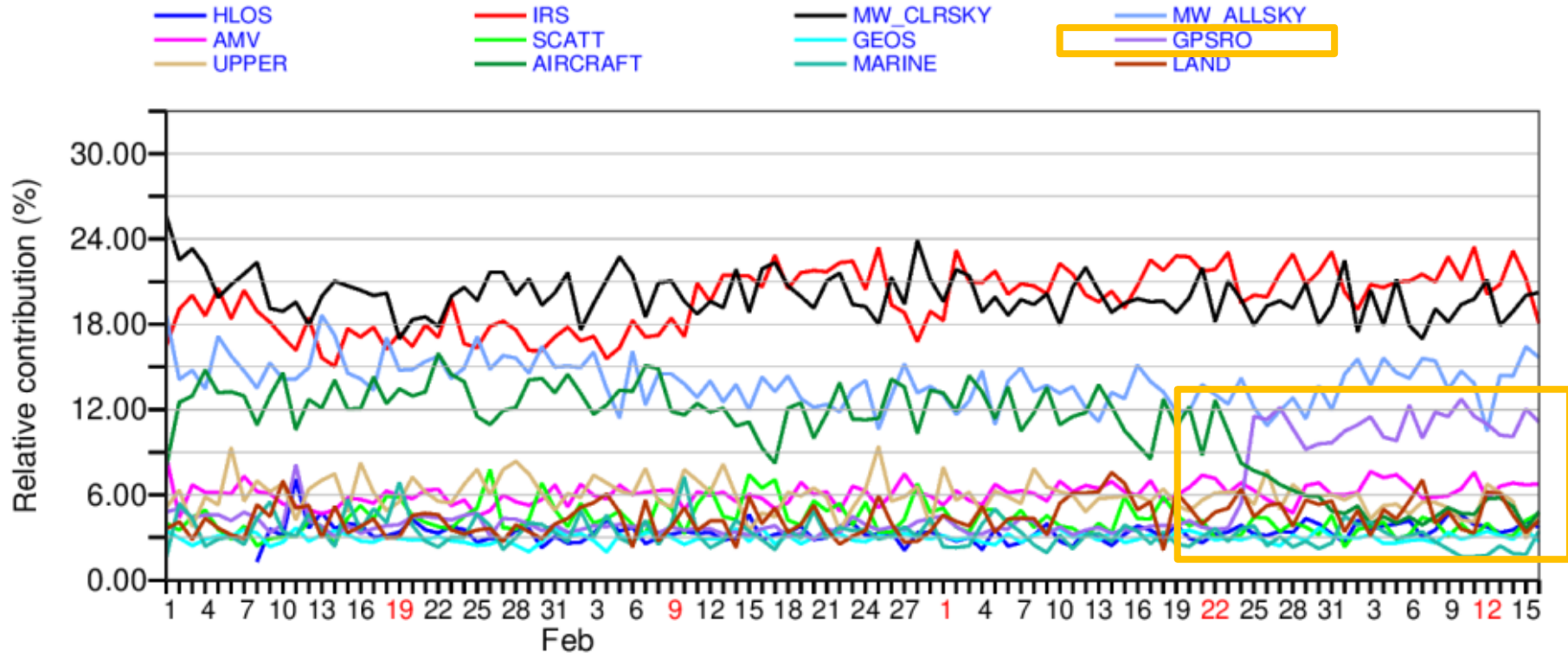
# IROWG-7 Science Highlights (1)

- The “GPS” RO technique has evolved to a true “**GNSS**” RO **technique**, where **signals from all GNSS constellations** are on a path to being exploited.
- The **FORMOSAT-7/COSMIC-2** constellation (launch: 25 June 2019) provides RO data with **very high SNR** ( $> 2000$  V/V), allowing for exciting new science applications.  
It should, however, be noted that COSMIC-2 data are confined to **latitudes below  $\sim 40^\circ$** , leaving a serious **gap in local time coverage at high latitudes**.
- IROWG has been invited by the **IPCC** to contribute to the upcoming **assessment report**.

# IROWG-7 Science Highlights (2)

- The **PAZ satellite** (launch: 22 Feb 2018) provides the **first GNSS polarimetric radio occultation results**. RO observables at two linear polarizations have proved sensitivity to heavy rain as well as other hydrometeors.
- Great progress has been made in the field of **GNSS reflectometry**. In addition to the extensive GNSS-R data set from NASA/CyGNSS, other missions are under preparation, some are ready for launch.
- Based on the evidence provided during the meeting, IROWG notes that the **commercial GNSS-RO missions** (in particular Spire) continue to make very good progress. Nevertheless, there remains strong support for a “backbone” of agency-funded RO missions with **long-term commitment**.

# Impact of RO data in NWP



Forecast Sensitivity Observation Impact (FSOI) at ECMWF: Contribution from RO increased sharply with COSMIC-2 (~3000 → ~8000 profiles per day)

# IROWG-7 Discussions

- RO in the forefront of commercial data discussions.
- The meeting was an important opportunity for the IROWG community to hear the progress of the NOAA Commercial Weather Data Pilot (CWDP) Study. The NOAA CWDP team was active throughout the meeting, in both the oral sessions and working groups.
- There remains strong support for the CWDP within IROWG because it is essential for assessing the actual capabilities of the various GNSS-RO mission options. We hope that we can maintain a good dialogue between the IROWG and the NOAA CWDP team in the coming years.
- Our main aim is to ***ensure long-term measurement continuity and maximise the number of high quality RO observations that can be freely exchanged.***

# Action Item Summary (1)

See working paper for details

- **A45.02:** IROWG to develop a detailed proposal for OSSEs regarding LEO-LEO MW occultation and GNSS-RO &-reflectometry.
  - Important progress has been made in the field of GNSS reflectometry. This part of the action is therefore regarded as not relevant anymore.
  - Key missing element: LEO-LEO OSSEs require the development of a LEO-LEO forward operator that can be used in NWP systems.
  - Development of the forward operator could be achieved with support for a two-year Postdoc, and 25% of senior researchers in the areas of (1) LEO-LEO instrument/observations, (2) radiative transfer, (3) microphysics and (4) NWP system integration (i.e. two senior researcher years in total), with nominal support for travel and publication.
- IROWG recommends to close or reformulate action A45.02.

# Action Item Summary (2)

- **A46.08:** IROWG to develop process and principles for RO data quality control to ease intercomparison of data from different providers.
  - There are about 10-30% observations rejected during the data processing and retrieval procedures for current missions. However, the quality control (QC) procedures are not consistent among different data providers and processing centers. They are very likely to differ between the current and future missions as well. Providers should document their QC procedures (e.g., QC pertains to orbits, space sampling/inhomogeneity, neutral atmosphere or space weather products, etc.) and share with IROWG.
- IROWG recommends an action to 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.

# Action Item Summary (3)

- **A47.04:** IROWG to provide recommendation on orbital planes in order to improve coverage.
  - 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 (such as COSMIC-2 **equatorial + polar**), or with satellites in six or more sun-synchronous orbit planes that provide an adequate sampling of the diurnal cycle.
  - The current (and near future) situation is unsatisfactory: Due to the cancellation of its polar component, COSMIC-2 data are confined to latitudes below  $\sim 40^\circ$ , leaving a serious gap in local time coverage at high latitudes – even more pronounced for ionospheric data, which are not provided by the first generation of MetOp satellites.

# Action Item Summary (4)

- **A47.05:** IROWG to evaluate the outcome of agency funded commercial weather data pilot following IROWG-7 and report to CGMS-48.
  - Status: This task cannot be taken by the IROWG as the results are not open to the community
  - IROWG encourages the institutes evaluating commercial data to share their reports publicly.
  - It is noted that the following institutions are currently performing an evaluation:
    - NOAA (Spire and GeoOptics, level 1-2, supported by EUMETSAT),
    - NRL (Spire and GeoOptics, level 2 bending angle, level 1 podTEC),
    - NASA, USAF, MetOffice (Spire, L1b),
    - ESA (supported by EUMETSAT and U. Graz, Spire; level 1-2)
- IROWG recommends that CGMS makes a co-ordinated request for results from all commercial data studies to be made public.

# Action Item Summary (5)

- **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
- **A47.32:** IROWG to review the CGMS baseline and validate wording that captures CGMS member contribution to RO data in terms of coverage, number, quality and sampling: and share impact studies of RO data between the CGMS baseline and WIGOS 2040 vision observing targets.
  - IROWG shares the concern of the WGIII risk assessment (03/2020), that there is “Continuity risk for the number and geographic distribution of radio occultations; especially in the low- to mid- latitudes”
  - This baseline is currently not sufficient to meet the HLPP objective (1.2) to advance the atmospheric RO constellation, with the long-term goal of providing 20000 occultations per day on a sustained basis.

**2021**

**April  
7-14**

**National Capital Region,  
USA**

**8<sup>th</sup>  
International  
Radio  
Occultation  
Working  
Group  
Workshop**

The eighth international workshop of the permanent Working Group of the Coordination Group for Meteorological Satellites (CGMS) focuses on the exchange of experiences in the exploitation of RO data for operational and research use.

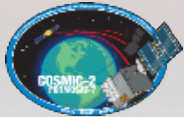


Image: Debojyotlahari/CC-BY-SA-4.0

# Summary

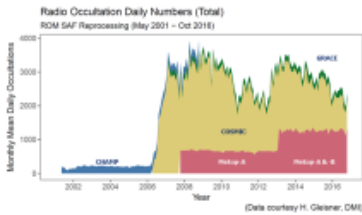
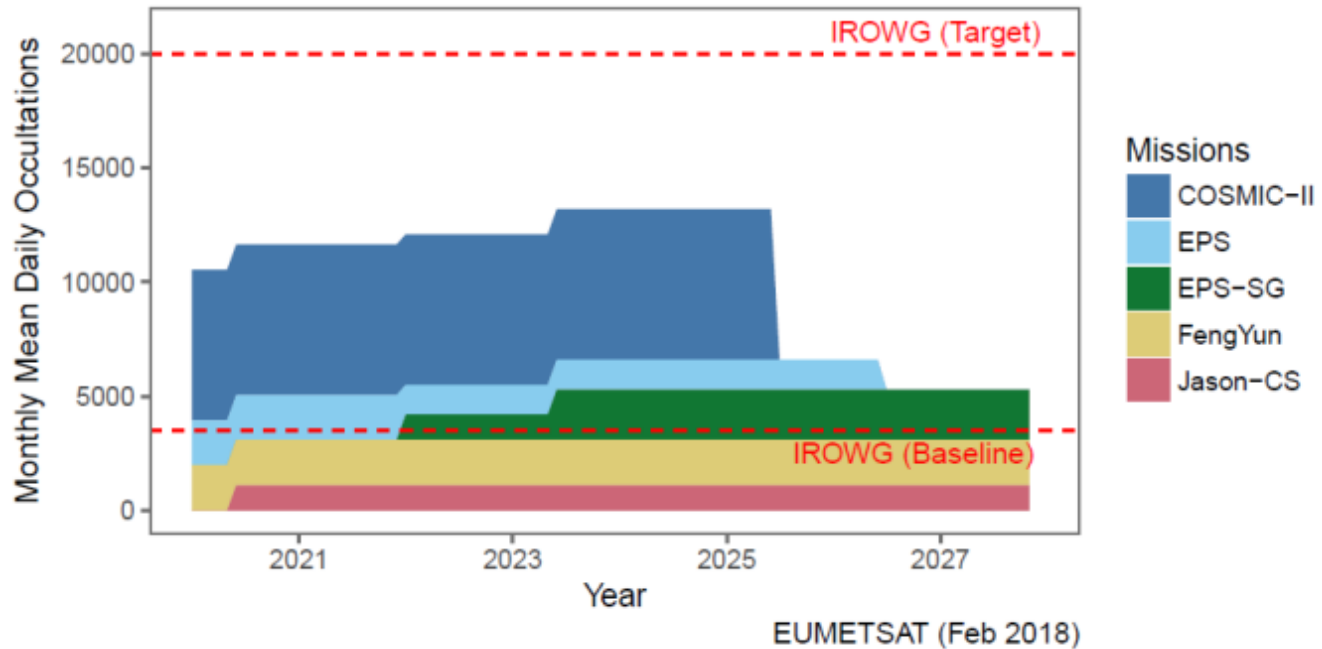
- Recommendations from IROWG-7. They include:
  - IROWG encourages all providers of RO observations to classify these as essential in the sense of WMO Res 40.
  - IROWG recommends that WMO and CGMS should co-ordinate any GNSS-RO data purchases to avoid duplication amongst agencies. If purchased, the commercial GNSS-RO data should be bought with a world license, so that the data – including raw data – are equally available to all agencies.
  - IROWG recommends that GNSS-RO data - with at least 20,000 occultations per day - are globally distributed and provide good sampling of the diurnal cycle (will not be achieved with current and upcoming operational missions)
- IROWG-8: April 7-14, 2021, National Capital Region, USA

# Backup

(mainly from CGMS-47/46)

# Future Status of RO

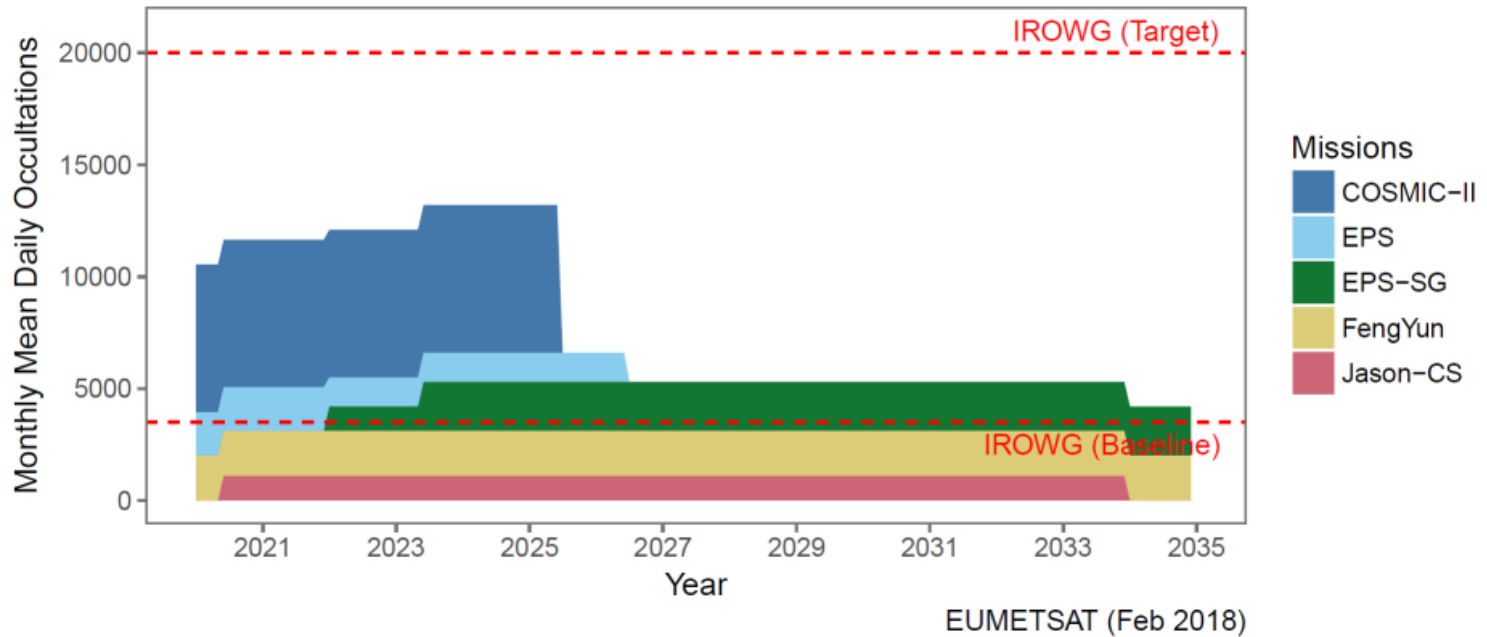
Expected Monthly Mean Daily Radio Occultation Numbers  
(WMO/OSCAR with updates)



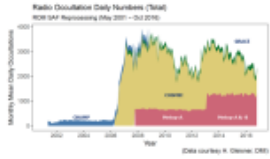
- Predicted numbers based on WMO/OSCAR
- Only operational missions with secured funding
- Nominal (baseline) mission performance
- GNSS constellations nominal

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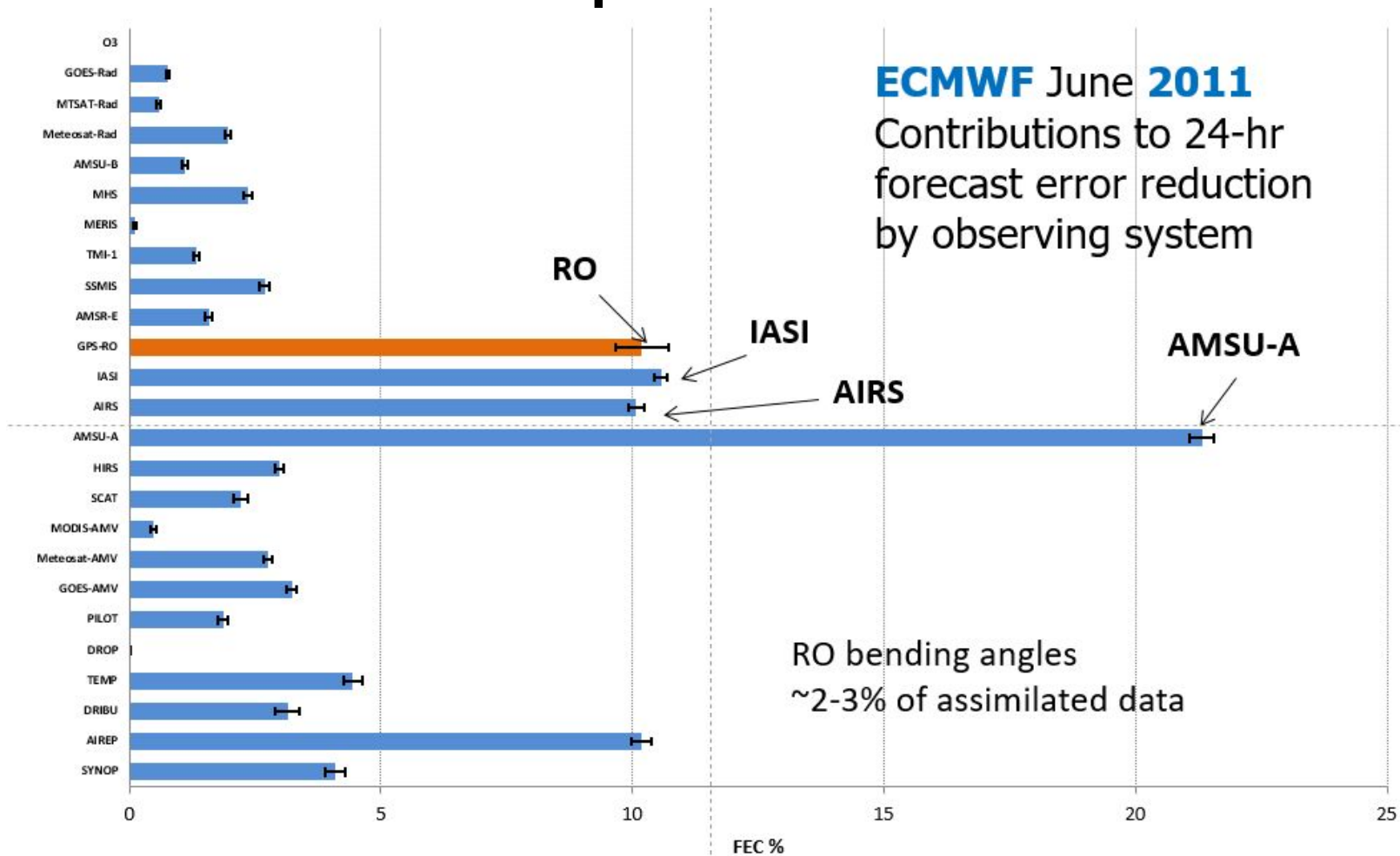
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# Coordination Group for Meteorological Satellites - CGMS

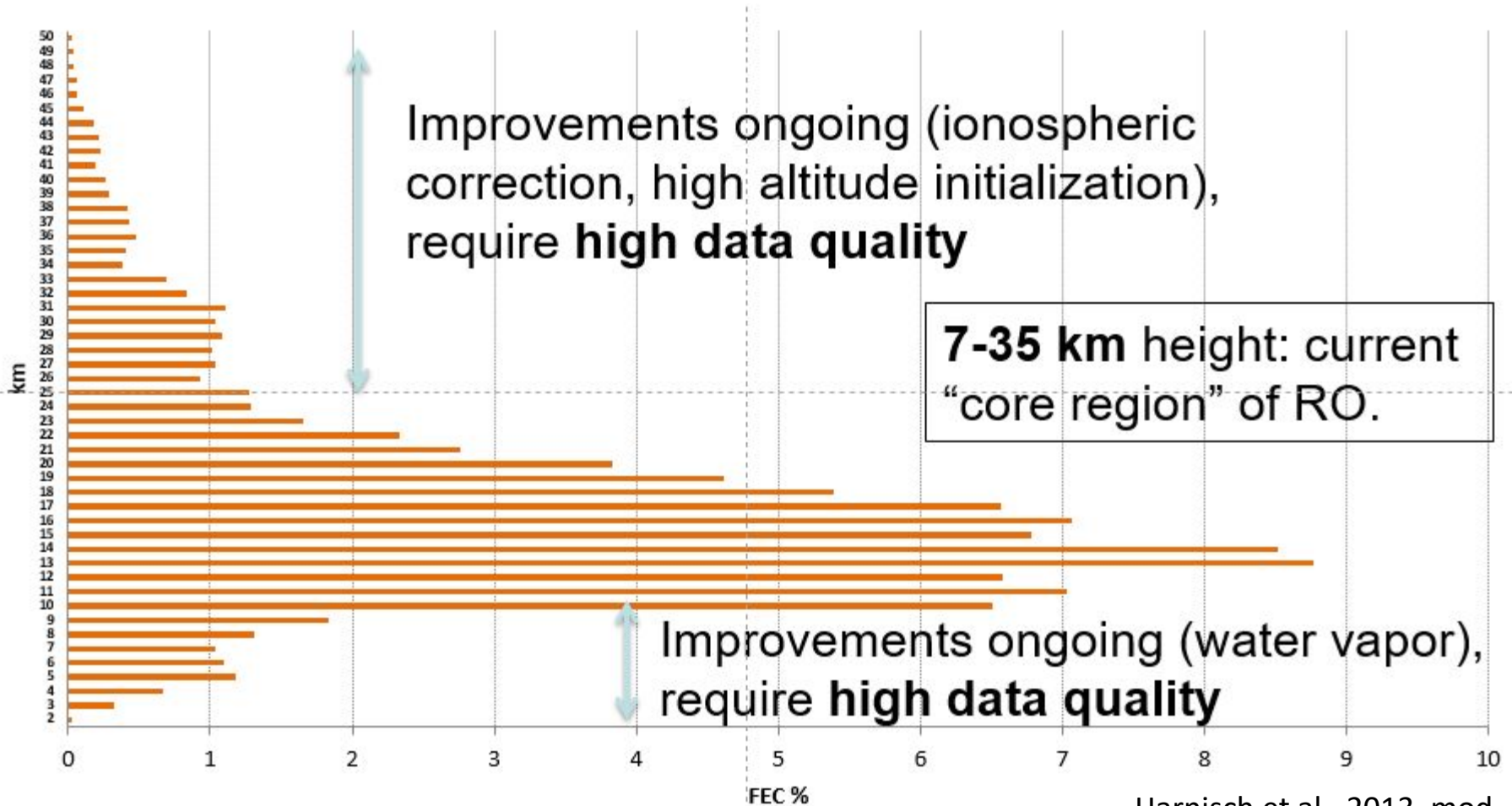
Satellite(s)	Dates	Number (1000)
Metop A,B,C		2 (currently)
COSMIC-2	2019-2026	5
Metop-SG-A1	2022-2029	1.5
Metop-SG-B1	2022-2029	1.5
Metop-SG-A2	2028-2035	1.5
Metop-SG-B2	2029-2036	1.5
JASON-CS-A	2020-2027	1
JASON-CS-B	2025-2032	1
FY-3D	>2022	1
FY-3E	2019-2024	1
FY-3F	2021-2026	1
FY-3G	2022-2027	1
FY-3H	2024-2029	1
FY-3RM	2020-2025	1
FY-3RM-2	2023-2028	1

# RO Impact on NWP



Past high NWP impact cannot be sustained

# RO Impact on NWP



Harnisch et al., 2013, mod.

# Impact of RO on Reanalyses

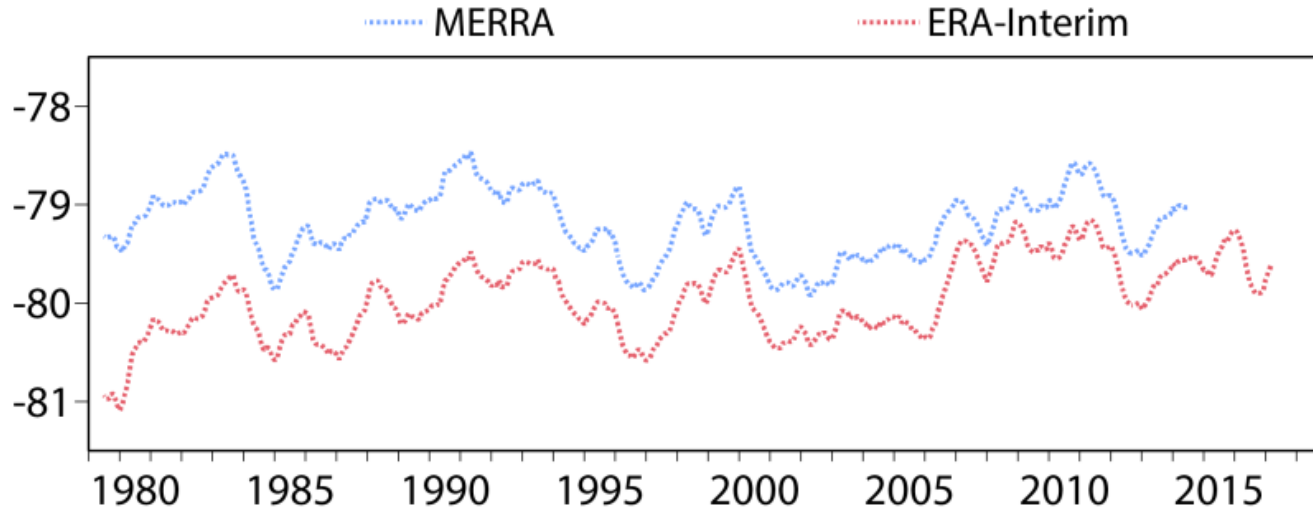
Input provided by Adrian Simmons, ECMWF

- **GPS-RO** is now considered an **essential measurement for climate reanalyses** (e.g., ERA-5, ERA-Interim, JRA-55, MERRA, MERRA-2).
- **Anchor measurements:** assimilated without bias correction.
- The **consistency of different climate reanalyses** in the lower/mid stratosphere has **improved significantly since the assimilation of COSMIC** in 2006.
- Suggests the observation set prior to COSMIC was not sufficient to constrain the mean state.

# Impact of RO on Reanalyses

## Tropical Tropopause Temperature

12-month running-mean tropical-mean 100hPa temperatures (°C)

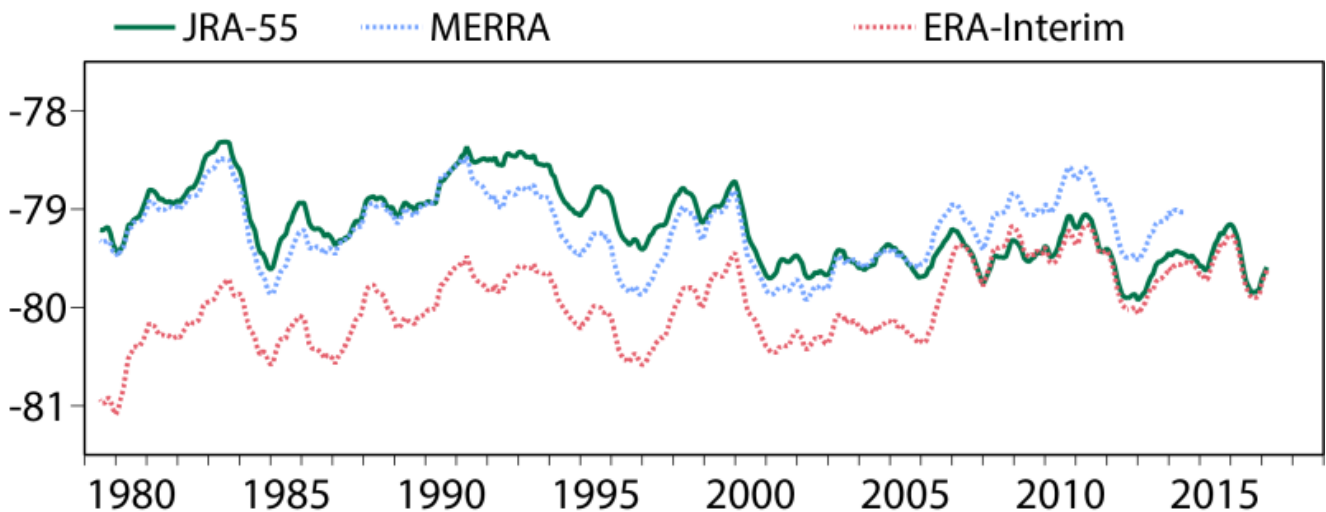


MERRA is warmer than ERA-Interim throughout.

# Impact of RO on Reanalyses

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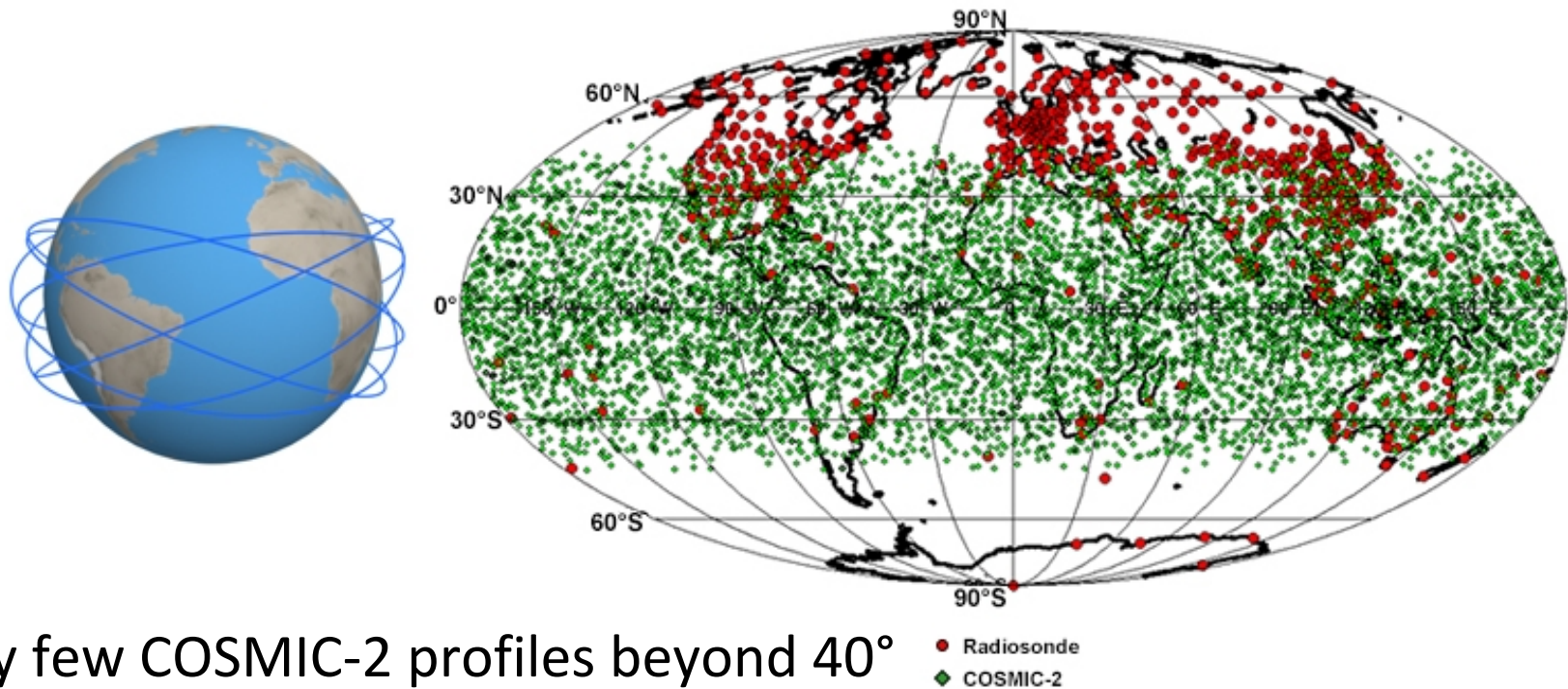


MERRA is warmer than ERA-Interim throughout. ERA-Interim and JRA-55 assimilate GPSRO data, and come together in 2006. ERA-Interim warms and JRA-55 cools when significant amounts of GPSRO data start to be assimilated.

→ Significant amounts of GPSRO data assimilated in ERA-Interim and JRA-55

# COSMIC-2 equatorial launch: Q3 2018

24-hour occultation locations for COSMIC-2 equatorial constellation



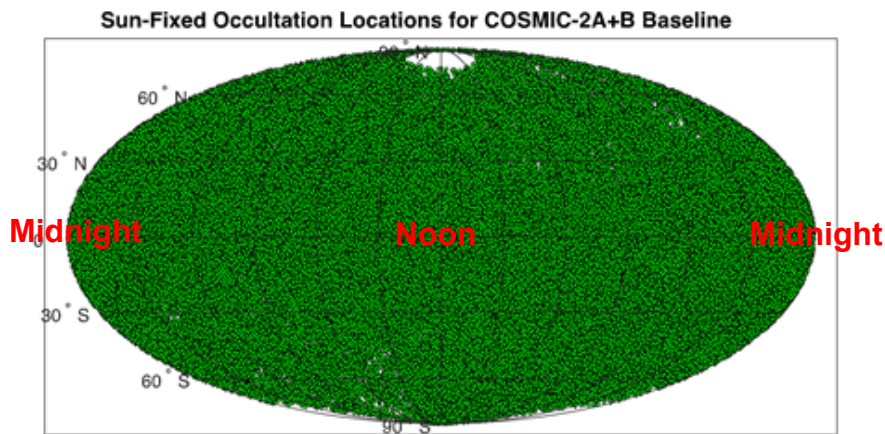
Very few COSMIC-2 profiles beyond 40° latitude, There will be additional RO profiles from **MetOp** and **FengYun**), but ..

©UCAR, The COMET Program

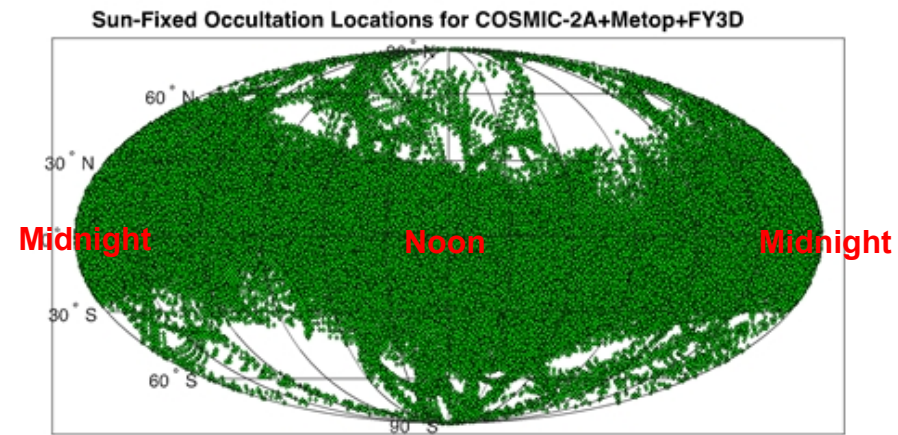
# Local Time Coverage

**Neutral** Atmospheric Soundings (input by W. Schreiner, UCAR)

COSMIC-2AB



COSMIC-2A + **Metop** + **FY-3D**



Note: Without C2B, **Ionospheric** LT coverage is **worse** than shown here for neutral atm. since Metop does **not** collect ionospheric soundings.

# Current/Upcoming RO missions

Mission	Country	Launch date	Receiver Heritage	# Soundings per day	Orbit (alt/inc)	Local Time	Near Real-Time
COSMIC-1	USA/Taiwan	2006	JPL/IGOR	400	800/72	-	Yes
Metop-A/B	Europe	2006/2012	GRAS	1300	830/98.7	0930	Yes
TerraSAR-X	Germany/USA	2007	JPL/IGOR	200	515/98.4	1800	Yes
TanDEM-X	Germany/USA	2010	JPL/IGOR	100	515/98.4	1800	Yes
FY-3C	China	2013	GNOS	400	836/98.7	1000	Yes
KOMPSAT-5	S. Korea	2013	JPL/IGOR+	500	850/98.7	0600	Apr 2018
PAZ	Spain	01/2018	JPL/IGOR+	300	515/98.7	1800	Late 2018
COSMIC-2A	USA/Taiwan	06/2018	JPL/TriG	5000 (lat < 40°)	520/24	-	Yes
FY-3D	China	2017	GNOS	1000	850/98.7	1400	Yes
Grace-FO	USA/Germany	04/2018	JPL/TriG	600	500/89.0	-	2018
Metop-C	Europe	10/2018	GRAS	650	830/98.7	0930	Yes
Jason-CS/ Sentinel-6	USA/Europe	2020	JPL/TriG	1000	1336/66	-	Yes
EPS-SG/A1/B1	Europe	2021	GRAS	2800	830/98.7	0930	Yes
Spire/GeoOptics /PlanetIQ tbd	Note: Metop-A,B,C and EPS-SG sats will not all be operating simultaneously						

# Recent ECMWF experiments

## Numbers, radiances, bending angles

