

Radio Occultation and IROWG Matters

Presented to CGMS-47, WG II

Co-Chairs: Ulrich Foelsche (University of Graz),
Sean Healy (ECMWF)

Rapporteur: Tony Mannucci (NASA/JPL)

**Coordination Group for
Meteorological Satellites**



Overview

- No meeting since IROWG-6 (September 2017)
- IROWG-7, September 19-25, nr Copenhagen
- Review IROWG-6 main recommendations
- 20,000 occultation per day target in 2020's
- Assessments of commercial data
- Action updates
- Summary

Main Recommendations IROWG-6

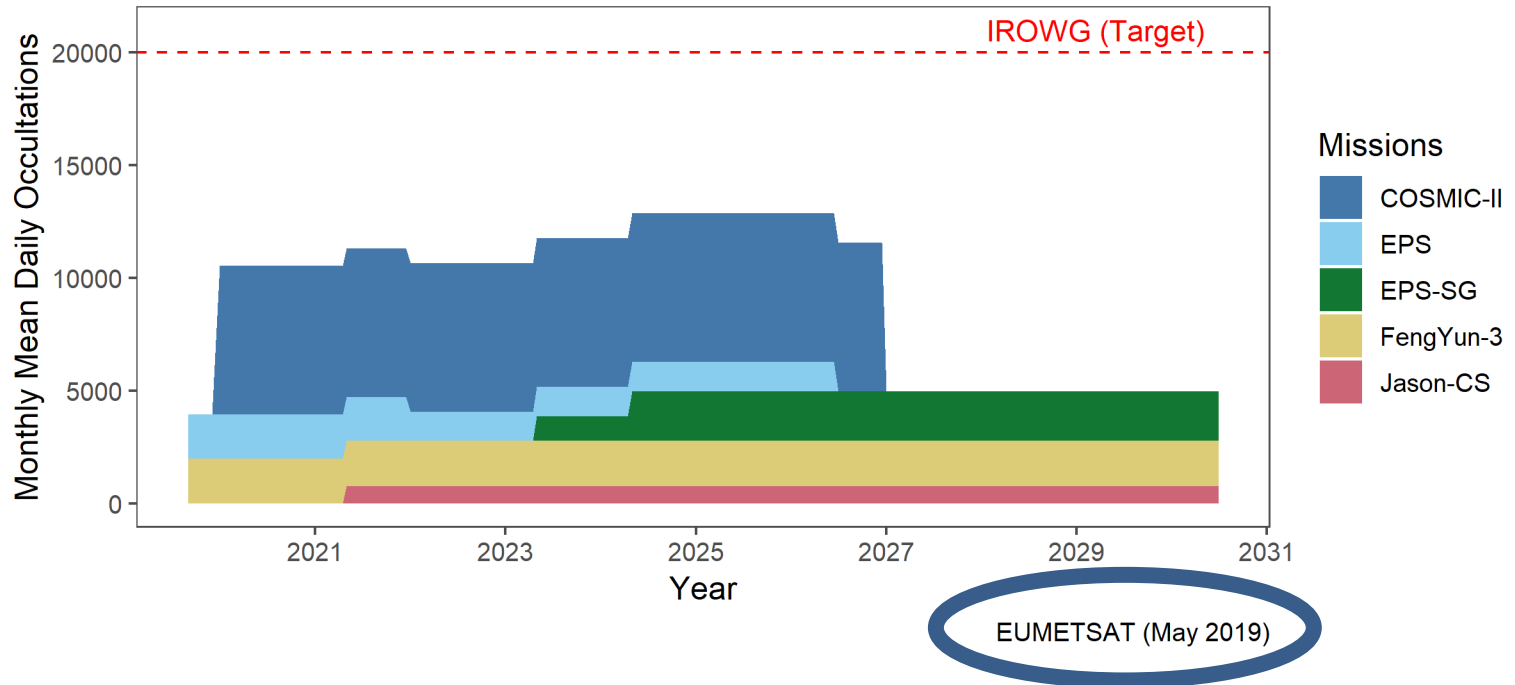
- Ensure that both, **equatorial and polar components of COSMIC-2 are fully funded and launched**;
- IROWG recommends targeting at least **20,000 occultations/day** providing **good spatial and local time coverage**, to be made **freely available** to the **operational and research communities** of Numerical Weather Prediction, Climate, and Space Weather.;
- International space agencies (in particular NASA, ESA and CNSA, where LEO-LEO and GNSS-RO&-Reflectometry proposals are pending) to support mission preparation and implementation projects towards **LEO-LEO microwave occultation and GNSS-RO&-Reflectometry demonstration missions**. This should include recommending new OSSEs for the LEO-LEO observations.
- IROWG stresses the importance of **long-term archiving** of the **Level0 data** – and all the relevant **meta data** – from both the agency-led and “commercial” missions. **These long term costs should be included in mission budgets**.

Current/Future data numbers

- Recent introduction of Metop-C GRAS has increased the total number of occultations per day to ~2900
- KOMPSAT-5 and FY-3D GNOS will be tested
- PAZ and GRACE-FO not yet NRT
- COSMIC-2 to be launched (~5000) in 2019
- Longer term, Sentinel-6 (formerly Jason-CS), EPS-SG, FY-3 E,F,G,H, FY-3RM-1, FY-3RM-2.
- Meteor-M N3, Meteor-MP N1, N2
- **Unlikely to meet the 20,000 per day in 2020s**

Future Status of RO

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



Caveats/assumptions

- The figure only includes numbers for confirmed missions by operational CGMS agencies (no research or even uncertain operational satellites);
- Numbers for upcoming missions are based on nominal requirements. Sometimes those are pessimistic (e.g. Jason-CS: the requirement is 770, although some people expect more like 1100);
- We assume that data from newly launched missions become available six months after the nominal launch to allow for commissioning activities.
- EPS/Metop:
 - Metop-A will stop in late 2021;
 - Metop-B and –C lifetimes are assumed to be as for Metop-A (13+ years); however we assume Metop-B and –C will enddelivering good data by 2026 as this is the current date for the termination of the encrypted legacy L2/P signals of GPS.
- COSMIC-II:
 - Data availability from early 2020 onwards (left side of the picture) with a lifetime of seven years;
- EPS-SG:
 - Only baseline performance (GPS + Galileo); Beidou will increase its contribution;
 - We assume two satellites being operated simultaneously at all times, no overlap between launches, no extended lifetimes
- FengYun-3:
 - We assume two satellites being operated simultaneously at all times, no overlap between launches, no extended lifetimes
- Jason-CS: No overlap between the two consecutive satellites

Assessment of commercial RO missions

- We recognise the importance and value of the on-going assessments of commercial data
- However, *we think* a number of similar assessments are being performed in parallel, and the results are not being shared with the broader community
- Strongly encourage all agencies involved in these assessments to attend and present at IROWG-7

Action Item Summary

See working paper for details

- WGII-A46.01: “unfilled spectroscopic needs”
- WGII-A46.08: Develop “Process and Principles” of RO QC to aid comparison.
Discuss IROWG-7
- WGII-A45.02: OSSE proposals for advanced technology (LEO-LEO and GNSS-Reflections).
Discuss at IROWG-7. **Fast Forward Model not yet developed for LEO-LEO**

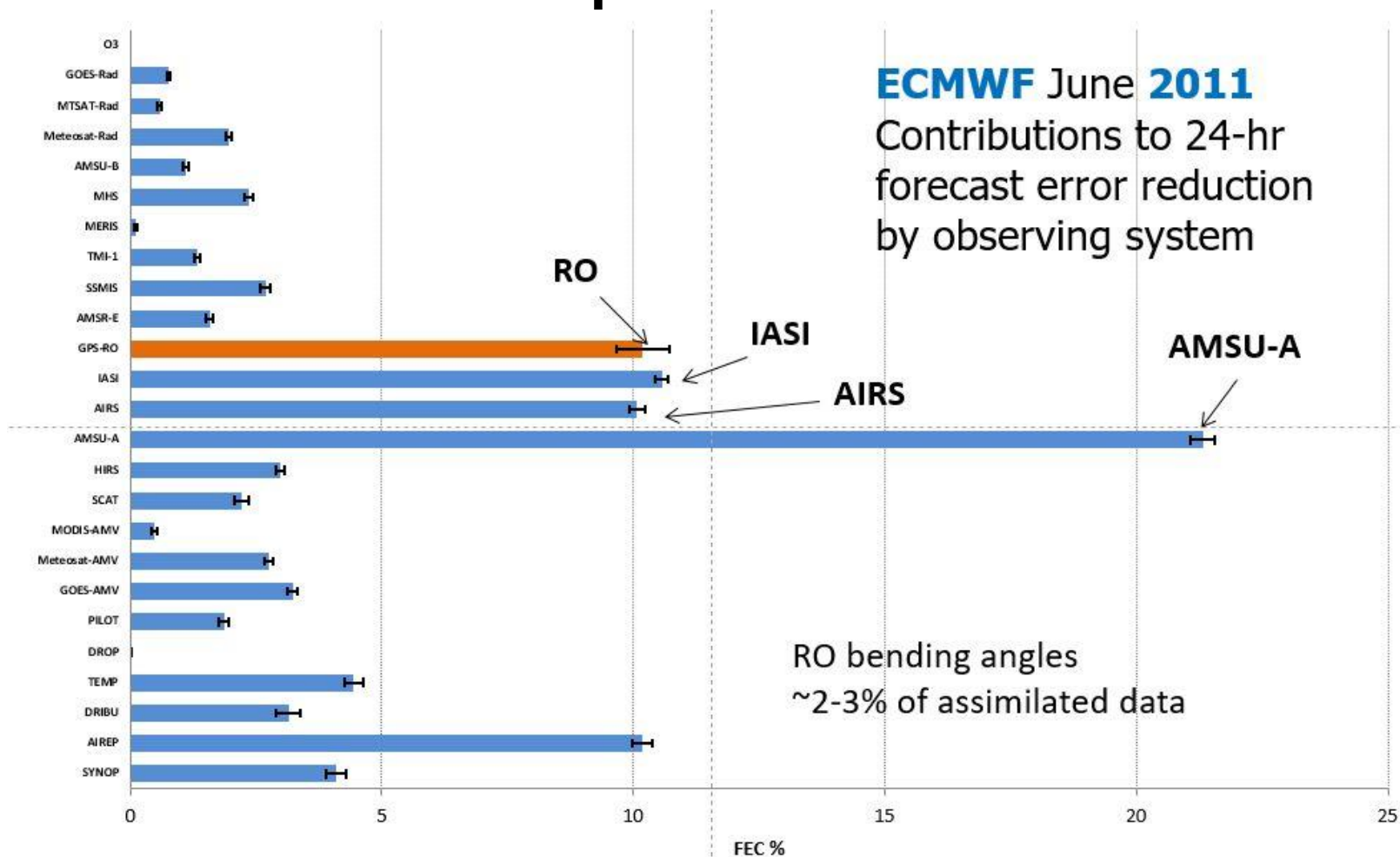
Summary

- No meeting since IROWG-6.
- IROWG-7: September 19-25, 2019, Elsinore, Denmark.
- Restated IROWG-6 recommendations here.
- Unlikely to meet 20,000 per day target with “agency led” missions in 2020’s.
- Encourage more information exchange when assessing commercial data.

Backup slides

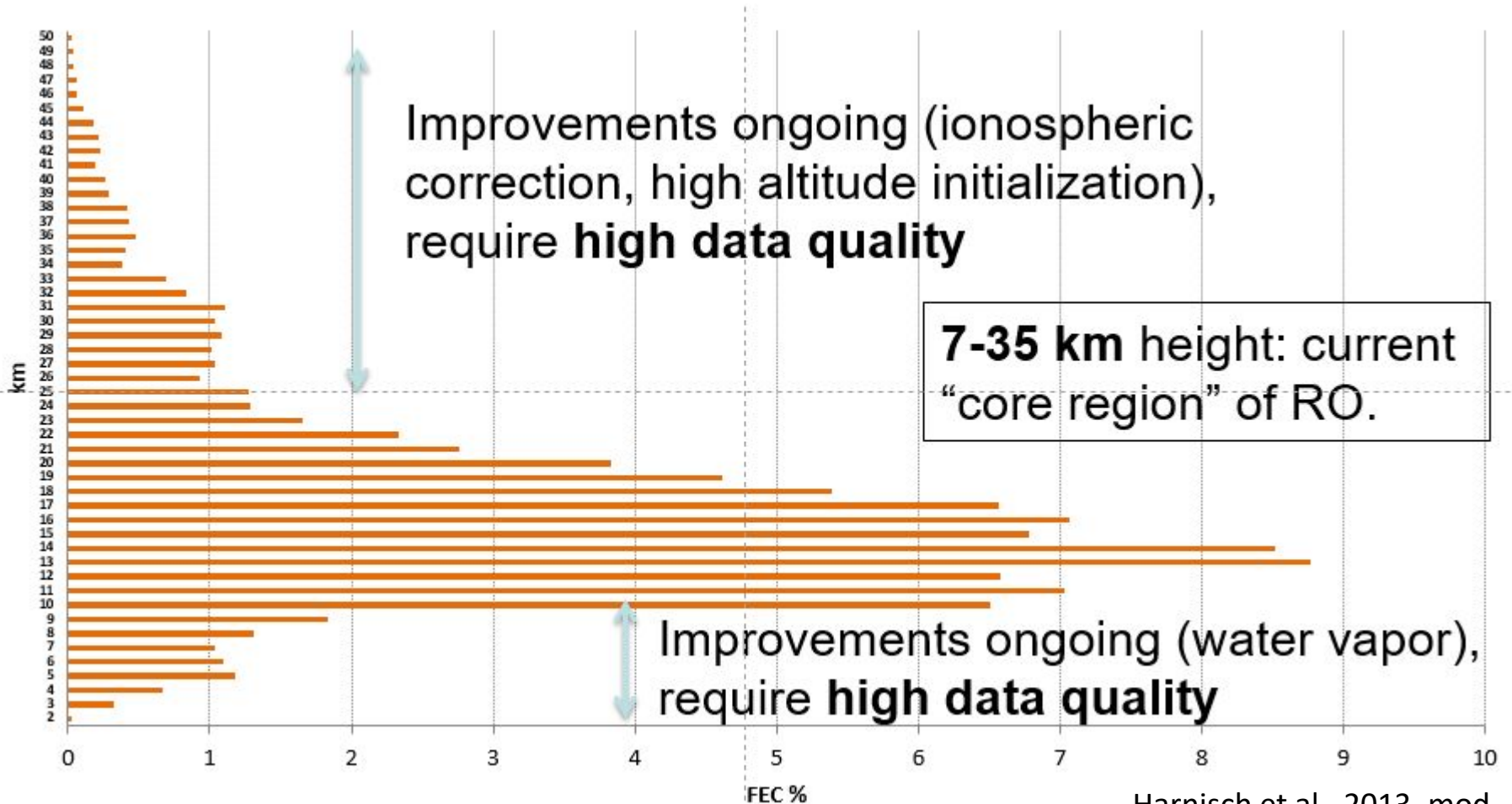
(mainly from CGMS-46)

RO Impact on NWP



Past high NWP impact cannot be sustained

RO Impact on NWP



Harnisch et al., 2013, mod.

Ongoing work: expand the RO “core region”

Impact of RO on Reanalyses

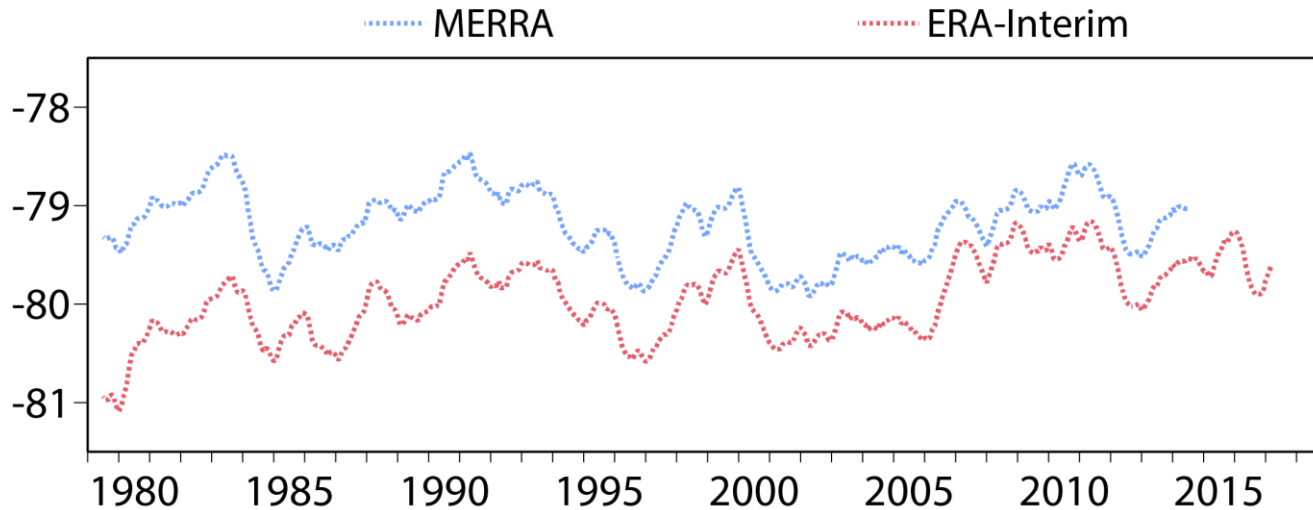
Input provided by Adrian Simmons, ECMWF

- **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)

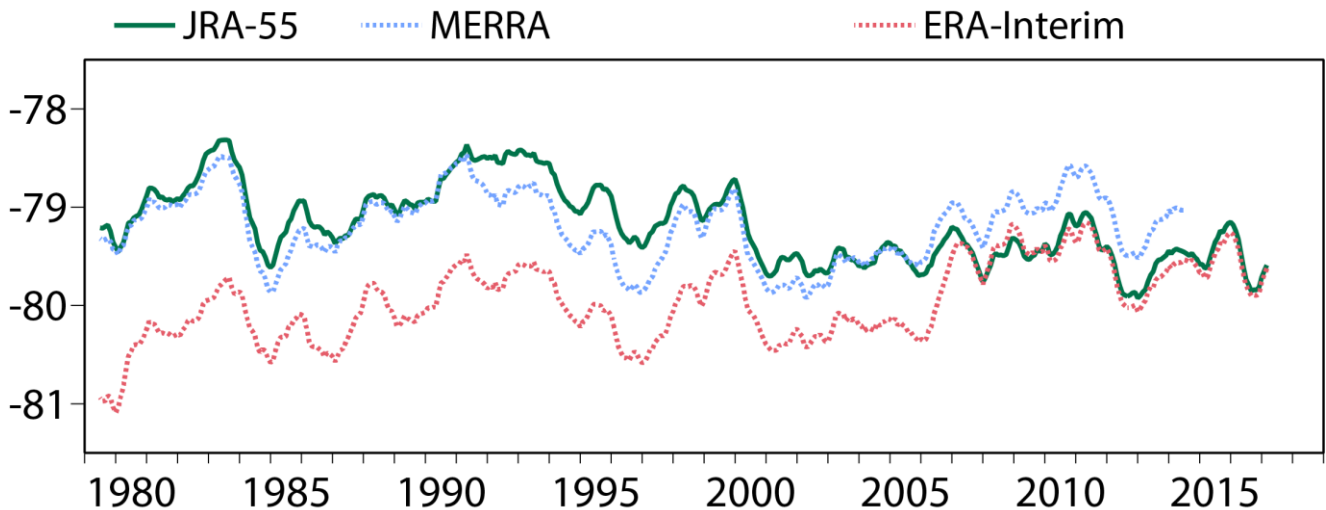


MERRA is warmer than ERA-Interim throughout.

Impact of RO on Reanalyses

Tropical Tropopause Temperature

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

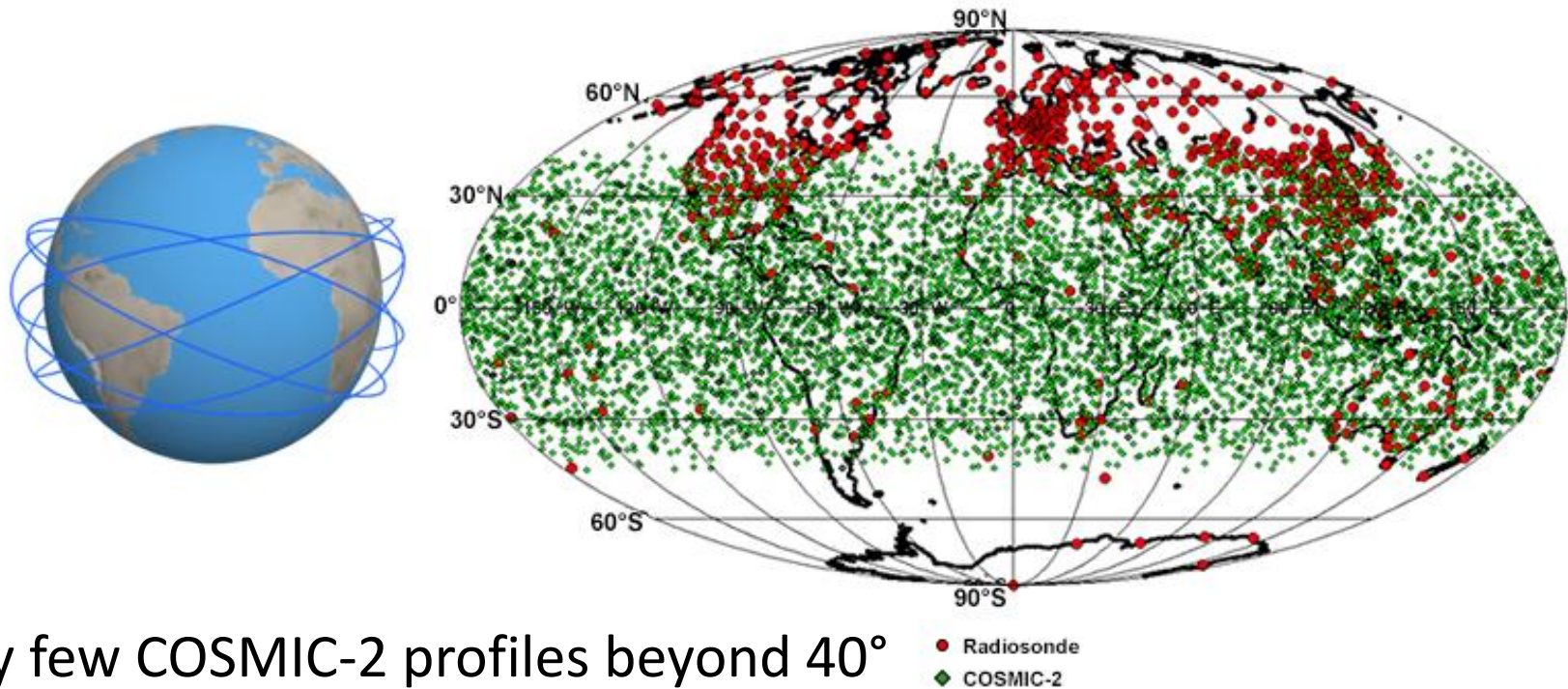


MERRA is warmer than ERA-Interim throughout. ERA-Interim and JRA-55 assimilate GPSRO data, and come together in 2006. ERA-Interim warms and JRA-55 cools when significant amounts of GPSRO data start to be assimilated.

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



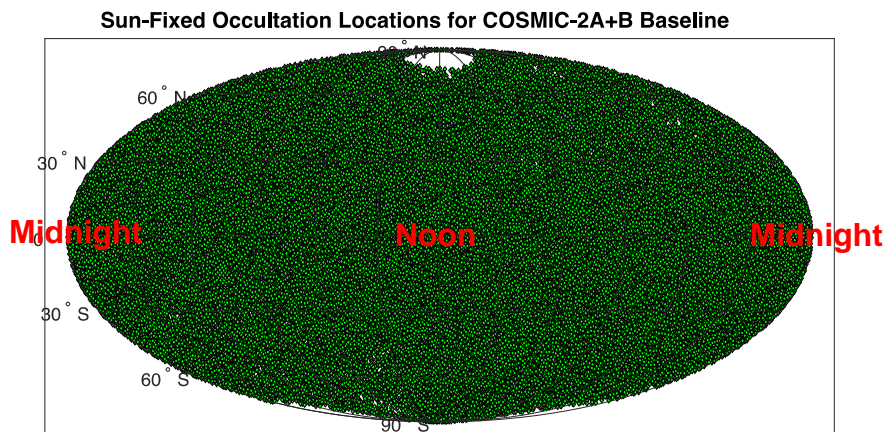
Very few COSMIC-2 profiles beyond 40° latitude, There will be additional RO profiles from **MetOp** and **FengYun**), but ..

©UCAR, The COMET Program

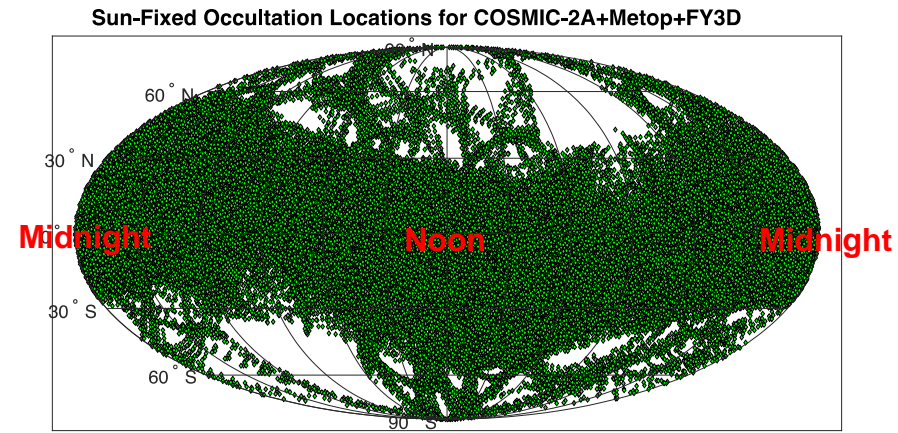
Local Time Coverage

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						

Coordination Group for Meteorological Satellites - CGMS

Satellite(s)	Dates	Number (1000) Rounded to nearest 0.5	Assumed Constellation Number	Notes
Metop A,B,C		2 (currently)	1	
COSMIC-2	2019-2026	5	2	
Metop-SG-A1	2022-2029	1.5	3	Shifted all EPS-SG dates by 1 year
Metop-SG-B1	2023-2030	1.5	3	
Metop-SG-A2	2029-2036	1.5	3	
Metop-SG-B2	2030-2037	1.5	3	
JASON-CS-A	2020-2027		2	770 requirement
JASON-CS-B	2025-2032	1	2	770 requirement
FY-3D	>2022	1	2	One const. so far.
FY-3E	2019-2024	1	2	
FY-3F	2021-2026	1	2	
FY-3G	2022-2027	1	2	
FY-3H	2024-2029	1	2	
FY-3RM-1	2020-2025	1	2	
FY-3RM-2	2023-2028	1	2	

Recent ECMWF experiments

Numbers, radiances, bending angles

