Recent RO Activities at EUMETSAT

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Agenda

Commercial RO/Spire

Europe's Commercial Data Pilot Procurement.

Metop/GRAS

Ionospheric measurements, a drop in SNR and the next reprocessing coming up.

Sentinel-6

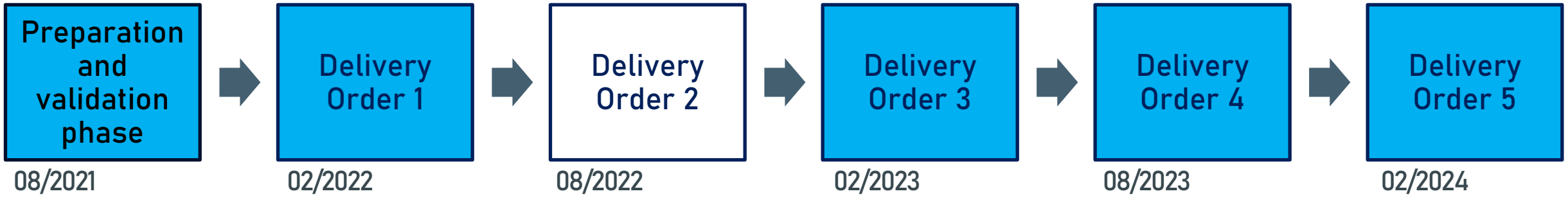
Non-Time Critical processing and L2.

Other

Summary

Commercial RO: Pilot Procurement

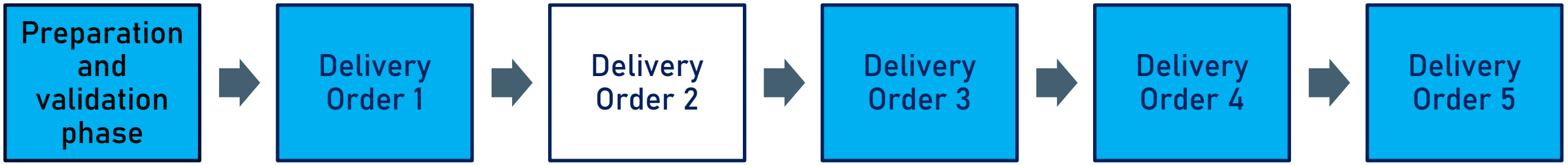
- Procuring data from Spire Global since August 2021 until August 2024.



- Each block covers a 6-month period;
  - Preparation and validation phase: European-only license (MSs, ROM SAF; free after 2 years)
  - Delivery Orders 1 & 2: Global license without restriction (i.e., NRT dissemination via GTS)

- All product levels (raw data from POD/zenith and occultation antennas, attitude, excess phases, bending angles, topside TEC)
- Processing to level 1b (bending angles) by EUMETSAT, higher levels by ROM SAF (soon).
- Used in operations at ECMWF, MetOffice, DWD.

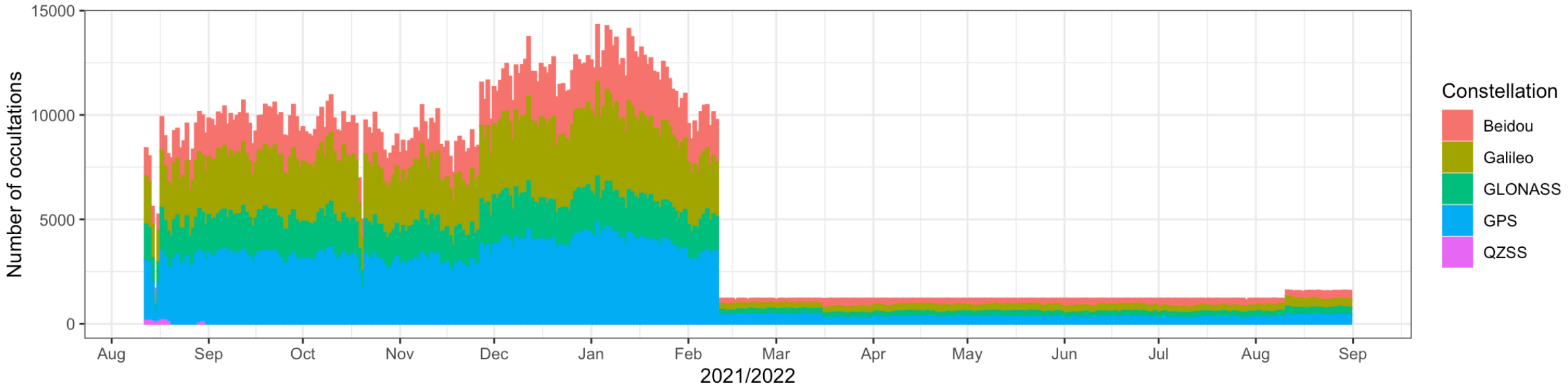
Commercial RO: Pilot Procurement



- For each delivery order, Member states decide:
  - Whether a delivery order should be placed;
  - What license should apply, and
  - Which data selection criteria should be used.

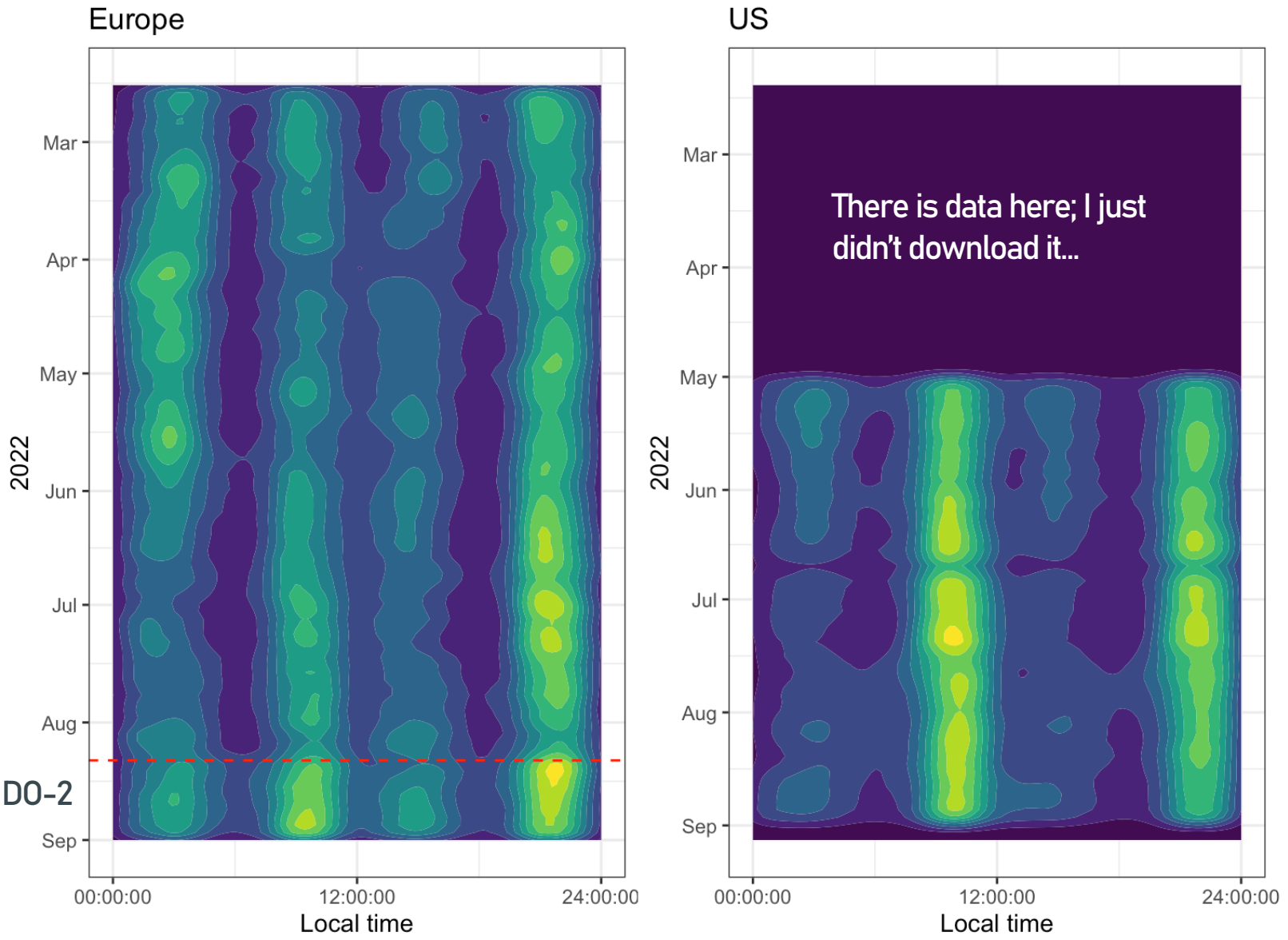
- Current data selection criteria:
  - Coverage: -100 – 80 km SLTA (both frequencies), globally distributed
  - SNRs: > 80 V/V for L1/E1/B1, > 50 V/V L2/E5/B2 for 60 – 80 km; though some SNR patterns found are under investigation
  - All GNSS systems, including Beidou

Commercial RO: Pilot Procurement



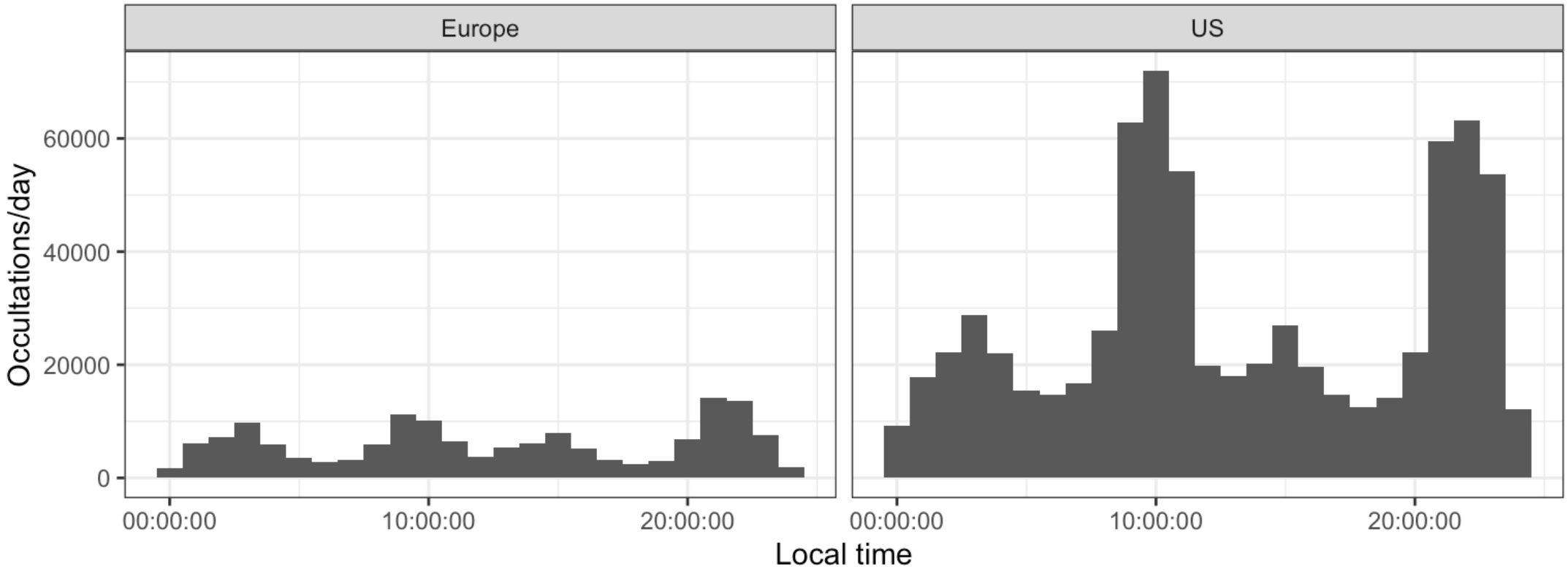
- Implementation and Validation phase (until mid-Feb 2022):
  - License limited to Member State NMHSs and the ROM SAF, data free after 2 years
  - > 10.000 occultations/day from late Nov 2021 onwards (requirement: 7000)
- Operational Delivery Orders:
  - Global unrestricted license for all product levels in NRT, unless Member States change their mind
  - > 1000 occultations/day until mid-Aug 2022
  - > 1400 occultations/day until mid-Aug 2023
  - > 1600 occultations/day until mid-Aug 2024 (when the pilot ends)

Commercial RO: Local time (relative numbers)



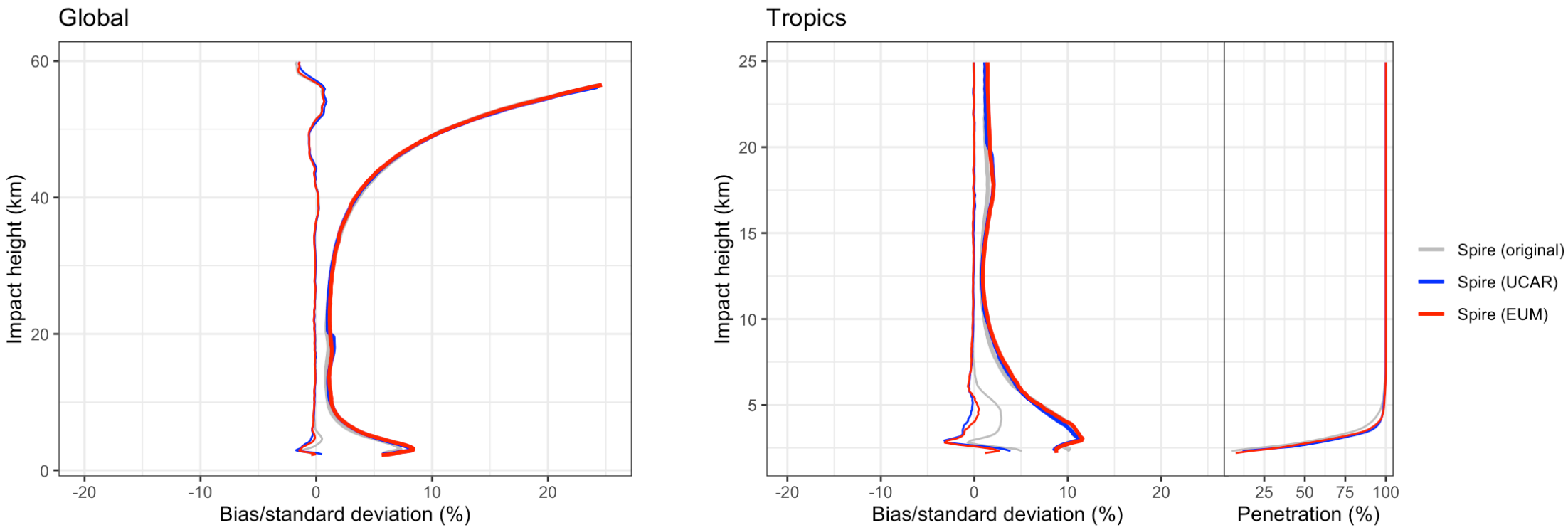
- Density of local time distribution for EUM and NOAA data buys (Spire only).
- Note slowly varying portion of data available around 03:00/ 15:00 local time
- Fewer data during daylight (9:30 and 15:00) than during nighttime in EUM data buy, vice versa for US data around 09:30/21:30
- Note: Colours indicate relative numbers; they refer to different absolute number of occultations in the two plots.

Commercial RO: Local time (absolute numbers)



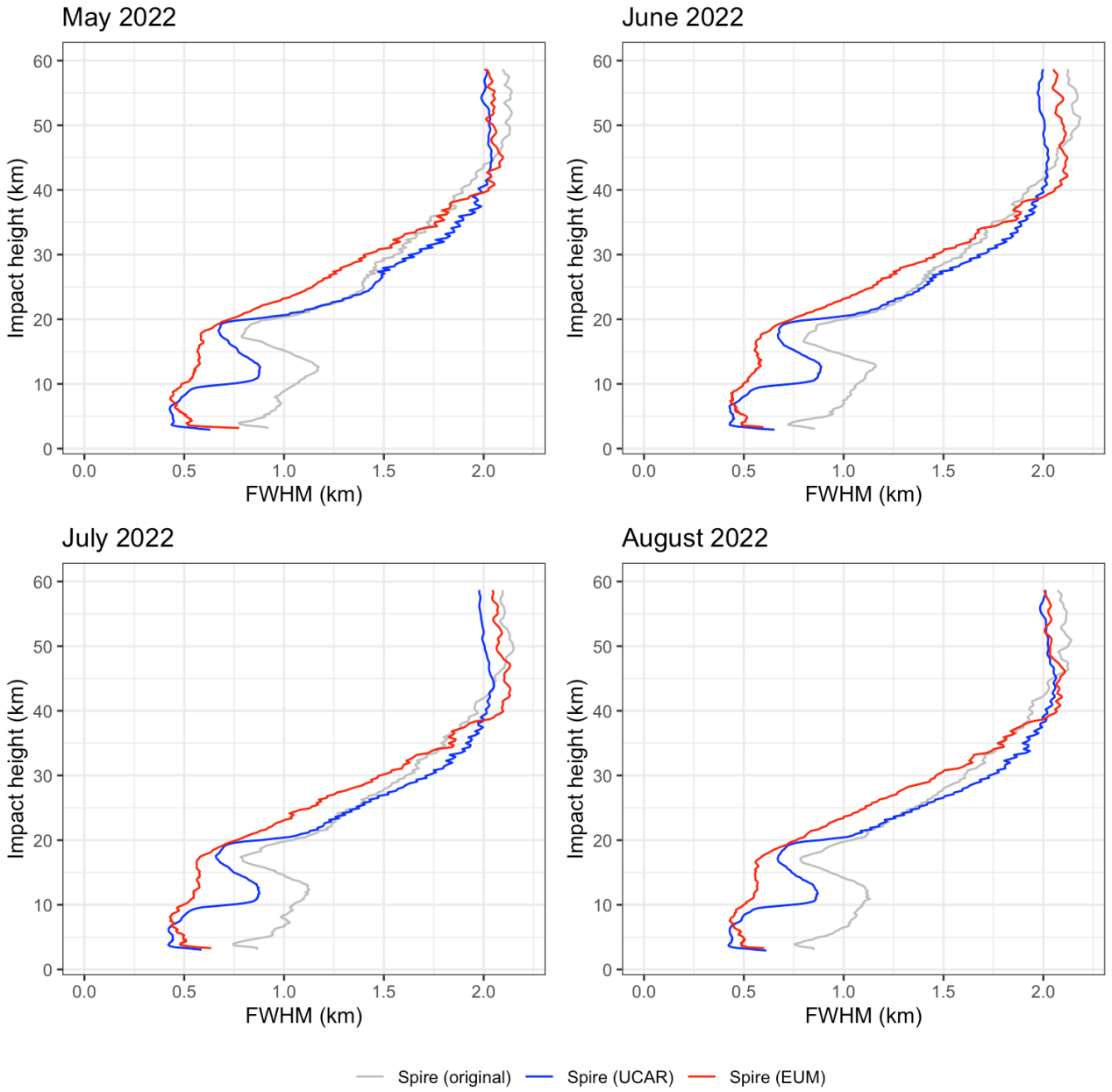
- Local time histograms of absolute numbers for EUM and NOAA data buys (Spire only) during May – Aug 2022.

Commercial RO: Statistics (global)



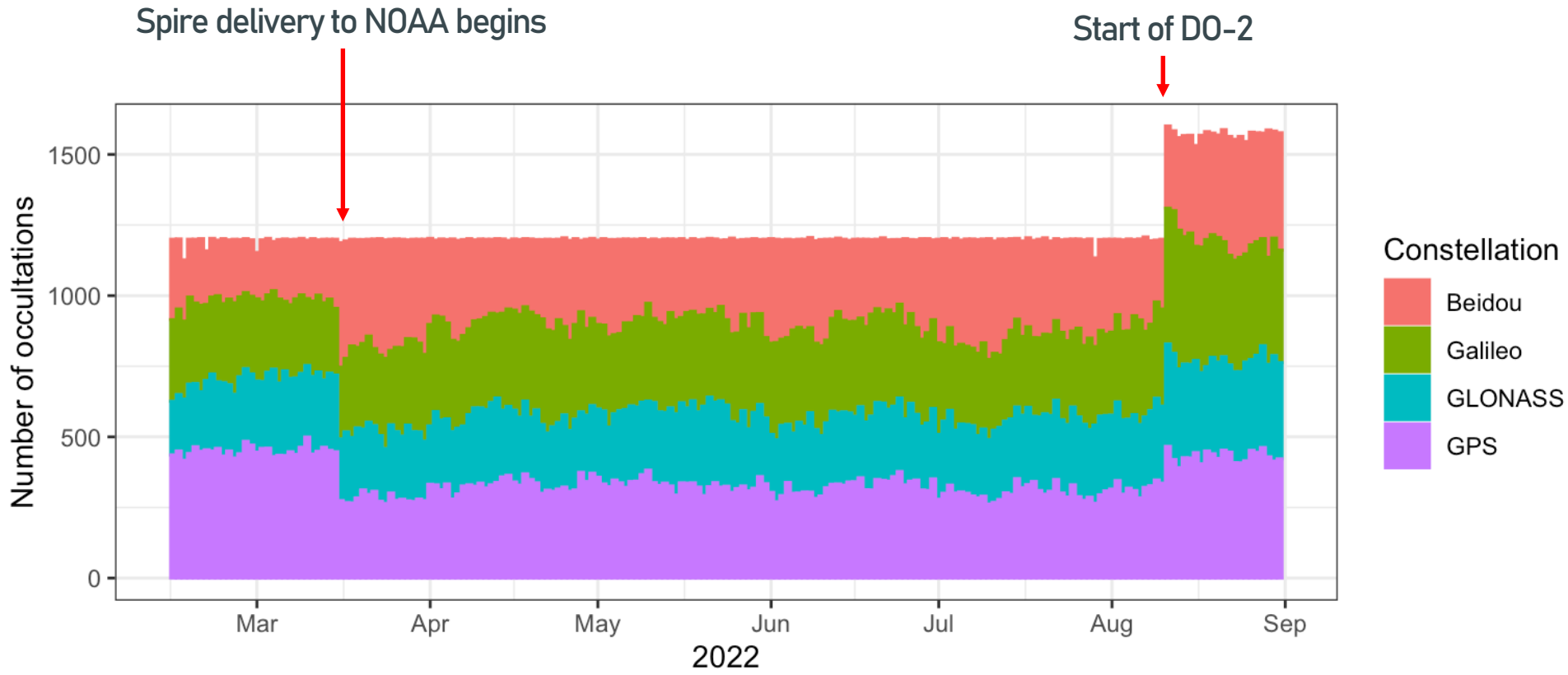
- Global (left) and tropical (right) statistics of bending angle data against ECMWF short-range forecasts for three processing centres
- Features known from other comparisons (e.g., StdDev bump around 20 km in UCAR processed data, positive bias in tropospheric Spire-processed data, …)
- Same for all months…

Statistics (O-B correlation lengths in the tropics)



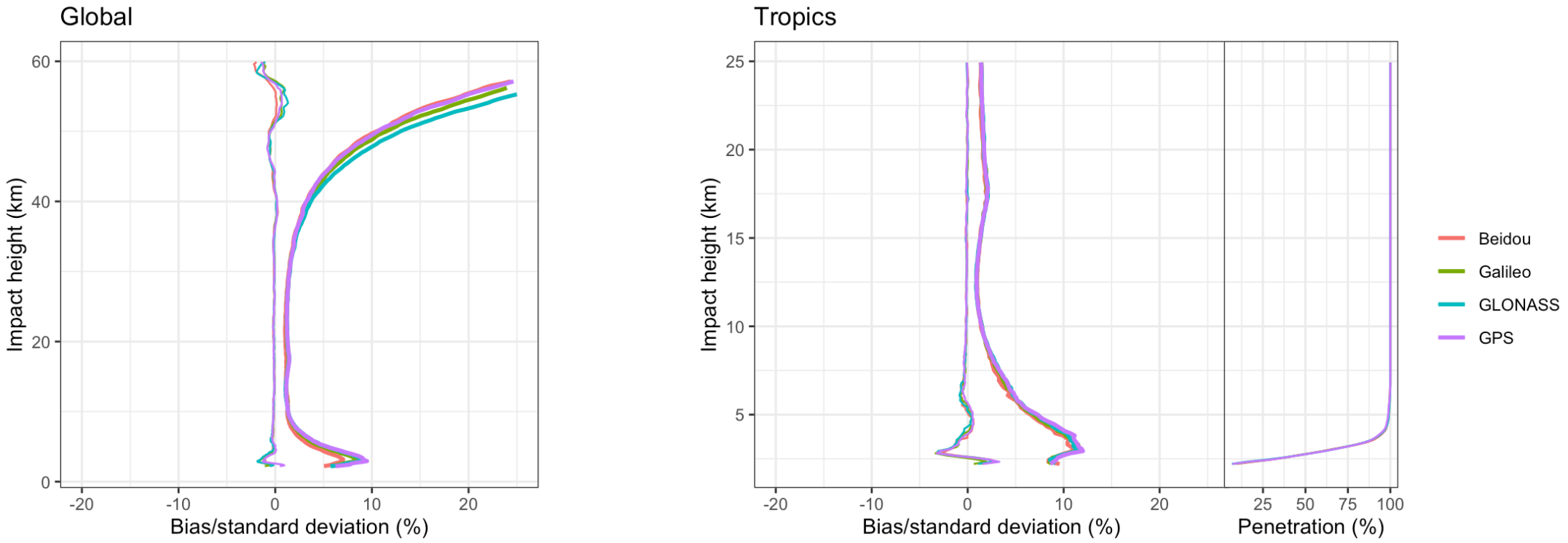
- Full-Width at Half-Max of the vertical O-B correlation as a proxy for vertical smoothing/resolution
- Interesting feature in the UCAR smoothing: – a sudden drop in vertical smoothing below 10 km.
- Overall, both UCAR and Spire smooth more than EUM.
  - ➢ See my talk on Monday

Commercial RO: GNSS constellations



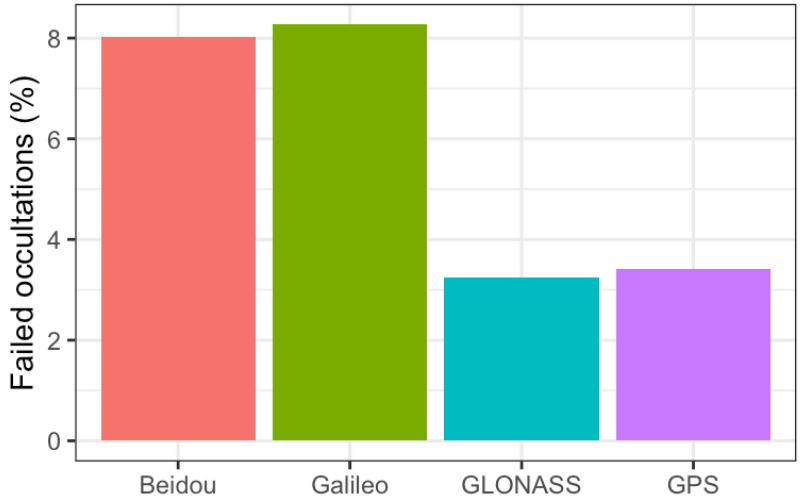
- Number of occultations during DO-1 by GNSS constellation
- Note the impact the beginning of Spire's contract with NOAA had on the composition of the European data set.
- By now, partition about GNSS constellation is about equal

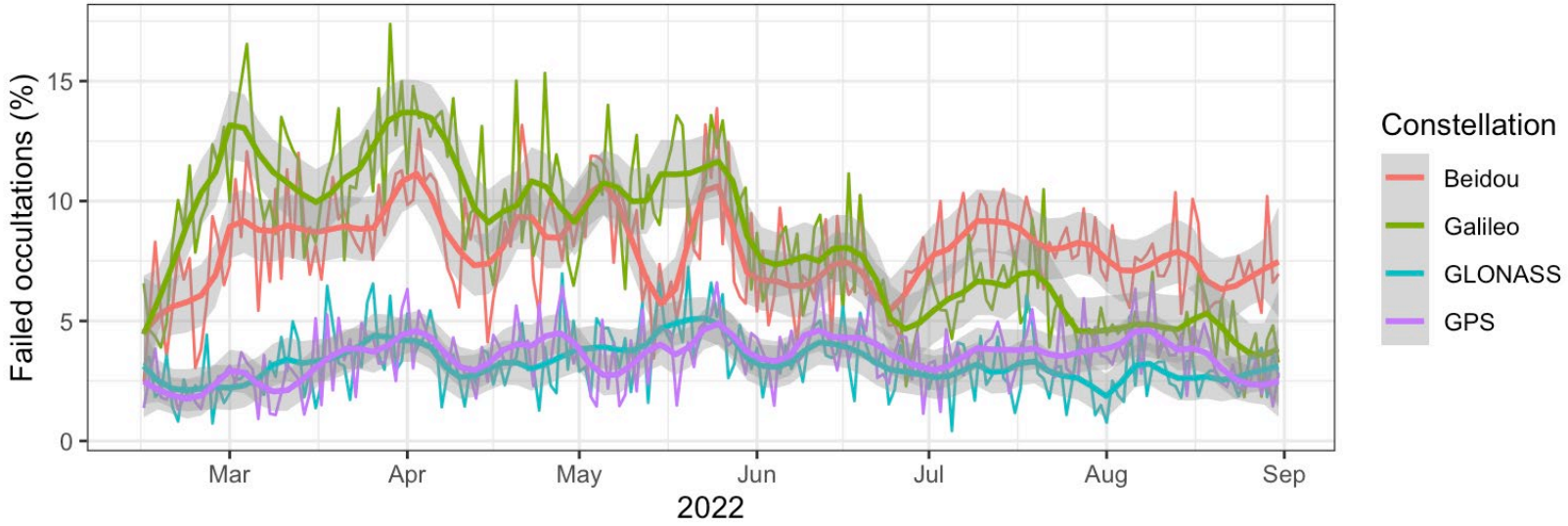
Commercial RO: GNSS constellations



- Global (left) and tropical (right) statistics of bending angle data against ECMWF short-range forecasts, stratified by GNSS constellation for the EUMETSAT processing during August 2022.
- Beidou data performs as well as GPS and Galileo, and slightly better than GLONASS high up.
- The apparent better statistics in the troposphere is likely caused by different spatial distribution; it doesn't show up in latitude band comparisons.

Commercial RO: Quality control





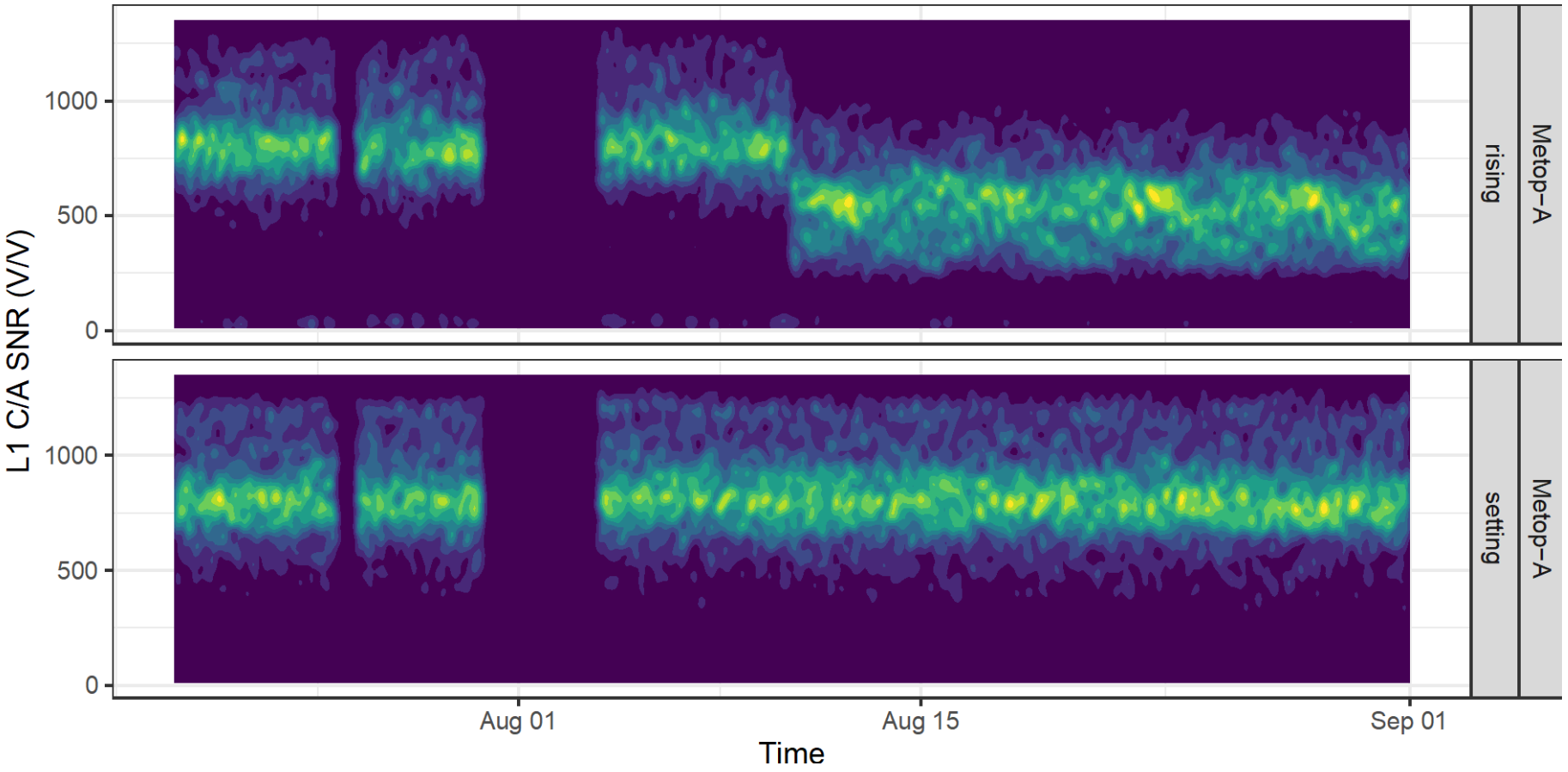
- Quality control rejection rates in EUMETSAT's processing, stratified by GNSS constellation; overall during DO-1 (left) and over time (right)
- About half of the QC rejection likely be caused by an overly conservative L2 data cutoff in the EUM processing; this might change
- The other half are real instrument issues: RF Interference, tracking issues at high altitudes (e.g., zero SNR high up – what carrier phase data from an open loop receiver mean in such a case?) - Well, we reject them…
- Other examples: Discontinuities in SNR high up, occultations showing SNR variations due to attitude changes during the occulation,… We are working with Spire what is acceptable and what not

Metop/GRAS: Ionospheric extension

- **Metop-A End-of-Life testing (2019)**
  - Feasibility of making ionospheric observations
  - Up to 300 km without significant impact on neutral occultation numbers
  - Up to 600 km (but fewer neutral occultations and degraded SNR above 300 km due to antenna gain patterns)

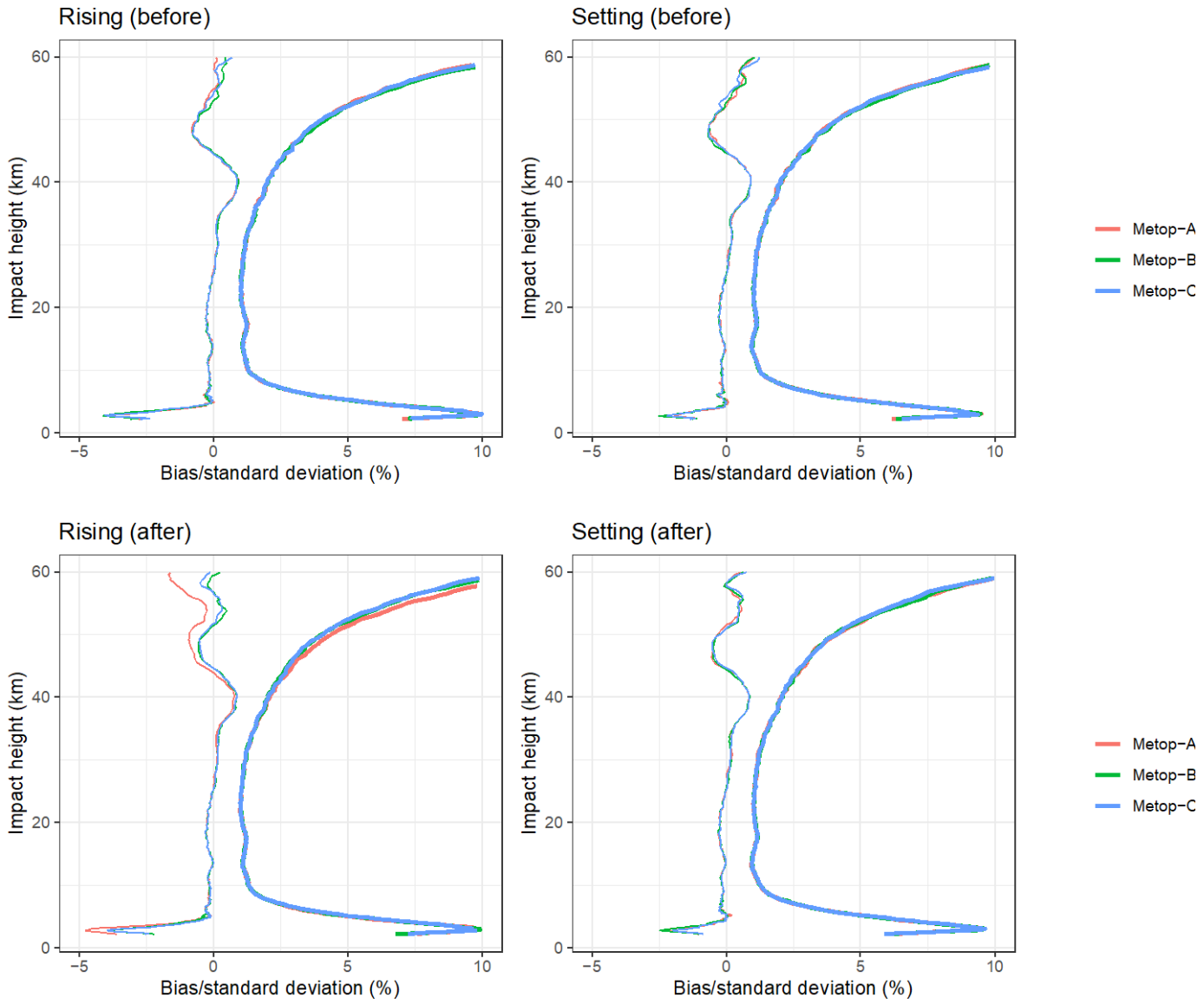
- **GRAS instruments were reconfigured to take measurements up to 300 km**
  - Metop-A: Jul 2021 until deorbiting in Nov 2021
  - Metop-B and –C: Feb 2022
  - Ionospheric products (scintillations, bending angles) will be operational later this year
  - GIMA study (DLR Neustrelitz & IEEC Barcelona) for the validation of ionospheric products, including topsideTEC
  - Electron densities may come in 2024
    - ➢ See talks by Mainul Hoque et al. and Riccardo on Monday

Metop/GRAS: SNR drop on Metop-A



- Median Metop-A L1 C/A SNR distribution for 21 days around 10 August 2019.
- The reason for the SNR drop is uncertain; we (BeyondGravity – formerly RUAG & EUM) believe that a feeder line for L1 data was compromised on the rising antenna, maybe due to thermal effects.

Metop/GRAS: SNR drop on Metop-A



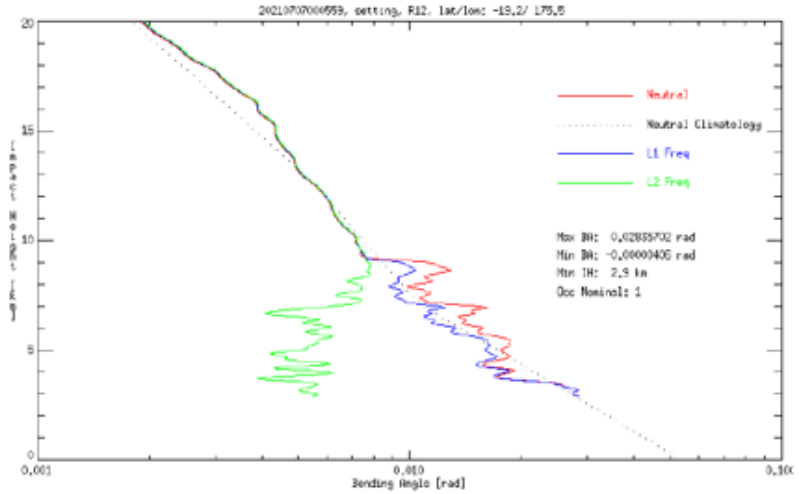
- If parts of the GRAS antenna stop working, the antenna phase centre might change.
- Antenna phase centre changes cause biases at high altitudes.

- We are working on estimating what the phase centre change might be to correct it in the reprocessing of Metop-A GRAS data.

Sentinel-6/RO

- Performing Non-Time-Critical processing of Sentinel-6 data since launch;
- Continued interactions with NASA/JPL to improve the quality of NRT data.
  - ➢ See talk by Axel on Tuesday

- L2 cutoffs below 20 km height: In the past, we learned that cutting off L2 data that high causes problems in refractivity retrievals as error correlations get too long; we want to cut off lower.
  This has opened a whole can of worms…
  - ➢ See talk by Saverio on Monday



Reprocessing

- A second round of reprocessing (GRAS, COSMIC-I, CHAMP, GRACE) was completed in 2020/2021 with current algorithms.

- Some issues:
  - Processing failures in the early GRAS data, especially Metop-A
  - Various small biases high up (including the one caused by SNR drop)
  - SNR Q/C too strict?
    - ➢ See Fran's talk later today.

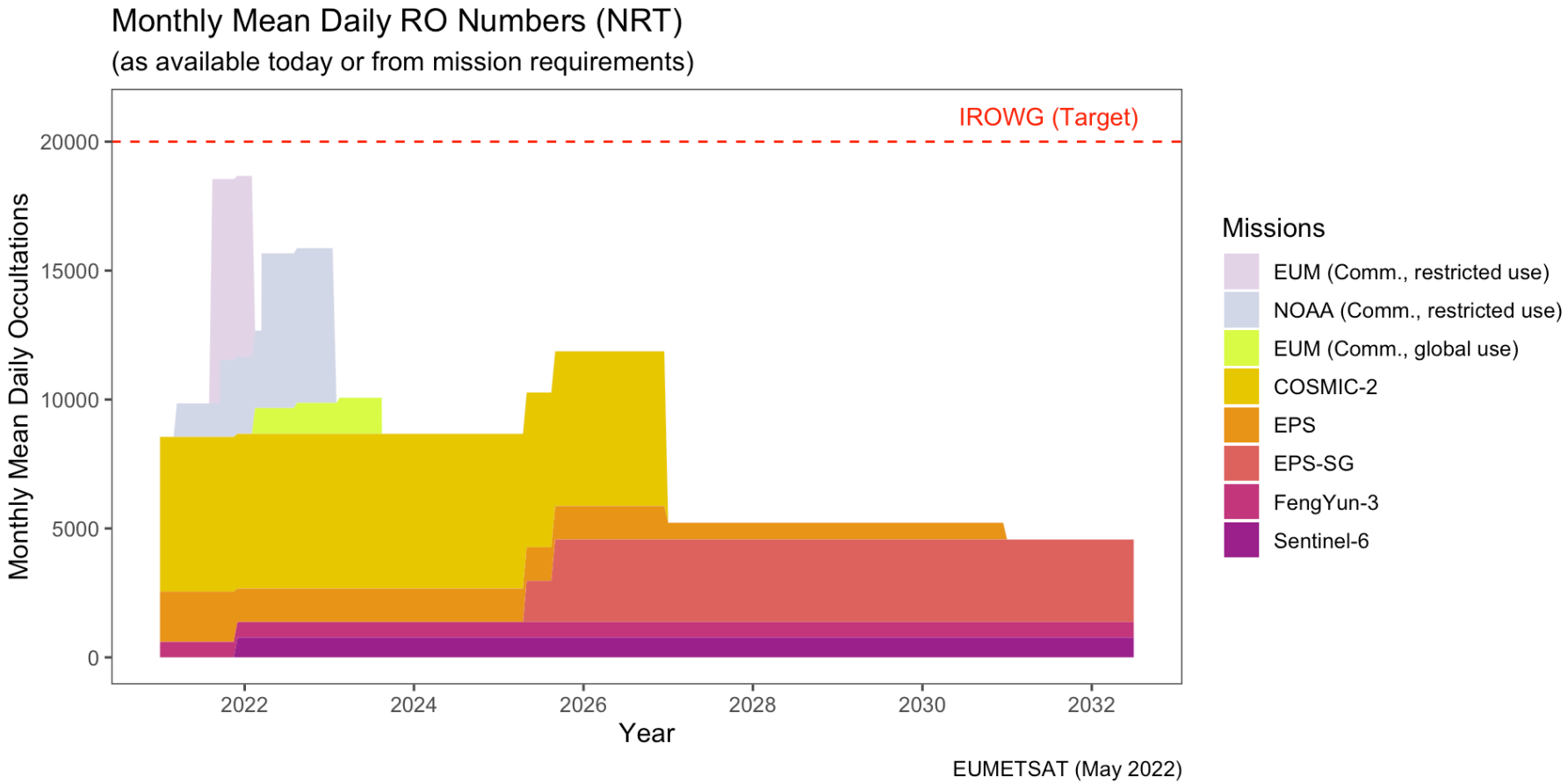
- Third round of reprocessing to begin later this year (in time for ROM SAF v2 repro) and will also include Sentinel-6/RO, commercial, and maybe COSMIC-II.

Other

- Precise Orbit Determination
  - Replacing NAPEOS POD software with Bernese
  - Looking into various interesting POD-related topics again, e.g., GLONASS clocks and RO performance
    - ➢ See talk by Sebastiano on Monday

- EPS/SG
  - Finalised launch specification of algorithms (and prototype)
  - Now focusing on supporting the implementation (by industry), integration and verification of the operational processor
  - Later on, launch preparations and…
  - First data and Cal/Val in the 2025 time frame

The future: Expected daily occultation numbers



- Figure based on requirements; we probably came close to 20.000/day for the first time at the end of 2021.
- If ROM(E)X would be implemented we'd be happy to provide the EUMETSAT dataset between August 2021 and February 2022 if the license can be unlocked before February 2024.

Summary

- EUMETSAT is running a pilot procurement of commercial RO data from Spire between 2021 and 2024 for its Member States.
- Data is procured under an unlimited global license and available in NRT via EUMETCast / GTS and also the EUMETSAT website.
- Data is used operationally at ECMWF, MetOffice, DWD, and hopefully soon by MeteoFrance and others as well.
- ROM SAF Level product generation is in preparation.
- Overall results are good; data quality is consistent with similar data processed by UCAR.
- Beidou data is included, with data quality as good as the other ones.
- We are learning a lot about occultation distribution and QC and are collaborating with Spire to improve some aspects of the data delivery.

Summary

- Ionospheric data from Metop/GRAS (scintillations, bending angles will be available soon; maybe electron densities in the lower ionosphere later on.
- A new round of reprocessing is coming up, with many improvements compared to earlier versions∞ this includes third-party data (CHAMP, GRACE, COSMIC-I) and will be base for the next ROM SAF reprocessing.
- Sentinel-6/RO and preparations for EPS-SG are progressing well.

Thank you.