



GRACE-FO

Science Operations Report

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On behalf of the SDS and operations teams

2025-10-07

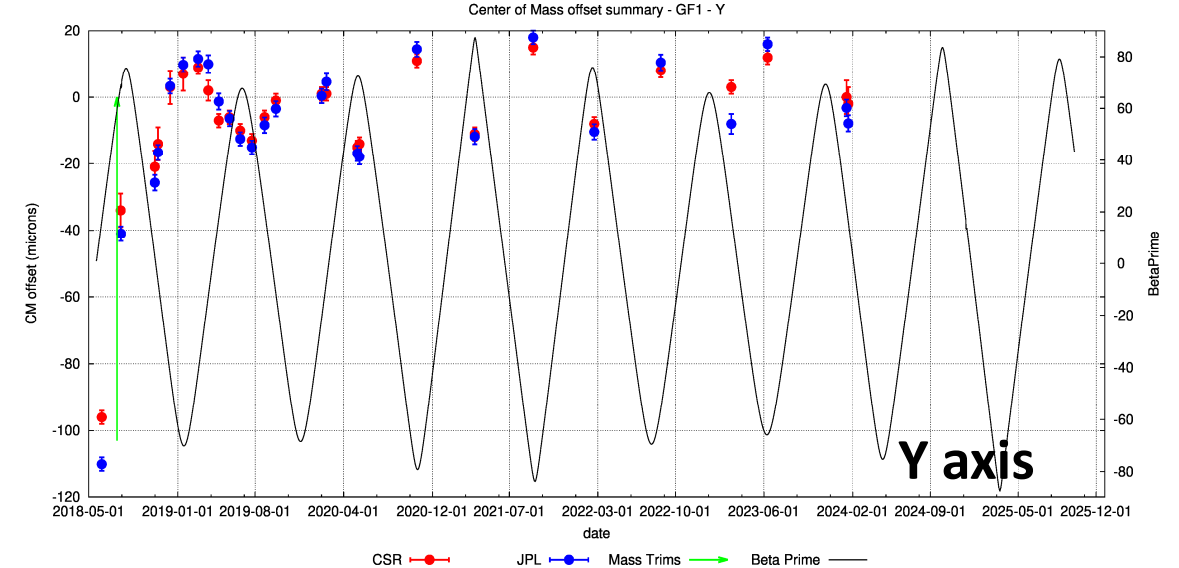
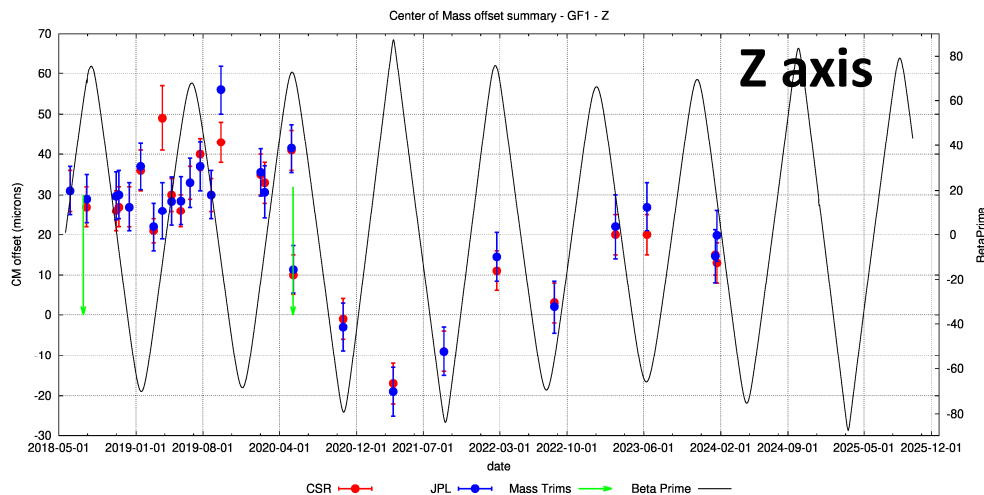
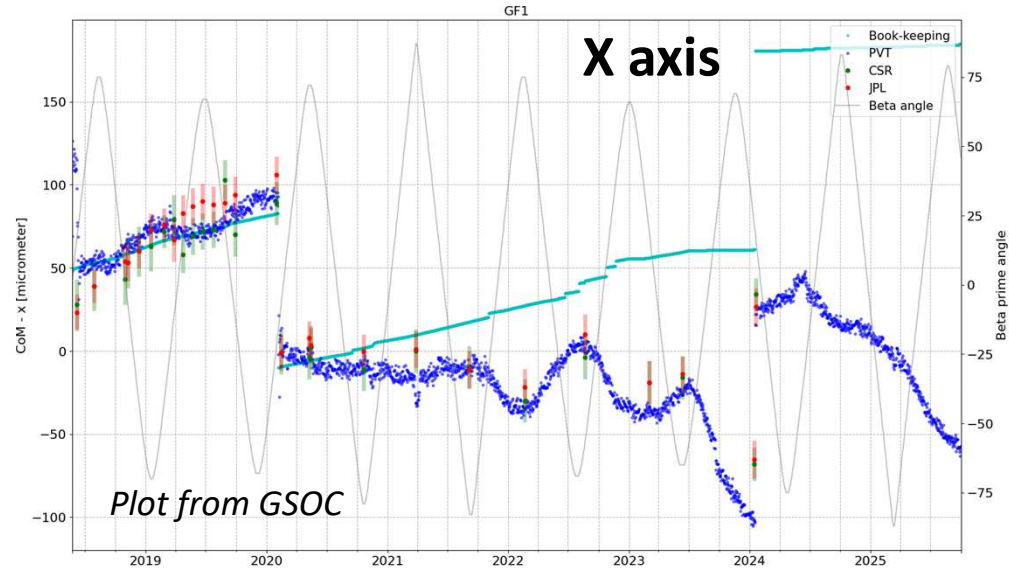
GRACE-FO Science Team Meeting 2025

Virtual

Science Operations Challenges and updates

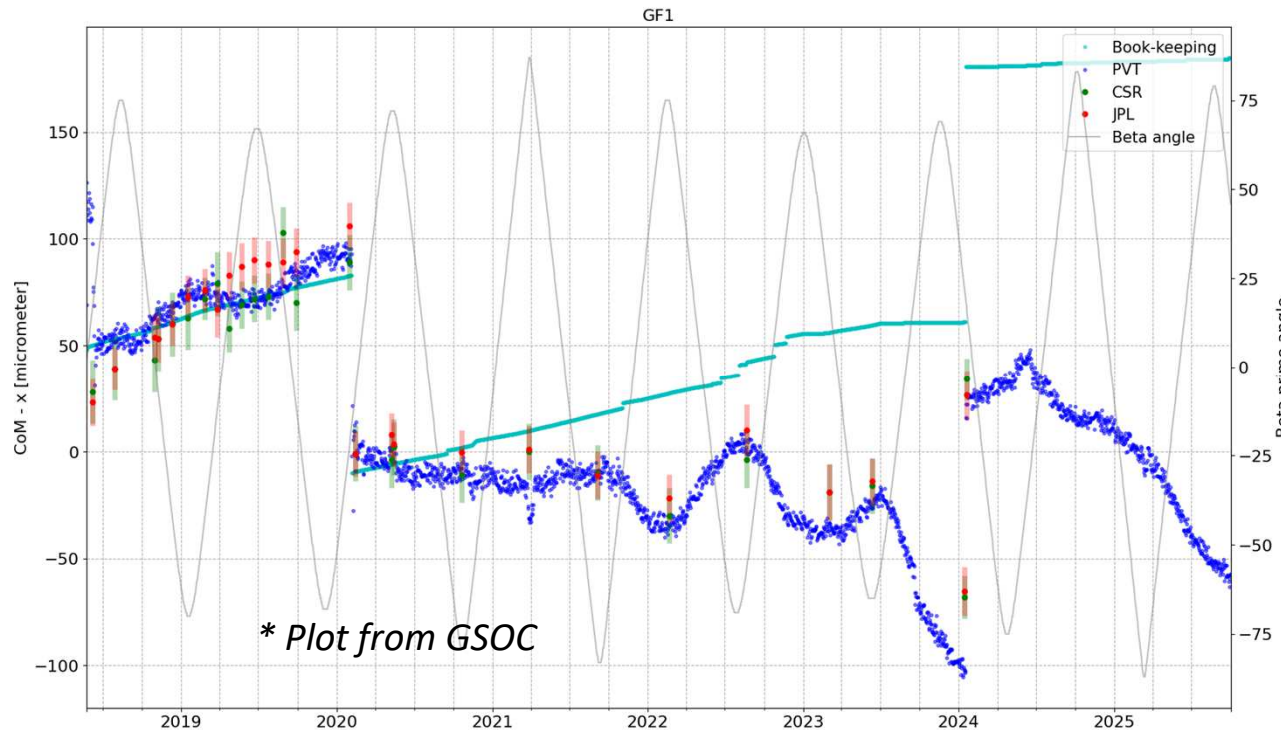
- GF2 accelerometer requires additional calibrations since June 2018
 - Non-grav accelerations for GF2 (ACH) are computed using GF1 ACC data, models & empirical calibrations, as well as GF2 ACC data
 - Results in very effective 'ACC transplant'
- Mission is operating in wide-dead-band attitude mode continuously since July 2023
 - thruster leak rate had increased rapidly in 2022 on both s/c
 - degraded data quality on the ACC transplant and hence gravity fields
 - Could have had a severe impact on the mission lifetime
 - Wide-pointing has mitigated further leak increases on both s/c,
 - **mitigated the mission life risk due to fuel leak**
 - **Improved science data quality** despite higher solar activity due to reduce variability in leak
- Future plans to minimize time spent in deep repeat orbits are being evaluated

Center of Mass tracking (GF1)



- Satellite center of mass (CoM) is maintained within 100 microns of the accelerometer proof mass for all axis on GF1
- GF1 Y CoM oscillates about ± 15 microns about zero as a function of beta prime
- Mass tracking model is tracking the CM offset estimates within the uncertainties in the X direction
- Independent verification from LRI team for Y and Z relative change
- CM cal does not result in realistic estimates for GF2 due to the issues with the ACC data

CM Cal and Thruster Leak (GF1)



- Comparing center of mass offset estimate in the along-track direction using
 - CM cal analysis using maneuvers
 - PVT method
 - TPC
- Clear character change in PVT behavior in 2020
 - accounts for the leaks
- CM offset estimate from PVT method confirms the estimates from CM cal maneuver analysis

In order to keep the leak-rate stable, CM cal maneuvers will only be performed when the mass tracking model shows CM offset nearing 100 microns

Thruster leak and Lifetime

Total Fuel lost to thruster leak on each spacecraft

- Fuel leak rate evolution in GF1 was following the trajectory of another spacecraft (Sat1) that has similar propulsion system as GRACE-FO (green)
- Sat1 is the best proxy for what we could expect with un-mitigated leak evolution
- Following the leak evolution of Sat1, GRACE-FO would have likely run out of fuel by 2028
- With the leak-rate being arrested at the current levels after AOCS operations changes in 2023, the fuel-leak *may not* be lifetime limiting factor any longer
- Note: there are large uncertainties in these estimates*

Switch to wide-deadband AOCS

Possible fuel-leak trajectories

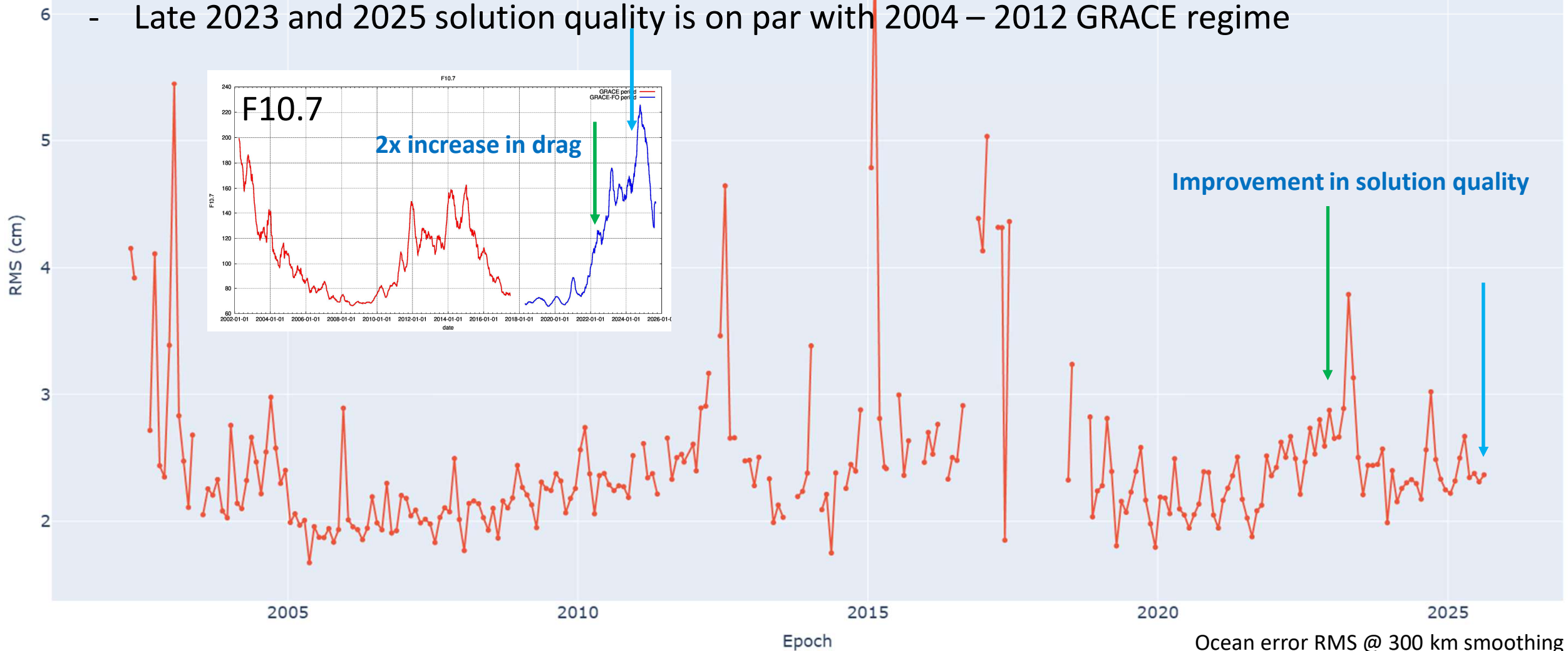
Fuel lost to leak on GF1
Fuel lost to leak on GF2
Fuel lost to leak on Sat1
3rd order polynomial fit

+/- 2 degree AOCS operational environment since July 2023

- GF2 ACC data is better behaved
 - Allows the use of more information from GF2 data
 - Allows better calibration of GF2 acc data
- 97+ % reduction in thruster activity
- Few bias jumps in ACC data due to leak variability at thrusts
 - Improved ACC transplant data => benefit for science
- Leak rate has stabilized on all branches
- **Fuel-leak may no longer be a lifetime limiting factor**

Improved Solution Quality with new AOCS Operations

- Late 2023 to 2025 solution quality is better than 2021 – 2022 despite significantly higher solar activity
- Late 2023 and 2025 solution quality is on par with 2004 – 2012 GRACE regime

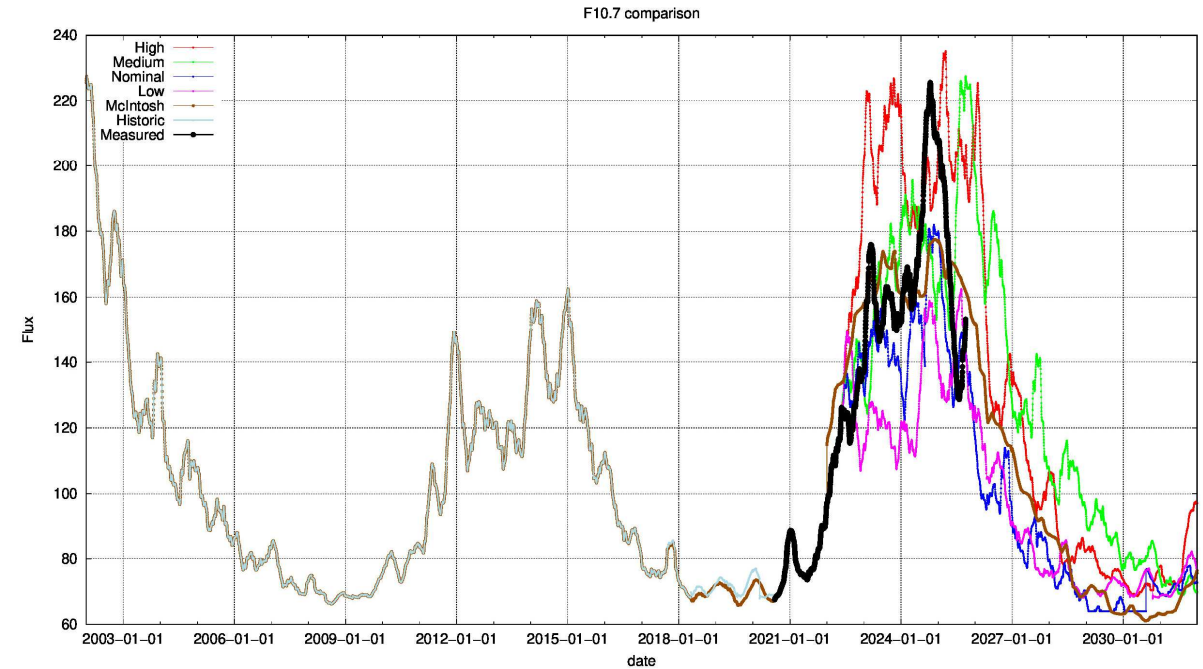
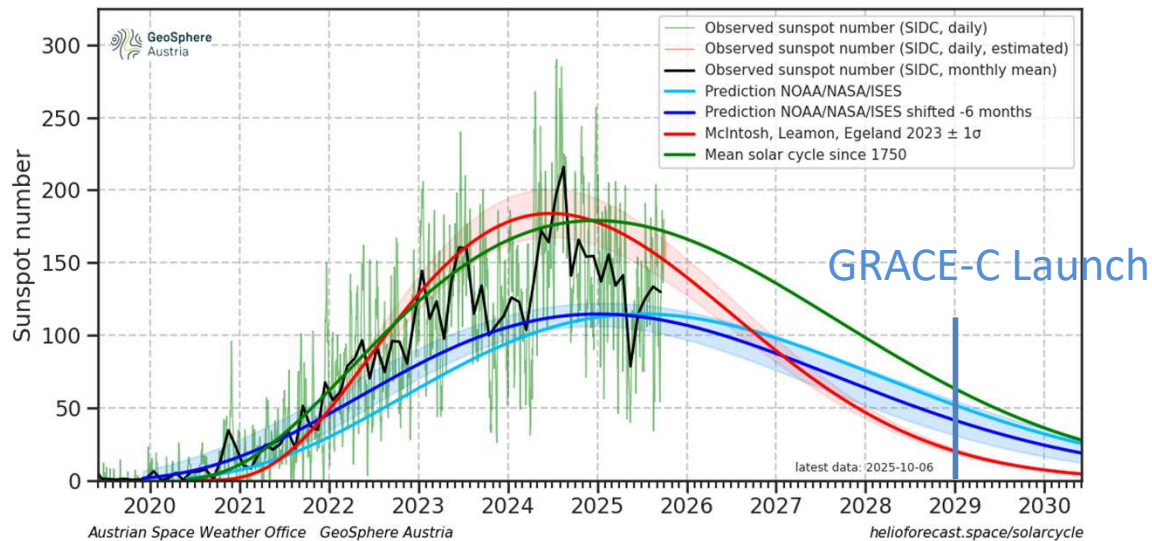
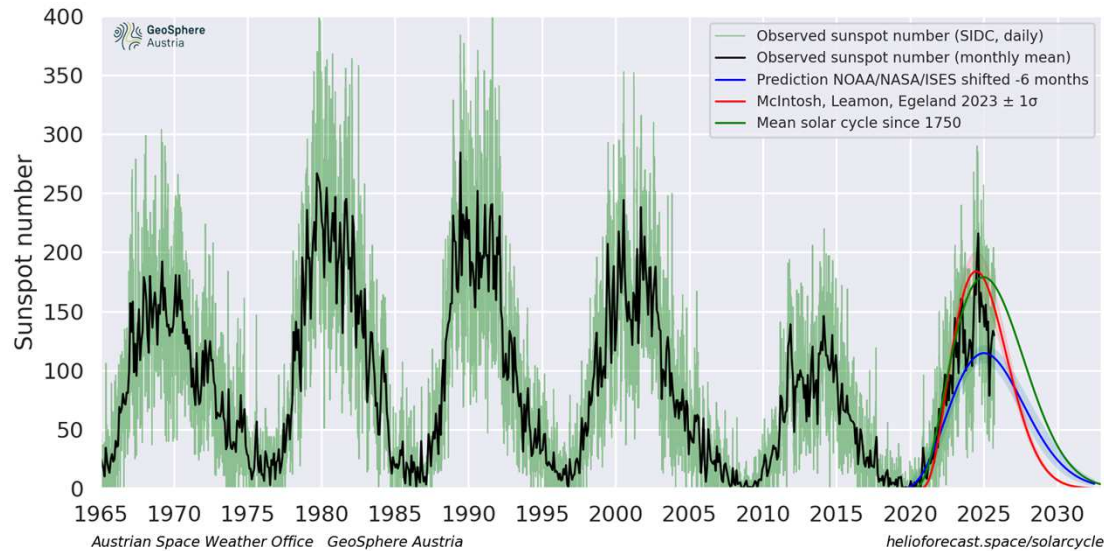


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Solar Cycle 25 predictions

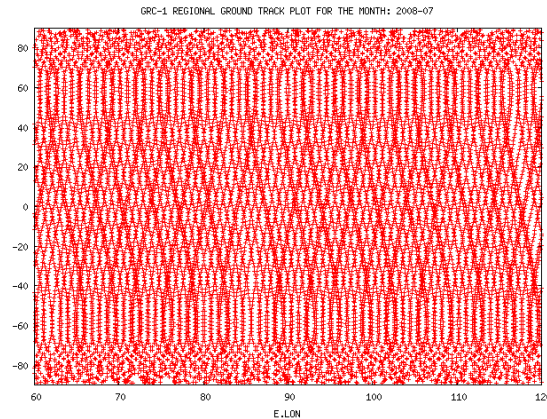


- Observed flux followed the updated predictions by McIntosh/Leamon 2022 (earlier onset and higher peak)
- We use realistic manifestation of Flux and Ap predictions for monitoring and lifetime predictions (right top)

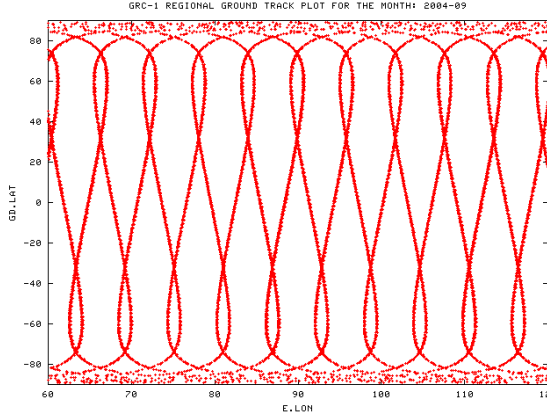
The cycle 25 has likely passed its peak and may be on a downward trajectory

GRACE-FO Orbit Repeat Configuration

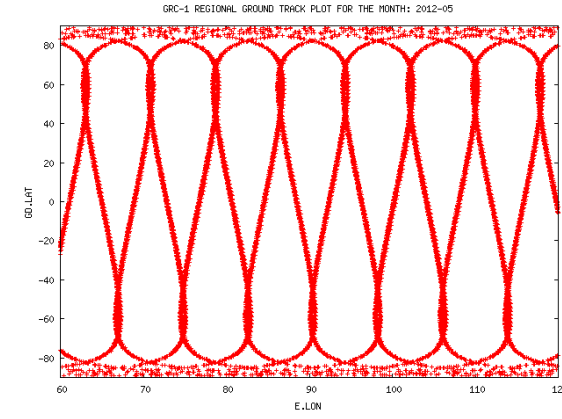
Poor coverage of the monthly ground track due to orbital repeat causes degradation in the gravity field



Good ground track coverage



4/61 repeat at 470 km (+/- 1.6km)
Impacted: Sep/Oct/Nov 2024 (~60 days)



3/46 repeat at 445 km (+/- 2.1 km)
Upcoming: *July 2026 to Feb 2027

Solar activity case ->	High case	Medium case	McIntosh case	Nominal case	Low case
Time spent in 3/46 repeat at 445 km ->	Jan 26 - Mar 26 (~2 mo)	Jun 26 - Nov 26 (~5 mo)	Jul 26 – Feb 27 (~7mo)	July 27 - Dec 28 (~ 18 mo)	Jun 27 - Nov 28 Aug 25 (~18 mo)

Orbit altitude will need to be actively managed to avoid long time spent in upcoming 3/46 repeat.

- **Using fuel to drop through this resonance may have to be considered**
- Lifetime impact of using fuel to drop through the resonance might be at most 6-8 months in 2035