

GRACE-FO: Science Mission Status and Plans towards the Extended Mission Phase

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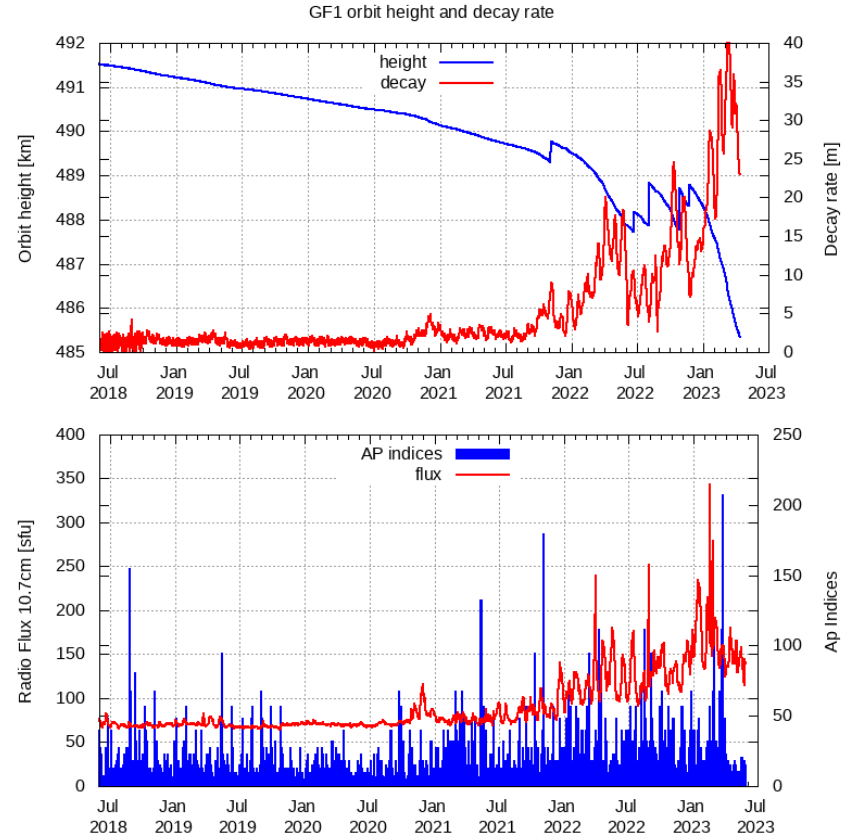
Outline

- 1) Mission Operations Status
- 2) Level-1 and Level-2 Product Status
- 3) Summary and Outlook

Orbit Height and Decay Rate

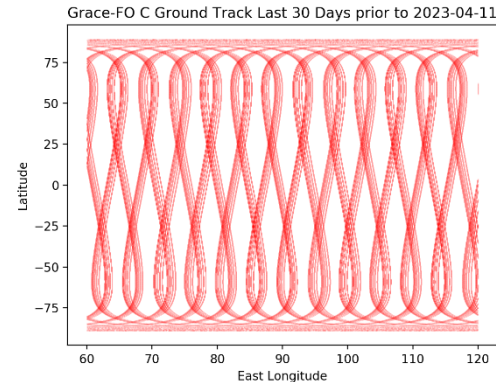
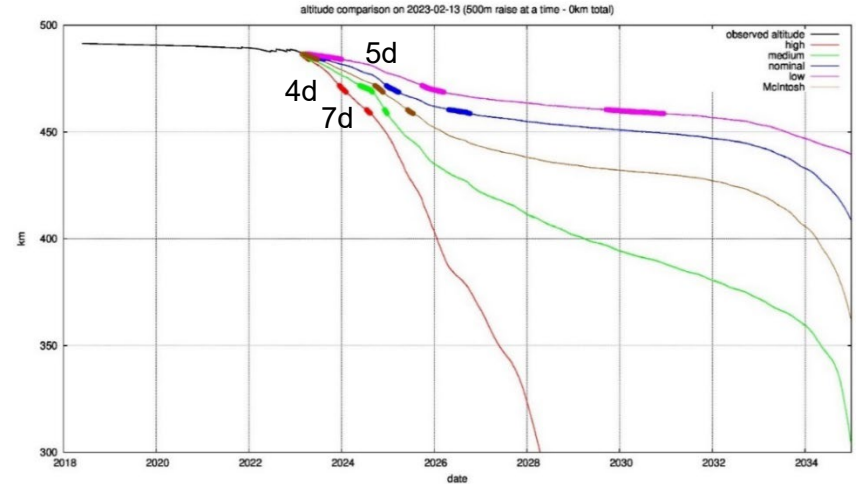
- **Orbital Height (as of April 14, 2023)**
 - 486.4 km (491.5 km after launch)
 - 7 raise maneuvers till end of 2022 (to avoid long exposure to repeat orbit between 484-487 km)
- **Decay rate (correlated with solar activity):**
 - May-2018 - May-2021: **1.6 m/d** (first three years)
 - May-2021 - Dec-2022: **8 m/d**
 - 2023: **28 m/d**

=> losing height 18 times faster than at the beginning



Decay Predictions (w/o new Raise Maneuvers)

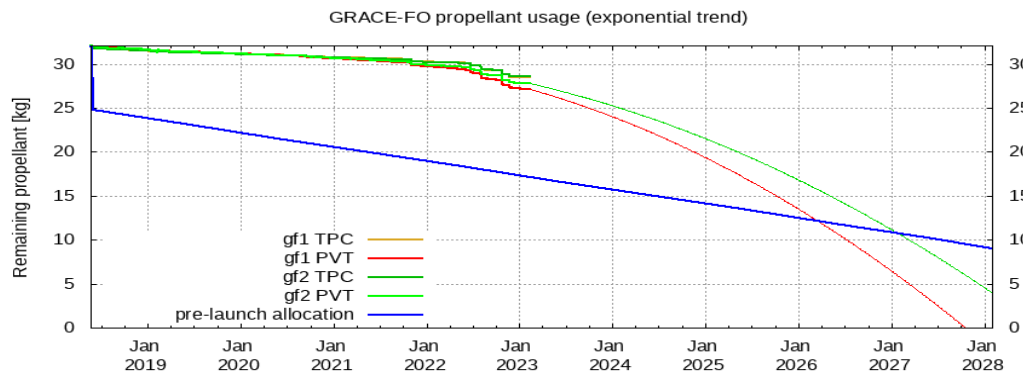
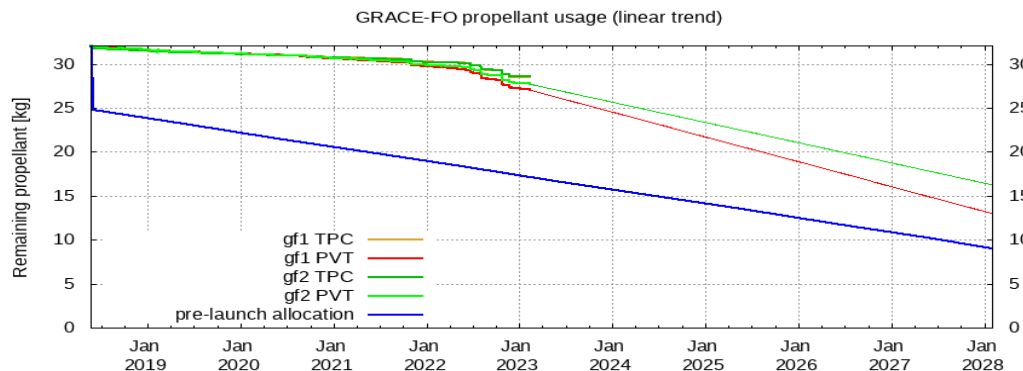
- In the most pessimistic case, assuming very high solar activity, the altitude of 300 km will be reached already in 2028.
- Resonance altitudes:
 - 5 day between 486.5 and 484 km
 - 4 day between 472 and 468.5 km
 - 7 day between 461 and 459 km
- Early 2023 a decision was made to decay quickly through the 1st resonance altitude (5d, currently! March/April 2023 fields impacted).
- Project is discussing various options of future additional orbit raises to avoid prolonged exposure to 4d/7d repeat orbits.



* Plots from Himanshu Save (CSR)

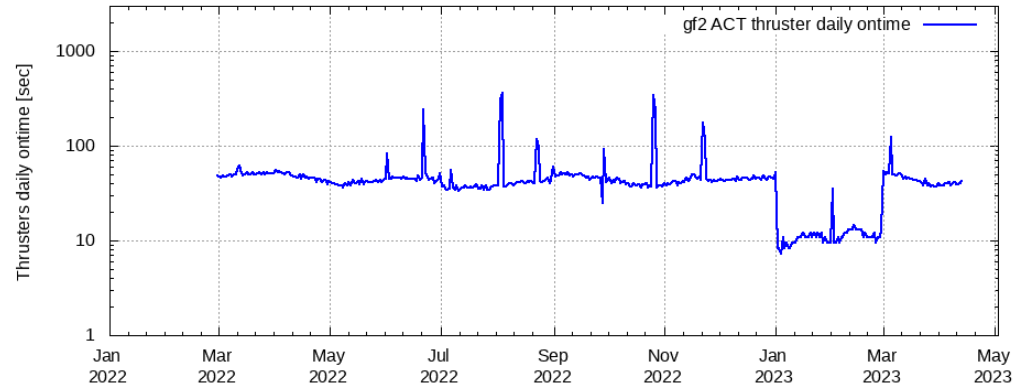
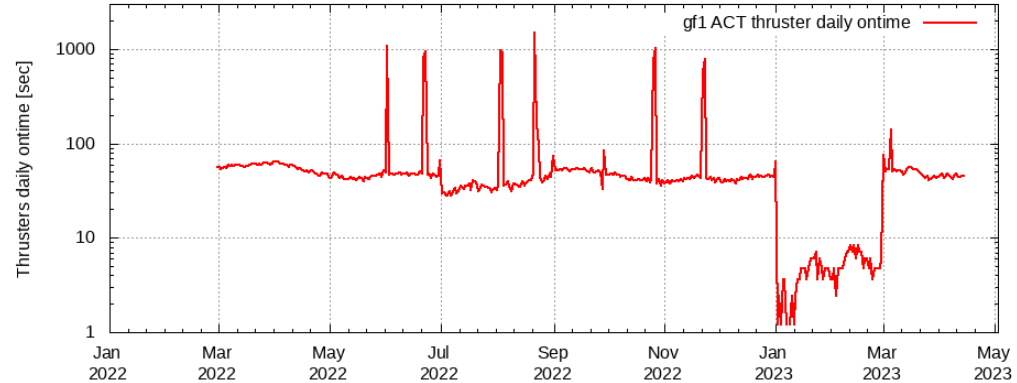
Propellant Usage

- Higher gas usage during last months due to
 - orbit raise maneuvers in 2022 and
 - increasing (linear) leak rate assumption.
- Gas usage on GF1 is higher
 - Two 180° turn-over maneuver needed during performed orbit raises.
 - Leak rate seems to be higher.
- Data from other Airbus satellites with the same cold gas system show that the leak could increase exponentially.
- In that case we could run out of fuel on GF1 already in 2028 - 2029.



Nadir Pointing Test Jan/Feb 2023

- Extended (± 2 deg) relative pointing angles.
- LRI in diagnostic mode during test.
- This configuration reduced thruster activity (ca. **Factor 8-10 GF1**, **Factor 5 GF2**).
- May also reduce fuel leak. Longer test may be needed to assess impact on fuel leak evolution.
- The main objective of the test was to assess science data quality in this mode (see next).

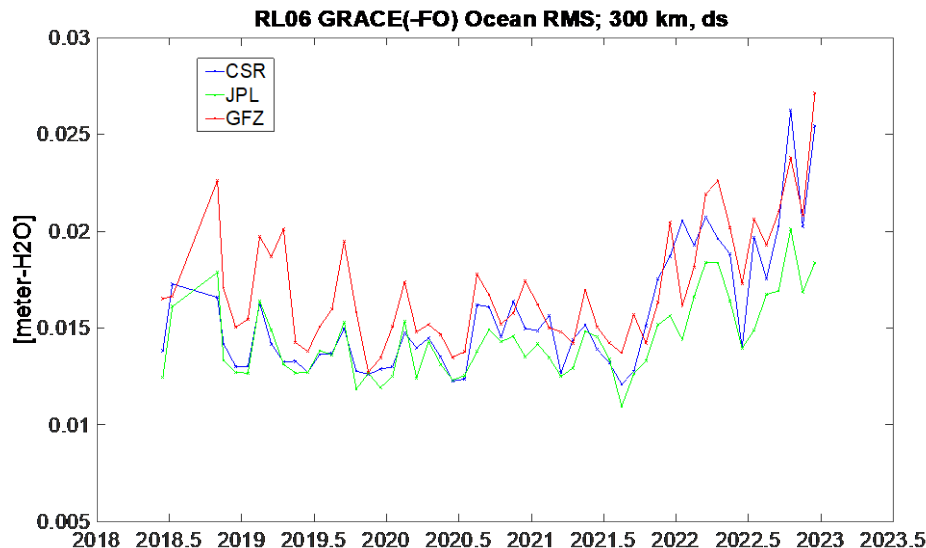


SDS Level-2 Overview

- GFZ, JPL and CSR routinely process L2 products as **RL06** and **RL06.1** versions
- Accelerometer transplant product is the main difference between both releases
- **RL06** is based on ACT1B (transplant product w/o ACC data from GFO-2)
 - Has a nominal latency of ca. 43 days (better than requirement: 60 days)
- **RL06.1** (only available for GFO) is based on ACH1B (hybrid transplant product that incorporates real GFO-2 ACC data)
 - Has had longer latency of ca. 60-80 days recently due to more intensive transplant procedure and validation

L2 Status (recently): SDS RL06 (incl. Dec 22)

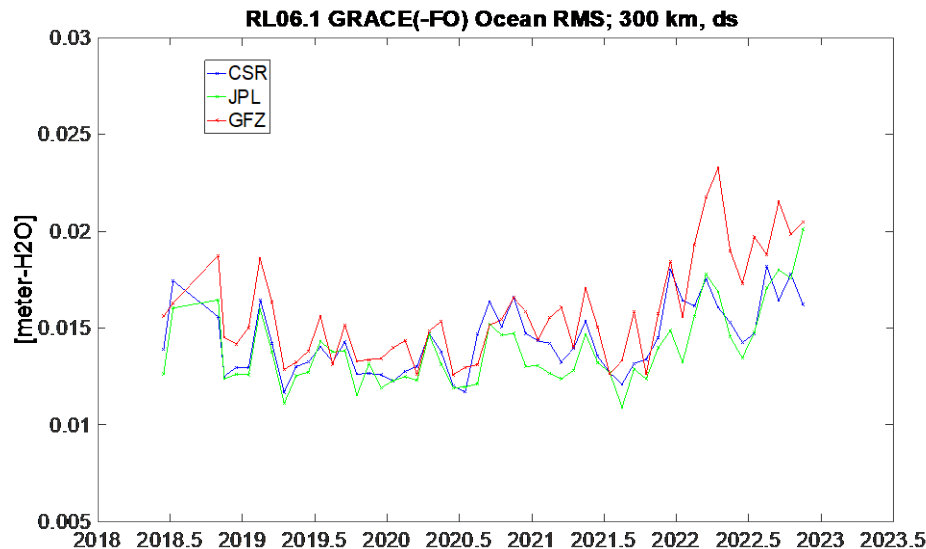
- Comparison of SDS solutions shows
 - Similar behavior for all 3 centers
 - Increased wRMS since beginning of 2022 (related with increase of solar activity)



wRMS over the oceans (Swenson destriped and 300km Gaussian smoothing, residuals relative to a GRACE/GRACE-FO climatology)

L2 Status (recently): SDS RL06.1 (incl. Nov 22)

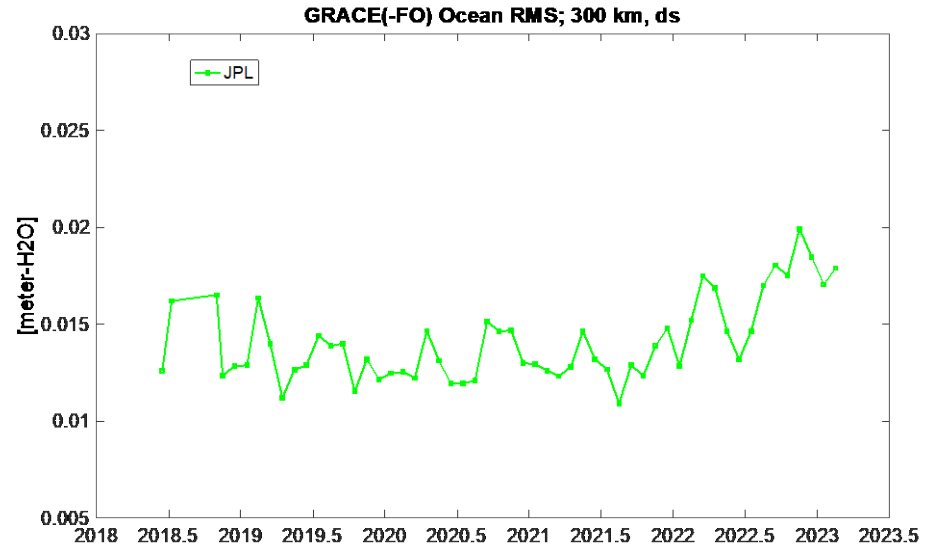
- Comparison of SDS solutions shows
 - Similar behavior for all 3 centers
 - Increased wRMS since beginning of 2022 (related with increase of solar activity)
 - Largely eliminated beta-prime dependency in 2018-2021
 - Improved wRMS from RL06



wRMS over the oceans (Swenson destriped and 300km Gaussian smoothing, residuals relative to a GRACE/GRACE-FO climatology)

L1 & L2 Status as of Today (incl. Jan/Feb 23)

- **RL06.1** solutions have been processed through Feb 2023
 - New GF2 ACC calibration ‘flavor’ (still ACH1B product) required additional testing
 - Reduced thrusting during relaxed pointing mode test allows use of mostly GF2 ACC data for Jan/Feb
 - Good solution quality for Jan/Feb



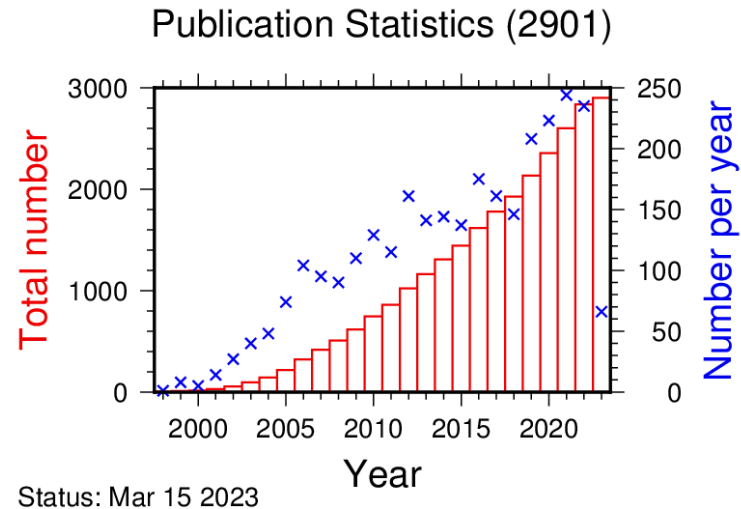
wRMS over the oceans (Swenson destriped and 300km Gaussian smoothing, residuals relative to a GRACE/GRACE-FO climatology)

Summary/Outlook

- Operational SDS RL06/RL06.1 processing is running nominally
 - Quality of RL06 and RL06.1 L2 data has slightly decreased throughout last months.
 - Related to increasing solar activity and associated uncertainty in the non-gravitational force knowledge on GFO-2 satellite.
- In Jan/Feb 2023, GRACE-FO operated in relaxed AOCS pointing mode
 - Goal: reduce thruster usage, assess viability of data collection & quality, and impact on Cold Gas Propulsion System (CGPS) leak rates.
 - LRI was not tracking (diagnostic mode), Level-2 products based on KBR data.
 - Impact on ACH and L2 quality has been investigated at JPL (and verified at CSR): Promising results, data (RL06.1) have been delivered to archives.
- Next steps
 - Since March 1 back to nominal fine-pointing with LRI tracking
 - GRACE-FO currently in 5d repeat orbit (will slightly affect March and April L2 quality)
 - From January onwards, operational GFO Level-2 processing switched from RL06 to RL06.1 (Note: C20/C30 still recommended to be substituted by SLR TN14 data)
 - In the future, SDS aims to provide the ACH1B and L2 data with <60 day latency. All other L1 data within 12 days.

Final Remarks

- Community continues to produce highly impactful science analysis!
- 2021 & 2022 highest numbers of publications collected at GFZ (244/235)
- Large interest in L3 products
- GSTM2023 in Boulder/Colorado Oct 16-18
- GRACE-FO project submitted NASA Senior Review proposal to extend mission through 2026
- NASA-DLR GRACE-FO successor mission to guarantee data continuity is on the way (launch May 2028)



2200+
users/month

<http://gravis.gfz-potsdam.de>