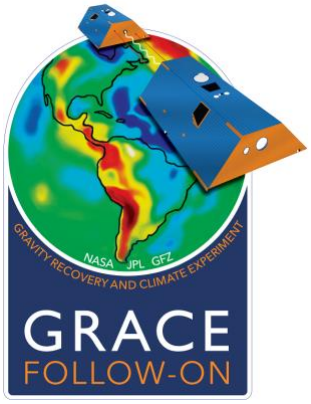

GRACE Follow-On

Science Data System Newsletter

Report: Jan – Mar 2022 (No. 20)

Contact: gracefo@jpl.nasa.gov

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GRACE Follow-On Science Data System: Highlights & Updates

- **Level-1:** The GRACE-FO SDS has reprocessed the Level-1 ACC data and released a new Level-1B ACX data product. ACX is an updated hybrid ACC-transplant that uses observations from both the GF1 and GF2 accelerometers. With this, we can better account for differential non-gravitational forces between GF1 and GF2 – which in turn results in improved monthly gravity fields.
    - The new monthly Leve-1B ACX data product is described in more detail below.
    - The ACX-L1B product requires significantly more validation and verification during its production. While the SDS team will strive to adhere to the weekly Level-1 delivery schedule, we anticipate that at least initially, ACX-L1B will be delivered in a delayed mode, together with the corresponding monthly L2/L3 data deliveries (current latency: ~40 days).
- **Level-2:** using the ACX-L1B data, the SDS centers have produced & released updated ***RL06.1*** gravity fields for the entire GRACE-FO mission time span through Jan-2022!
    - The RL06.1 fields mitigate biases in low-degree harmonics described at the last GFOSTM-2022, and reduce error levels for most months. A paper describing the changes and improvements in details is in preparation.
- The following **Level1 - 3 SDS data products** are now available at NASA's Physical Oceanography Distributed Active Archive Center (PO.DAAC) and GFZ's Information System and Data Center (ISDC):
    - **Level-1** SDS data products through **Apr 2022.**
    - **Level-2 & 3** data products through **Mar 2022.**
        - **RL06.1:** will be the preferred data version.
        - **RL06:** we will likely cease production of RL06 (which is based on [v04 ACT]) over the next ~3 months. However, ACT-L1 will remain available.
- Please note the following regarding **RL06** and **RL06.1 availability** and **data analysis**:
    - GRACE data version remains at RL06 and is fully compatible with GRACE-FO RL06.1

  - TN-13 products are available for both GRACE-FO RL06 and RL06.1
  - C20: SDS still recommends replacing C20 in GRACE(-FO) L2 solutions with the SLR-derived value, provided in TN-14
  - C30: the C30 coefficient in RL06.1 is significantly improved in the GRACE-FO solutions; we encourage users to assess the fidelity of the GRACE-FO-C30 time series – please let us what you find! In the meantime, we recommend replacing the native C30 with the SLR-derived value, provided in TN-14
  - AOD1B monthly GAx fields remain unchanged but have been copied from RL06 to RL06.1 (as GAx*_0601) to minimize interruptions in users' workflow and processing scripts
  - The current ACT transplant (based on GF1 only) will remain available in a non-delayed mode, but SDS will likely not release L2/L3 fields based on ACT-L1.
- The following corresponding **Level-3 data** products (global, land, ocean, ice) are available:
  - JPL Tellus global mascon products: https://grace.jpl.nasa.gov/data/get-data/jpl_global_mascons/
  - GFZ GravIS land, ocean and ice products: http://gravis.gfz-potsdam.de/
  - UT-CSR global mascon solutions: http://www2.csr.utexas.edu/grace/RL06_mascons.html
- GRACE-FO science data collection and processing has been nominal.
- Solar Cycle #25 continues to ramp up. Increased solar activity has resulted in increased orbit altitude decay rates (see Fig.1 below), as well as increased non-gravitational acceleration on the two GRACE-FO satellites. The SDS team continues to closely monitor the Level-1 data & measurement system performance.
- *Attention:* JPL/NASA PO.DAAC is migrating all data sets and data access to the Cloud. Please visit https://podaac.jpl.nasa.gov/cloud-datasets/about and set up your new data retrieval process accordingly.
- Do you have new GRACE-FO results, a conference presentation or paper publication you would like to share? Please send a copy of your GRACE and GRACE-FO related publications to landerer@jpl.nasa.gov and flechtne@gfz-potsdam.de (please also consider a 1-slide highlight summary of the main findings).
- When using GRACE-FO data, please cite the **GRACE-FO Mission reference paper**:
  Landerer, F.W., Flechtner, F., et al., 2020, Extending the global mass change data record: GRACE Follow-On instrument and science data performance, Geophys. Res. Lett., https://doi.org/10.1029/2020GL088306.

Calendar & Upcoming Events:

- **GRACE-FO Science Team Meeting 2022** will take place **Oct 18-20, 2022** at GFZ (Potsdam, Germany). We are planning for an in-person meeting – stay tuned for updates.

Science Team Resources:

- Proceedings and presentations from the **2021 GRACE/GRACE-FO Science Team Meeting** are available online.
- GGHS2022, the 3rd joint meeting of the International Gravity Field Service and Commission 2 of the International Association of Geodesy, will be held in Austin Texas from Sep 12-16, 2022. The abstract submission deadline is Friday August 7, 2022 (https://www.csr.utexas.edu/gghs2022/abstract-submission).

GRACE Follow-On: Mission Status

GRACE Follow-On: Orbit (Data and plots provided by K. Snopek, GFZ)

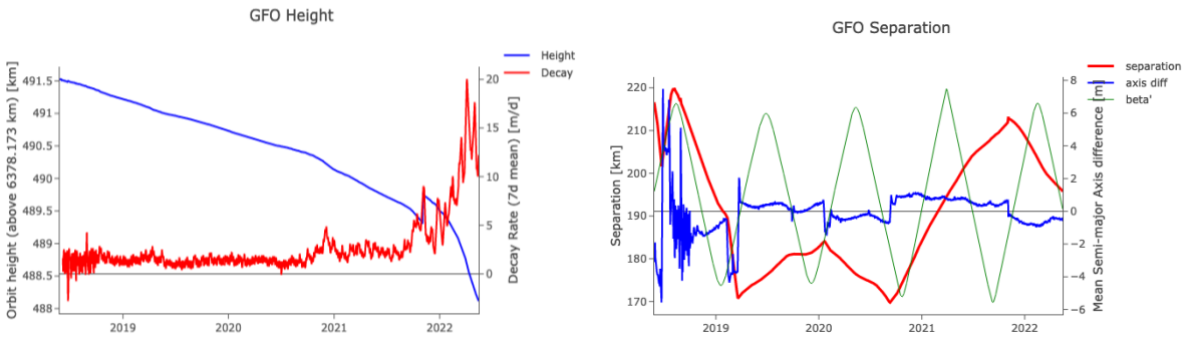


Figure 1: (left) Orbit altitude and daily decay rates [m/d] since GRACE-FO launch. (right) Separation distance and semi-major axis difference bewteen the two GRACE-FO spacecraft, as well as beta-prime angle of the orbit plane.

The GRACE Follow-On orbital parameters on 2022-05-16 (day 136) were as follows:

Sun Beta (deg)	-9
Absolute Distance (km)	195.8
Drift (km/d)	-0.11
Mean Altitude (>6378.1 km)	488.1
Decay Rate (GF1/GF2) (7d mean, m/d)	12.2 / 12.2

Science-relevant Mission Events & Plans:

- Both accelerometers (ACCs) are operating and collecting observations in their nominal mode, Normal Range Mode (NRM). GF1 ACC data are used to generate an ACC transplant data product which is provided as the ACT1B product and should be used to substitute the GF2 ACC measurements (please check the ACT-Readme document for details at PO.DAAC).
- Center-of-Mass (CM) offset determinations are performed approx. every 6 months (See SOE/SCE files for details).
- Additional calibration periods, spacecraft activities and events are highlighted in the Level-1 release notes and event logs.

Level-1, Level-2, Level-3 Data Products and Processing

Level-1 Data Processing & Delivery

- [2022-05-10]: JPL SDS Level-1 has updated the GF2 ACC transplant data product:
  A new hybrid-transplant, using data from both GF1 and GF2, has been developed and released by the GFO SDS. We are publishing individual components of this new product (called 'ACX'), invite the community to have more insight into our accelerometer transplant process, and evaluate and provide feedback on the products as the drag environment of the GFO satellites evolves (solar cycle changes and altitude decay). This new framework allows us to be agile and better adapt to evolving satellite conditions.
  The v04 ACX L1B product consists of:
  - **AC0** – accelerometer thruster model data only (this is the same model as used in the ACT data)
  - **ACU** – an updated accelerometer transplant procedure (this contains the thruster free data transplanted to the other spacecraft – no thrusts – accounting for pitch offsets between the spacecraft)
  - **ACS** – an SRP/albedo correction to the transplanted data derived primarily from the GF2 accelerometer data
  - **ACM** – a correction to the transplanted data to account for drag and other non-conservative forces
  - **ACH** – an updated transplant product (this is a replacement for the ACT product and can be used in gravity field determination). This product is defined as:
    ACH = ACU + ACS + ACM + AC0 (for the 3 linear components only)
- [2020-07-10]: JPL SDS Level-1 has updated the v04 LRI data processing to (1) improve the removal of LRI phase jumps, and to (2) reduce the noise of the time-of-flight (TOF) correction for range-acceleration to the level of 1 nm/s^2. Please see Level-1 Release Notes for details.

- Level-1 data products (current version: v04), which are available at NASA's Physical Oceanography Distributed Active Archive Center (PO.DAAC) and GFZ's Information System and Data Center (ISDC), are continuously updated approximately every 7 days. The Level-1 data includes all data required for the generation of Level-2 gravity field products. Please refer to Level-1 release notes, documentation, as well as to the Sequence-of-Events (SOE) logfile for important updates, comments and detailed description of the data, file formats, and conventions (PO.DAAC / ISDC).

KBR Performance Statistics

KBR-GPS performance statistics are available in file [TN-01b_KBR_GPS] at (PO.DAAC / ISDC).

Level-1 Data Product Availability

- [see Appendix 1A (p. 7) for GRACE-FO Level-1 data]
- [see Appendix 1B (p. 7) for de-aliasing AOD1B model data]

Level-1 Release Notes & Sequence of Events

- [see Appendix 1C (p. 7)]

Level-2 Data Processing & Delivery

Level-2 Data availability

- Level-2 Release 06 data have been processed at JPL, GFZ and CSR and are archived at JPL PO.DAAC and GFZ ISDC. The Level-2 products include the monthly gravity fields from the three mission Science Data System centers (JPL, GFZ, CSR), as well as the corresponding atmosphere and ocean dealiasing (AOD) background model data.
- Please refer to the Level-2 Release Notes and documentation description of the data for file formats, updates, conventions, as well as important processing recommendations (PO.DAAC / ISDC).
- [see Appendix 2A (p. 8) for overview tables on data availability].

Level-2 Ancillary Products and Comments

- TN-14 contains C20 & C30 estimates derived from SLR and using Level-2 RL06 standards, updated in synch with Level-2 monthly releases. It is recommended to replace the native GRACE & GRACE-FO C20 & C30 coefficients with this product (Loomis et al., 2019).
- TN-13[a,b,c] contains geocenter estimates using the methods of Swenson et al. (2010) and Sun et al. (2016), and is updated in synch with Level-2 monthly releases. It is recommended to augment the GRACE / GRACE-FO geocenter with this product for surface mass change estimation.

Level-3 Data Processing & Delivery & Availability

- SDS Level-3 monthly global grids of mass changes are generated by JPL and available at PO.DAAC.
- The following corresponding **Level-3 data** products (global, land, ocean, ice) are available:
    - JPL Tellus global mascon & SDS harmonic products: https://grace.jpl.nasa.gov/data/get-data/jpl_global_mascons/
    - GFZ GravIS land, ocean and ice products: http://gravis.gfz-potsdam.de/
    - UT-CSR global mascon solutions: http://www2.csr.utexas.edu/grace/RL06_mascons.html
    - GSFC global mascon products: https://earth.gsfc.nasa.gov/geo/data/grace-mascons

- Interactive GRACE & GRACE-FO data browsers (Level-3):
    - NASA/JPL: https://grace.jpl.nasa.gov/data-analysis-tool
    - GFZ: http://gravis.gfz-potsdam.de/

Resources and Links:

SDS Data Archives (Level 1-3):

- JPL/NASA PO.DAAC (http://podaac.jpl.nasa.gov)
- GFZ ISDC (https://isdc.gfz-potsdam.de/grace-fo-isdc)

Miscellaneous Links:

- For GRACE Follow-On mission updates and news, please visit https://gracefo.jpl.nasa.gov and http://gfz-potsdam.de/en/grace-fo.
- The proceedings of previous GRACE / GRACE-FO Science Team Meetings are available at https://www.gfz-potsdam.de/en/grace/ or at https://grace.jpl.nasa.gov/events/
- **GRACE and GRACE-FO related publications** are available via searchable databases:
    - http://www-app2.gfz-potsdam.de/pb1/op/grace/references/sort_date.html
    - https://grace.jpl.nasa.gov/publications/
    - For missing publications in the database, please contact Frank Flechtner (flechtne@gfz-potsdam.de) and the JPL team (grace_feedback@jpl.nasa.gov)

Appendix

1.A – Level-1 GRACE-FO Data Availability

Level-1 A/B	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2002												
2003												
2004												
2005												
2006												
2007												
2008												
2009												
2010												
2011												
2012												
2013												
2014												
2015												
2016												
2017												
2018												
2019												
2020												
2021												
2022												

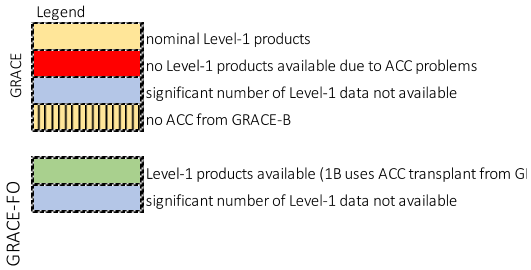
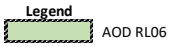


Table 1: Current version: Level-1 v04.

1.B – Level-1 De-aliasing Model AOD1B Data Availability

AOD1B	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1976												
1980												
…												
2017												
2018												
2019												
2020												
2021												
2022												



- For more information on the AOD de-aliasing AOD1B model please visit https://www.gfz-potsdam.de/en/aod1b/.

1.C - Level-1 Release Notes & Sequence of Events

A machine-readable Sequence-of-Events file is available: [TN-01_SOE.txt]. An additional Spacecraft-Event log from JPL Level-1 operators is available as [TN-01a_SCE.txt].

- https://podaac-tools.jpl.nasa.gov/drive/files/allData/gracefo/docs/
- ftp://isdcftp.gfz-potsdam.de/grace-fo/

2.A – Level-2 Product and Data Availability

JPL, GFZ & CSR

- Current Level-2 version: RL06
- All centers provide GSM solutions
    - Please check the Level-2 Release Notes for further details
- JPL and GFZ provide corresponding monthly de-aliasing models [GAA, GAB, GAC, GAD]; CSR provides [GAC, GAD].

Level-2 (JPL)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2002				1	2			3	4	5	6	7
2003	8	9	10	11	12		13	14	15	16	17	18
2004	19	20	21	22	23	24	25	26	27	28	29	30
2005	31	32	33	34	35	36	37	38	39	40	41	42
2006	43	44	45	46	47	48	49	50	51	52	53	54
2007	55	56	57	58	59	60	61	62	63	64	65	66
2008	67	68	69	70	71	72	73	74	75	76	77	78
2009	79	80	81	82	83	84	85	86	87	88	89	90
2010	91	92	93	94	95	96	97	98	99	100	101	102
2011		103	104	105	106		107	108	109	110	111	112
2012	113	114	115	116		117	118	119	120		121	122
2013	123	124		125	126	127	128			129	130	131
2014	132		133	134	135	136		137	138	139	140	
2015	141	142	143	144	145		146	147	148			149
2016	150	151	152		153	154	155	156			157*+	158*+
2017	159*+		160*+	161*+	162*	163*+						
2018						1*+	2*+			3*+	4+	5+
2019	6+	7*+	8+	9+	10+	11+	12+	13+	14+	15+	16+	17+
2020	18+*	19+*	20+	21+	22+	23+	24+	25+	26+	27+	28+	29+
2021	30+	31+	32+	33+	34+	35+	36+	37+	38+	39+	40+	41+
2022	42+	43+	44+									

GRACE
Level-2 products
no Level-2 products available

GRACE-FO
Level-2 products available

Current Level-2 Release: RL06

\+ Level-2 products (with ACC transplant)
* partial / overlapping calendar-months

Table 2: GRACE and GRACE-FO Level-2 product availability.

3.A – Level-3 Product and Data Availability

JPL, GFZ & CSR

- JPL provides Land (LND) and Ocean (OCN) global data grids for all three SDS centers (JPL, GFZ, CSR) via PO.DAAC.

Level-2 (JPL)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2002				1	2			3	4	5	6	7
2003	8	9	10	11	12		13	14	15	16	17	18
2004	19	20	21	22	23	24	25	26	27	28	29	30
2005	31	32	33	34	35	36	37	38	39	40	41	42
2006	43	44	45	46	47	48	49	50	51	52	53	54
2007	55	56	57	58	59	60	61	62	63	64	65	66
2008	67	68	69	70	71	72	73	74	75	76	77	78
2009	79	80	81	82	83	84	85	86	87	88	89	90
2010	91	92	93	94	95	96	97	98	99	100	101	102
2011		103	104	105	106		107	108	109	110	111	112
2012	113	114	115	116		117	118	119	120		121	122
2013	123	124		125	126	127	128			129	130	131
2014	132		133	134	135	136		137	138	139	140	
2015	141	142	143	144	145		146	147	148			149
2016	150	151	152		153	154	155	156			157*+	158*+
2017	159*+		160*+	161*+	162*	163*+						
2018						1*+	2*+			3*+	4+	5+
2019	6+	7*+	8+	9+	10+	11+	12+	13+	14+	15+	16+	17+
2020	18+*	19+*	20+	21+	22+	23+	24+	25+	26+	27+	28+	29+
2021	30+	31+	32+	33+	34+	35+	36+	37+	38+	39+	40+	41+
2022	42+	43+	44+									

GRACE
Level-3 products
no Level-3 products available

GRACE-FO
Level-3 products available

Current Level-2 Release: RL06

\+ Level-3 products (with ACC transplant)
* partial / overlapping cal-months

Table 3: GRACE and GRACE-FO Level-3 product availability