JPL Level-2 GRACE-FO Products - Release Notes Version 6.1

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1 Overview

The following note accompanies the JPL GRACE-FO Level-2 products, version 6.1. It replaces any preceding release notes associated with the version 6.1 product release. GRACE-FO RL06.1 is an updated version of the initial GRACE-FO RL06 Level-2 data products. RL06.1 differs from RL06 only in the Level-1B accelerometer transplant data that is used for the GF2 satellite: Level-2 RL06.1 uses ACH1B RL04, which replaces ACT1B RL04 that was used for Level-2 RL06. All GRACE-FO RL06.1 Level-2 products are fully compatible with the GRACE RL06 Level-2 fields. For each month, there are typically 6 available products, as listed below where **YYYY** corresponds to a 4 digit year and **DDD** corresponds to a 3 digit day of year (for details see the Level-2 User Handbook [Yuan, 2019b]).

GAA-2_YYYYDDD-YYYYDDD_GRFO_JPLEM_BC01_0601
The average of the 'atm' coefficients from the AOD1B RL06 product, for degree/order 180, over the same time span as the computed monthly solution. While the file contains values for degrees 0 and 1, these harmonic coefficients are not used in the JPL Level-2 data processing. Note that the averaging is computed over entire days, regardless of whether the full day (as opposed to a partial day) was included in the Level-2 data processing. For further details, see the RL06 AOD1B Product Description Document [Dobslaw et al., 2017].

GAB-2_YYYYDDD-YYYYDDD_GRFO_JPLEM_BC01_0601
The average of the 'ocn' coefficients from the AOD1B RL06 product, for degree/order 180, over the same time span as the computed monthly solution. While the file contains values for degrees 0 and 1, these harmonic coefficients are not used in the JPL Level-2 data processing. Note that the averaging is computed over entire days, regardless of whether the full day (as opposed to a partial day) was included in the Level-2 data processing. For further details, see the RL06 AOD1B Product Description Document [Dobslaw et al., 2017].

GAC-2_YYYYDDD-YYYYDDD_GRFO_JPLEM_BC01_0601
The average of the 'glo' coefficients from the AOD1B RL06 product, for degree/order

180, over the same time span as the computed monthly solution. These harmonic coefficients are modeled in the background during Level-2 data processing. While the file contains values for degrees 0 and 1, these harmonic coefficients are not used in the JPL Level-2 data processing. Note that the averaging is computed over entire days, regardless of whether the full day (as opposed to a partial day) was included in the Level-2 data processing. For further details, see the RL06 AOD1B Product Description Document [Dobslaw et al., 2017].

GAD-2_YYYYDDD-YYYYDDD_GRFO_JPLEM_BC01_0601

The average of the 'oba' coefficients from the AOD1B RL06 product, for degree/order 180, over the same time span as the computed monthly solution. While the file contains values for degrees 0 and 1, these harmonic coefficients are not used in the JPL Level-2 data processing. Note that the averaging is computed over entire days, regardless of whether the full day (as opposed to a partial day) was included in the Level-2 data processing. For further details, see the RL06 AOD1B Product Description Document [Dobslaw et al., 2017].

GSM-2_YYYYDDD-YYYYDDD_GRFO_JPLEM_BA01_0601

The unconstrained monthly gravity field solution, computed out to degree/order 60.

GSM-2_YYYYDDD-YYYYDDD_GRFO_JPLEM_BB01_0601

The unconstrained monthly gravity field solution, computed out to degree/order 96. Note that due to satellite ground track coverage, this solution may not always be published.

2 General Usage Notes

For typical months, those where satellite ground track coverage is sufficient, 60x60 (BA01) and 96x96 (BB01) solutions are provided. It is left to the user's discretion which solution best suits their particular application. Additionally, it is suggested that a suitable smoothing technique is applied, examples of which are available in the literature. The uncertainties provided with the gravity field solutions have NOT been calibrated and represent only the formal uncertainties.

2.1 Geocenter

Consistent with GRACE, GRACE-FO is not sensitive to degree 1 harmonics (geocenter). GRACE/GRACE-FO Technical Note TN-13[a,b,c] contains geocenter estimates using the methods of Swenson et al. [2008] and Sun et al. [2016], and is updated in synch with Level-2 monthly releases. These have been reprocessed for the entire GRACE and GRACE-FO time span to be consistent with the below-mentioned TN-14, so users need to replace the entire TN-13 time series. It is recommended to augment the GRACE and GRACE-FO geocenter with this product for surface mass change estimation.

2.2 $C_{2,0}$

Consistent with the GRACE SDS recommendations, GRACE-FO SDS recommends the replacement of the native GRACE-FO $C_{2,0}$ coefficient with that from SLR. Note that GRACE Technical Note TN-11 will no longer be updated; it is replaced by GRACE/GRACE-FO Technical Note TN-14. GRACE/GRACE-FO Technical Note TN-14 is now provided and contains both $C_{2,0}$ and $C_{3,0}$ estimates derived from SLR and using Level-2 RL06 standards, updated in synch with Level-2 monthly releases. It is recommended to replace/substitute the native GRACE and GRACE-FO $C_{2,0}$ coefficients with this product [Loomis et al., 2019] for all months (04/2002 – current).

2.3 $C_{3,0}$

The GRACE-FO SDS has determined that the $C_{3,0}$ coefficient in GRACE-FO shows comparatively more variability relative to the long-term climatology derived from the GRACE $C_{3,0}$ coefficient. Therefore, SDS recommends that users assess the impact on regional mass budgets of substituting the GRACE-FO $C_{3,0}$ coefficient with one derived from SLR (similar to the $C_{2,0}$ approach). GRACE/GRACE-FO Technical Note TN-14 is now provided and contains both $C_{2,0}$ and $C_{3,0}$ estimates derived from SLR and using Level-2 RL06 standards, updated in synch with Level-2 monthly releases. It is recommended to replace/substitute the native GRACE and GRACE-FO $C_{3,0}$ coefficients with this product [Loomis et al., 2020] from 08/2016 onwards (08/2016 – current).

2.4 Feedback is Requested

The GRACE-FO project SDS is looking for feedback from the Science Team and wider community on the impact of $C_{2,0}$ and $C_{3,0}$ replacements, either from these or other candidate SLR time series, on regional mass balances to support the project in further improving the handling of low-degree harmonics in GRACE and GRACE-FO data processing.

3 Gravity Field Solutions

Gravity field solutions are outlined in Table 1. Each solution gives a general GSM filename (with a Linux glob string inserted for the solution mnemonic), the first date included in the solution, the last date included in the solution, the total number of days included in the solution (accounting for any days that were skipped), the spherical harmonic solution sizes available, and comments associated with each solution (for solution specific annotations). Additionally, for further details on filenames, formats, and a more complete overview of the processing see the Level-2 User Handbook [Yuan, 2019b] and Processing Standards Document [Yuan, 2019a].

Table 1: Overview of gravity field solutions (GSM filenames are given using Linux glob strings).

Gravity Field Solution	Span Start	Span End	Number of Days	Degree/Order	Comments
GSM-2_2018152-2018181_GRFO_JPLEM_????_0601	2018-06-01	2018-06-30	29	60x60, 96x96	(1)
GSM-2_2018182-2018199_GRFO_JPLEM_????_0601	2018-07-01	2018-07-18	18	60x60, 96x96	(3), (5)
GSM-2_2018295-2018313_GRFO_JPLEM_????_0601	2018-10-22	2018-11-09	19	60x60, 96x96	(3), (5)
GSM-2_2018305-2018334_GRFO_JPLEM_????_0601	2018-11-01	2018-11-30	30	60x60, 96x96	(3), (5)
GSM-2_2018335-2018365_GRFO_JPLEM_????_0601	2018-12-01	2018-12-31	31	60x60, 96x96	(3), (5)
GSM-2_2019001-2019031_GRFO_JPLEM_????_0601	2019-01-01	2019-01-31	31	60x60, 96x96	(3), (5)
GSM-2_2019026-2019063_GRFO_JPLEM_????_0601	2019-01-26	2019-03-04	25	60x60, 96x96	(3), (5)
GSM-2_2019060-2019090_GRFO_JPLEM_????_0601	2019-03-01	2019-03-31	31	60x60, 96x96	(3), (5)
GSM-2_2019091-2019120_GRFO_JPLEM_????_0601	2019-04-01	2019-04-30	30	60x60, 96x96	(3), (5)
GSM-2_2019121-2019151_GRFO_JPLEM_????_0601	2019-05-01	2019-05-31	31	60x60, 96x96	(3), (5)
GSM-2_2019152-2019181_GRFO_JPLEM_????_0601	2019-06-01	2019-06-30	30	60x60, 96x96	(3), (5)
GSM-2_2019182-2019212_GRFO_JPLEM_????_0601	2019-07-01	2019-07-31	31	60x60, 96x96	(3), (5)
GSM-2_2019213-2019243_GRFO_JPLEM_????_0601	2019-08-01	2019-08-31	31	60x60, 96x96	(3), (5)
GSM-2_2019244-2019273_GRFO_JPLEM_????_0601	2019-09-01	2019-09-30	30	60x60, 96x96	(3), (5)
GSM-2_2019274-2019304_GRFO_JPLEM_????_0601	2019-10-01	2019-10-31	31	60x60, 96x96	(3), (5)
GSM-2_2019305-2019334_GRFO_JPLEM_????_0601	2019-11-01	2019-11-30	30	60x60, 96x96	(3), (5)
GSM-2_2019335-2019365_GRFO_JPLEM_????_0601	2019-12-01	2019-12-31	31	60x60, 96x96	(3), (5)
GSM-2_2020001-2020031_GRFO_JPLEM_????_0601	2020-01-01	2020-01-31	26	60x60, 96x96	(3), (5)
GSM-2_2020032-2020060_GRFO_JPLEM_????_0601	2020-02-01	2020-02-29	23	60x60, 96x96	(3), (5)
GSM-2_2020061-2020091_GRFO_JPLEM_????_0601	2020-03-01	2020-03-31	31	60x60, 96x96	(3), (5)
GSM-2_2020092-2020121_GRFO_JPLEM_????_0601	2020-04-01	2020-04-30	30	60x60, 96x96	(3), (5)
GSM-2_2020122-2020152_GRFO_JPLEM_????_0601	2020-05-01	2020-05-31	31	60x60, 96x96	(3), (5)
GSM-2_2020153-2020182_GRFO_JPLEM_????_0601	2020-06-01	2020-06-30	30	60x60, 96x96	(3), (5)
GSM-2_2020183-2020213_GRFO_JPLEM_????_0601	2020-07-01	2020-07-31	31	60x60, 96x96	(3), (5)
GSM-2_2020214-2020244_GRFO_JPLEM_????_0601	2020-08-01	2020-08-31	31	60x60, 96x96	(3), (5)
GSM-2_2020245-2020274_GRFO_JPLEM_????_0601	2020-09-01	2020-09-30	30	60x60, 96x96	(3), (5)
GSM-2_2020275-2020305_GRFO_JPLEM_????_0601	2020-10-01	2020-10-31	31	60x60, 96x96	(3), (5)

Gravity Field Solution	Span Start	Span End	Number of Days	Degree/Order	Comments
GSM-2_2020306-2020335_GRFO_JPLEM_????_0601	2020-11-01	2020-11-30	30	60x60, 96x96	(3), (5)
GSM-2_2020336-2020366_GRFO_JPLEM_????_0601	2020-12-01	2020-12-31	31	60x60, 96x96	(3), (5)
GSM-2_2021001-2021031_GRFO_JPLEM_????_0601	2021-01-01	2021-01-31	31	60x60, 96x96	(3), (5)
GSM-2_2021032-2021059_GRFO_JPLEM_????_0601	2021-02-01	2021-02-28	28	60x60, 96x96	(3), (5)
GSM-2_2021060-2021090_GRFO_JPLEM_????_0601	2021-03-01	2021-03-31	31	60x60, 96x96	(3), (5)
GSM-2_2021091-2021120_GRFO_JPLEM_????_0601	2021-04-01	2021-04-30	30	60x60, 96x96	(3), (5)
GSM-2_2021121-2021151_GRFO_JPLEM_????_0601	2021-05-01	2021-05-31	31	60x60, 96x96	(3), (5)
GSM-2_2021152-2021181_GRFO_JPLEM_????_0601	2021-06-01	2021-06-30	30	60x60, 96x96	(1), (5), (7)
GSM-2_2021182-2021212_GRFO_JPLEM_????_0601	2021-07-01	2021-07-31	31	60x60, 96x96	(1), (5), (7)
GSM-2_2021213-2021243_GRFO_JPLEM_????_0601	2021-08-01	2021-08-31	31	60x60, 96x96	(1), (5), (7)
GSM-2_2021244-2021273_GRFO_JPLEM_????_0601	2021-09-01	2021-09-30	30	60x60, 96x96	(1), (5), (7)
GSM-2_2021274-2021304_GRFO_JPLEM_????_0601	2021-10-01	2021-10-31	31	60x60, 96x96	(1), (5), (7)
GSM-2_2021305-2021334_GRFO_JPLEM_????_0601	2021-11-01	2021-11-30	30	60x60, 96x96	(1), (5), (7)
GSM-2_2021335-2021365_GRFO_JPLEM_????_0601	2021-12-01	2021-12-31	31	60x60, 96x96	(1), (5), (7)
GSM-2_2022001-2022031_GRFO_JPLEM_????_0601	2022-01-01	2022-01-31	31	60x60, 96x96	(1), (5), (7)
GSM-2_2022032-2022059_GRFO_JPLEM_????_0601	2022-02-01	2022-02-28	28	60x60, 96x96	(1), (5), (7)
GSM-2_2022060-2022090_GRFO_JPLEM_????_0601	2022-03-01	2022-03-31	31	60x60, 96x96	(3), (5)
GSM-2_2022091-2022120_GRFO_JPLEM_????_0601	2022-04-01	2022-04-30	30	60x60, 96x96	(3), (5)
GSM-2_2022121-2022151_GRFO_JPLEM_????_0601	2022-05-01	2022-05-31	31	60x60, 96x96	(3), (5)
GSM-2_2022152-2022181_GRFO_JPLEM_????_0601	2022-06-01	2022-06-30	30	60x60, 96x96	(3), (5)
GSM-2_2022182-2022212_GRFO_JPLEM_????_0601	2022-07-01	2022-07-31	31	60x60, 96x96	(3), (5), (8)
GSM-2_2022213-2022243_GRFO_JPLEM_????_0601	2022-08-01	2022-08-31	31	60x60, 96x96	(3), (5), (8)
GSM-2_2022244-2022273_GRFO_JPLEM_????_0601	2022-09-01	2022-09-30	30	60x60, 96x96	(3), (5), (9)
GSM-2_2022274-2022304_GRFO_JPLEM_????_0601	2022-10-01	2022-10-31	31	60x60, 96x96	(3), (5)
GSM-2_2022305-2022334_GRFO_JPLEM_????_0601	2022-11-01	2022-11-30	30	60x60, 96x96	(3), (5)
GSM-2_2022335-2022365_GRFO_JPLEM_????_0601	2022-12-01	2022-12-31	31	60x60, 96x96	(3), (5)
GSM-2_2023001-2023031_GRFO_JPLEM_????_0601	2023-01-01	2023-01-31	31	60x60, 96x96	(4), (6), (8)
GSM-2_2023032-2023059_GRFO_JPLEM_????_0601	2023-02-01	2023-02-28	28	60x60, 96x96	(4), (6), (8)
GSM-2_2023060-2023090_GRFO_JPLEM_????_0601	2023-03-01	2023-03-31	31	60x60, 96x96	(4), (5), (10)
GSM-2_2023091-2023120_GRFO_JPLEM_????_0601	2023-04-01	2023-04-30	30	60x60, 96x96	(4), (5), (10)

Gravity Field Solution	Span Start	Span End	Number of Days	Degree/Order	Comments
GSM-2_2023121-2023151_GRFO_JPLEM_????_0601	2023-05-01	2023-05-31	31	60x60, 96x96	(4), (5), (10)
GSM-2_2023152-2023181_GRFO_JPLEM_????_0601	2023-06-01	2023-06-30	30	60x60, 96x96	(4), (5)
GSM-2_2023182-2023212_GRFO_JPLEM_????_0601	2023-07-01	2023-07-31	31	60x60, 96x96	(4), (6), (8)
GSM-2_2023213-2023243_GRFO_JPLEM_????_0601	2023-08-01	2023-08-31	31	60x60, 96x96	(2), (6), (8)
GSM-2_2023244-2023273_GRFO_JPLEM_????_0601	2023-09-01	2023-09-30	30	60x60, 96x96	(2), (6), (8)
GSM-2_2023274-2023304_GRFO_JPLEM_????_0601	2023-10-01	2023-10-31	31	60x60, 96x96	(2), (6), (8)
GSM-2_2023305-2023334_GRFO_JPLEM_????_0601	2023-11-01	2023-11-30	30	60x60, 96x96	(2), (6), (8)

4 Solution Comments

(1) The solution is parameterized using nominally 5 second KBR range-rate data and nominally 30 second GRACE-FO GPS data. The solved for local/common parameters include the satellite initial states (solved per arc - nominally 1 day), accelerometer biases/rates in the GRACE-FO SRF XYZ directions (solved per arc in the XZ directions and every 3 hours in the Y direction), a full accelerometer scale matrix (9 parameters solved per arc), GPS phase biases (solved per GPS satellite pass), and empirical biases/drifts/once per revolution sinusoids for the KBR range-rate data (solved every 90 minutes). The solved for global parameters include the spherical harmonic coefficients.

(2) The solution is parameterized using nominally 5 second KBR range-rate data and nominally 30 second GRACE GPS data. The solved for local/common parameters include the satellite initial states (solved per arc - nominally 1 day), accelerometer biases/rates in the GRACE SRF XYZ directions (solved per arc in the XZ directions and every 3 hours in the Y direction), a full accelerometer scale matrix (9 parameters solved per arc), GPS phase biases (solved per GPS satellite pass), and empirical biases/drifts/once per revolution sinusoids for the KBR range-rate data (solved every 90 minutes). Additionally, bias and 1 cycle per revolution empirical accelerations in the normal and along track directions are solved for GRACE-D only (solved every 90 minutes). The solved for global parameters include the spherical harmonic coefficients.

(3) The solution is parameterized using nominally 5 second KBR range-rate data and nominally 30 second GRACE-FO GPS data. The solved for local/common parameters include the satellite initial states (solved per arc - nominally 1 day), accelerometer biases/rates in the GRACE-FO SRF XYZ directions (solved per arc in the XZ directions and every 3 hours in the Y direction), GPS phase biases (solved per GPS satellite pass), and empirical biases/drifts/once per revolution sinusoids for the KBR range-rate data (solved every 90 minutes). The solved for global parameters include a full accelerometer scale matrix (9 parameters) and the spherical harmonic coefficients.

(4) The solution is parameterized using nominally 5 second KBR range-rate data and nominally 30 second GRACE-FO GPS data. The solved for local/common parameters include the satellite initial states (solved per arc - nominally 1 day), accelerometer biases/rates in the GRACE-FO SRF XYZ directions (solved per arc in the XZ directions and every 3 hours in the Y direction), GPS phase biases (solved per GPS satellite pass), and empirical biases/drifts/once per revolution sinusoids for the KBR range-rate data (solved every 90 minutes). Additionally, bias and 1 cycle per revolution empirical accelerations in the along and cross directions are solved for GRACE-D only (solved every 90 minutes). The solved for global parameters include a full accelerometer scale matrix (9 parameters) and the spherical harmonic coefficients.

(5) Accelerometer data for GRACE-D is derived using the accelerometer data from GRACE-C (accelerometer transplant) and augmented with corrections utilizing filtered/preprocessed GRACE-D accelerometer data.

(6) Accelerometer data for GRACE-D is derived primarily from the GRACE-D accelerometer data and augmented with corrections utilizing a transplant from GRACE-C.

(7) We do not do estimation of a global full accelerometer scale matrix (9 parameters) as that would unacceptably degrade this monthly solution due to off-nominal (nadir) satellite pointing on each of the following days: 2021-06-01, 2021-06-02, 2021-06-07, 2021-06-08, 2021-06-14, 2021-06-15, 2021-06-21, 2021-06-22, 2021-06-28, 2021-06-29, 2021-07-05, 2021-07-06, 2021-07-12, 2021-07-13, 2021-07-26, 2021-07-27, 2021-08-02, 2021-08-03, 2021-08-09, 2021-08-10, 2021-08-16, 2021-08-17, 2021-08-30, 2021-08-31, 2021-09-13, 2021-09-14, 2021-09-27, 2021-09-28, 2021-10-31, 2021-11-01, 2021-12-20, 2021-12-21, 2021-12-27, 2021-12-28, 2022-01-03, 2022-01-04, 2022-01-10, 2022-01-11, 2021-01-17, 2022-01-18, 2022-01-24, 2022-01-25, 2022-01-31. 2022-02-01, 2022-02-07, 2022-02-08, 2022-02-14, 2022-02-15, 2022-07-01 through 2022-08-31, 2023-01-01 through 2023-02-28, and 2023-07-01 onward.

(8) The entire solution period has off-nominal (nadir) satellite pointing. We may thus still do estimation of a global full accelerometer scale matrix (9 parameters) with no degradation.

(9) A span of data from approximately 0600 on 2022-09-27 to 0600 2022-09-28 is excluded due to an AOCS parameter test where the spacecraft are in nadir pointing with much wider attitude control deadbands.

(10) The GRAFO satellites are passing through a 76 revolution/5 day repeat ground track which peaks in 2023-04. This causes reduced observability of the spherical harmonic coefficients and solution analysis may require more aggressive than normal post-processing.

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