This document contains a historical log of notes for successive GRACE-FO Level-1 data releases and release versions. Each successive dated entry shall be appended to the end of this log, and the date in the file name of this document shall be updated at each revision.

Date: 2019-05-28

Author: Hui Ying Wen

This is the first release of Level-1A and 1B products for the GRACE-FO mission, which is based on JPL Level-1 processing software release version RL04 ("v04"). This release contains products for 2018-05-22 (launch date) through 2019-05-10. V04 products beyond 2019-05-10 will be made available on JPL's PO.DAAC and GFZ's ISDC.

The following products are included in this release:

- Attitude: IMU1A, IMU1B, SCA1A, SCA1B

- Accelerometer: ACC1A, ACT1A, ACT1B

- Calibration (these products are produced for 2018-05-22 only):
  QCP1B, QSA1B, VGB1B, VGN1B, VGO1B, VKB1B, VSL1B

- Clock Offsets: CLK1B, TIM1B, USO1B

- GPS: GNV1A, GPS1A, GPS1B

- Housekeeping Data: AHK1A, AHK1B, IHK1A, IHK1B, ILG1A, MAG1A, MAG1B, MAS1A, MAS1B, THR1A, THR1B, TNK1A, TNK1B

- K-Band ranging: KBR1A, KBR1B, PCI1A

- Orbit Determination: GNI1B, GNV1B, PLT1A

The introduction of the ACT1A and ACT1B products in this release is accompanied by the document "Description of Calibrated GRACE-FO Accelerometer Data Products (ACT)" by C. M. McCullough et al. (May 20, 2019).

Date: 2019-07-26
Author: Hui Ying Wen

For 2019-05-25 and later v04 products, the maximum allowable formal error for clock estimates included in the CLK1B product has been reduced from 10 cm to 2 cm. This is commensurate with the reduction in formal error going from low-rate 300-second clock estimates used in GRACE v02 and earlier to high-rate 10-second clock estimates used in v04 products. The differences in clock estimate values due to this change are expected to be minor. (Analysis by W. Bertiger.)

Date: 2019-07-26
Author: Hui Ying Wen

For 2019-06-16 and later v04 products, an error has been corrected in the antenna calibration configuration used in Precision Orbit Determination. This error had previously resulted in release orbits with a dynamically inconsistent radial bias of about 9 mm. The Level-1 standard quality checks, clock overlaps, and KBR-GPS range differences show very tiny effects, as did a test month of spherical harmonic gravity field recovery. (Analysis by W. Bertiger.)

Date: 2019-07-26

Author: Hui Ying Wen

This is the first release of LRI (Laser Ranging Interferometer) Level-1A and 1B products for the GRACE-FO mission, which is based on JPL Level-1 processing software release version RL04 ("v04"). This release contains products for 2018-06-11 (first instrument power-on) through 2019-07-05. V04 products beyond 2019-07-05 will be made available on JPL's PO.DAAC and GFZ's ISDC.

The following products are included in this release:

- Housekeeping: LHK1A, LHK1B, LLG1A

- Orbit Determination / Clock Error Estimation: LLK1B, LLT1A

- Ranging: LRI1A, LRI1B

- Steering Mirror Pointing: LSM1A, LSM1B

For an explanation of these products and usage notes, refer to the latest version of the "GRACE-FO Level-1 Data Product User Handbook" by H. Y. Wen et al., July 26, 2019. The main LRI science products consist of ranging data (LRI1A, LRI1B) and inter-satellite line-of-sight pointing data from the LRI steering mirrors (LSM1A, LSM1B). The following are special notes on LRI ranging data, with references to the relevant sections in "GRACE-FO Level-1 Data Product User Handbook".

The formulation of the LRI range quantity is described in Section 3.3.2, as well as the following corrections applied to it. Phase jumps, or "glitches," occur in the LRI1A phase measurements from both satellites; for the most part, the phase glitches seen in the two satellites' measurements correspond to each other. A process to identify and remove glitches from phase measurements in the creation of the LRI1B product has been implemented in the Level-1 RL04 software version. However, due to imperfect removal of the glitches, remaining residuals can be seen in the final LRI1B range quantity and its time derivatives that have passed through CRN filtering. In addition, a scale correction is estimated and applied to the range quantity and its time derivatives to account for drift in the onboard LRI ranging frequency from nominal ground-measured values; this estimation is performed by comparing LRI versus K-Band ranging data.

LRI timing is described in Section 3.2.2, and corrections applied to LRI measurement time-tags are described in Section 3.3.1. These corrections include known biases as well as an additional estimated

time offset. This time offset, like the aforementioned scale correction, is estimated by comparing LRI versus K-Band ranging data.

Differences can be observed when comparing the LRI and K-Band range quantities that are corrected with light time and K-Band phase center corrections. The accuracy of the aforementioned scale correction and time offset estimation may be one of many factors contributing to these differences. Ongoing work is needed to understand these differences.

Date: 2019-09-23
Author: Hui Ying Wen

For 2019-08-10 and later v04 LRI products, the treatment of the "datation bias" in LRI time-tags has been improved. The LRI datation bias is an offset between LRI Time and Receiver Time that changes at each LRI instrument reboot and IPU reset, and is accounted for in the correction of time-tags from LRI Time (LRI1A) to Receiver Time (LRI1B). (The datation bias is technically sampled as the offset of LRI Time from OBC Time, but OBC Time is synchronized very closely to Receiver Time). The datation bias is reported at least daily in LRI telemetry datation packets.

Previously, the change in datation bias that occurred at IPU resets was estimated by the Level-1 LRI time offset estimation. Now, the Level-1 software is updated so that the datation bias changes reported in telemetry are used. As a result, the Level-1 estimated LRI time

offset is much smaller since it does not contain these IPU-reset-related datation bias changes. This can result in improved smaller LRI-KBR range differences. In addition, updated LRI datation value entries are now added to the Level-1 SOE (Sequence of Events) file at each IPU reset.

Date: 2019-09-23
Author: Hui Ying Wen

For 2019-09-07 and later v04 products, the following updates were made in Level-1 processing:

- In GPS1B processing, a phase break is now marked only at gaps > 100 seconds; previously, a phase break was marked at all gaps. This affects the GPS filtering window, since the filtering window is not allowed to include phase breaks.

- CLK1B now contains additional qualflg bits to indicate if a clock correction value was extrapolated from POD (Precision Orbit Determination) clock estimates, and such extrapolated values will not be used to correct K-band and GPS data. CLK1B values are extrapolated at, for example, IPU resets when there is no GPS data to allow estimation of clock corrections.

These updates were verified by Level-2 reprocessing of the July 2019 (and GRACE June 2016) gravity field; the resulting changes in the gravity field were minor.

Date: 2020-06-30

Author: Gene Fahnestock

For 2020-06-27 and later v04 products, the following updates were made in Level-1 processing:

- In LRI processing, the methods for removing LRI phase jumps have been significantly overhauled. The so-called "mega" phase jumps (jumps with magnitudes of order 10^5 Cycles) are now replaced with interpolated samples in the LRI piston phase time series. Normal-magnitude(order 10 Cycles) single and double-jumps (two phase jumps within a few samples of each other) are fit using templates and subtracted without leaving significant artifacts in the LRI piston phase time series.

- Changes to LRI_compress and LRI_scale to be able to catch rare cases of gaps in data without a phase break being flagged.

- Various other minor cumulative changes to LRI_datation, LRI_debreak, LRI_order, LRI_compress, LRI_estimate, LRI_scale

These updates were verified by Level-2 solution of the January 2019, June 2019, July 2019, and August 2019 gravity fields to degree and order 180, using the new LRI1B together with a consistently-edited (in Level-2) set of GPS data. For all months, negligible changes in the gravity fields resulted between doing manual editing of LRI range-rate data based upon pre-fit (w.r.t. gravity) residuals, and doing no LRI data editing at all. For January

2019, negligible difference in the gravity field resulted vs. using the
AEI LRI1B for that month instead (also with no LRI data editing).

Date: 2020-07-10
Author: Meegyeong Paik

For 2020-06-27 and later v04 products, the following update was made in
Level-1 processing:

- In LRI1B processing, the bandwidth of CRN filter for TOF (Time of Flight)
  correction has been changed from 250 mHz to 30 mHz to reduce noises in TOF
  correction for range-acceleration to the level of 1 nm/s**2. This change makes
  differences in range of LRI1B at the level of 0.1 nm, which is corresponding
  to the numerical noise.

These updates were verified by Level-1 team.

Date: 2022-05-10
Author: Christopher McCullough

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. Individual components of this new product (called â€˜ACXâ€™),
are provided to provide more insight into our accelerometer transplant process,

and enable feedback from users and developers on these 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 â€“ accelerometer thruster model data only (this is the same model as used in the ACT data)

- ACU â€“ an updated accelerometer transplant procedure (this contains the thruster free data transplanted to the other spacecraft â€“ no thrusts â€“ accounting for pitch offsets between the spacecraft)

- ACS â€“ an SRP/albedo correction to the transplanted data derived primarily from the GF2 accelerometer data

- ACM â€“ a correction to the transplanted data to account for drag and other non-conservative forces

- ACH â€“ 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)