GRACE-FO MONTHLY SOLUTIONS USING THE GRACE-SIGMA SOFTWARE

Mathias Duwe[1], Igor Koch, Jakob Flury, Akbar Shabanloui

A – Abstract

In this contribution we present gravity field monthly solutions from GRACE and GRACE Follow-On (GRACE-FO) Level-1B sensor data. The monthly solutions are computed with our recently updated GRACE-SIGMA software developed at the Institute of Geodesy, Leibniz University Hannover. The solutions are obtained using a two-step approach. In a first step, the orbits of the two satellites are pre-adjusted by estimating local arc parameters. In a second step, the monthly gravity field potential in terms of normalized spherical harmonic coefficients is recovered. Our new pre time series from GRACE is presented in terms of error degree standard deviation and equivalent water height values from Greenland. In addition the estimation of C_{20} now fits much better to SLR data. We further present some LRI only solution from GRACE-FO and compare them to KBR only solutions.

B – GRACE-SIGMA

The processing approach for the solutions is the method of dynamic orbit and gravity field determination based on the equations of motion, also often referred to as the variational equations (VE) approach [1]. The VE approach is implemented in a compact all-Matlab program named GRACE-SIGMA. A generalized overview over the gravity field recovery from GRACE and GRACE-FO Level-1B data products based on VE can be seen in Fig. 1.

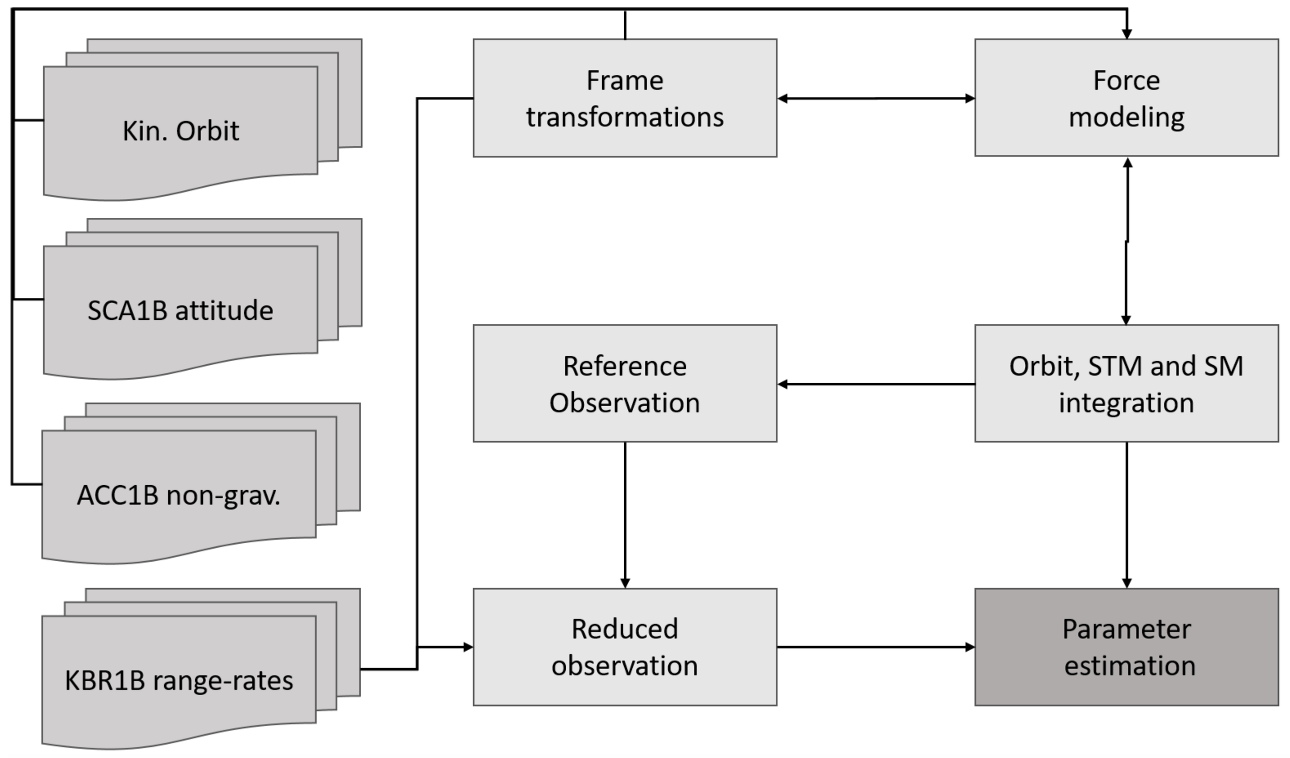

Fig. 1: Simplified gravity field recovery procedure.

C – Current GFR standard processing

Tab. 1: Force models applied for orbit modeling.

Effect	Old version	Updates
Gravity field	GIF48 (d/o 300) [2]	GOCO06s, static: d/o 300, time-variable: d/o 200 [3]
Direct tides	Moon and Sun, ephemerides: DE405 [4]	+ Mercury, Venus, Mars, Jupiter, Saturn, J2 for the Moon, ephemerides: DE430 [5]
Solid Earth tides	IERS Conventions 2010 [6]	-
Ocean tides	EOT11a (d/o 80) [7]	FES2014b (d/o 180) [8]
Solid Earth pole tides	IERS Conventions 2010	linear mean pole
Ocean pole tides	IERS Conventions 2010 (d/o 60)	linear mean pole, (d/o 180)
Relativistic	IERS Conventions 2010	-
Non-tidal	AOD1B RL06 (d/o: 180) [9]	-
Atmospheric tides	Biancale and Bode, N1, seasonal means [10]	AOD1B RL06 (d/o 180)

- Arc-length: 3h
- Numerical integration: modified Gauss-Jackson
- Empirical kinematic KBRR parameters [11] including a low-low bias + bias-rate (two sets per arc) and 4 low-low periodic bias + bias-rates (one set per arc)
- No constrains + No regularization

D – New GRACE time series

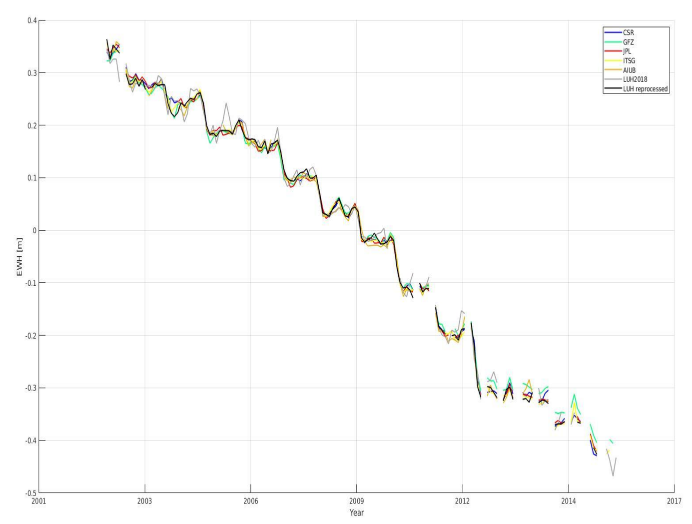

Fig. 2: Mass variations in terms of Equivalent Water Height [EWH] in Greenland GRACE (2003-2016) w.r.t GOCO06s. Gaussian filter applied (400km). C20 replaced with SLR values. Grey: old, Black: new

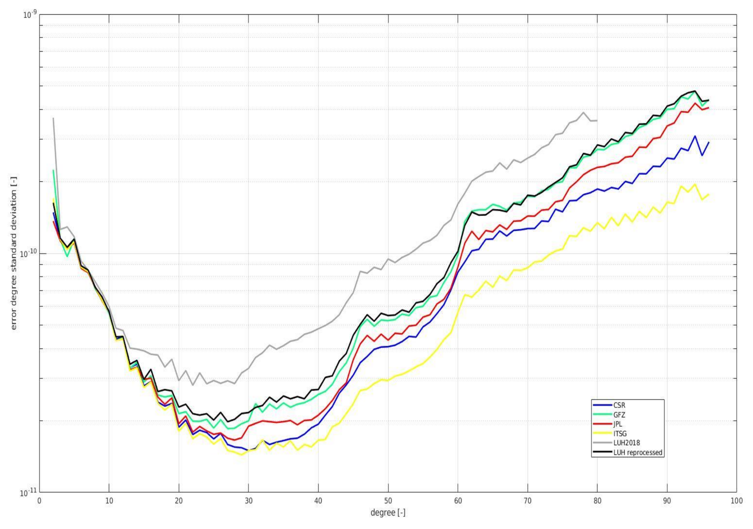

Fig. 3: Corresponding error degree standard deviations w.r.t. mean model of all centers. Old: Grey, new: Black

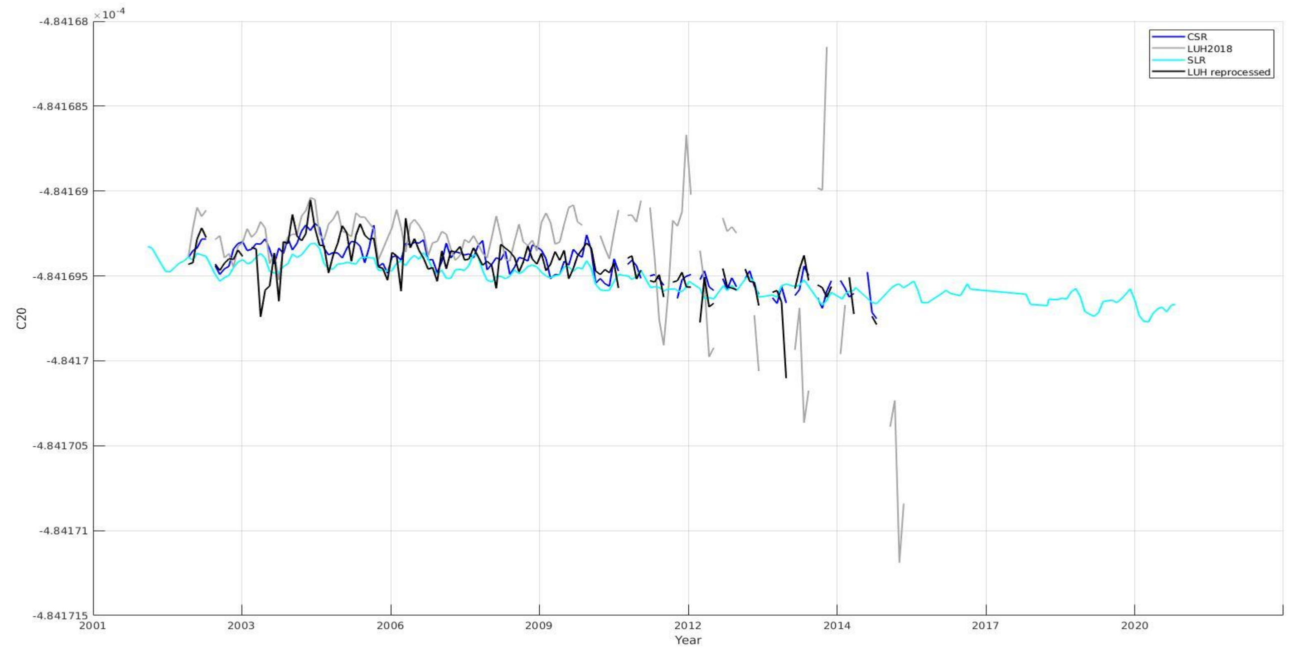

Fig. 4: C_{20} spherical harmonic coefficient compared to SLR data. Grey: old, Black: new

F – GRACE Follow-On Post-Fit Residuals

We compute the post-fit range rate residuals as

$$\hat{\mathbf{v}} = \mathbf{A}_{\sim\mathrm{CD}}\,\hat{\mathbf{x}}_{\sim} + \mathbf{A}_{\oplus\mathrm{CD}}\,\hat{\mathbf{x}}_{\oplus} - \mathbf{l}_{\mathrm{CD}}$$

where $\hat{\mathbf{v}}$: estimated LRI range rate post-fit residuals, $\mathbf{A}_{\sim\mathrm{CD}}$: design matrix of arc-specific parameters, $\mathbf{A}_{\oplus\mathrm{CD}}$: design matrix of spherical harmonic coefficients, $\hat{\mathbf{x}}_{\sim}$: estimated arc-specific parameters, $\hat{\mathbf{x}}_{\oplus}$: estimated spherical harmonic coefficients, and $\mathbf{l}_{\mathrm{CD}}$: reduced KBRR observations.

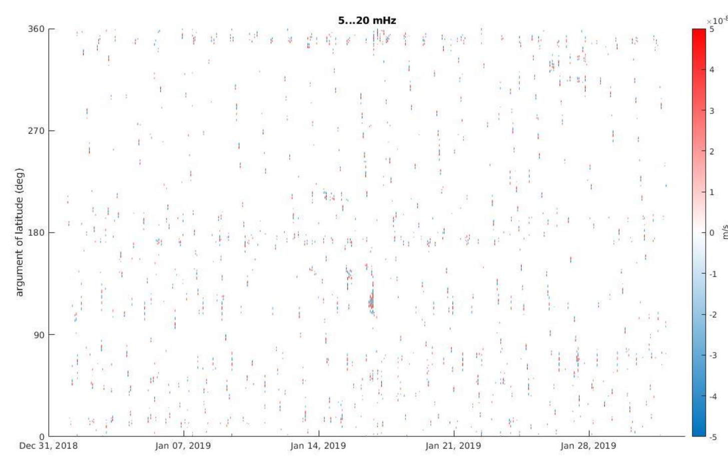

Fig. 5: LRI range rate post-fit residuals as Time/Argument of Latitude (TAL) diagram. Values above 3 σ. For Jan. 2019

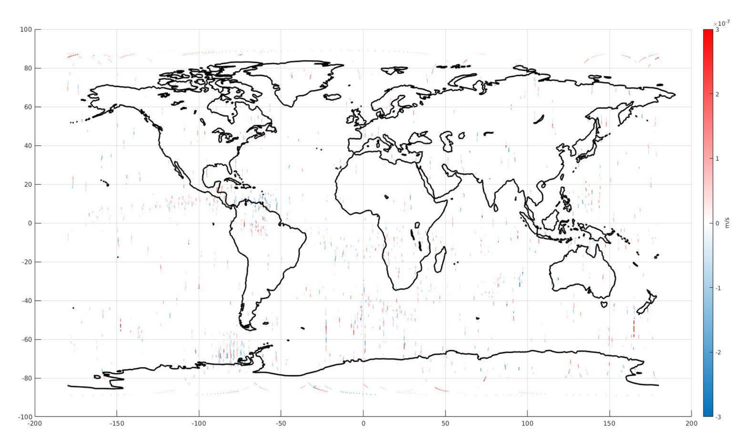

Fig. 6: Mean LRI range rate post-fit residuals in spatial domain. Values above 3 σ. For Jan. 2019

G – GFO error degree standard deviation

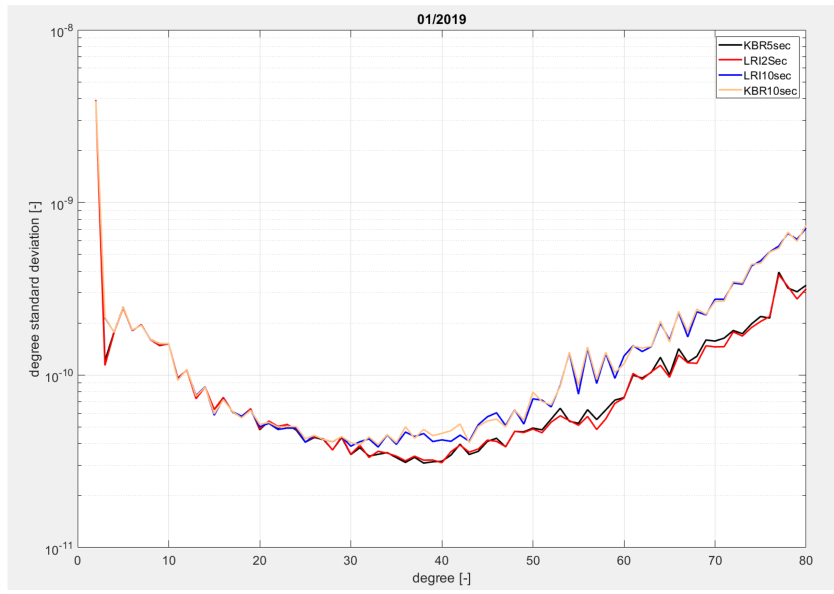

Fig. 7: Error degree standard deviation comparison from KBR and LRI. Black: KBR 5s sample rate, Red: LRI 2s sample rate, Yellow: KBR 10s sample rate, Blue: LRI 10s sample rate

- Using 2s sampling rate from LRI benefits the solutions
- Using the same samplerate (without interpolation) there is only a minimal difference

H – GFO combined solution

We are experimenting on combined solutions from KBR range rates and LRI range rates. They are currently combined on NEQ-Level with different weightings. We are using the equation

$$\boldsymbol{N} = \sum_{i=\{C,D,K,L\}} \boldsymbol{A}_i^T \boldsymbol{P}_i \boldsymbol{A}_i$$

Where C and D denote the GNSS observation of the two Satellites and K and L are the KBR rsp. LRI observations (range rate). A_i is the corresponding design matrix and P_i the specific weighting matrix.

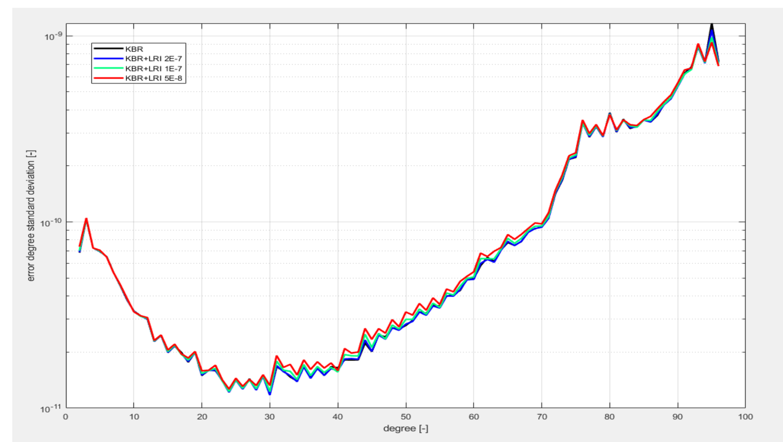

Fig. 8: Error degree standard deviation of combined solutions on NEQ-Level with different weights

References

[1] ***Koch, Igor, et al***. "Earth's Time-Variable Gravity from GRACE Follow-On K-Band Range-Rates and Pseudo-Observed Orbits." Remote Sensing 13.9 (2021): 1766. [2] ***Ries et al.*** (2011): Mean background gravity fields for GRACE processing, GRACE Science Team Meeting Austin, TX, August 8-10. [3] ***Kvas et al.*** (2019): The satellite-only gravity field model GOCO06s. EGU General Assembly 2019, 7.-12. April 2019, Vienna, Austria. [4] ***Standish*** (1998): JPL planetary and lunar ephemerides, DE405/LE405, Jet Propulsion Laboratory Interoffice Memorandum IOM 312.F-98-048. [5] ***Folkner et al.*** (2014): The Planetary and Lunar Ephemerides DE430 and DE431, IPN Progress Report 42-196. [6] ***Petit and Luzum*** (2010): IERS Conventions (2010), IERS technical note 36, Verlag des Bundesamts für Kartographie und Geodäsie, Frankfurt am Main. [7] ***Savchenko and Bosch*** (2012): EOT11a - empirical ocean tide model from multi-mission satellite altimetry. DGFI Report No. 89, Deutsches Geodätisches Forschungsinstitut (DGFI), München, Germany. [8] ***Carrere et al.*** (2015): FES2014, a new tidal model on the global ocean with enhanced accuracy in shallow seas and in the Arctic region. Geophys Res Abstr, EGU2015-5481. EGU General Assembly 2015, Vienna, Austria. [9] ***Dobslaw et al.*** (2017): A new high-resolution model of non-tidal atmosphere and ocean mass variability for de-aliasing of satellite gravity observations: AOD1B RL06, Geophysical Journal International, Volume 211, Issue 1, Pages 263—269. [10] **Biancale and Bode** (2016): Mean Annual and Seasonal Atmospheric Tide Models Based on3-hourly and 6-hourly ECMWFSurface Pressure Data, Technical Report, GeoForschungsZentrum. [11] ***Kim* (2000):** Simulation study of a low-low satellite-to-satellite tracking mission, PhD thesis, The University at Austin Texas.

GRACE Science Team Meeting (GSTM)
Fall meeting 2021

Contact: [1] Institute of Geodesy, Leibniz University Hannover, Schneiderberg 50, 30167 Hannover, Germany
e-mail: duwe@ife.uni-hannover.de