GRACE-FO Line-of-sight Gravity From Laser Ranging to Mass Change

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Introduction

- July 2019 was very warm in Greenland and GRACE-FO observed record melt in this time period.
- Ghobadi-Far et al. (2022) showed the possibility to use the inter-satellite laser ranging measurements on the GRACE Follow-On satellites for the analysis of the gravity signal along their orbit.
- We focus on the region around Ilulissat glacier. This glacier shows some of the highest ice velocities in Greenland and shows a clear negative trend in elevation over the last decade.

Method

Data used:

- Dynamic orbit fit with respect to a static gravity field using the GROOPS software (Mayer-Gürr et al. 2021) for both satellites.
- Measured range rate from the Laser Ranging (LRI) data.
- Static gravity field GOCO06s by Kvas et al. (2019)
- Time-variable gravity fields ITSG-GRACE2018 by Mayer-Gürr et al. (2018)

Processing steps:

- Compute residual range rate.

Relative velocity vector from dynamic orbit fit — Unit vector in the Line-of-sight direction

$$\delta\dot{\rho}(t) = \dot{\rho}_{LRI}(t) - \dot{\vec{x}}_{12}(t) \cdot \vec{e}_{12}(t) \qquad (1)$$

- Derive residual range acceleration.

$\delta\ddot{\vec{x}}_{12}(t)$ — Centrifugal Term

$$\delta\ddot{\rho}\,(t) = \delta\vec{g}_{12}(t) \cdot \vec{e}_{12}(t) - \delta\left(\dot{\vec{x}}_{12}(t) \cdot \dot{\vec{e}}_{12}(t)\right)$$

Desired observation — Filtered out using a transfer function

$$= \delta g_{12}^{LOS}(t) + \Delta_0(t) \qquad (2)$$

- Apply transfer function by Ghobadi-Far et al. (2018) to separate the centrifugal term and the difference in line-of-sight gravity (LGD).
- Evaluate the monthly gravity field, reduced by a static field at orbit height to get the monthly LGD.

$$g_{12}^{LOS}(t) = \vec{\nabla}V(\vec{x}_{12}, t) \cdot \vec{e}_{12}(t) \qquad (3)$$

- Replace the long wave-lengths by the monthly LGD signal using a band-pass filter.

Results

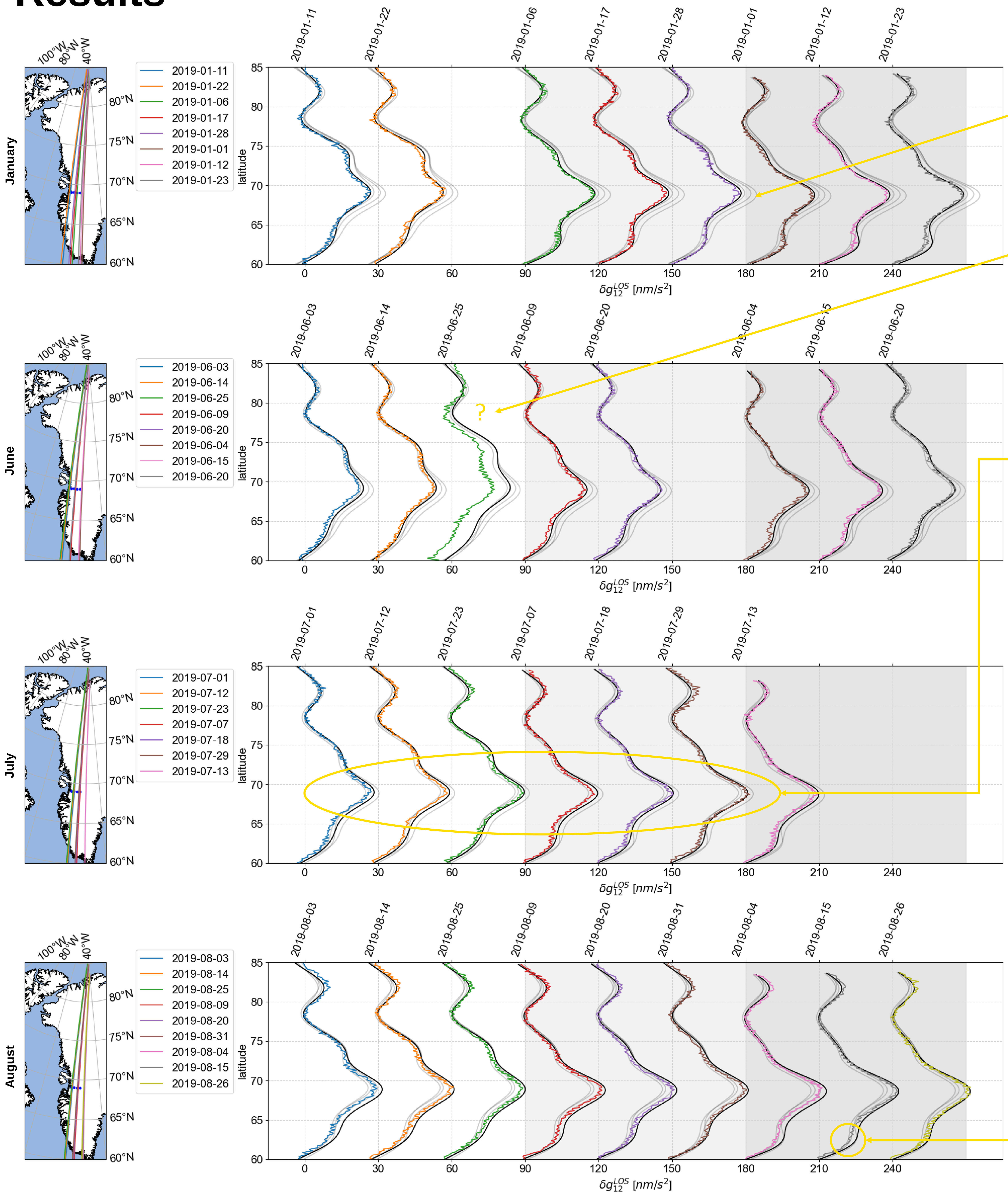


Figure 1: Difference in line-of-sight gravity (LGD) for January, June, July and August 2019. The left figures show the ground tracks and the right figure the LGD signal based on LRI (coloured lines) and monthly solutions from TU Graz (black and grey lines). All orbits shown are ascending (moving from the equator to the pole) orbits.

Discussion and Outlook

The orbits are grouped into three clusters with similar ground tracks. In these three clusters, the orbits are sorted from the beginning to end of the month from left to right.

The LGD shows the deviation from the static field and gets bigger with increasing ice loss. The four lines showing the monthly signals are thus showing the ice melt for summer 2019 and the peak is over the Ilulissat glacier.

2019-06-25 shows a significantly lower LGD than the monthly signal. We have not yet figured out if this is a real signal or an outlier. Since it is the only day showing this behaviour, it is probably an outlier.

Coloured line: Line-of-sight gravity difference (LGD). This is the filtered residual range acceleration showing the difference of the static signal and the LRI measurements on-board.

Black line: LGD from the corresponding monthly solution reduced by the static signal. This represents the monthly signal which is a solution based on all orbits for this month.

Grey lines: LGD from the three other monthly solutions reduced by the static signal

Blue dots on the left figures: rough position of the Ilulissat glacier

These two clusters both show a trend of slightly lower observed LGD at the beginning of July and a reduction in the gap towards the end of the month. This could be explained by gradual melt over this time period.

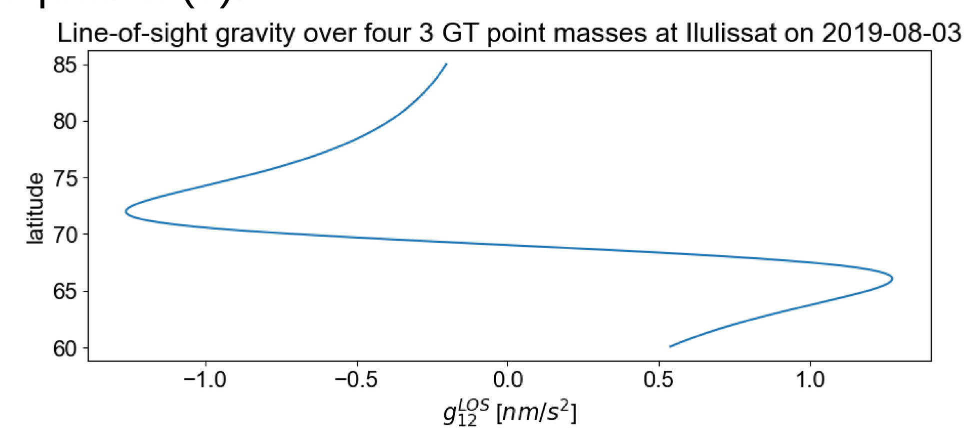
Generally, the observed LGD is slightly smaller in the beginning of July and August and increases up to the monthly signal over the month.

The differences are only of the order of a few nm/s² with a signal of up to 30nm/s².

The biggest source of noise are the dynamic orbits. We filtered the observed LGD using a moving mean over 10s to reduce some of the noise. This affects the amplitude of the signal and might be the source of some of the lower LGD especially over latitudes where the signal changes fast.

To get an idea of how mass change is reflected in the LGD signal, we looked at the effect of placing four point masses on the location of the blue dots in figure 1. We calculated the resulting line-of-sight gravity from just these point masses along one orbit in August using equation (3).

Figure 2: Forward computation of four 3 GT point masses at the location of Ilulissat (blue dots in figure 1) for one of the orbits in August. This is the evaluation of equation (3) for the potential of a point mass.



References

- Ghobadi-Far, K., Han, S.-C., McCullough, C. M., Wiese, D. N., Ray, R. D., Sauber, J., et al. (2022). Along orbit analysis of GRACE Follow-On inter-satellite laser ranging measurements for sub-monthly surface mass variations. Journal of Geophysical Research: Solid Earth, 127, e2021JB022983. https://doi.org/10.1029/2021JB022983
- Mayer-Guerr, T., Behzadpour, S., Eicker, A., Ellmer, M., Koch, B., Krauss, S., Pock, C., Rieser, D., Strasser, S., Suesser-Rechberger, B., Zehentner, N., Kvas, A. (2021). GROOPS: A software toolkit for gravity field recovery and GNSS processing. Computers & Geosciences, 104864. https://doi.org/10.1016/j.cageo.2021.104864
- Ghobadi-Far, K., Han, S.-C., Weller, S., Loomis, B. D., Luthcke, S. B., Mayer-Gürr, T., & Behzadpour, S. (2018). A transfer function between line-of-sight gravity difference and GRACE intersatellite ranging data and an application to hydrological surface mass variation. Journal of Geophysical Research: Solid Earth, 123, 9186–9201. https://doi.org/10.1029/2018JB016088
- Kvas, A., Brockmann, J. M., Krauss, S., Schubert, T., Gruber, T., Meyer, U., Mayer-Gürr, T., Schuh, W.-D., Jäggi, A., Pail, R. (2021). GOCO06s - a satellite-only global gravity field model. Earth System Science Data, 13(1), 99–118. doi.org/10.5194/essd-13-99-2021
- Kvas, Andreas; Mayer-Gürr, Torsten; Krauss, Sandro; Brockmann, Jan Martin; Schubert, Till; Schuh, Wolf-Dieter; Pail, Roland; Gruber, Thomas; Jäggi, Adrian; Meyer, Ulrich (2019): The satellite-only gravity field model GOCO06s. GFZ Data Services. http://doi.org/10.5880/ICGEM.2019.002
- Kvas, A., Behzadpour, S., Ellmer, M., Klinger, B., Strasser, S., Zehentner, N., & Mayer-Gürr, T. (2019).ITSG-Grace2018: Overview and evaluation of a new GRACE-only gravity field time series. Journal of Geophysical Research: Solid Earth, 124. https://doi.org/10.1029/2019JB017415
- Mayer-Gürr, Torsten; Behzadpur, Saniya; Ellmer, Matthias; Kvas, Andreas; Klinger, Beate; Strasser, Sebastian; Zehentner, Norbert (2018): ITSG-Grace2018 - Monthly, Daily and Static Gravity Field Solutions from GRACE. GFZ Data Services. http://doi.org/10.5880/ICGEM.2018.003

Unfiltered solutions