

Assessment of gravity field models derived from Sentinel GPS data

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Citation: Grombein, T., Lasser, M., Arnold, D., Meyer, U., and Jäggi, A. (2022): Assessment of gravity field models derived from Sentinel GPS data, EGU General Assembly, 23–27 May 2022, EGU22-5202, <https://doi.org/10.5194/egusphere-egu22-5202>



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Introduction

- **Motivation**
 - Any Low Earth Orbiting (LEO) satellite with a GPS receiver may serve as a gravity field sensor (in addition to dedicated missions)
 - GPS tracking data may be used to derive kinematic LEO positions that can subsequently be utilized for gravity field recovery
- **Our goal:** Multi-LEO gravity field time series taking advantage of
 - Large number of observations
 - Complementary orbital configurations
- **Focus here:** contribution of Sentinel GPS data

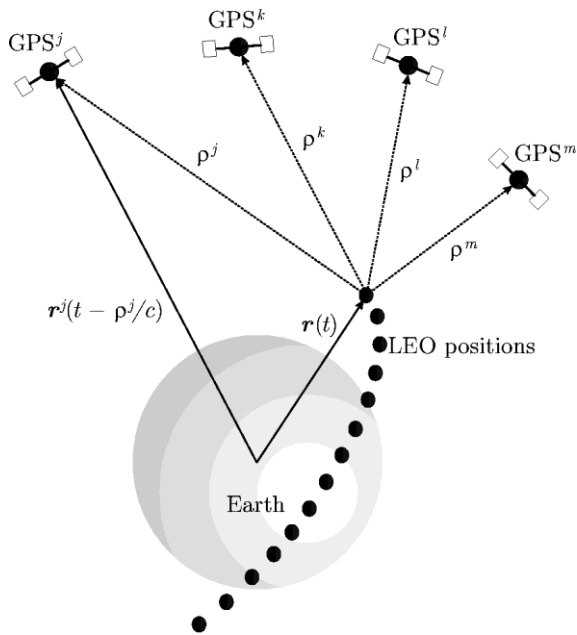
- 1) Which quality can be expected from Sentinel gravity field solutions?
- 2) Can a Swarm gravity field time series profit from additional Sentinel data?



Source: ESA

GPS-based orbit and gravity field determination

Kinematic orbits

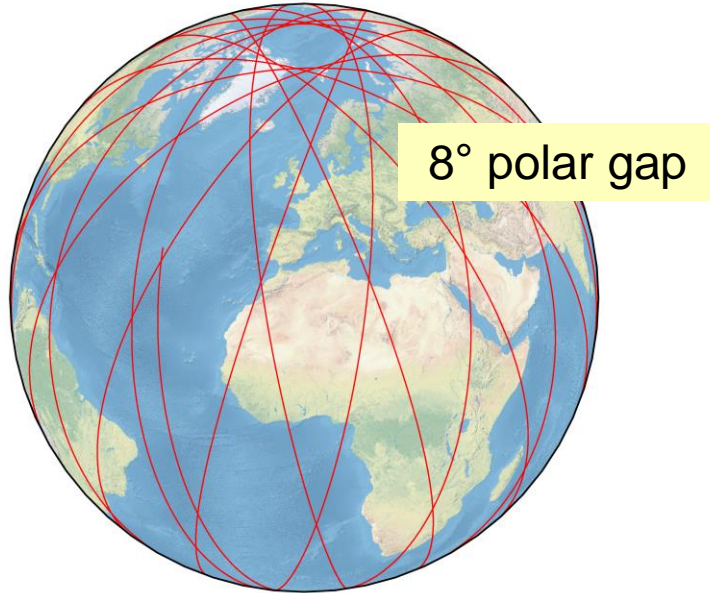


- LEO positions at discrete epochs
- Purely geometrically determined
- Suitable for gravity field recovery

- **Precise orbit determination**
 - GPS-based kinematic orbits are routinely processed at AIUB for various LEO satellites like GRACE/-FO, GOCE, Swarm, Sentinel, ...
 - Bernese GNSS Software with GNSS products of CODE
 - In-flight calibrated phase center variation (PCV) maps
 - Ambiguity-float and nowadays also ambiguity-fixed orbit solutions
- **Gravity field recovery (generalized orbit determination problem)**
 - Celestial Mechanics Approach ([Beutler et al., 2010](#))
 - Pseudo-observations: kinematic orbit positions (covariance information)
 - Orbit and gravity field parameters are estimated simultaneously
 - Unmodeled forces are absorbed by empirical or stochastic parameters

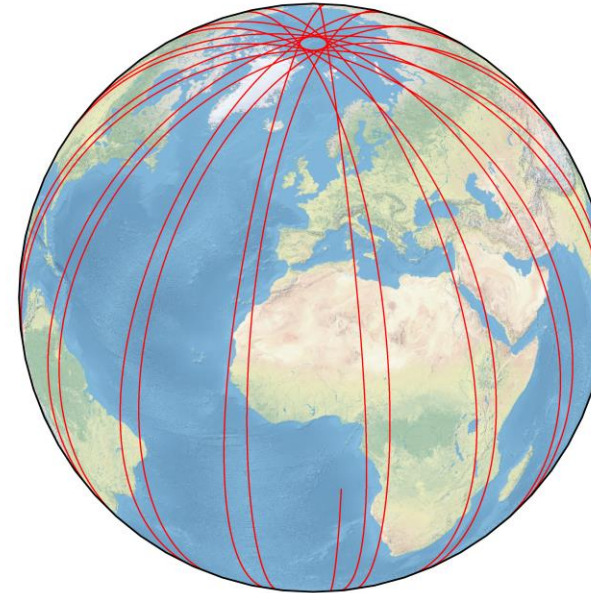
Overview of LEO satellite missions

Sentinel-1-2-3 missions
(3 x 2 LEO satellites)



Inclination: $\sim 98^\circ$
Altitudes: 700 to 800 km

Swarm mission
(3 LEO satellites)



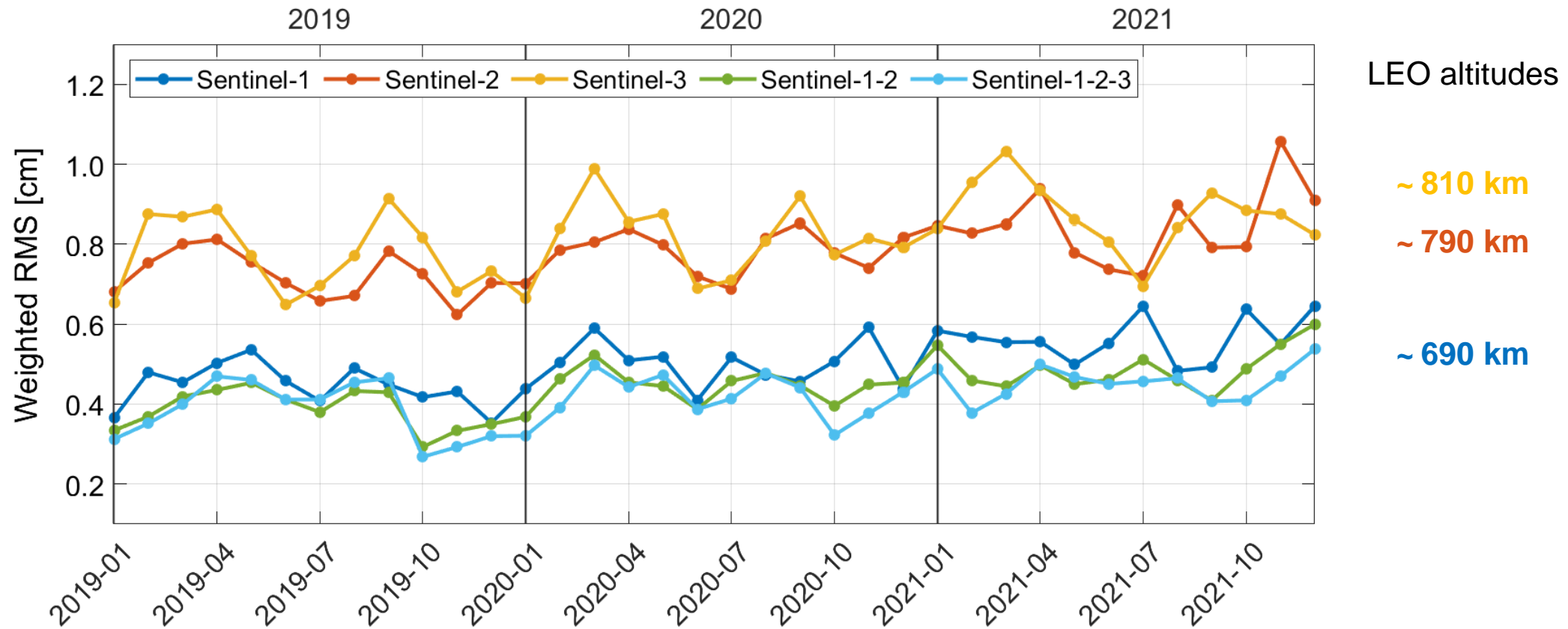
Inclination: $\sim 88^\circ$
Altitudes: 450 to 500 km

Sentinel gravity field solutions

2019 – 2021

Assessment of Sentinel gravity field solutions

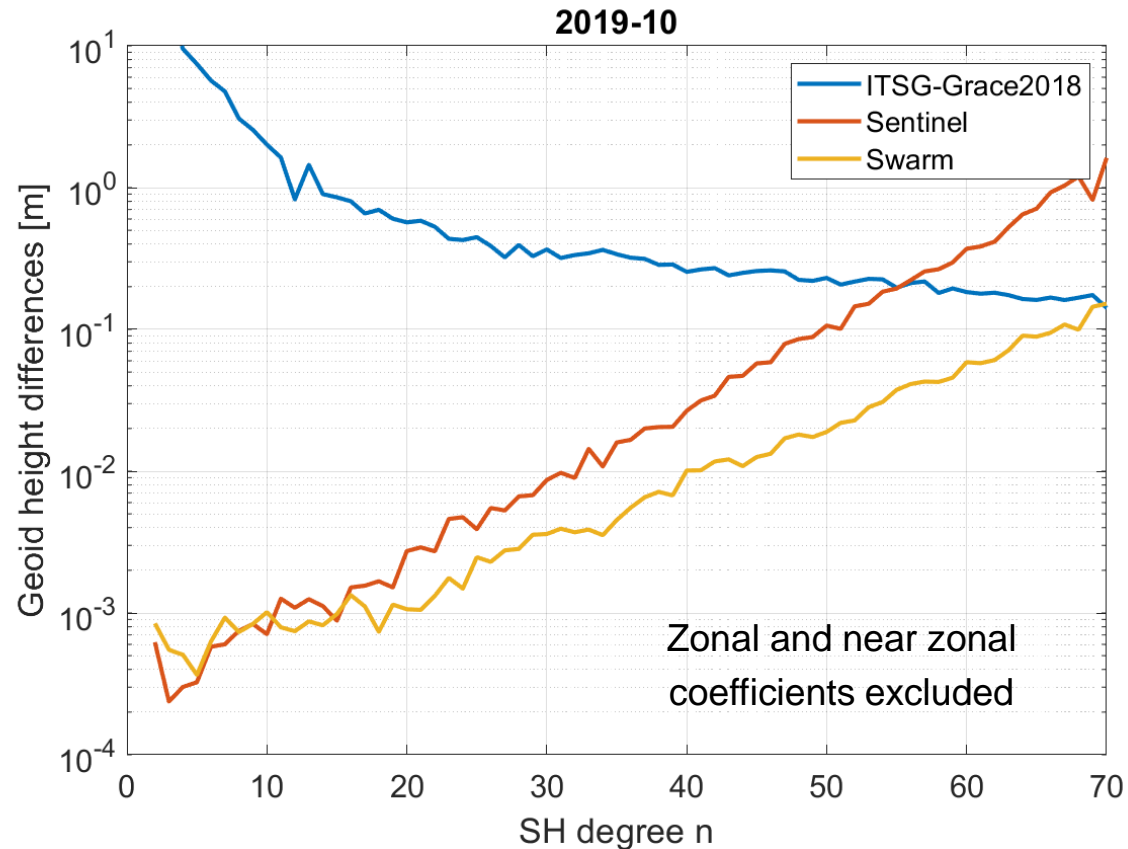
- Quality of gravity fields: RMS values of geoid height diff. w.r.t. ITSG-Grace2018 (Mayer-Gürr et al., 2018)



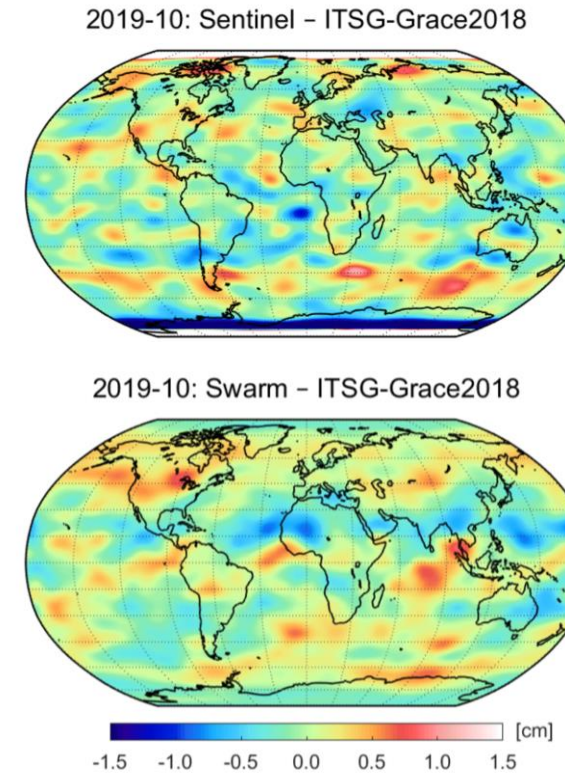
700 km Gauss filter | RMS values refer to regions with latitudes $|\varphi| < 80^\circ$

Comparison of Sentinel and Swarm gravity field solutions

- Difference degree amplitudes



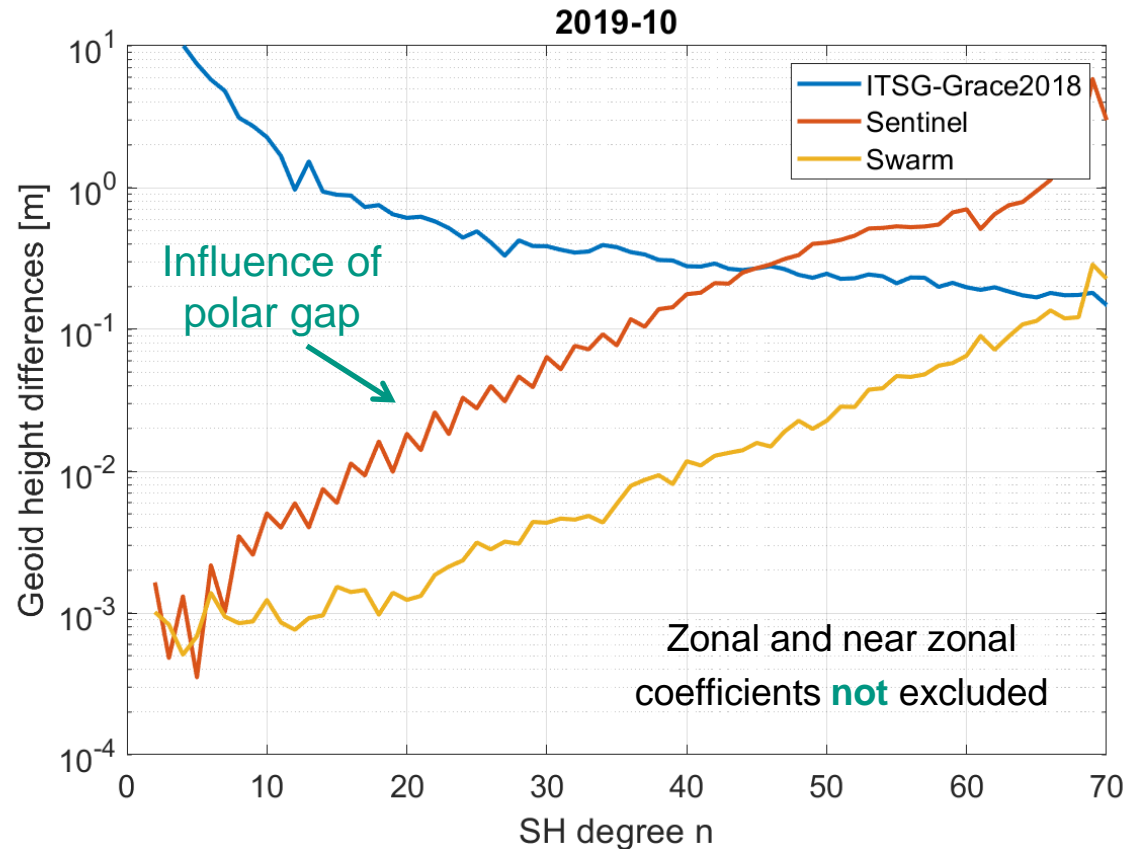
- Geoid height differences (700km Gauss-filtered)



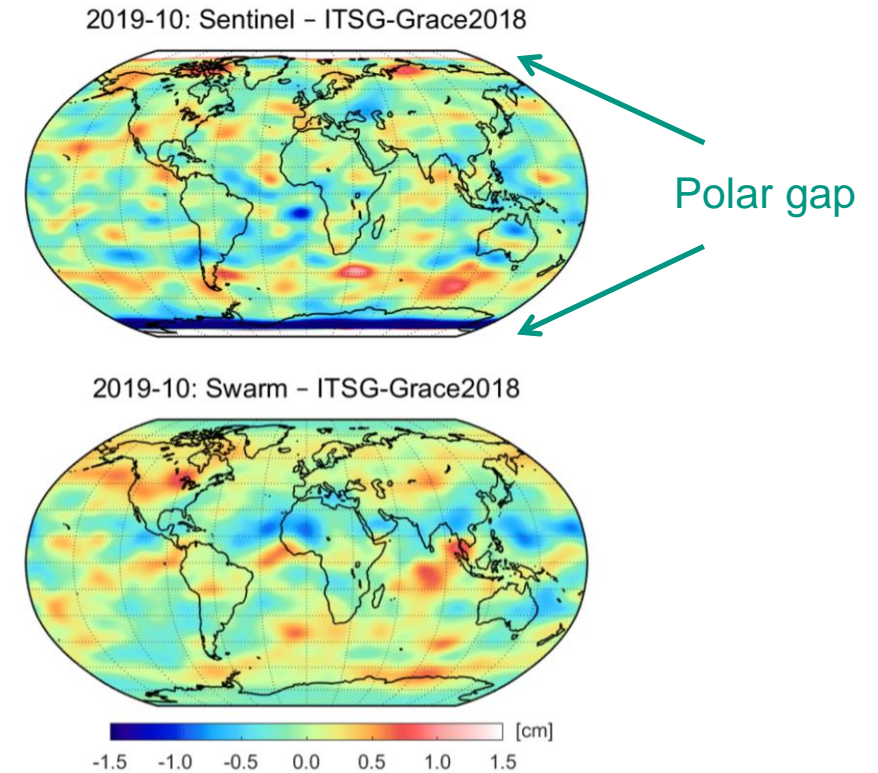
Sentinel solutions may contribute to the low-degree coefficients

Comparison of Sentinel and Swarm gravity field solutions

- Difference degree amplitudes



- Geoid height differences (700km Gauss-filtered)



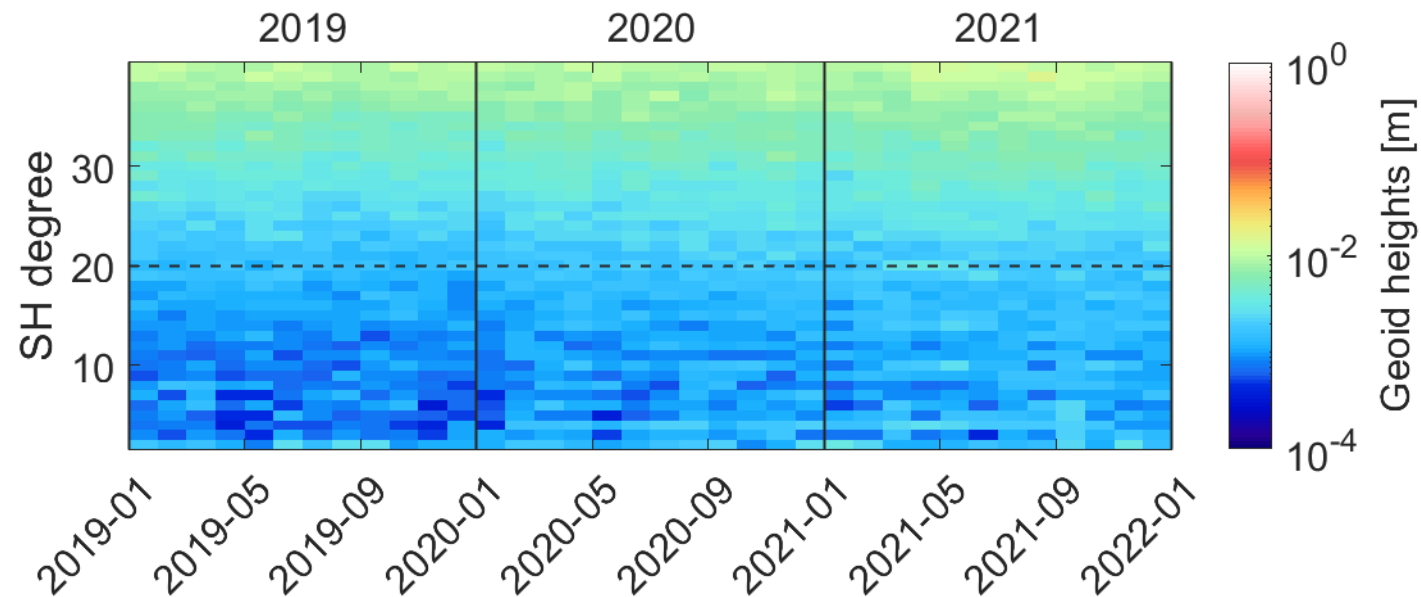
Sentinel solutions may contribute to the low-degree coefficients

Swarm–Sentinel combination

Swarm–Sentinel combination

- Time series of monthly difference degree amplitudes (w.r.t. ITSG-Grace2018)

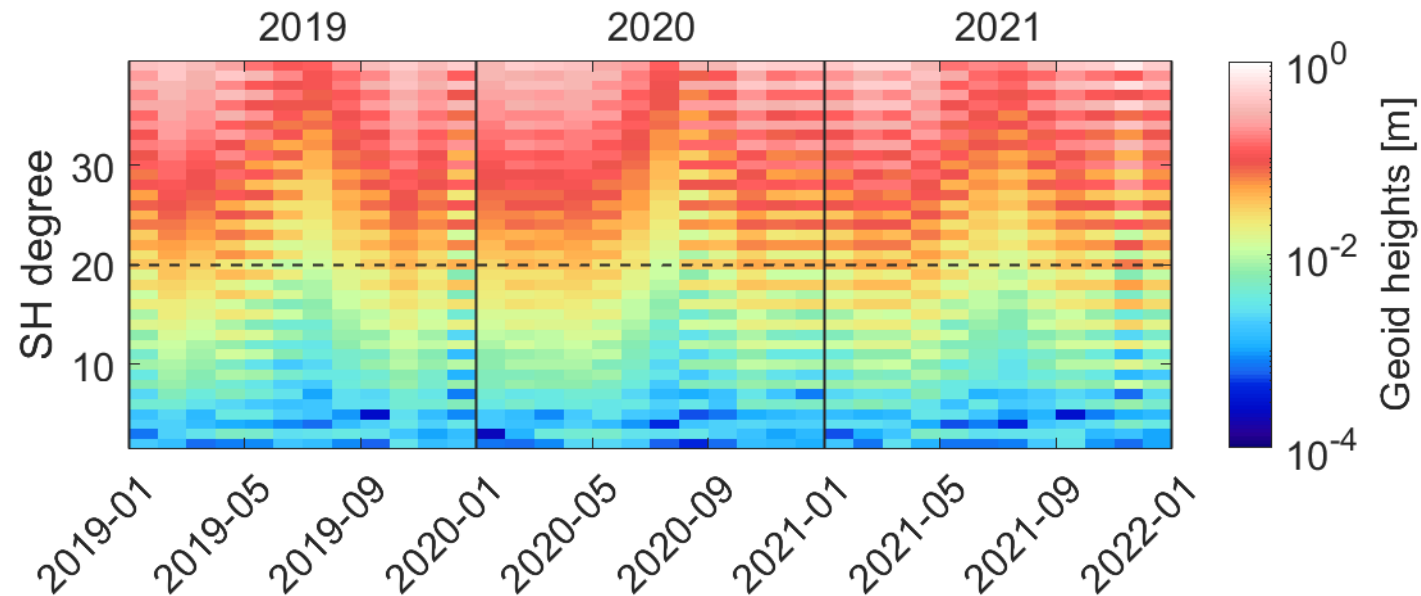
Swarm-A-B-C solution (Dahle et al. 2017)



Swarm–Sentinel combination

- Time series of monthly difference degree amplitudes (w.r.t. ITSG-Grace2018)

Weighted combination at solution level (based on formal errors)

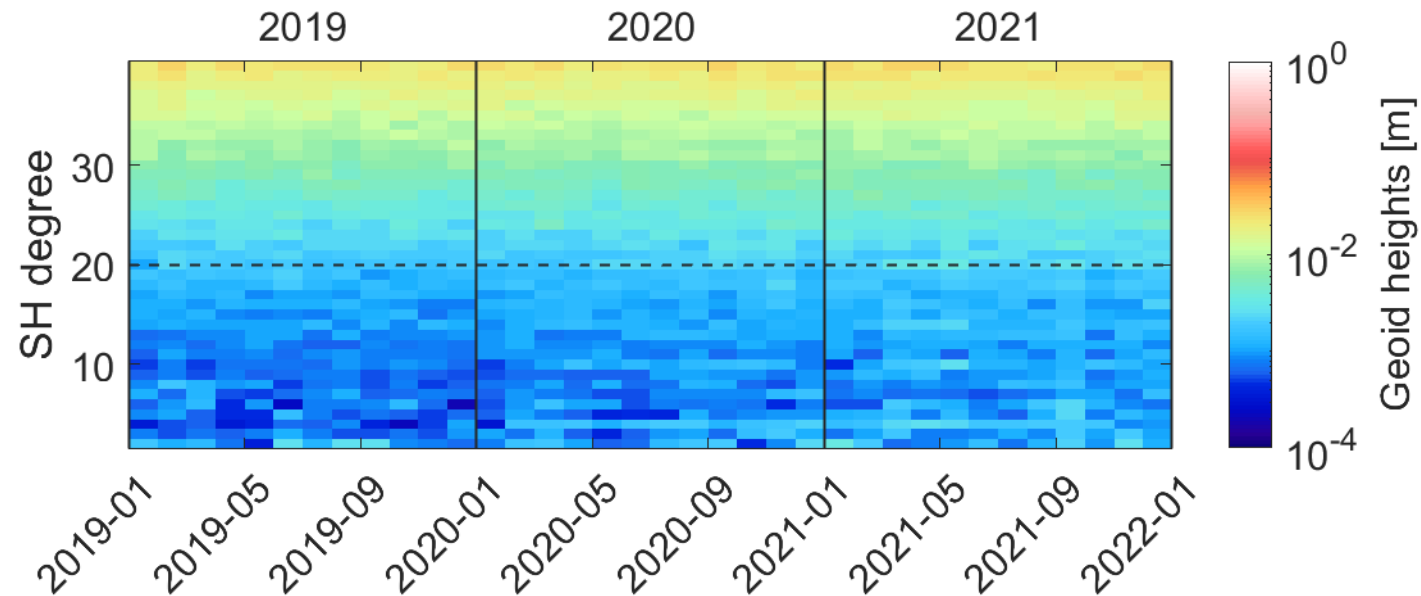


Zonal + near zonal coefficients
are impaired by the influence of
Sentinel's polar gap

Swarm–Sentinel combination

- Time series of monthly difference degree amplitudes (w.r.t. ITSG-Grace2018)

Weighted combination at solution level (based on formal errors)

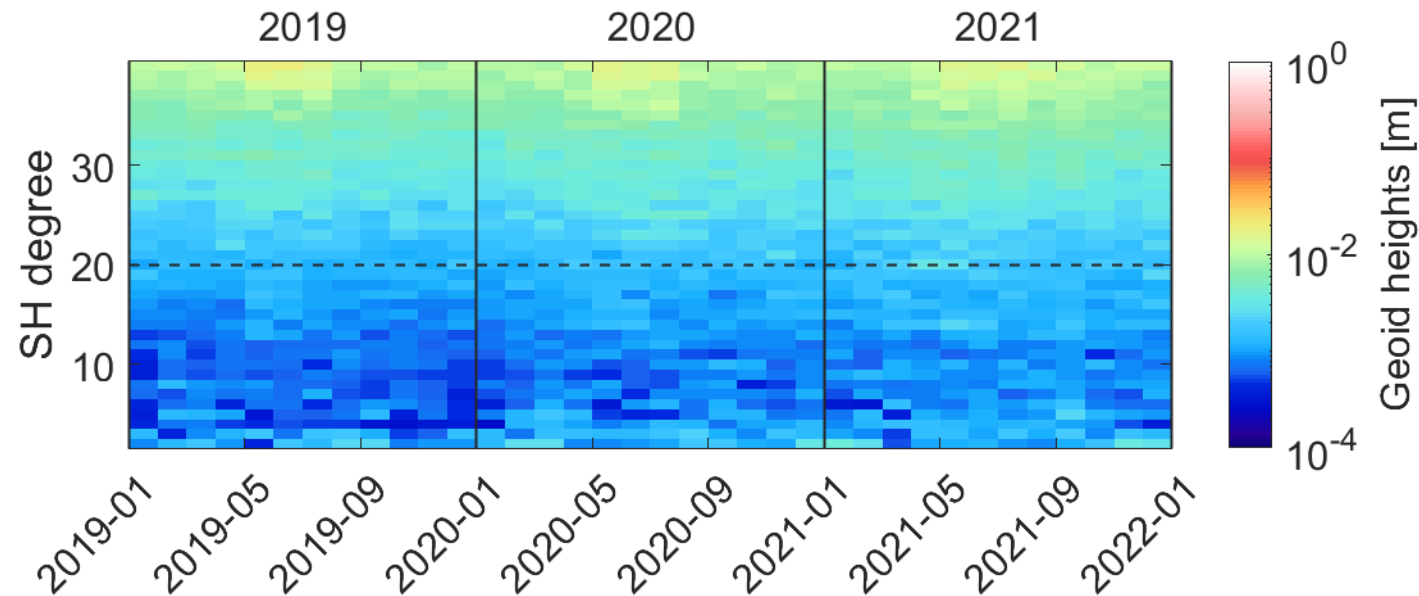


Zonal + near zonal coefficients
are excluded from combination
(solely based on Swarm data)

Swarm–Sentinel combination

- Time series of monthly difference degree amplitudes (w.r.t. ITSG-Grace2018)

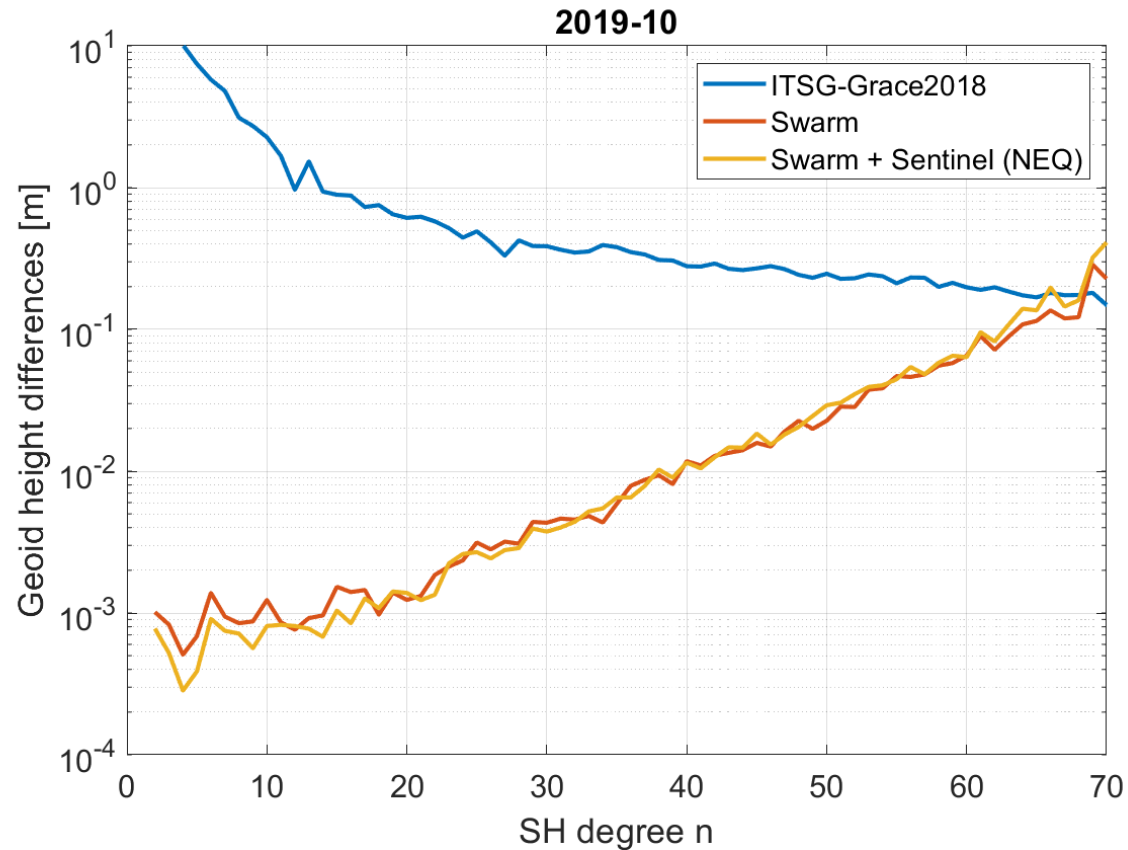
Combination at normal equation (NEQ) level (using variance component estimation)



Quality of lower degrees can be further improved; no special handling of polar gap

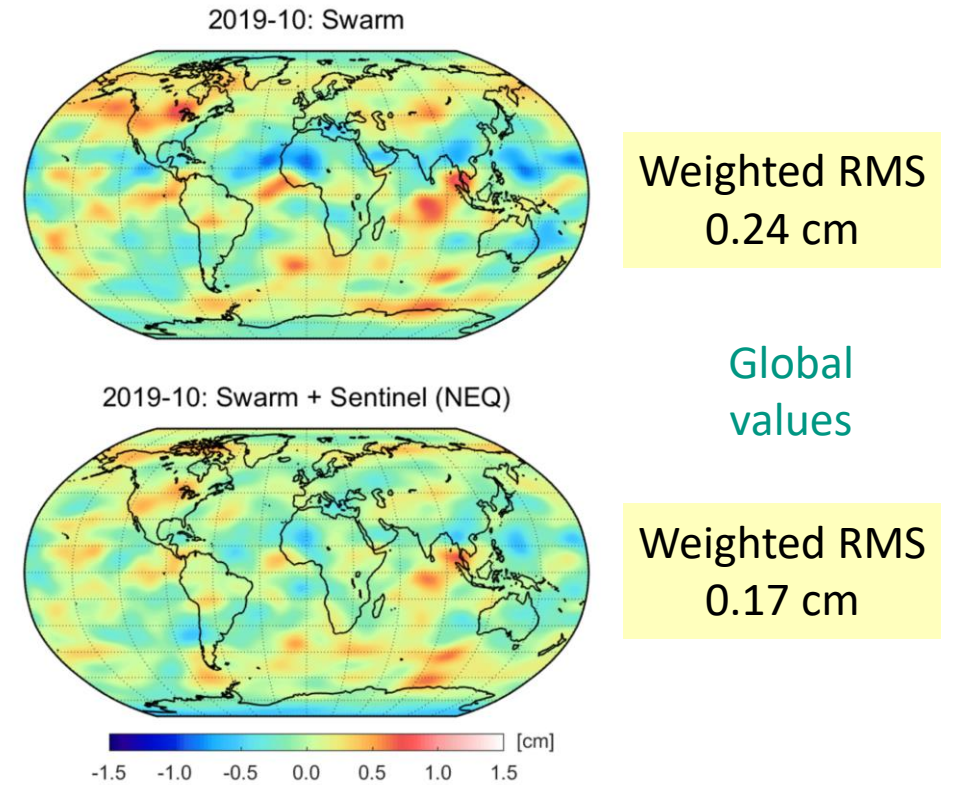
Swarm–Sentinel combination

- Difference degree amplitudes



Improvements are visible for degrees up to 15

- Geoid height differences (700 km Gauss filter)



Reduced RMS between 15 – 30% in most months

Summary

- Main findings
 - Sentinel solutions can contribute to the most relevant lower degrees (up to degree 15)
 - Influence of Sentinel's polar gap propagates into combination at solution level
 - Full potential is exploited by a combination at NEQ level (profits from correlations)
- Next steps
 - Extension of Sentinel times series + inclusion of new LEO satellites
 - Refined handling of non-gravitational forces (reduced use of stochastic parameters)



Source: ESA

Thank you for your attention



Source: ESA

References

Beutler G, Jäggi A, Mervart L et al. (2010): The celestial mechanics approach: theoretical foundations, Journal of Geodesy 84(10):605–624, DOI: 10.1007/s00190-010-0401-7

Dahle C, Arnold D, Jäggi A (2017): Impact of tracking loop settings of the Swarm GPS receiver on gravity field recovery. Advances in Space Research 59(12):2843–2854, DOI:10.1016/j.asr.2017.03.003

Mayer-Gürr T, Behzadpur S, Ellmer M et al. (2018): ITSG-Grace2018 - Monthly, Daily and Static Gravity Field Solutions from GRACE. GFZ Data Services, DOI: 10.5880/ICGEM.2018.003