Assessment of gravity field models derived from Sentinel GPS data

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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

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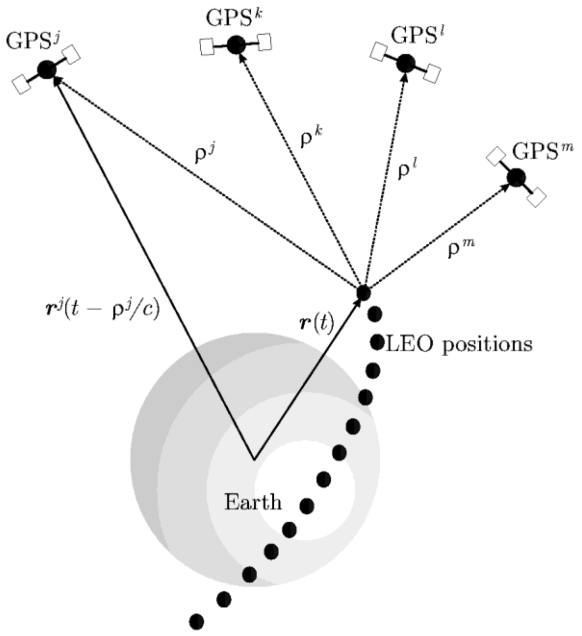
GPS-based orbit and gravity field determination

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

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Overview of LEO satellite missions

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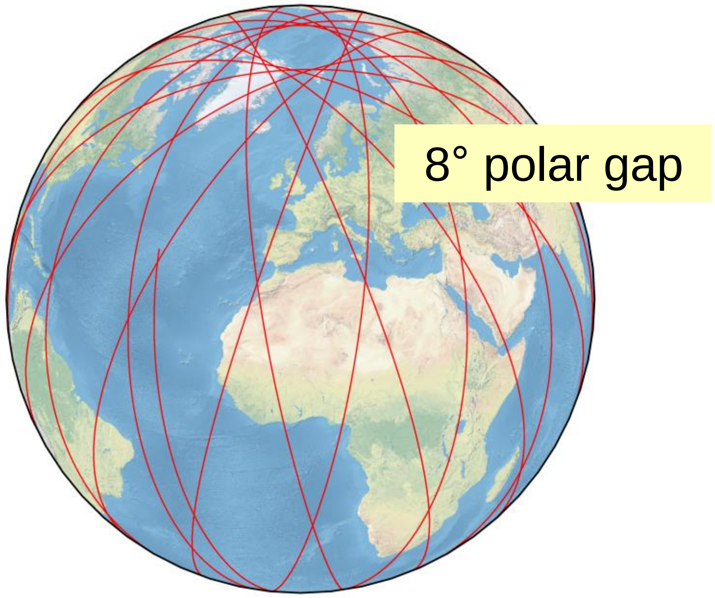
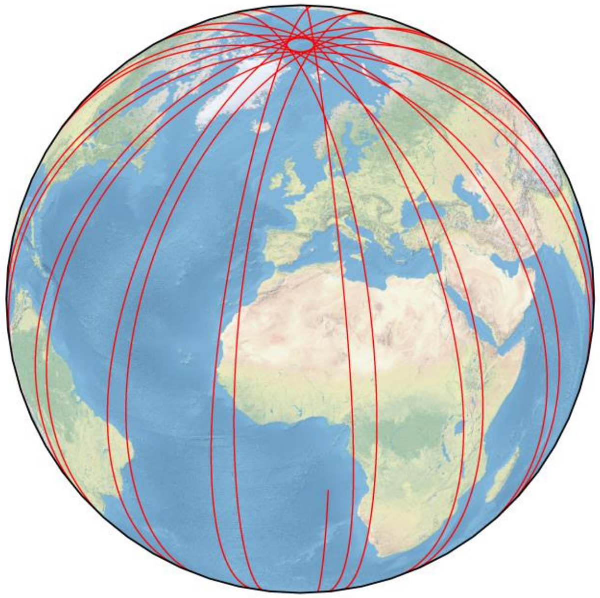
Sentinel-1-2-3 missions
(3 x 2 LEO satellites)



Inclination: ~ 98°

Altitudes: 700 to 800 km

Swarm mission
(3 LEO satellites)



Inclination: ~ 88°

Altitudes: 450 to 500 km

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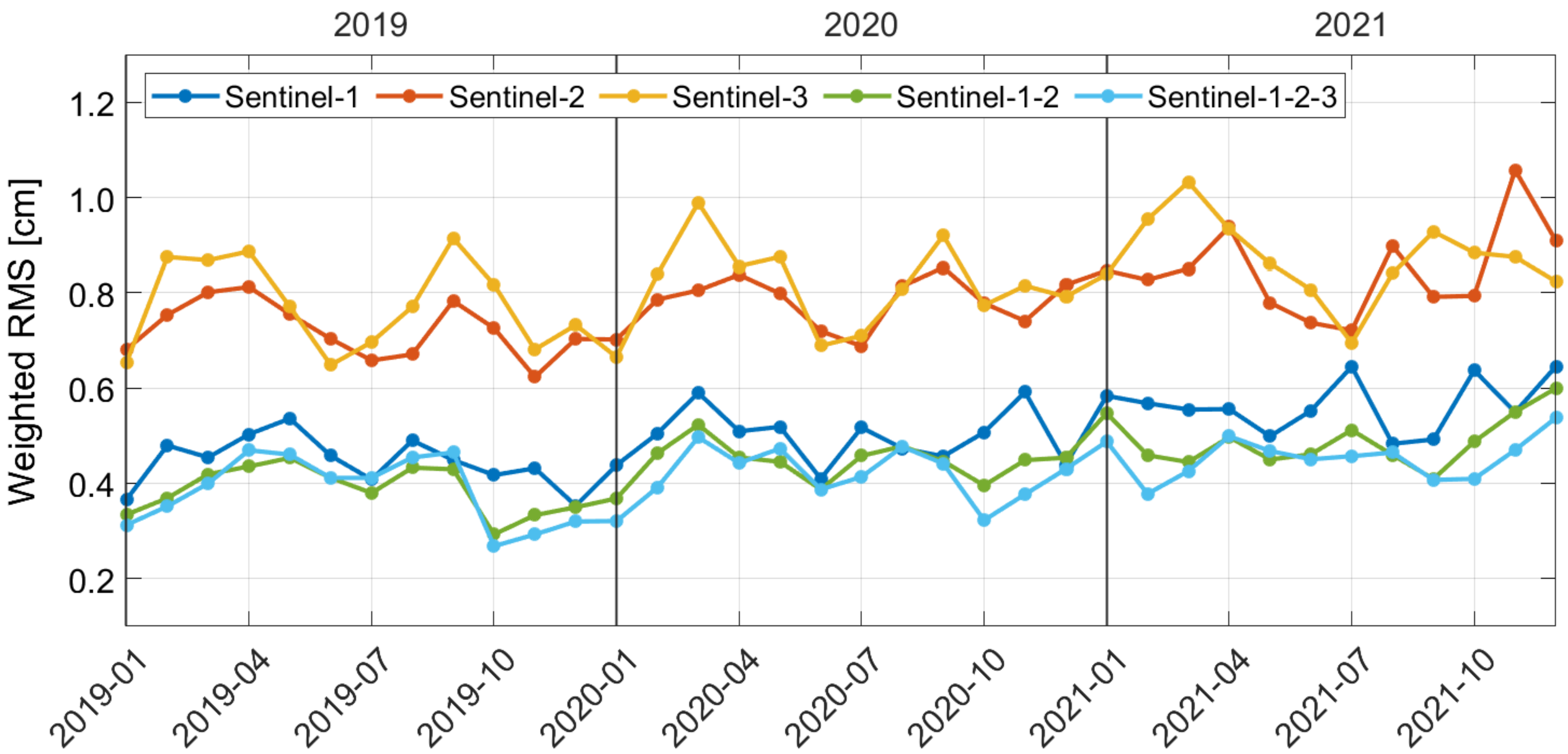
Sentinel gravity field solutions

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)



LEO altitudes

~ 810 km

~ 790 km

~ 690 km

700 km Gauss filter | RMS values refer to regions with latitudes |φ| < 80°

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Comparison of Sentinel and Swarm gravity field solutions

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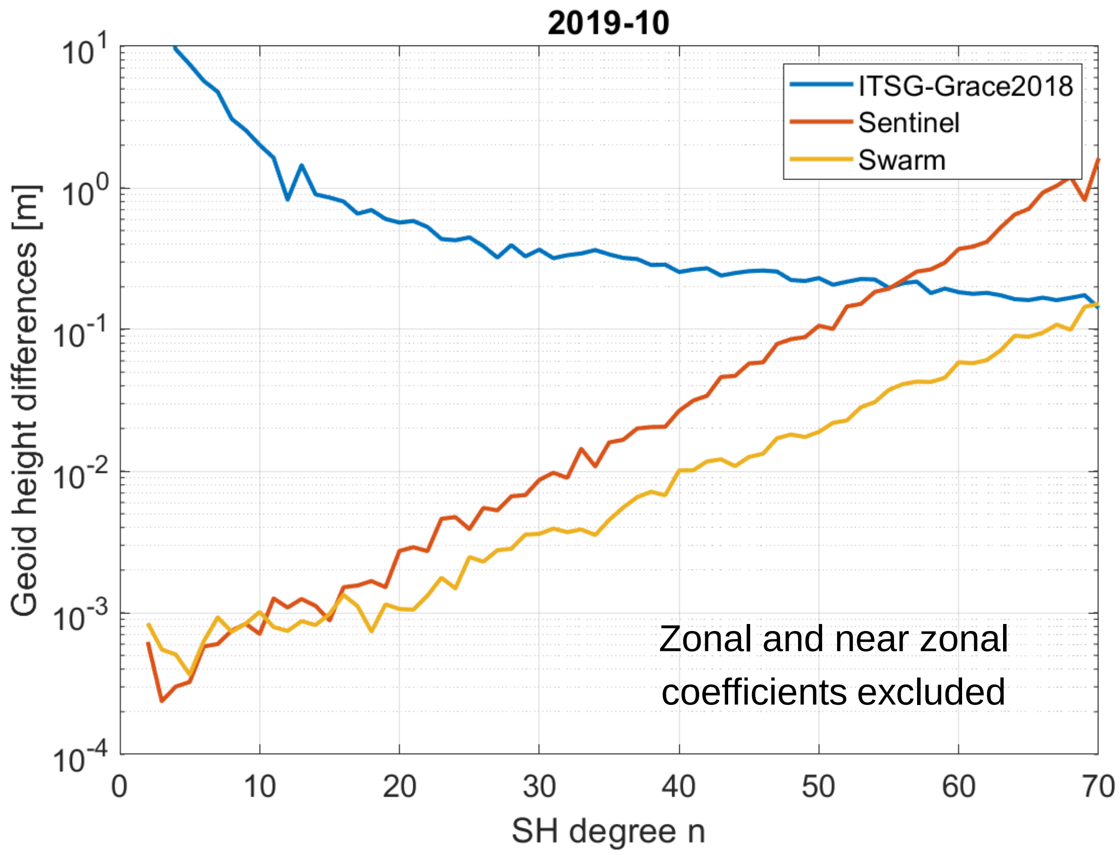
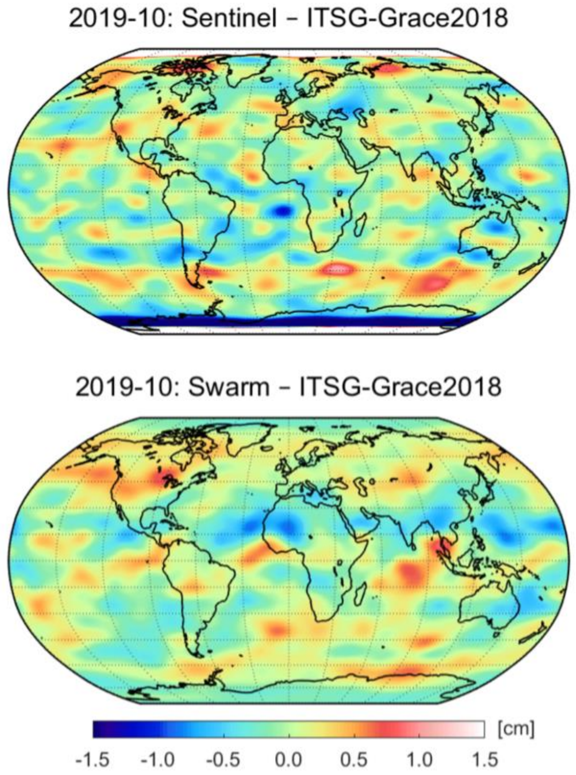
- Difference degree amplitudes



- Geoid height differences (700km Gauss-filtered)



Sentinel solutions may contribute to the low-degree coefficients

Comparison of Sentinel and Swarm gravity field solutions

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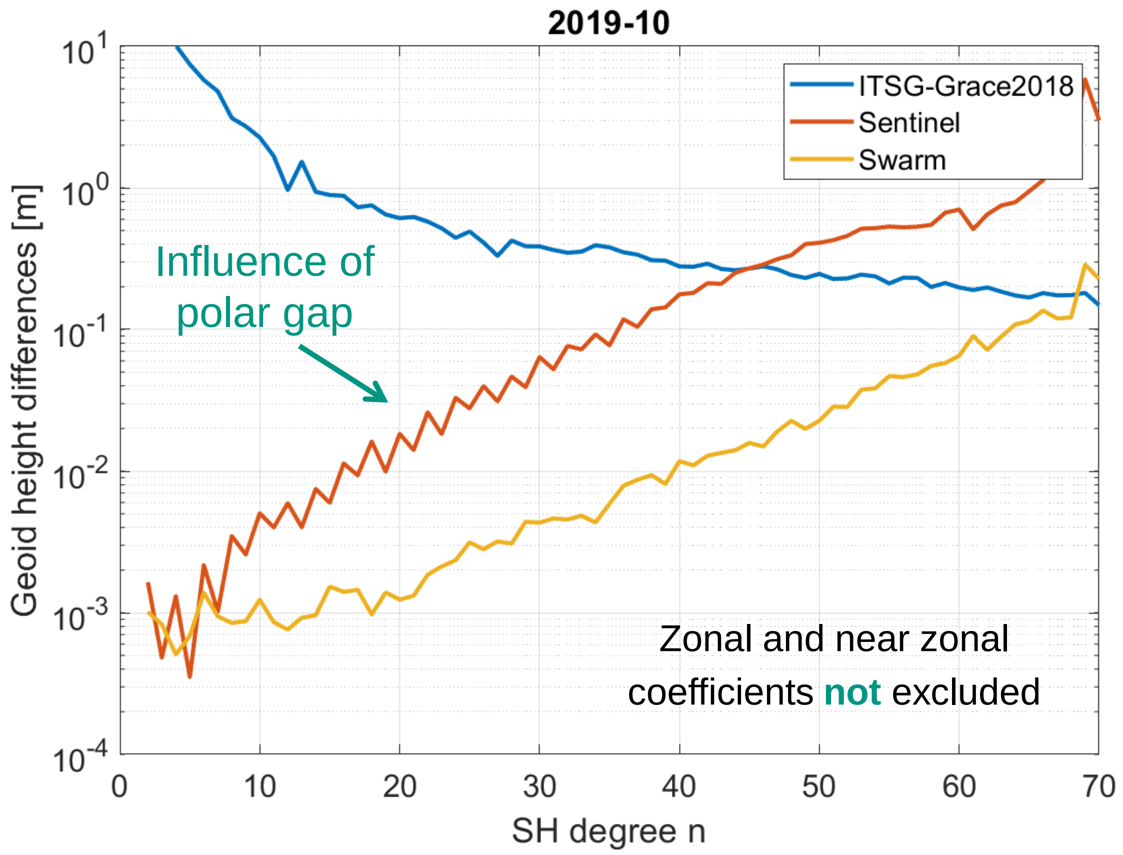

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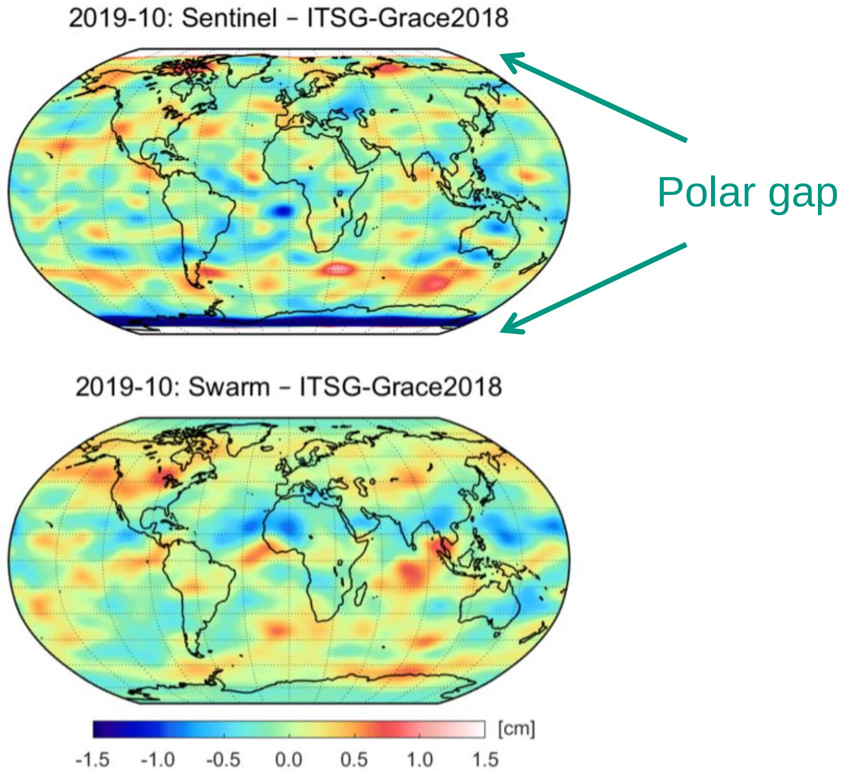

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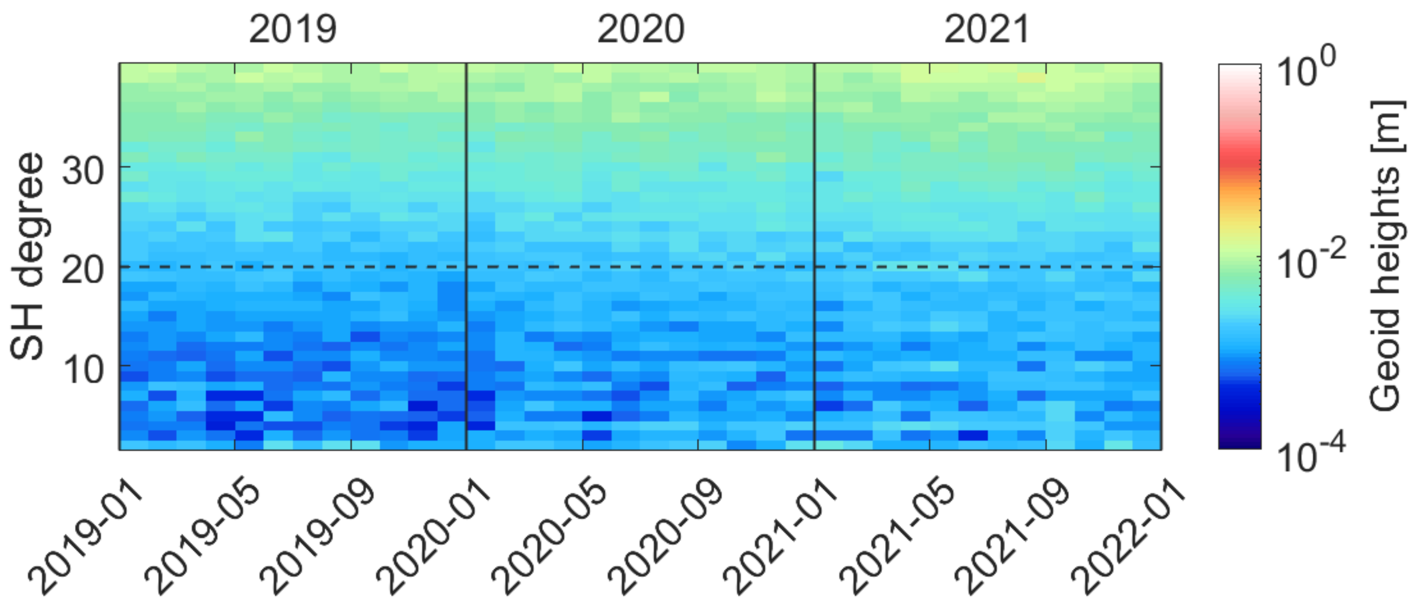
Swarm−Sentinel combination

Swarm–Sentinel combination

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

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



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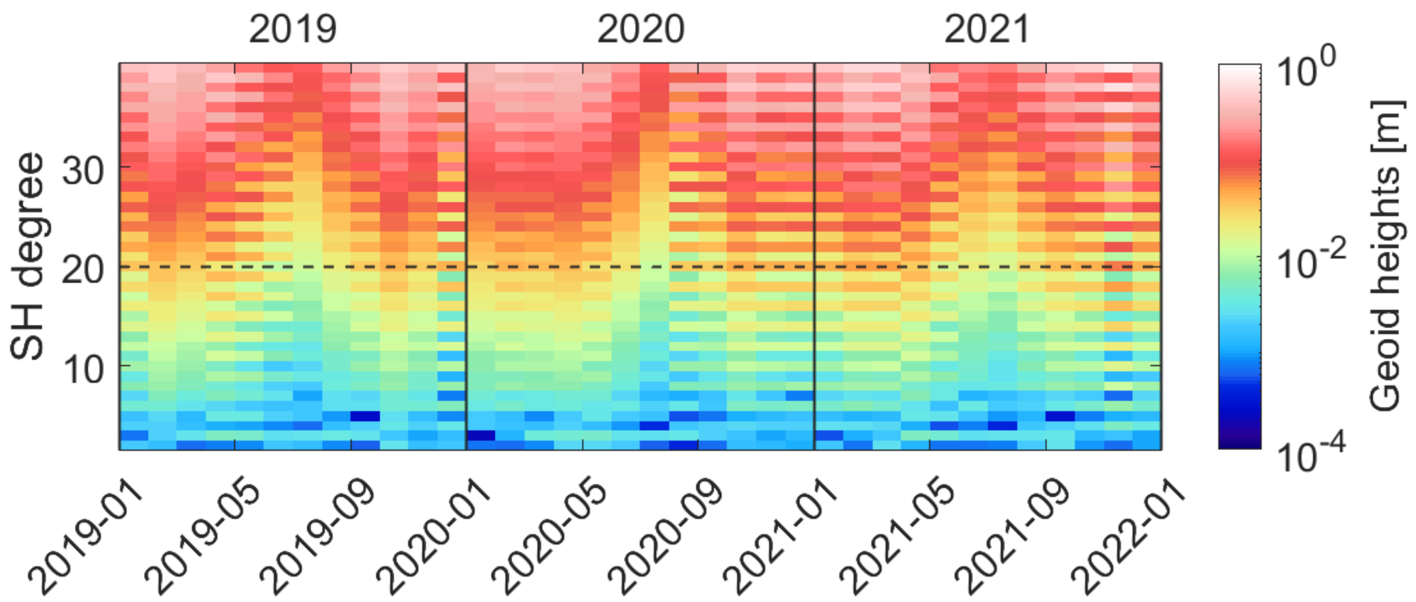
Swarm–Sentinel combination

- 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

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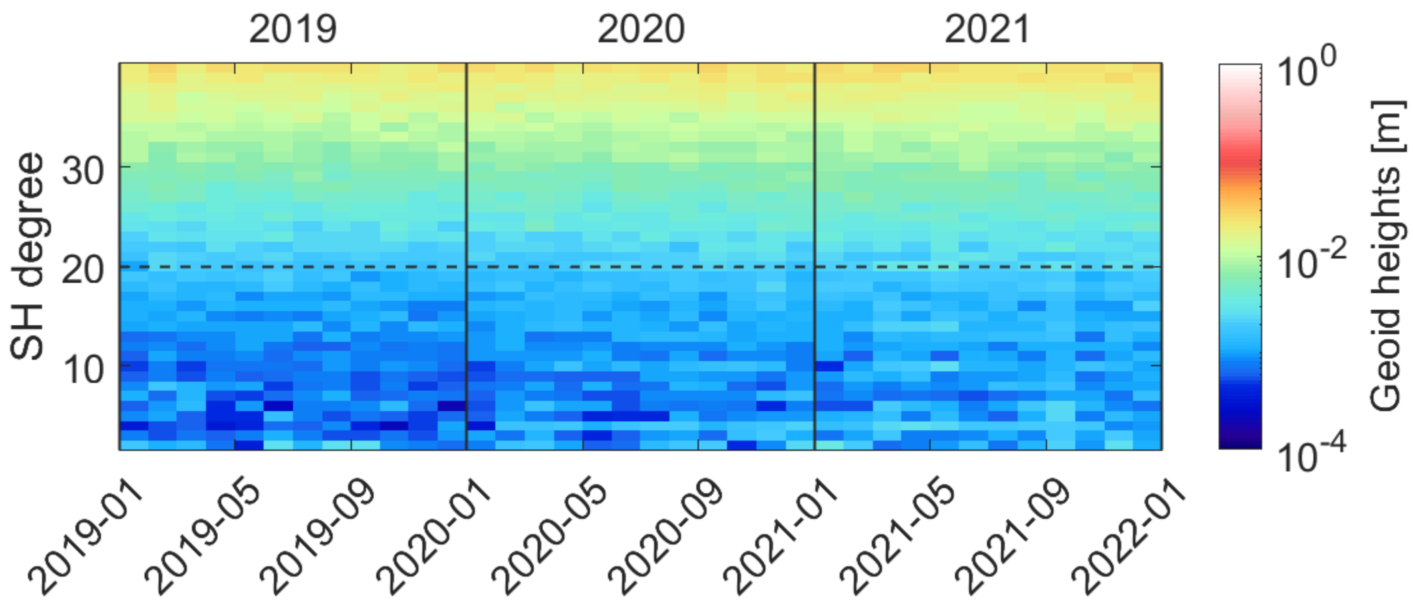

Zonal + near zonal coefficients are excluded form combination (solely based on Swarm data)

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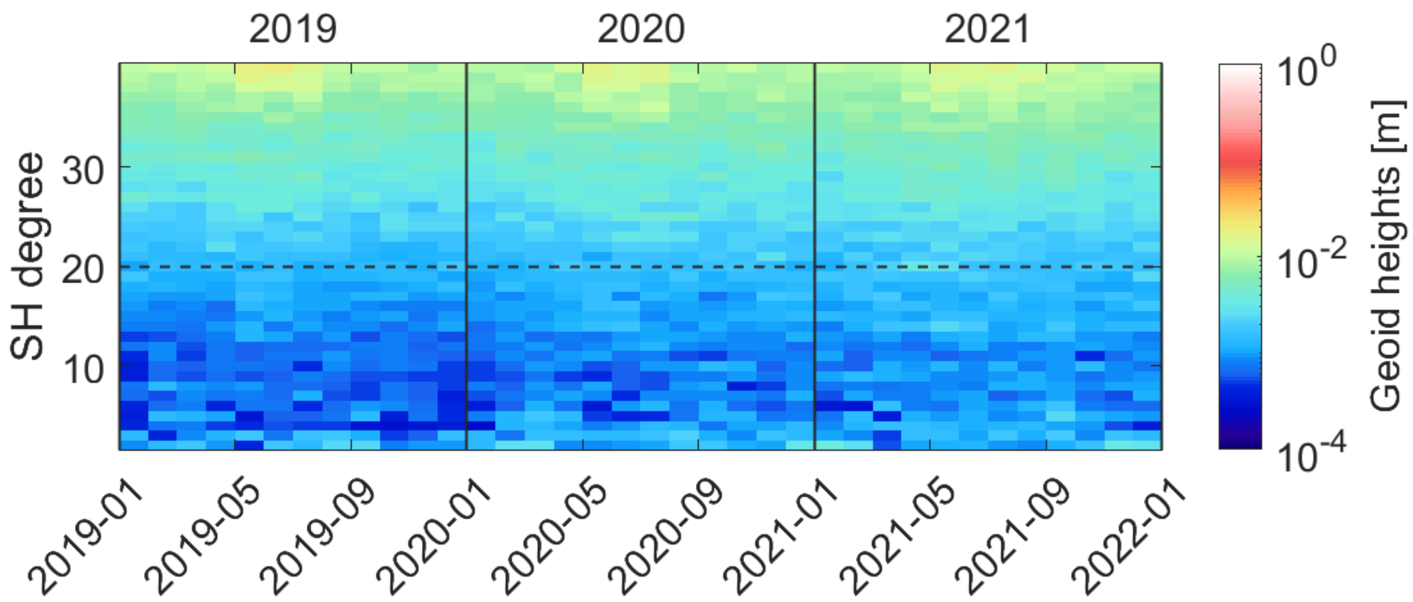
Swarm–Sentinel combination

- 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

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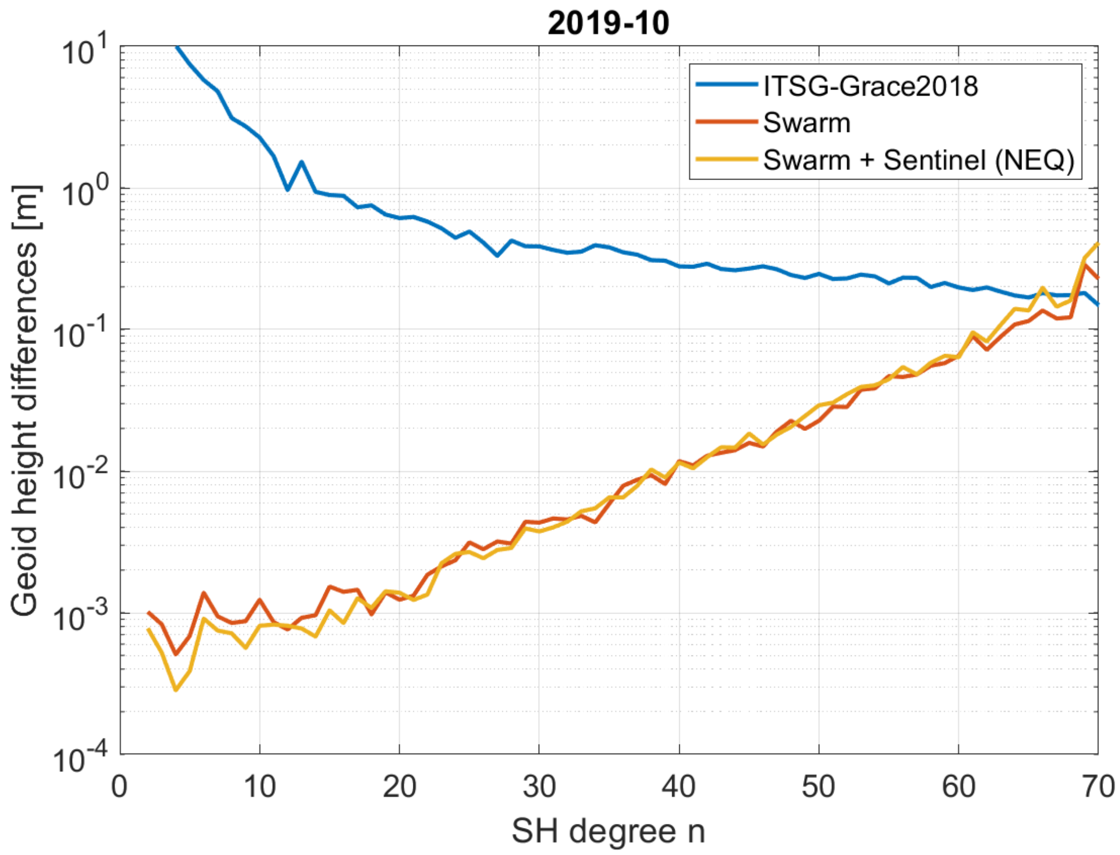
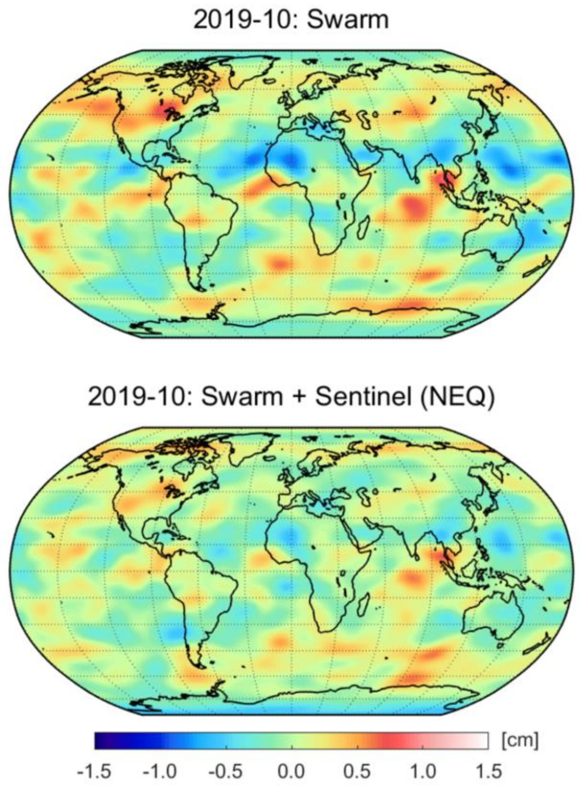
Swarm–Sentinel combination

- Difference degree amplitudes



Improvements are visible for degrees up to 15

- Geoid height differences (700 km Gauss filter)



Weighted RMS 0.24 cm

Global values

Weighted RMS 0.17 cm

Reduced RMS between 15 – 30% in most months

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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

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