

# Combined gravity field time series derived from Swarm and Sentinel GPS data

and GRACE-FO

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# Introduction

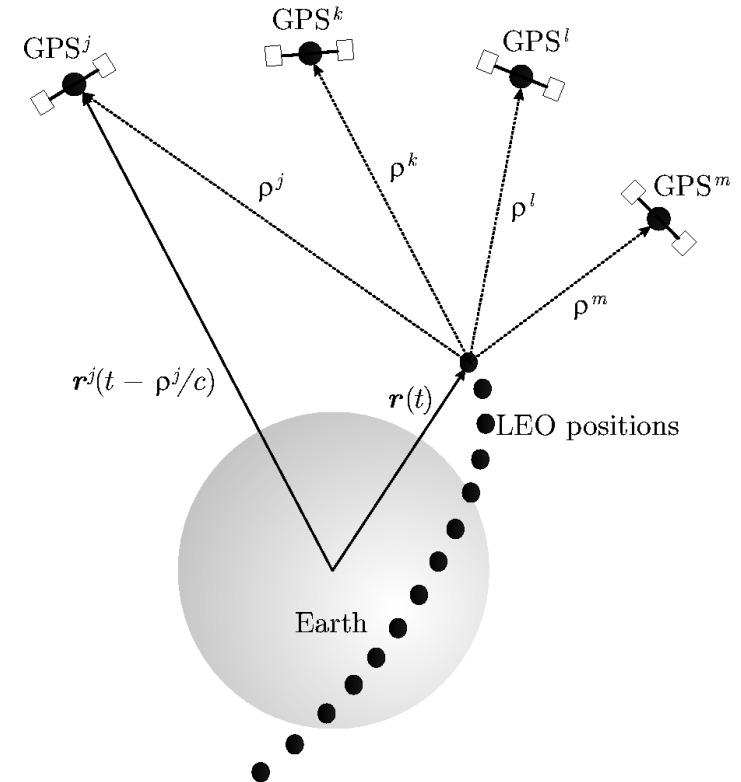
- **Motivation**
  - Any Low Earth Orbiting (LEO) satellite with a GPS receiver may serve as a gravity field sensor (in addition to dedicated missions)
  - GPS tracking data of LEO satellites may be used to derive large-scale (time-variable) gravity field information
- **Our goal:** Multi-LEO gravity field time series taking advantage of a
  - Large number of continuous observations
  - Complementary orbital configurations
- **Focus here:** contribution of Swarm, Sentinel and GRACE-FO GPS data
  - 1) Which quality can be expected from individual LEO gravity field solutions?
  - 2) Can a Swarm gravity field time series profit from additional LEO data?



Source: ESA, NASA

## Gravity field recovery

- Celestial Mechanics Approach (Beutler et al., 2010)
- Two-step procedure
  - 1) GPS tracking data → Kinematic orbit positions
  - 2) Kinematic orbit positions → Gravity field recovery
- Processing with the Bernese GNSS software



# Monthly gravity field solutions

May 2015 – April 2021

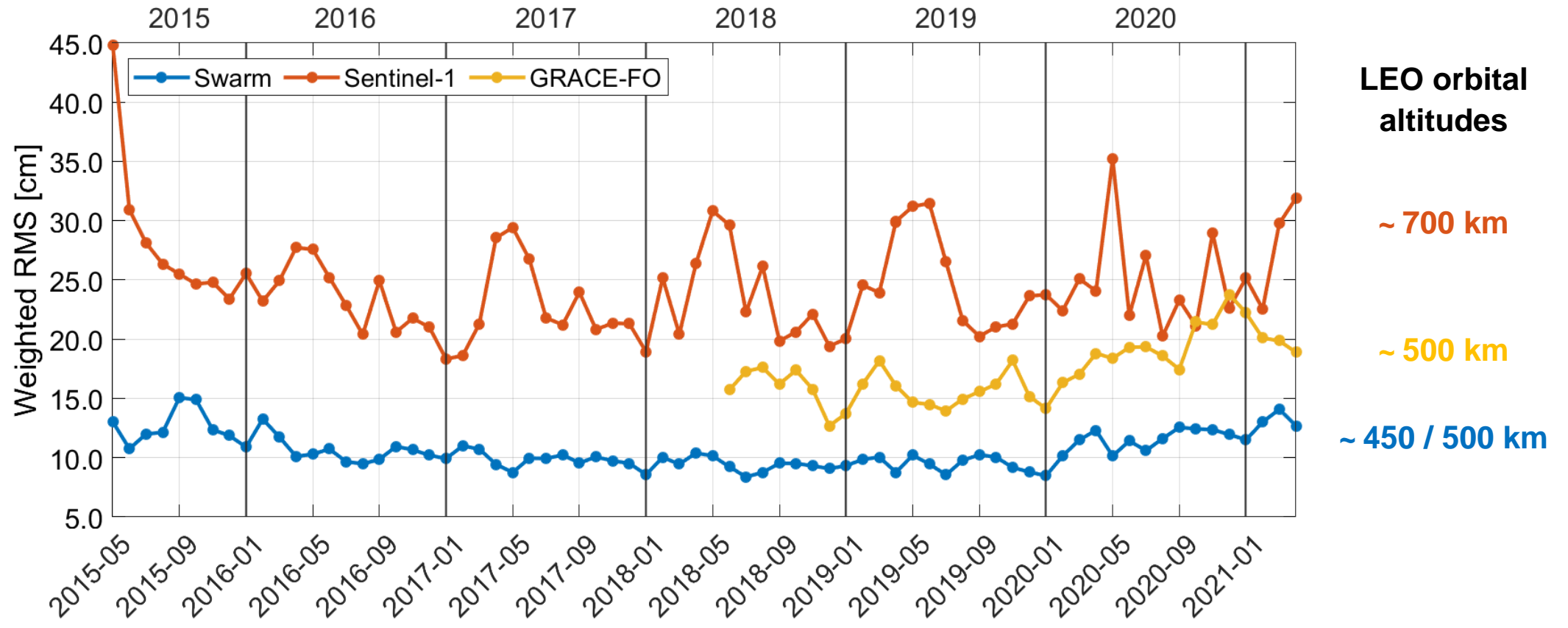
Swarm-A/B/C  
(3 LEOs)

Sentinel-1A/B  
(2 LEOs)

GRACE-FO-C/D  
(2 LEOs)

# Quality of LEO gravity field solutions

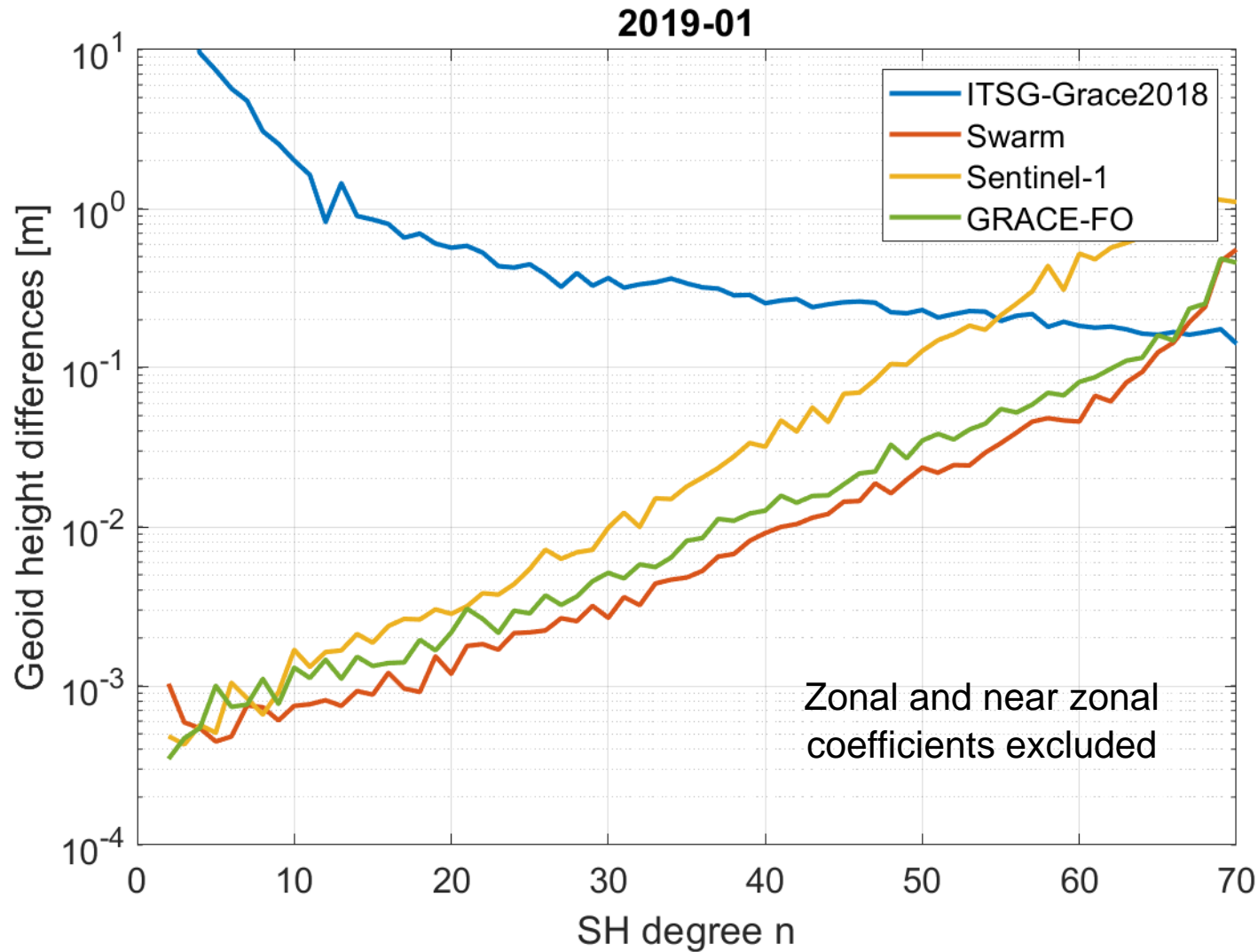
- Ocean RMS values of equivalent water height differences w.r.t. ITSG-Grace2018 (Mayer-Gürr et al., 2018)



700 km Gauss filtered

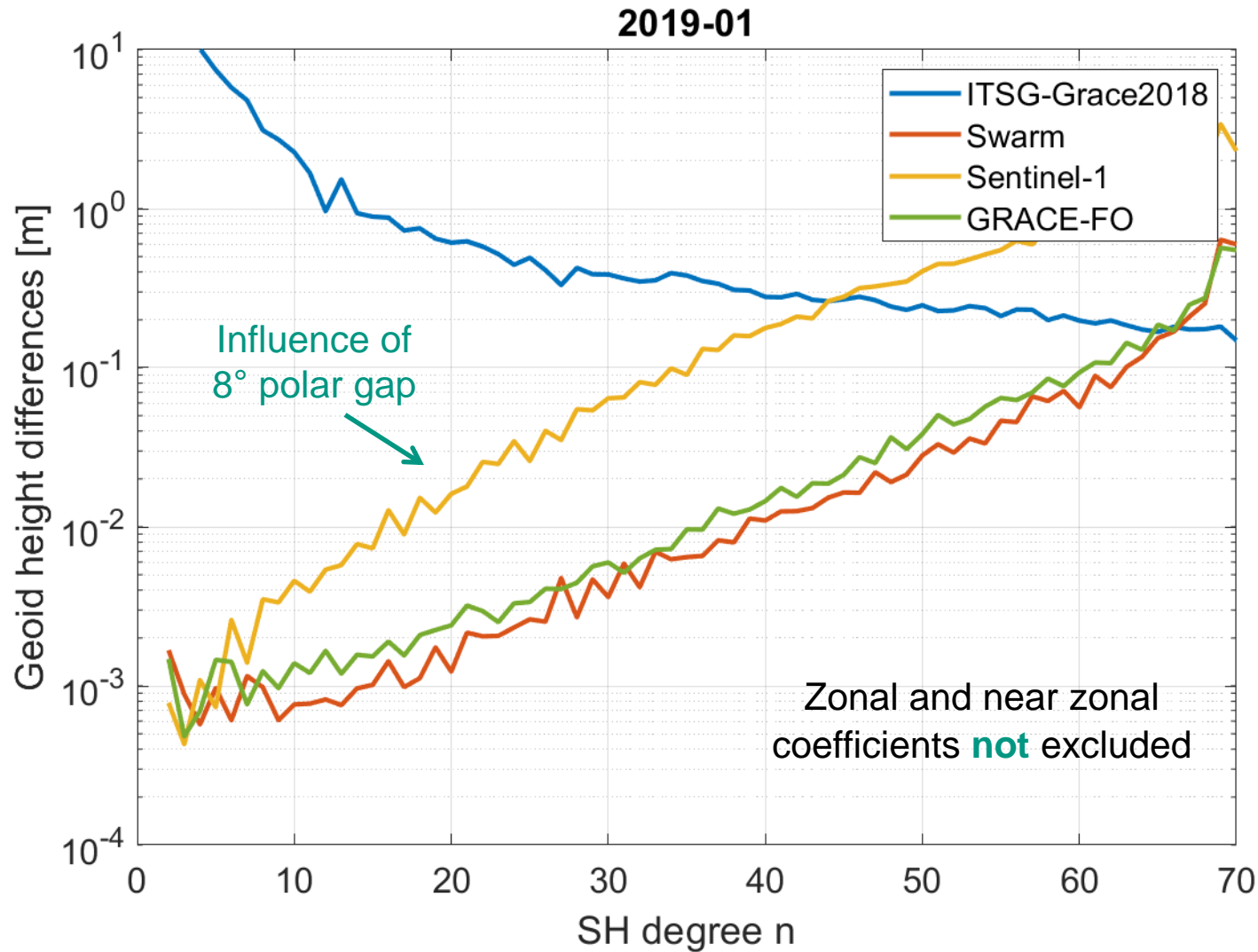
T. Grombein, M. Lasser, D. Arnold, U. Meyer, A. Jäggi: Combined gravity field time series derived from Swarm and Sentinel GPS data. Gravity, Geoid, and Height Systems 2022 Symposium (GGHS2022), Austin, USA, 12–14 Sep 2022

# Difference degree amplitudes w.r.t. ITSG-Grace2018



Sentinel-1 and GRACE-FO solutions may contribute to the low-degree coefficients

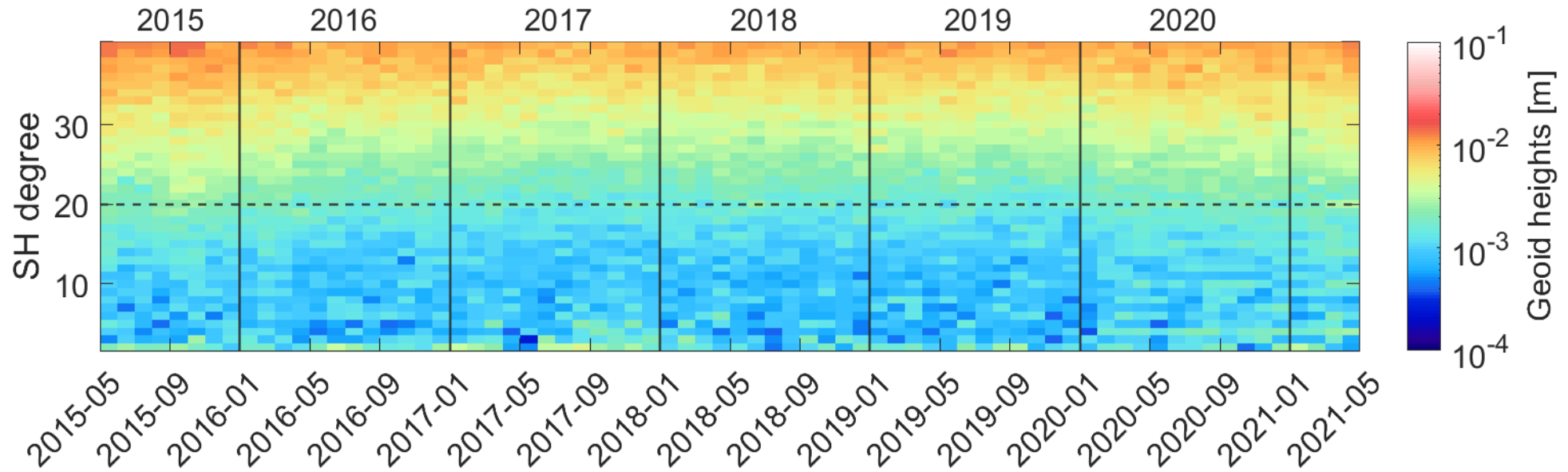
# Difference degree amplitudes w.r.t. ITSG-Grace2018



Sentinel-1 and GRACE-FO solutions may contribute to the low-degree coefficients

# Time series of monthly difference degree amplitudes

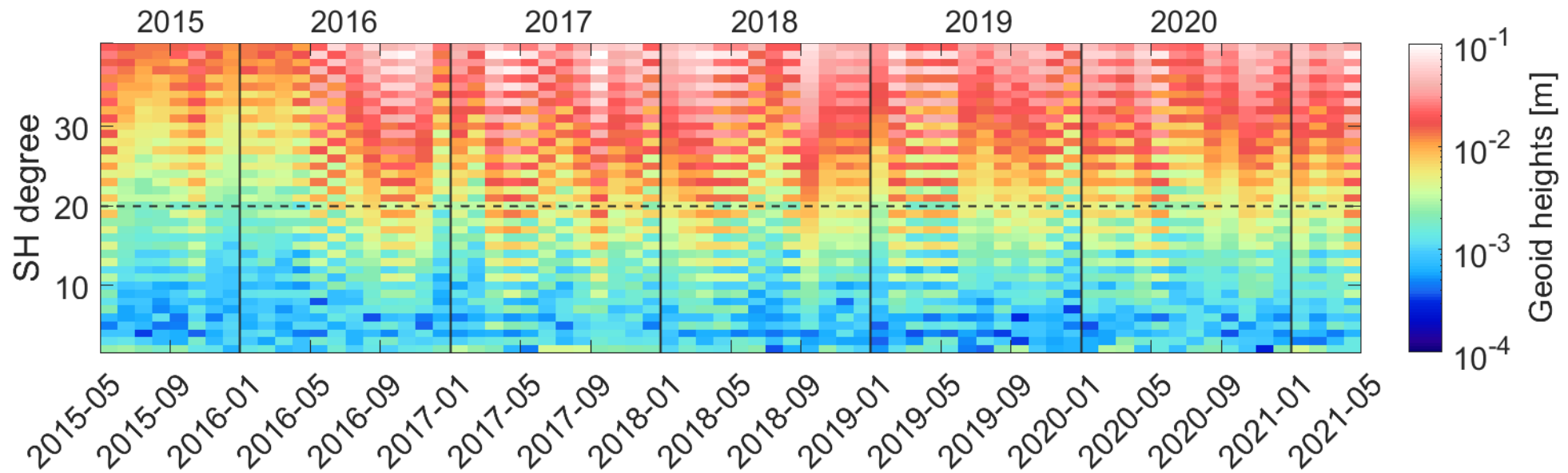
- Swarm-only solution





# Time series of monthly difference degree amplitudes

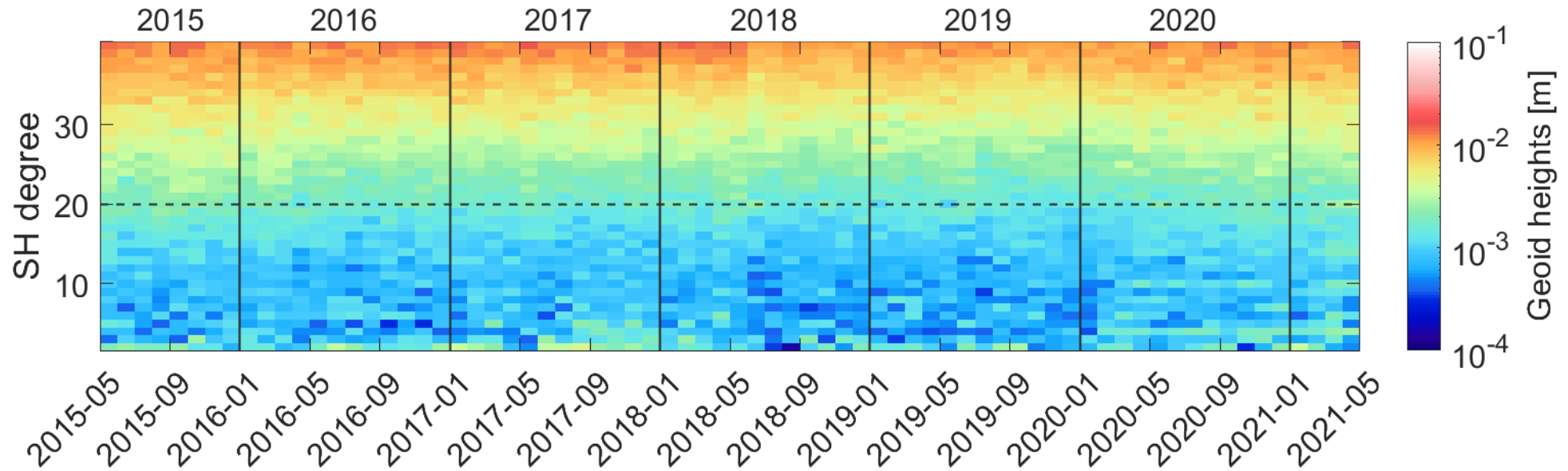
- Weighted combination at solution level (based on formal errors)



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

# Time series of monthly difference degree amplitudes

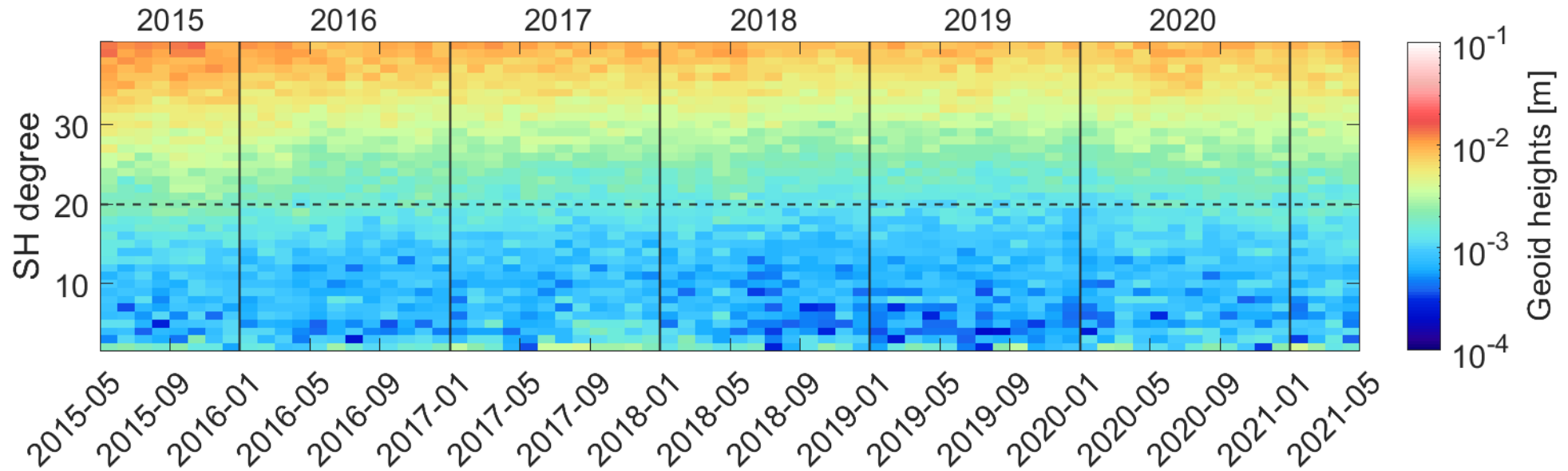
- Weighted combination at solution level (based on formal errors)



Zonal + near zonal coefficients are solely based on  
Swarm and GRACE-FO data

# Time series of monthly difference degree amplitudes

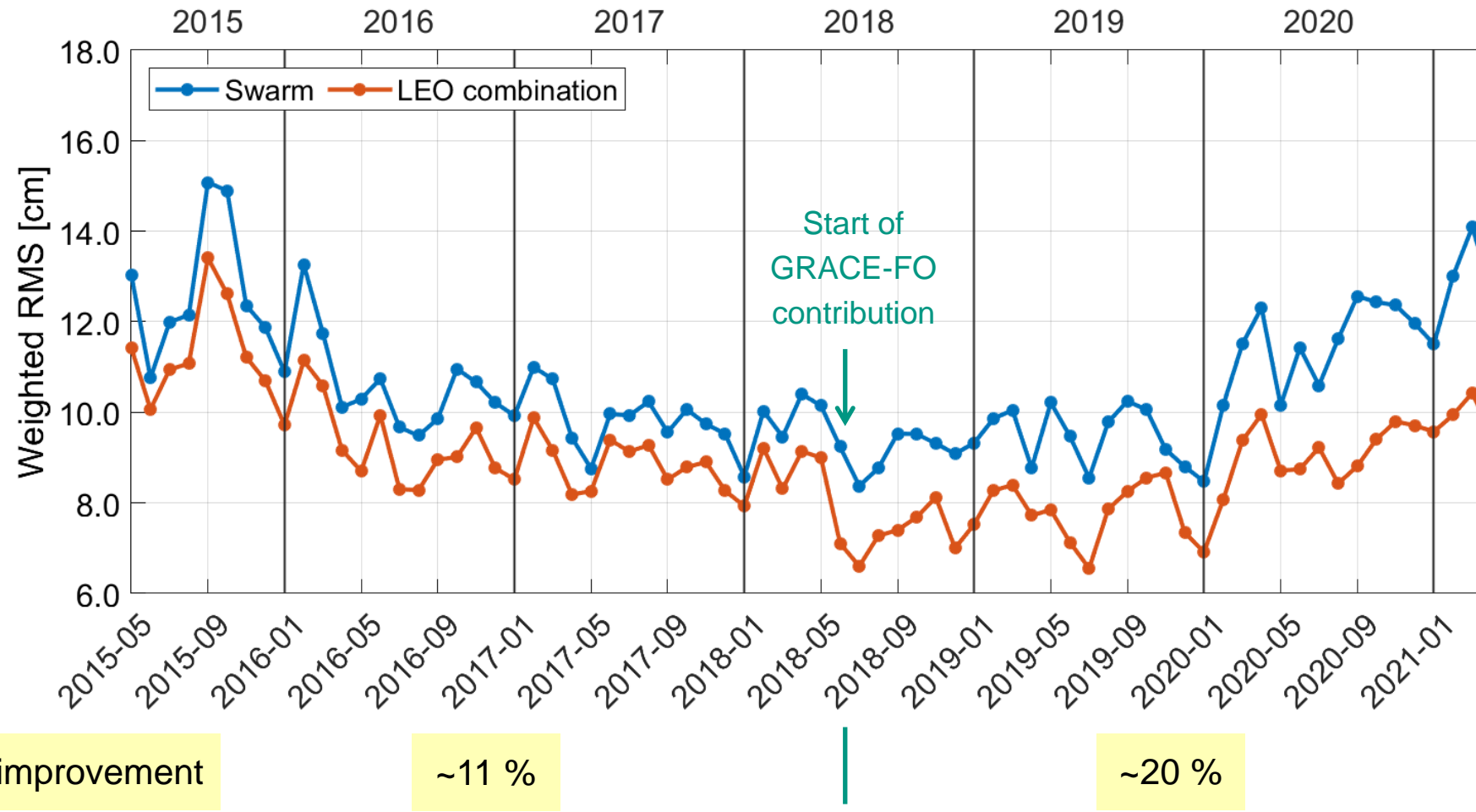
- Combination at normal equation (NEQ) level (using variance component estimation)



Quality of lower degrees can be further improved  
(no special handling of polar gap needed)

# Quality of combined gravity field solution

- Ocean RMS values of filtered EWH differences w.r.t. ITSG-Grace2018



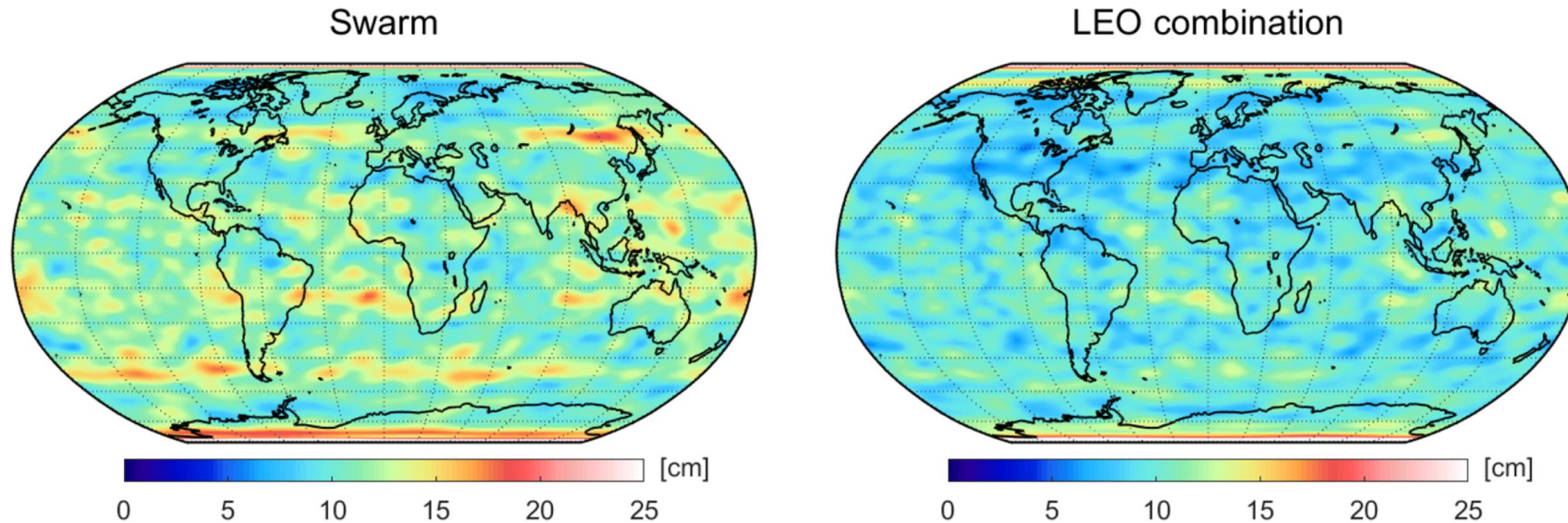
Mean RMS improvement

~11 %

~20 %

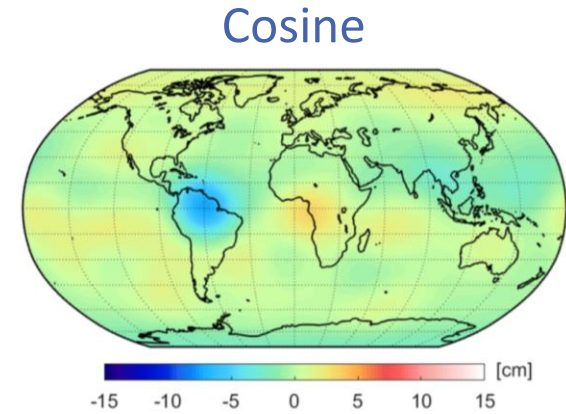
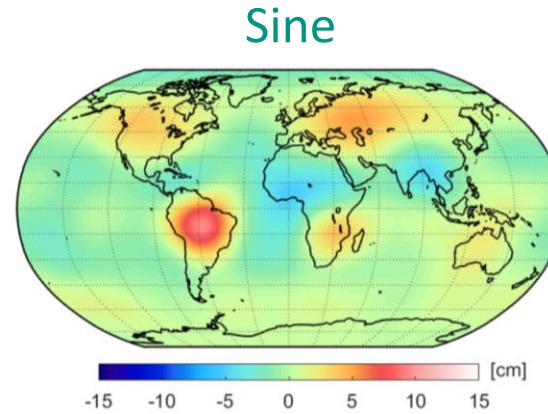
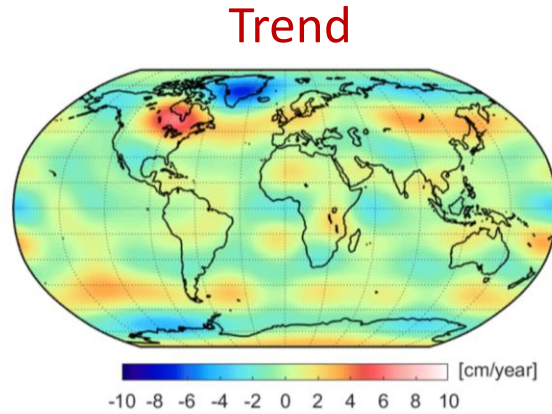
# Quality of combined gravity field solution

- RMS values over all months for each grid cell (EWH differences w.r.t. ITSG-Grace2018)

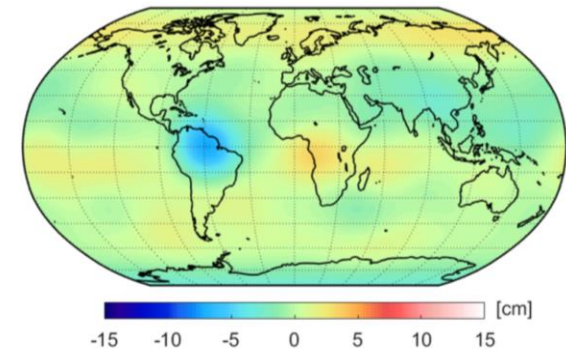
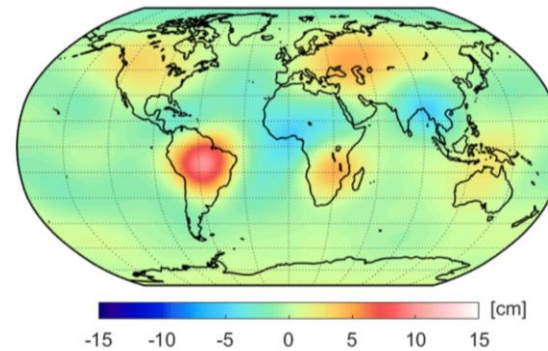
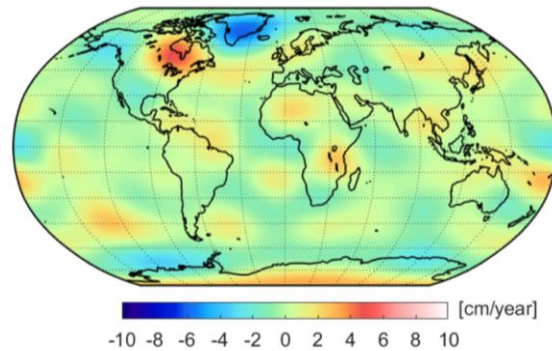


# Time-variable gravity field signals (fit of monthly solutions)

Swarm



LEO  
combination



500 km Gauss-filtered

1500 km Gauss-filtered

1500 km Gauss-filtered

Reduction of  
Ocean RMS

24 %

12 %

11 %

# Summary and outlook

- Combined gravity field time series based on GPS data of 7 LEOs from 6 years
- Main findings
  - Swarm gravity field time series can be improved using further LEO GPS data
  - Sentinel-1 / GRACE-FO data can contribute to the most relevant lower degrees
  - Influence of Sentinel's polar gap propagates into combination at solution level
  - Full potential is exploited by a combination at normal equation level
- Outlook: Extension of time series and inclusion of data from further LEO satellites



Source: ESA, NASA

# Thank you for your attention