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

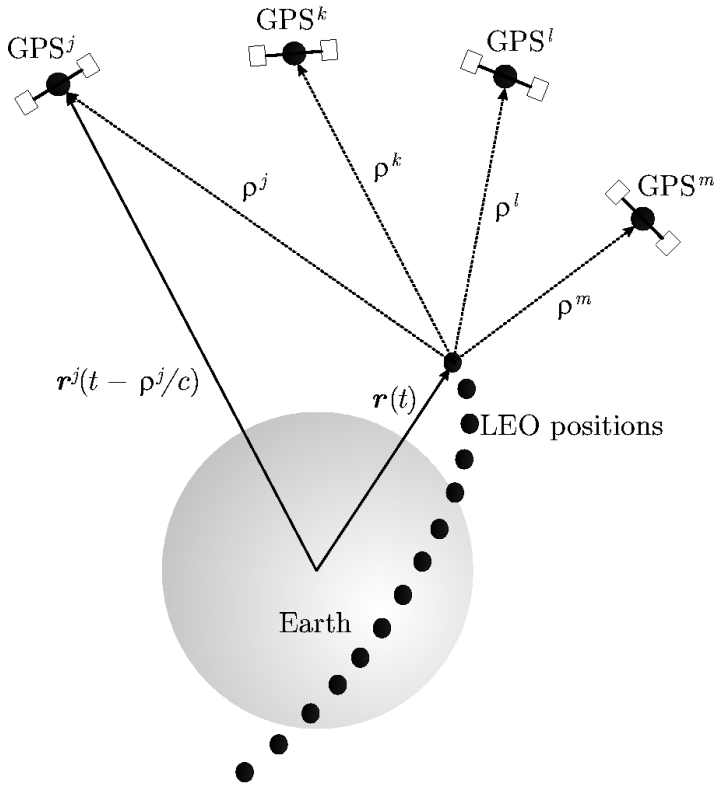
1) Which quality can be expected from individual LEO gravity field solutions?
2) Can a Swarm gravity field time series profit from additional LEO data?

Source: ESA, NASA

Introduction

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



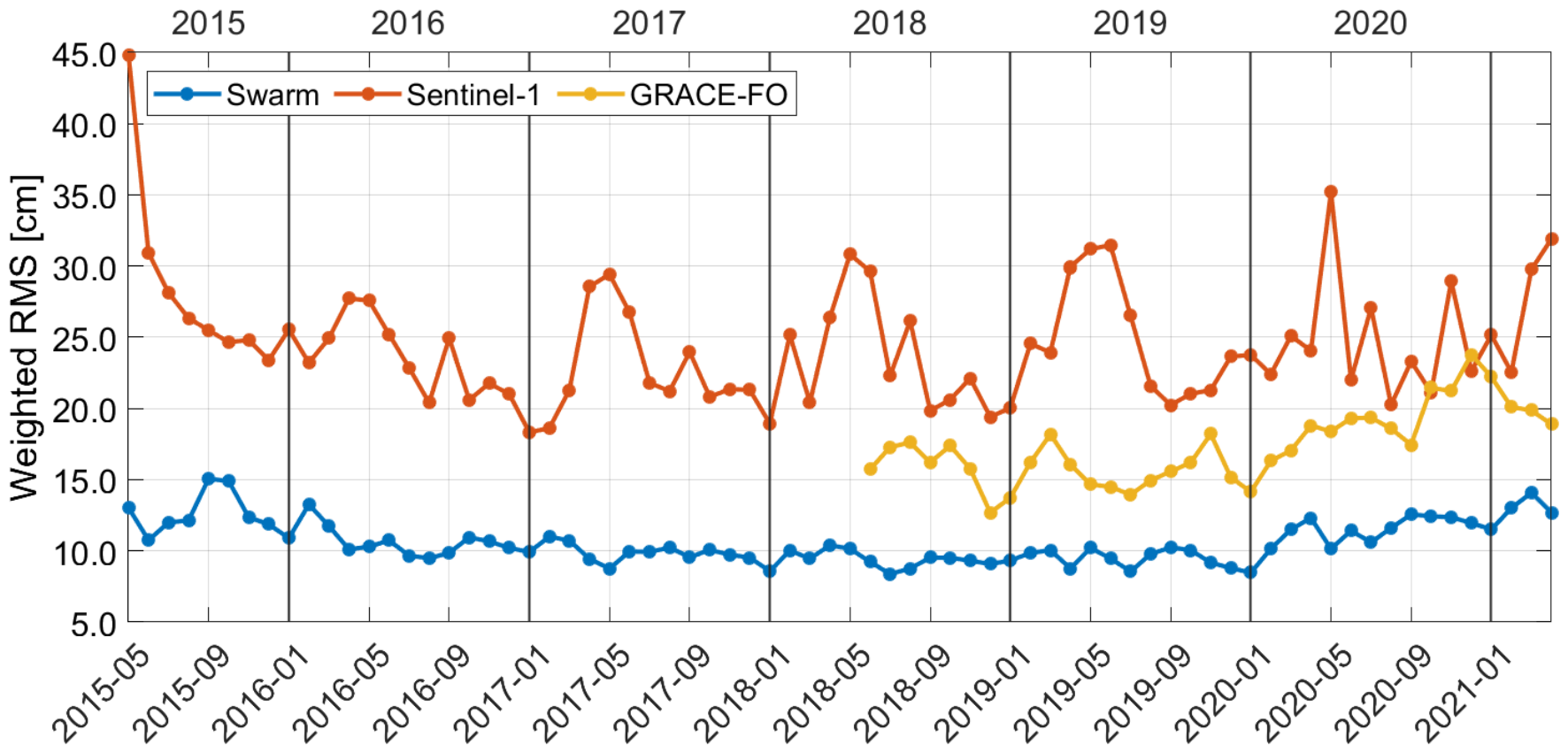
Monthly gravity field solutions

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)



LEO orbital altitudes

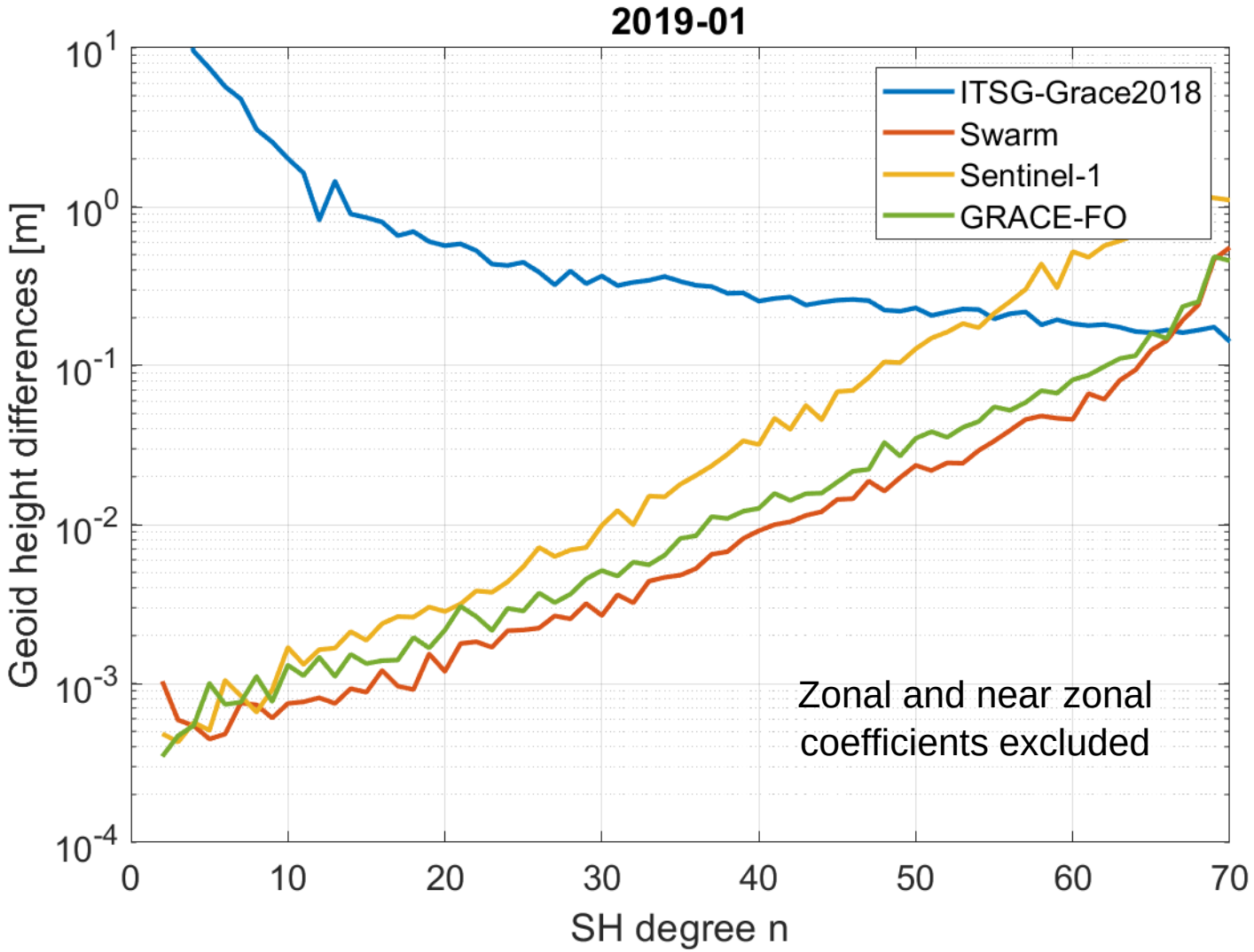
~ 700 km

~ 500 km

~ 450 / 500 km

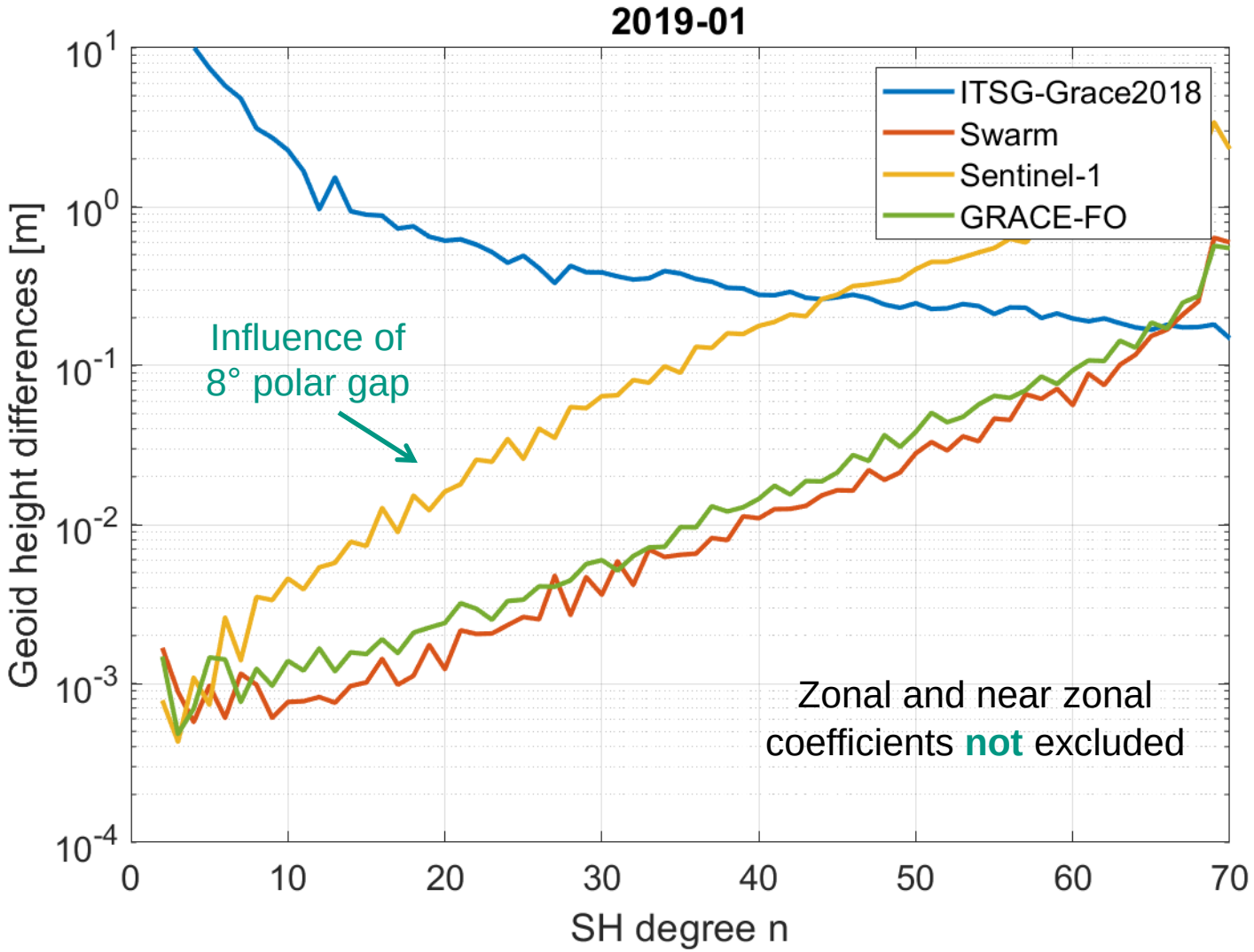
700 km Gauss filtered

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



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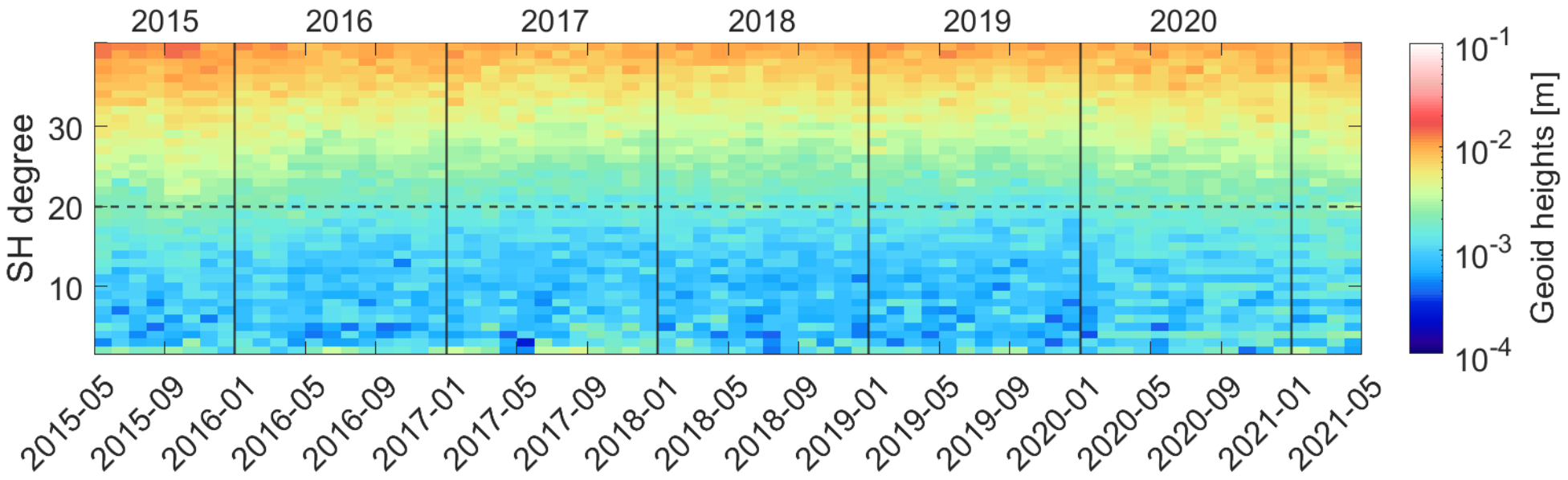
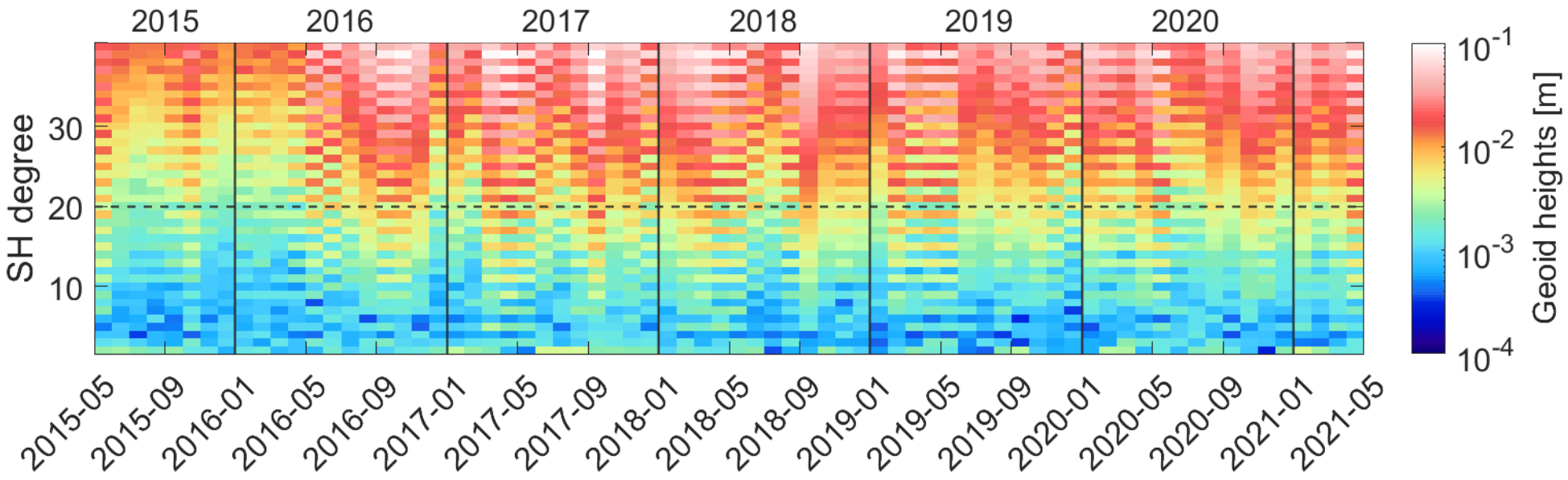
Time series of monthly difference degree amplitudes

- Swarm-only solution



Time series of monthly difference degree amplitudes

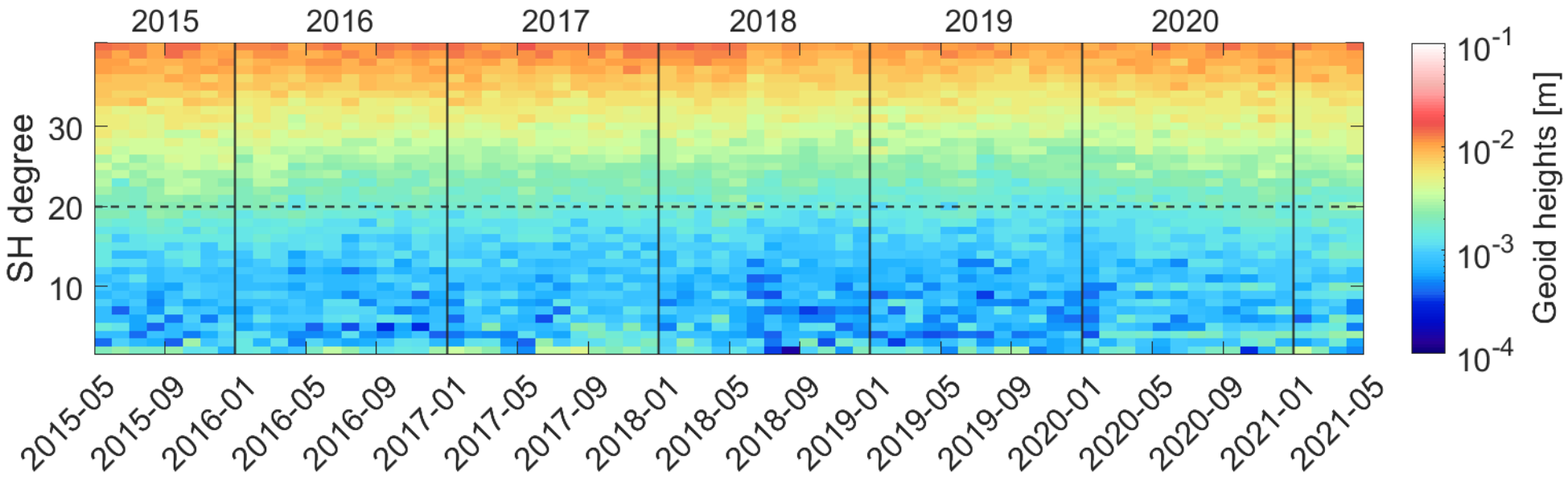
- Weighted combination at solution level (based on formal errors)



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

Time series of monthly difference degree amplitudes

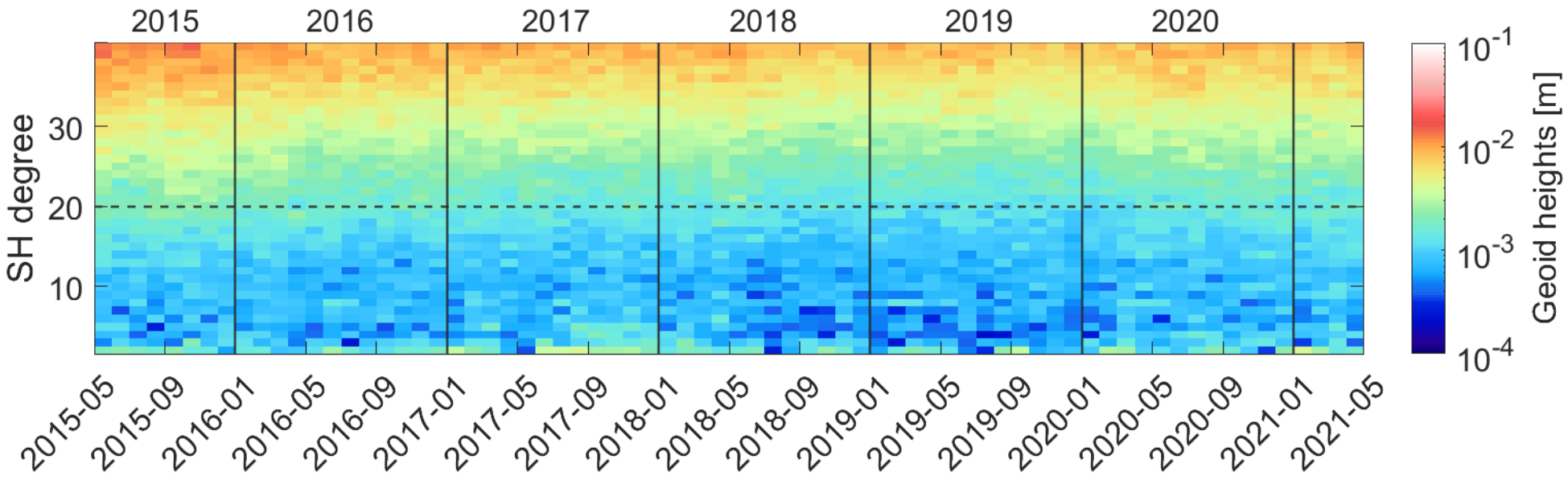
- Weighted combination at solution level (based on formal errors)



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)

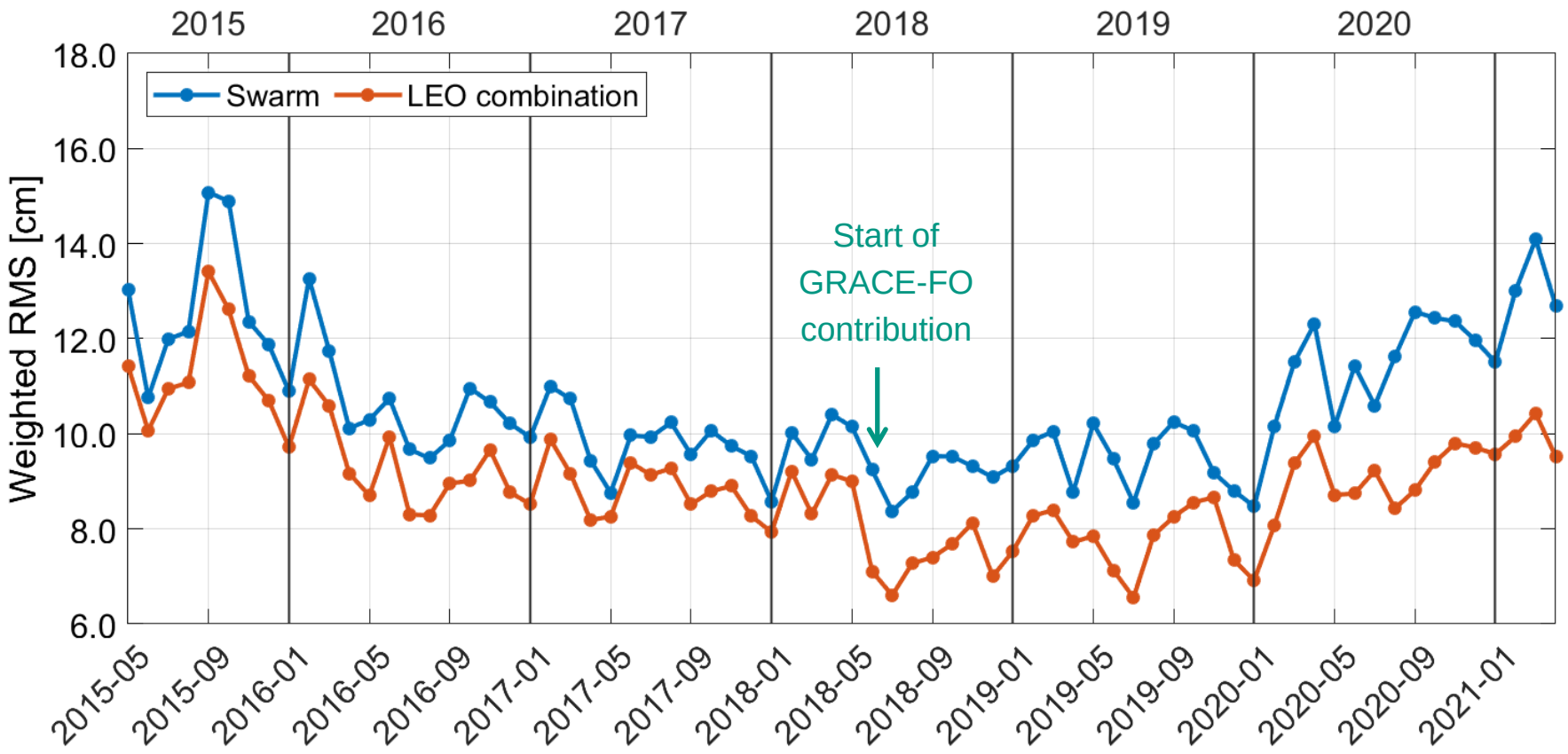


Quality of lower degrees can be further improved

(no special handling of polar gap needed)

Quality of combined gravity field solution

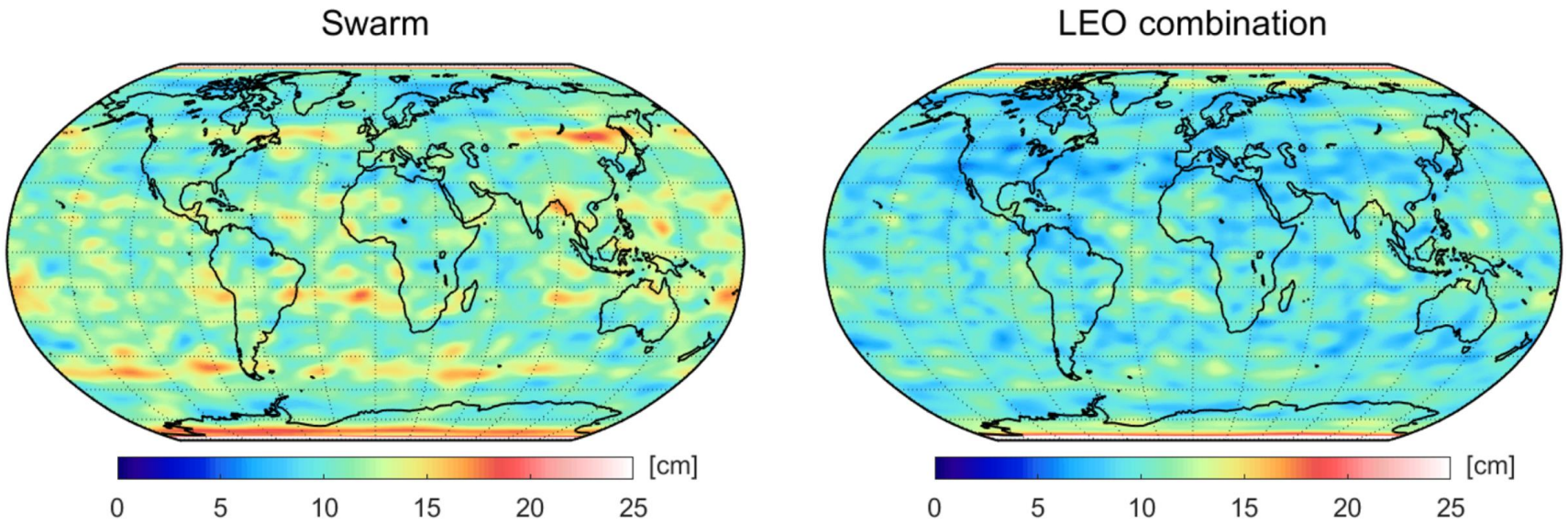
- Ocean RMS values of filtered EWH differences w.r.t. ITSG-Grace2018



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)



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

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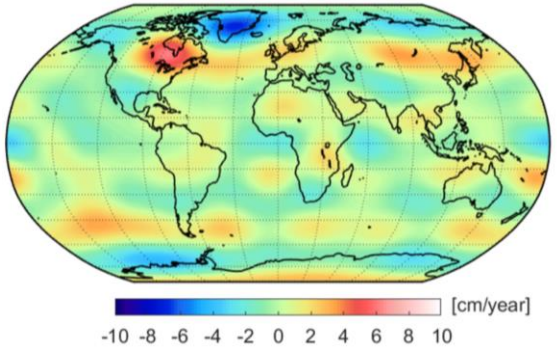
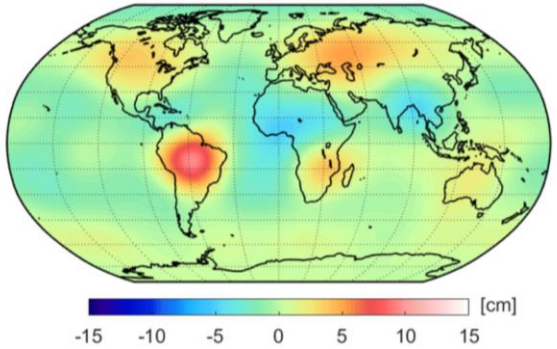
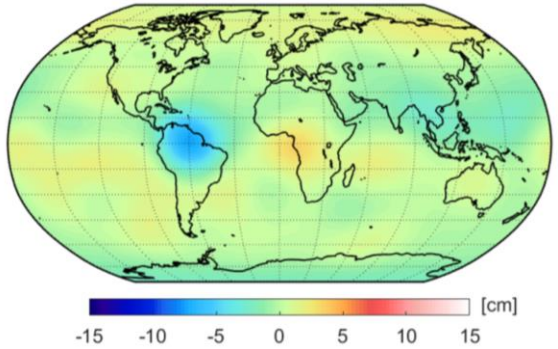
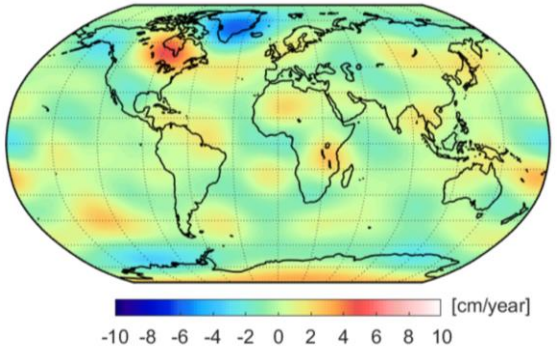
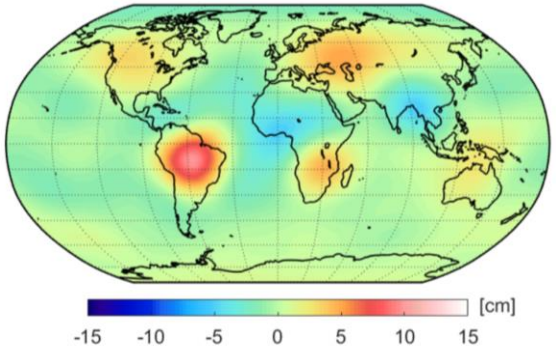
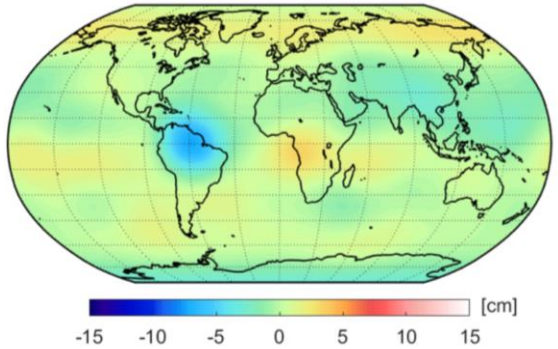
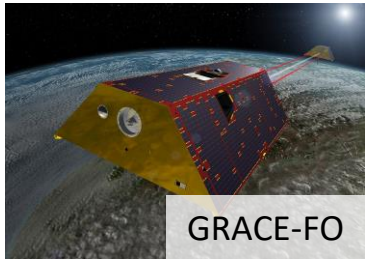
	Trend	Sine	Cosine
Swarm			
LEO combination			
	500 km Gauss-filtered	1500 km Gauss-filtered	1500 km Gauss-filtered
Reduction of Ocean RMS	24 %	12 %	11 %

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