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

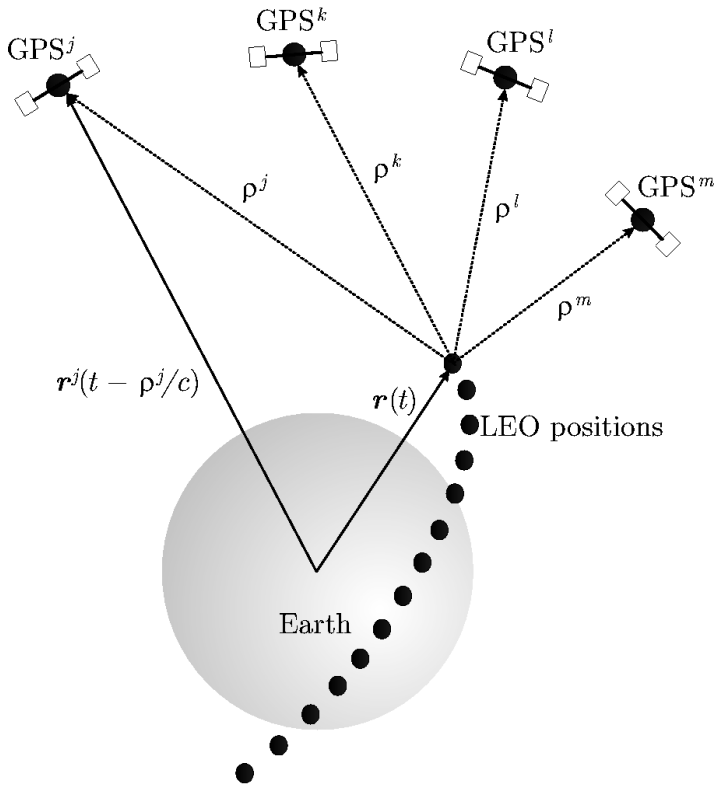
1) Which quality can be expected from individual LEO gravity field solutions?
2) Can a Swarm gravity field time series profit from additional LEO data?

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



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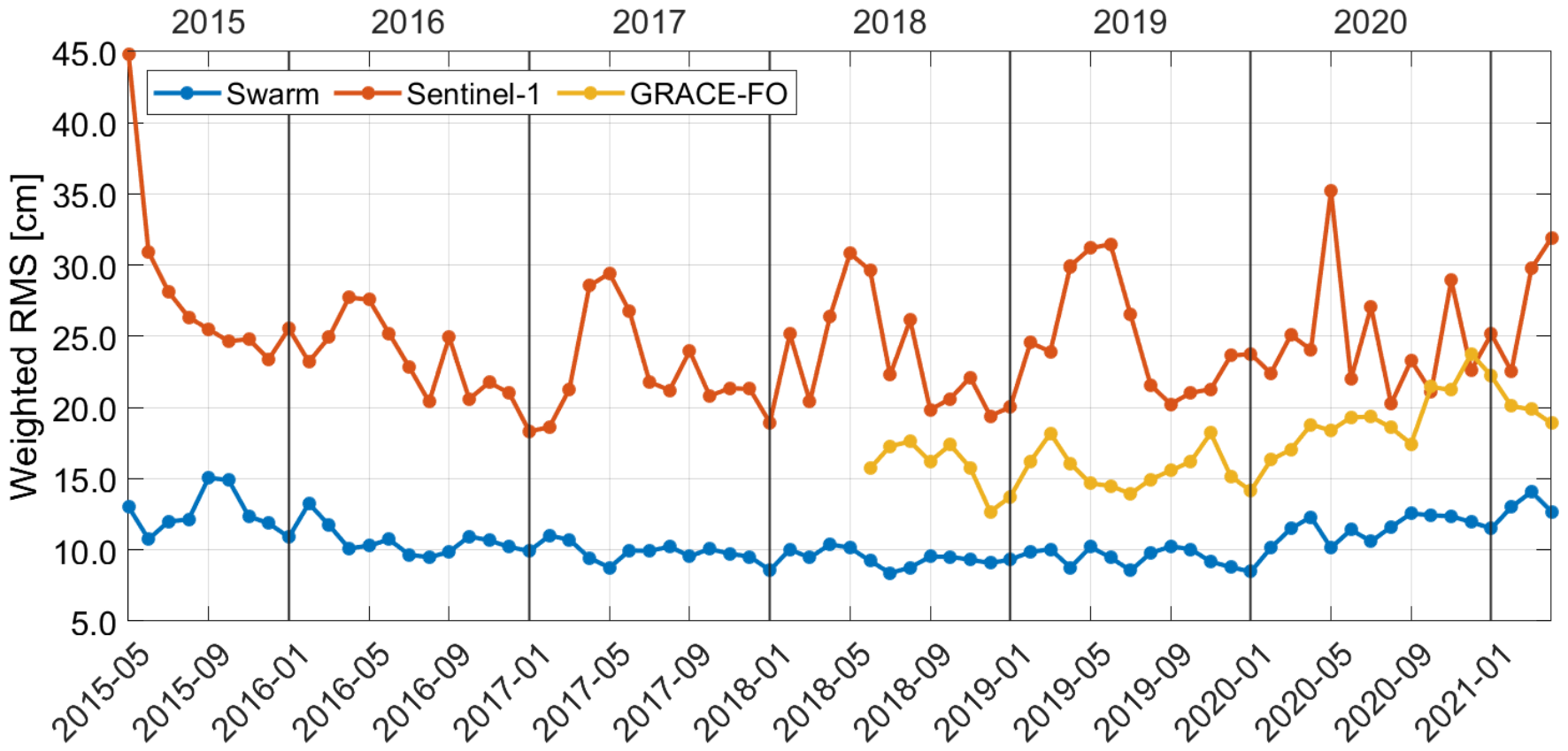
Monthly gravity field solutions

May 2015 – April 2021

Swarm-A/B/C	Sentinel-1A/B	GRACE-FO-C/D
(3 LEOs)	(2 LEOs)	(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

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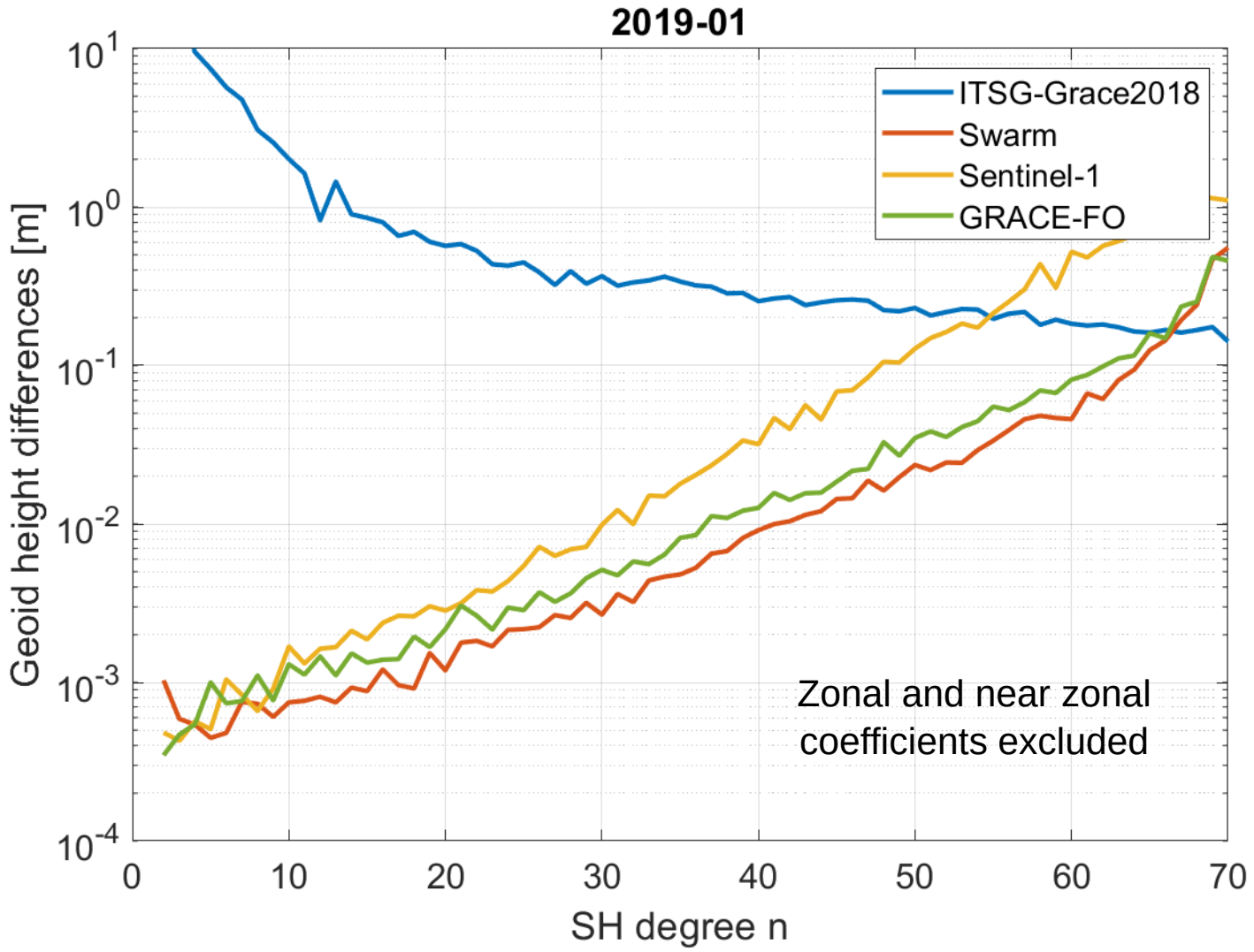
Difference degree amplitudes w.r.t. ITSG-Grace2018



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

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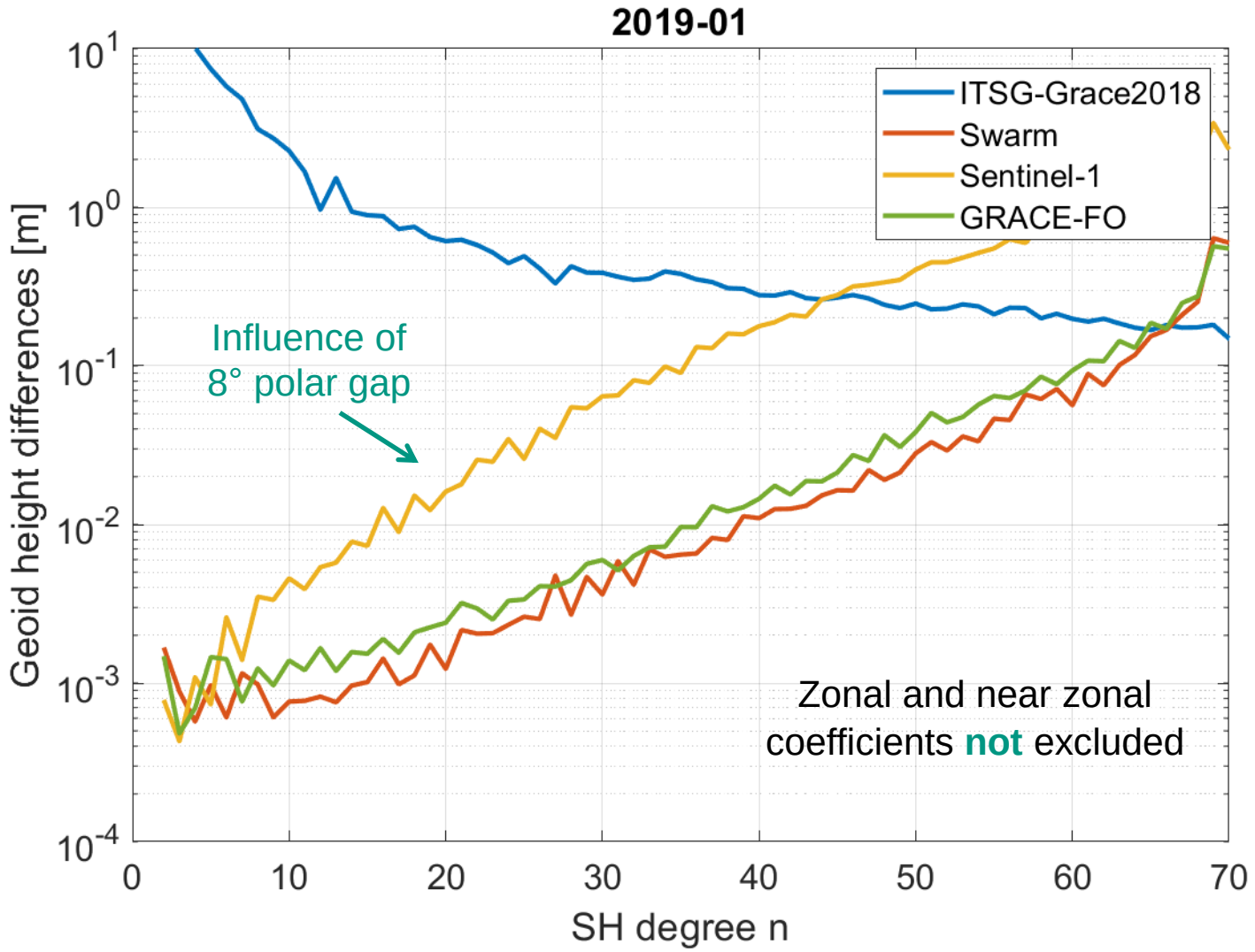

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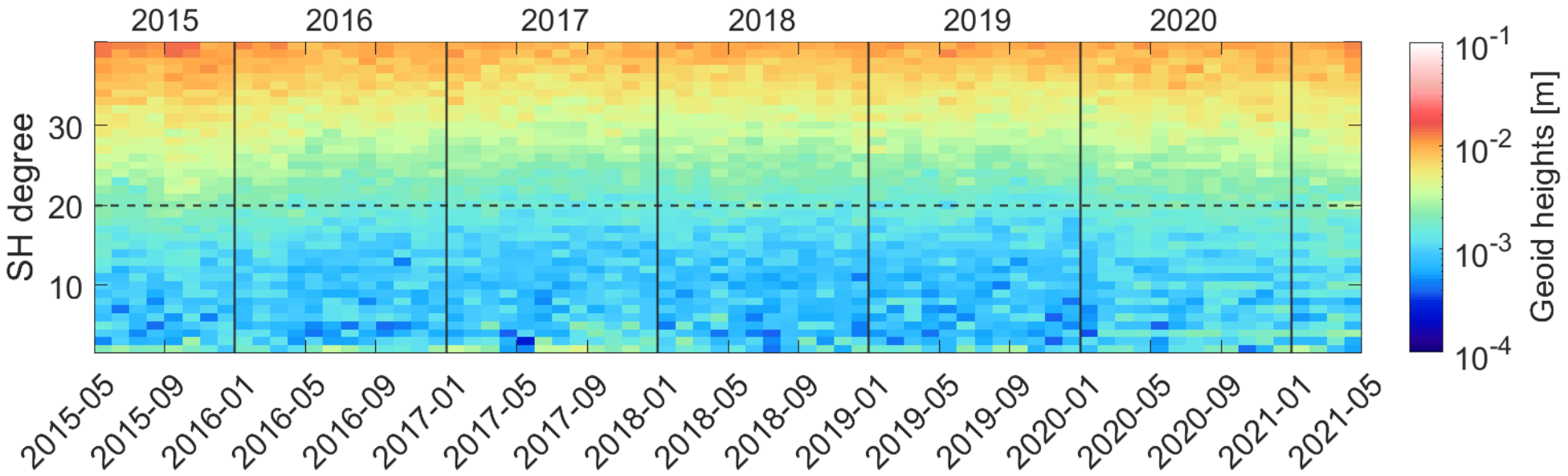
Time series of monthly difference degree amplitudes

- Swarm-only solution



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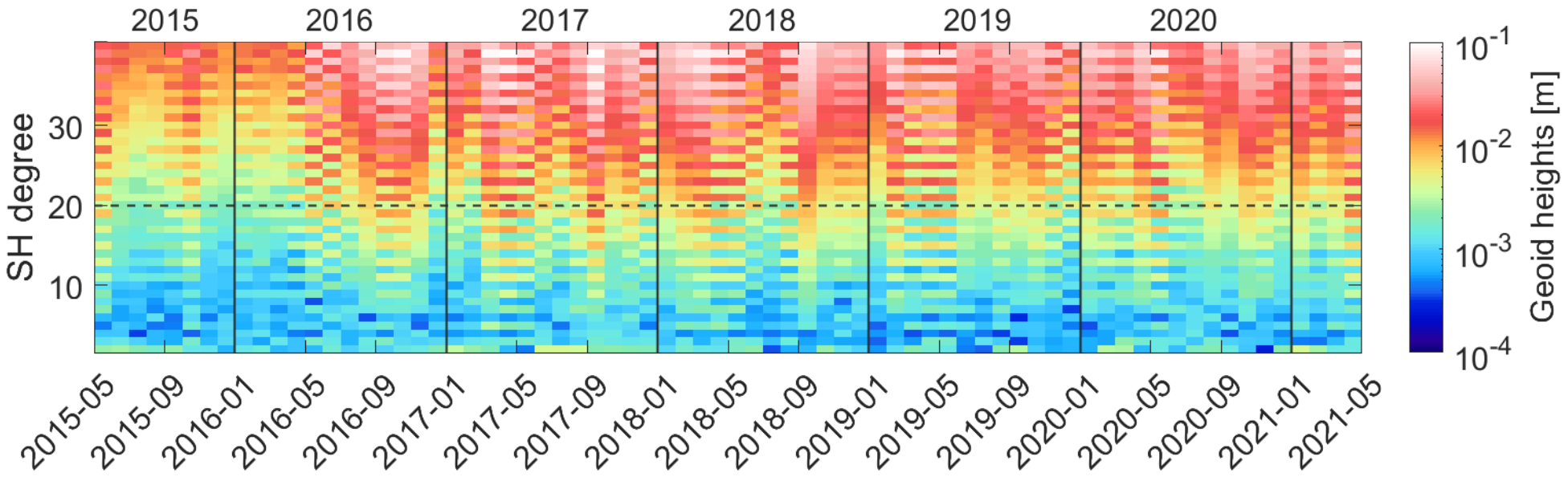
Time series of monthly difference degree amplitudes

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



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

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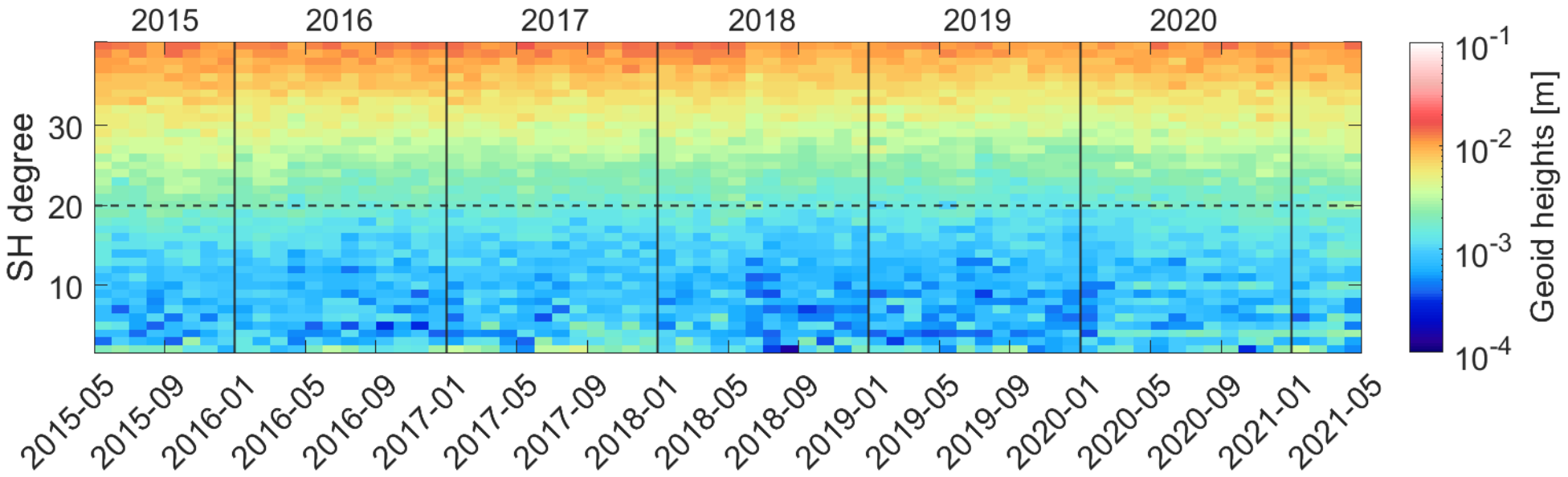

Zonal + near zonal coefficients are solely based on Swarm and GRACE-FO data

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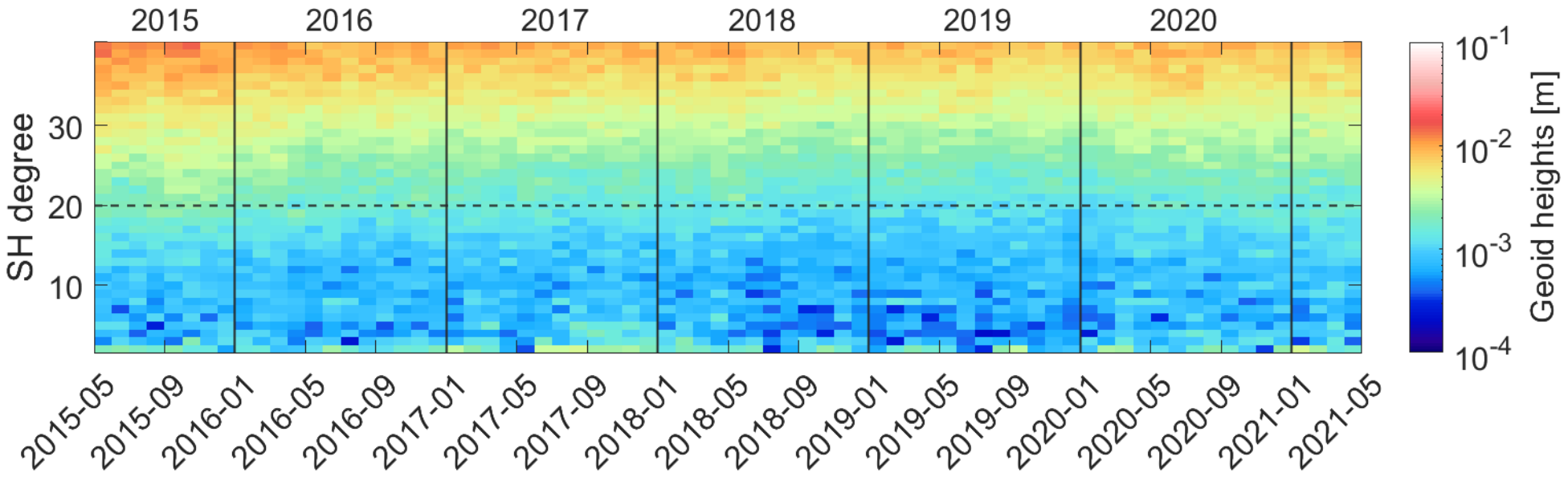
Time series of monthly difference degree amplitudes

- 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)

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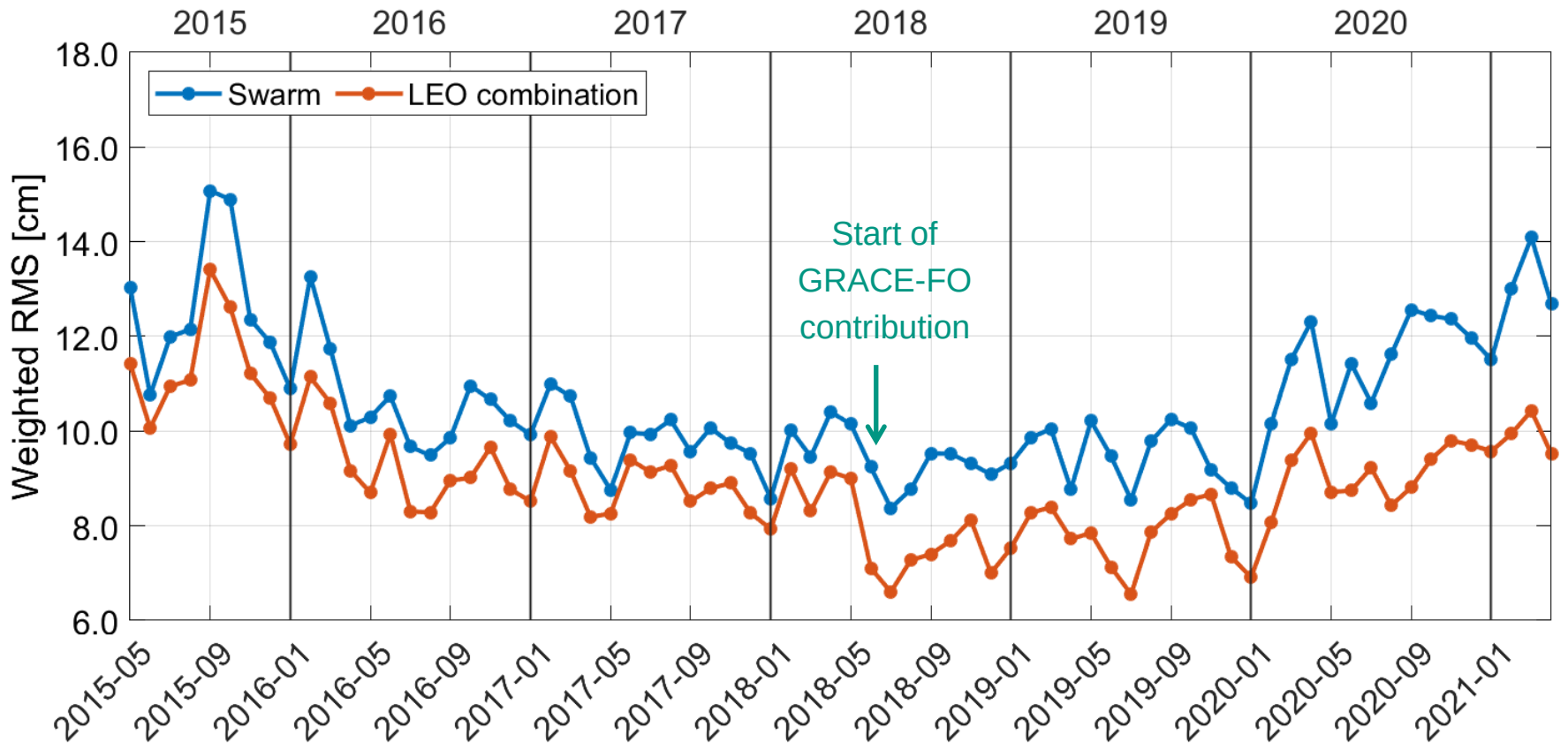
Quality of combined gravity field solution

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



Mean RMS improvement	~11 %	~20 %

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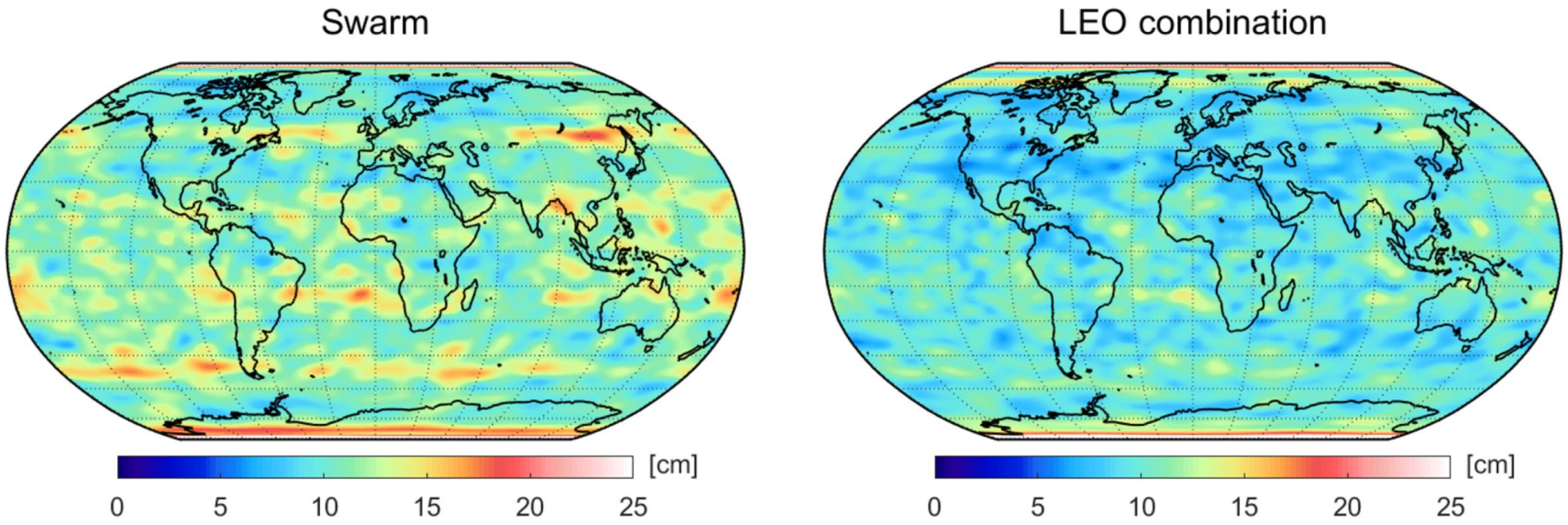
Quality of combined gravity field solution

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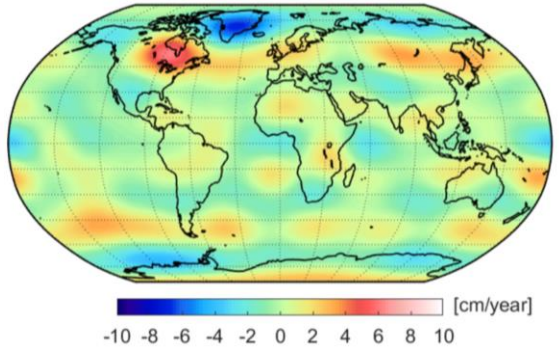
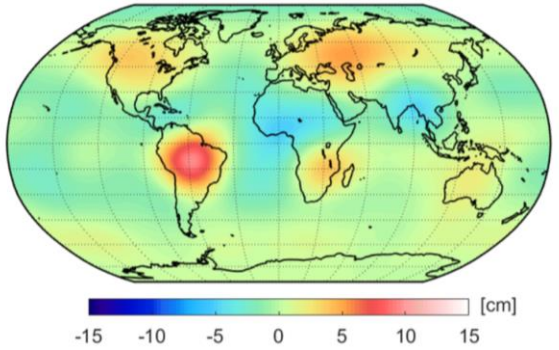
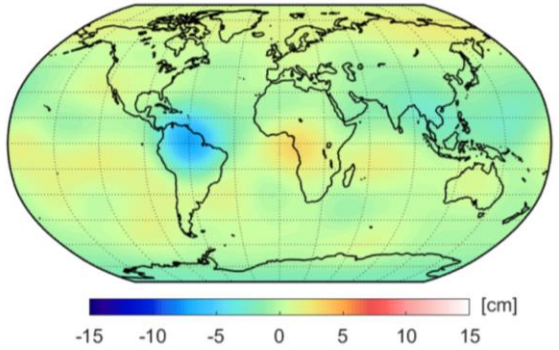
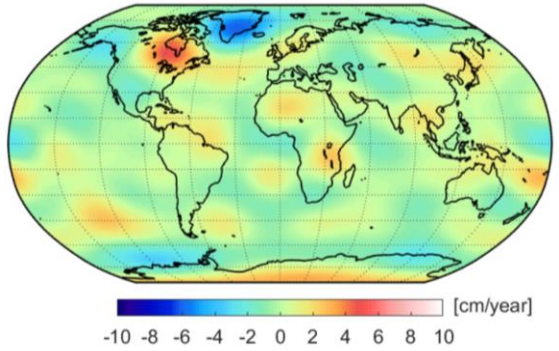
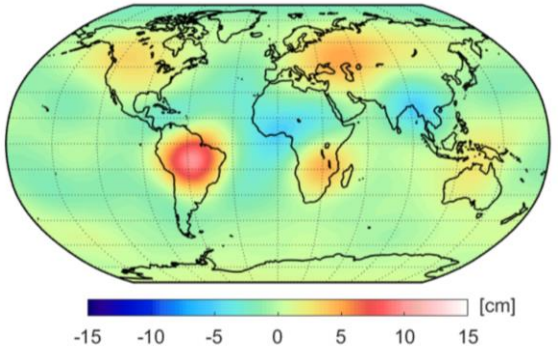
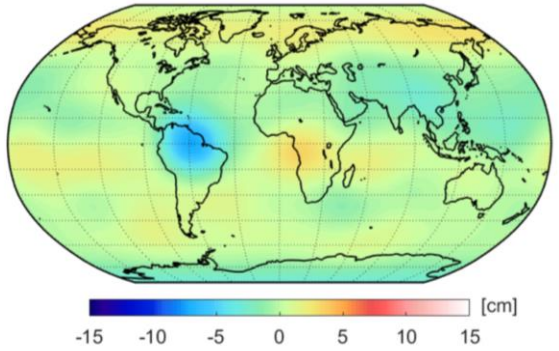
	Trend	Sine	Cosine
Swarm			
LEO combination			
	500 km Gauss-filtered	1500 km Gauss-filtered	1500 km Gauss-filtered
Reduction of Ocean RMS	24 %	12 %	11 %

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

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Thank you for your attention