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Gravity field recovery with nano-satellites of the Spire constellation

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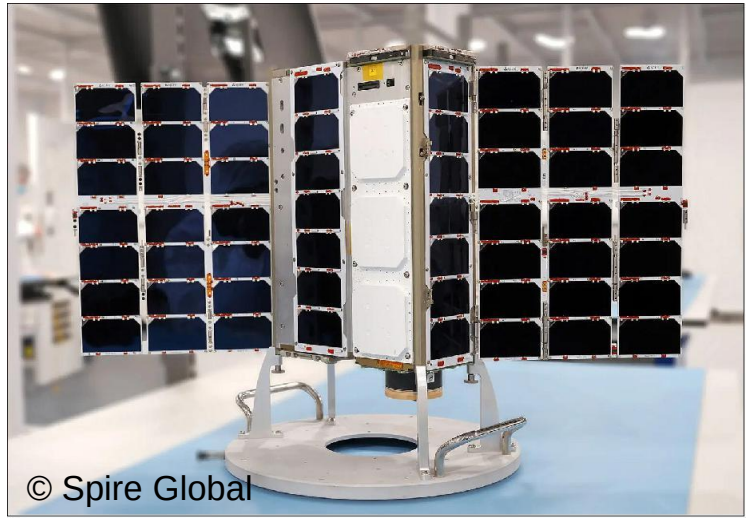
Introduction

Nano-satellites as gravity field sensors

- A huge number of nano-satellites is collecting GPS data
- Data allows to recover large-scale gravity field information
- Big potential to increase the spatial-temporal coverage
- However: limited data access and quality

Spire Global constellation

- More than 100 nano-satellites in low Earth orbit
- CubeSats (standardized platform, low cost)
- High-quality dual-frequency GPS receivers
- Data provision via ESA project (Third Party Mission)



10 x 10 x 34 cm, 4.7 kg

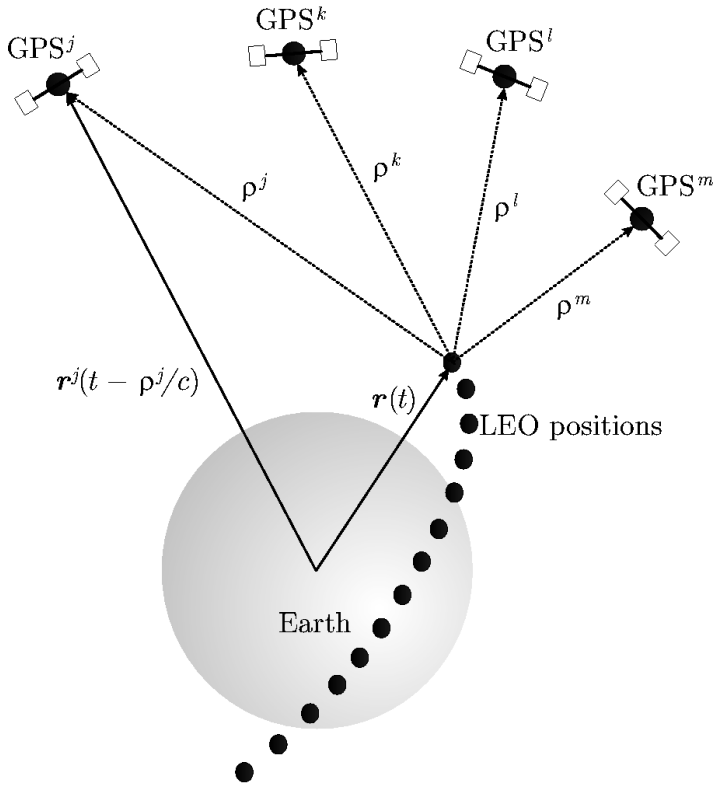
Research questions

1) What can be expected from monthly Spire-based gravity fields?

2) Can a Swarm gravity field profit from additional Spire data?

Method overview

- Orbit and gravity field recovery
  - Celestial Mechanics Approach
  - Two-step procedure
    1) GPS tracking data → Kinematic orbit positions
    2) Kinematic orbit positions → Gravity field recovery



- Processing with the Bernese GNSS software
  - GNSS products of the CODE analysis center
  - In-flight calibrated phase center variation (PCV) maps
  - Unmodeled forces are absorbed by empirical parameters

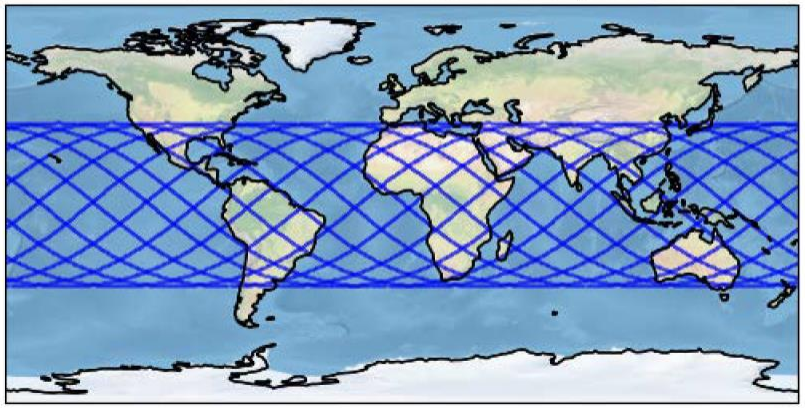
Data overview (May – Oct 2020)

Spire CubeSats	Altitude	Inclination	Sampling
 FM099 FM101 FM102	~ 505 km	~ 97.5°	1s
 FM103 FM104 FM106 FM107 FM108	~ 530 km	~ 97.5°	1s
 FM115	~ 570 km	~ 37.0°	1s

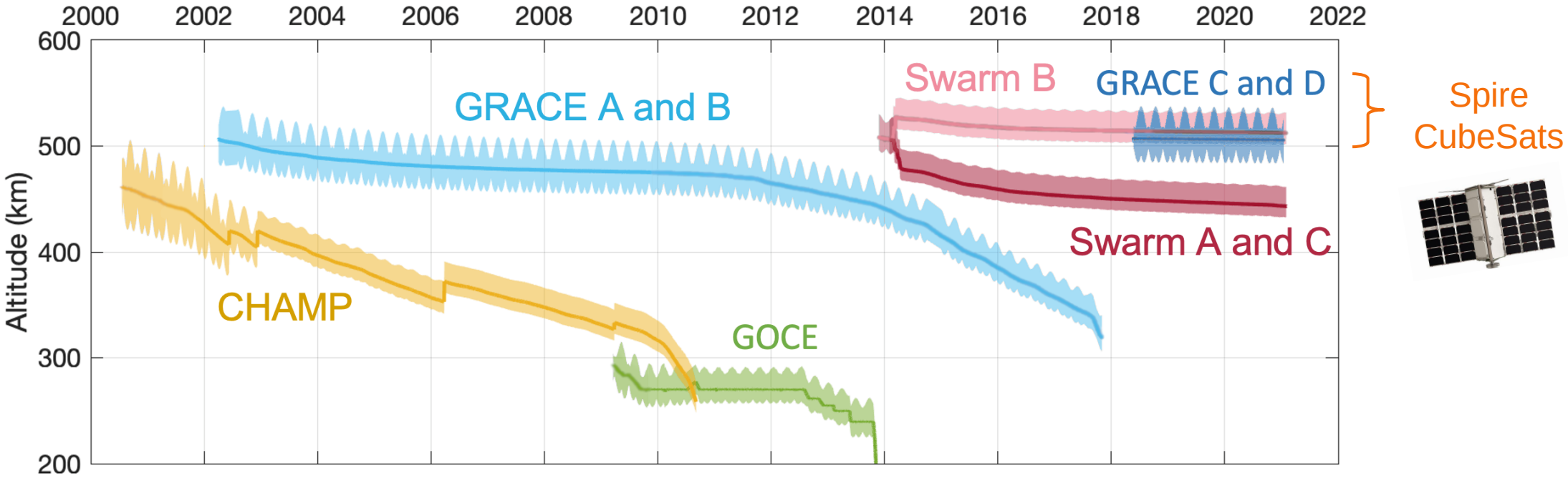
Data overview (May – Oct 2020)

Selected Spire CubeSats	Altitude	Inclination	Sampling
FM099, FM101, FM102			
FM103, FM104, FM106, FM107, FM108			
FM115	~ 570 km	~ 37.0°	1s

Ground track of Spire FM115



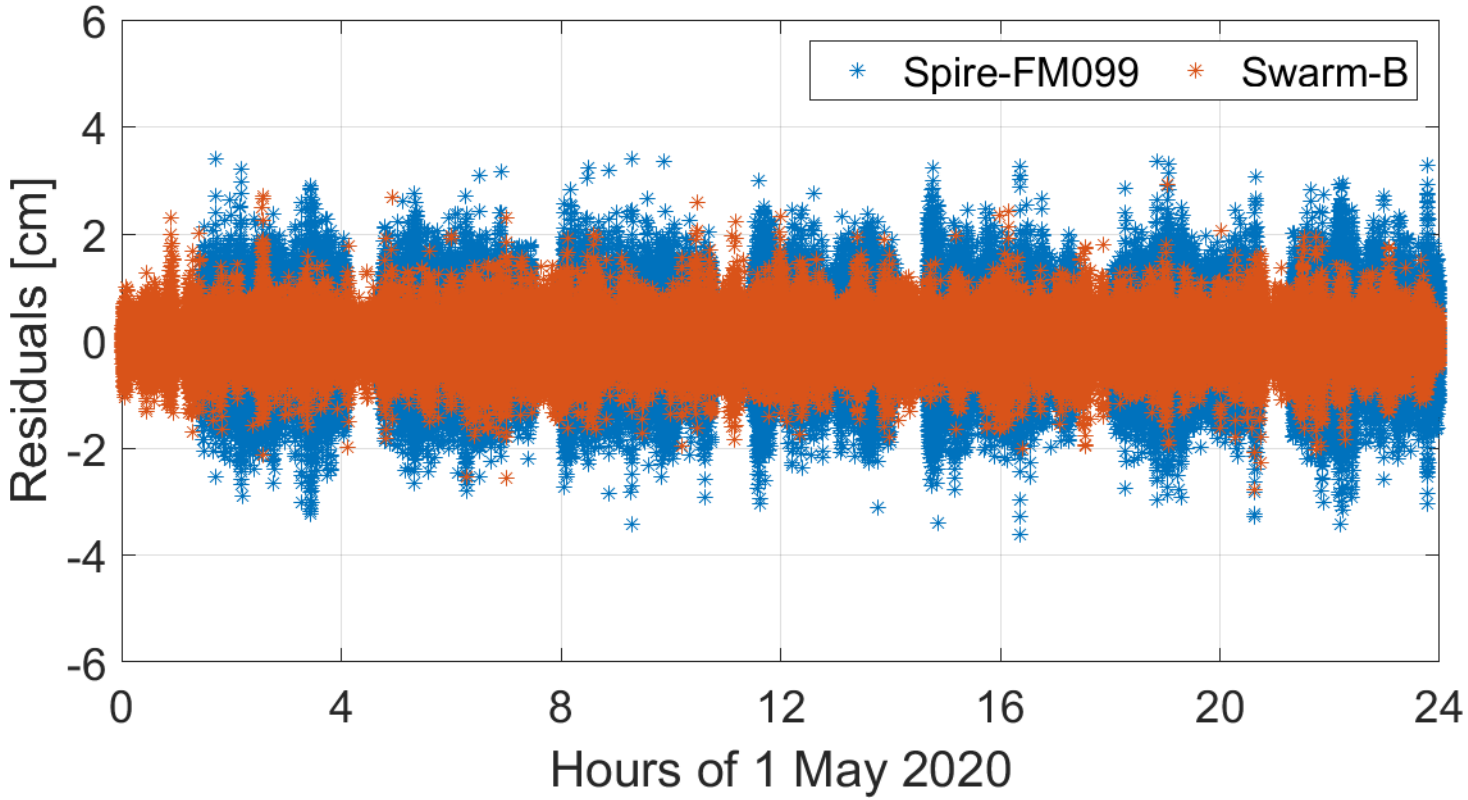
Satellite altitudes



Modified from http://thermosphere.tudelft.nl/page1.html

Spire orbit determination

- GPS carrier phase residuals



Commercial CubeSat

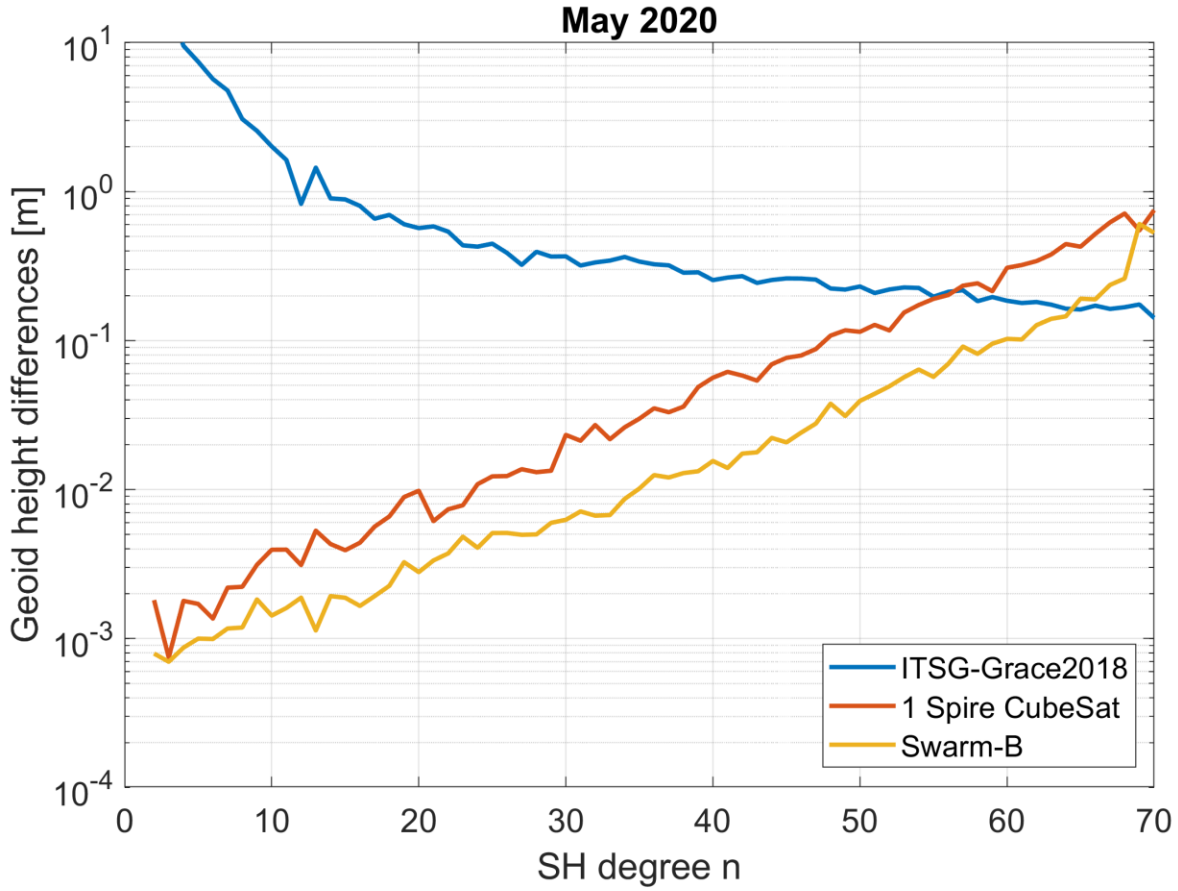
Scientific satellite

Monthly Spire gravity fields

Spire gravity fields

FM099

- Difference degree amplitudes

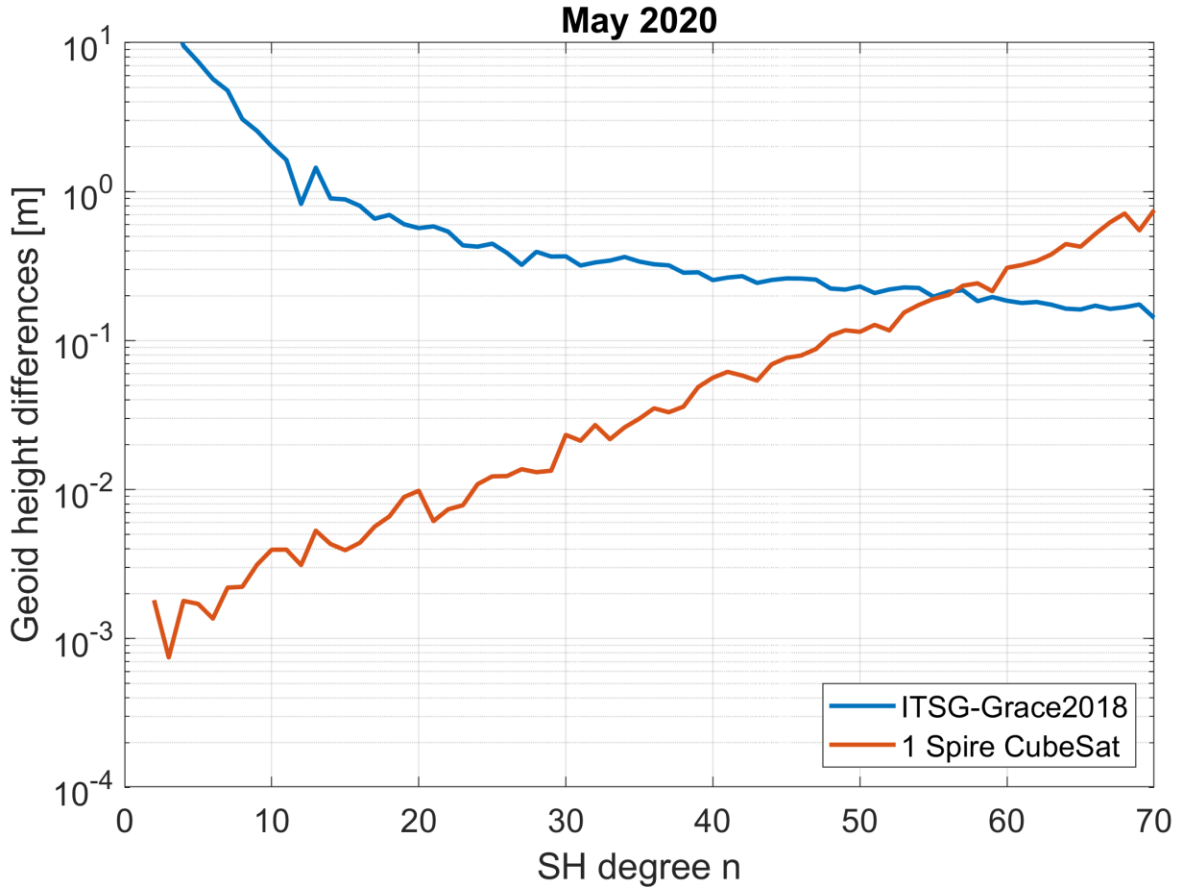


Differences with respect to a superior GRACE-FO model

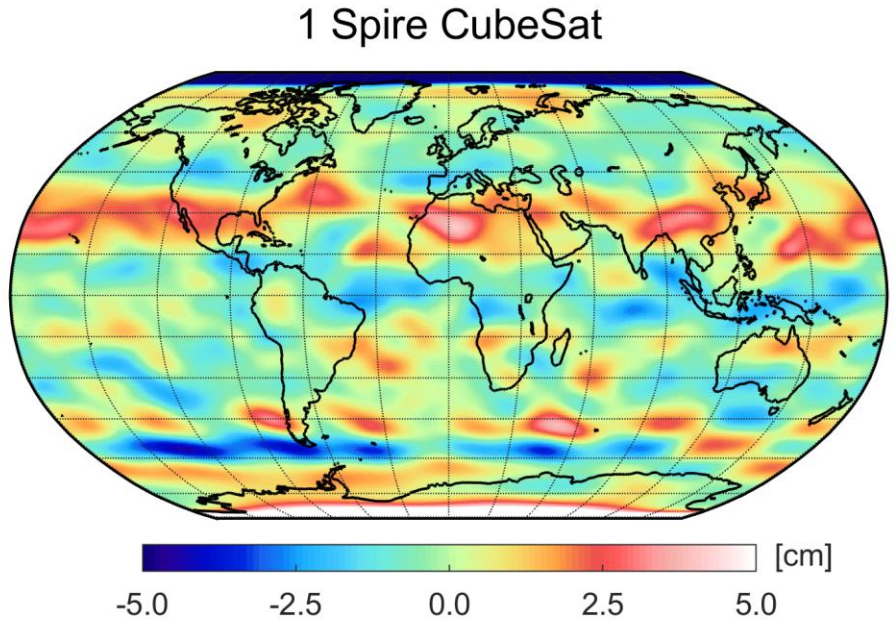
Spire gravity fields

FM099

- Difference degree amplitudes



- Geoid height differences

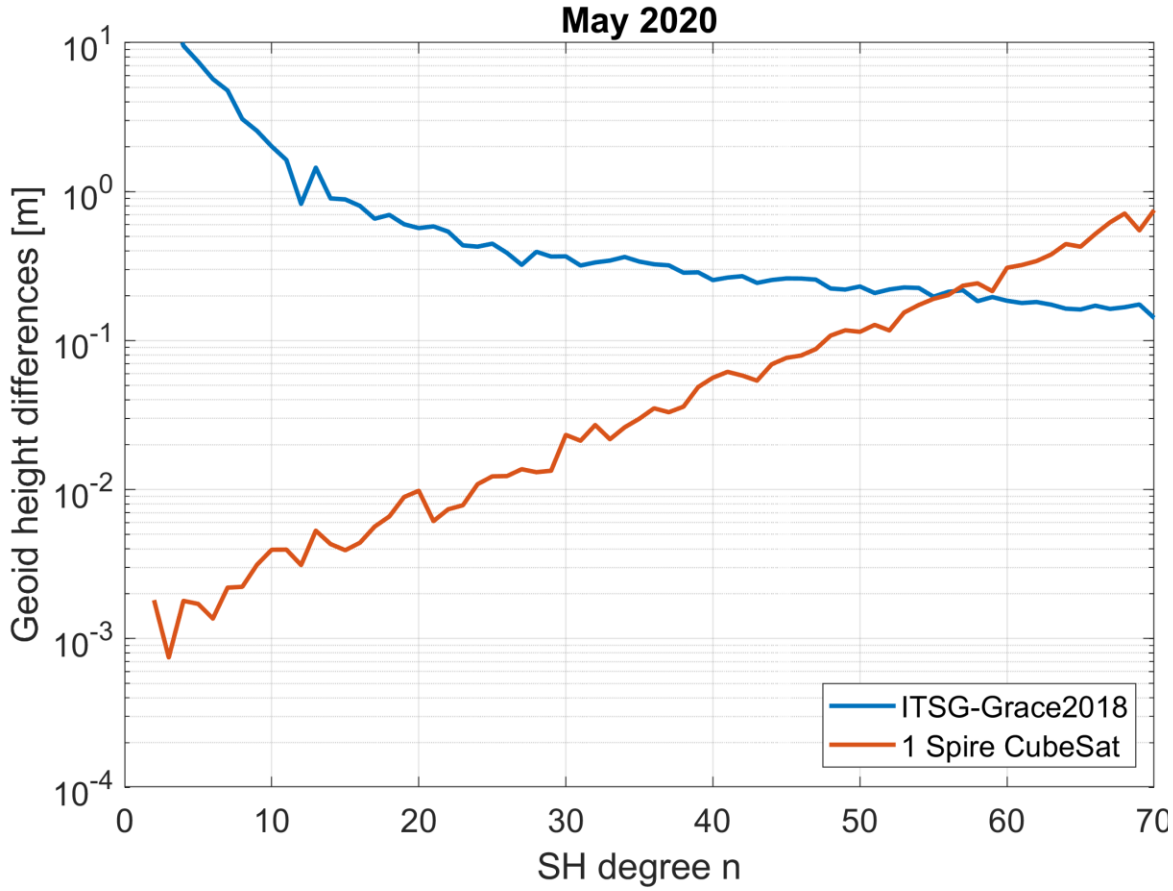


700 km Gauss-filtered

Spire gravity fields

FM099

- Difference degree amplitudes



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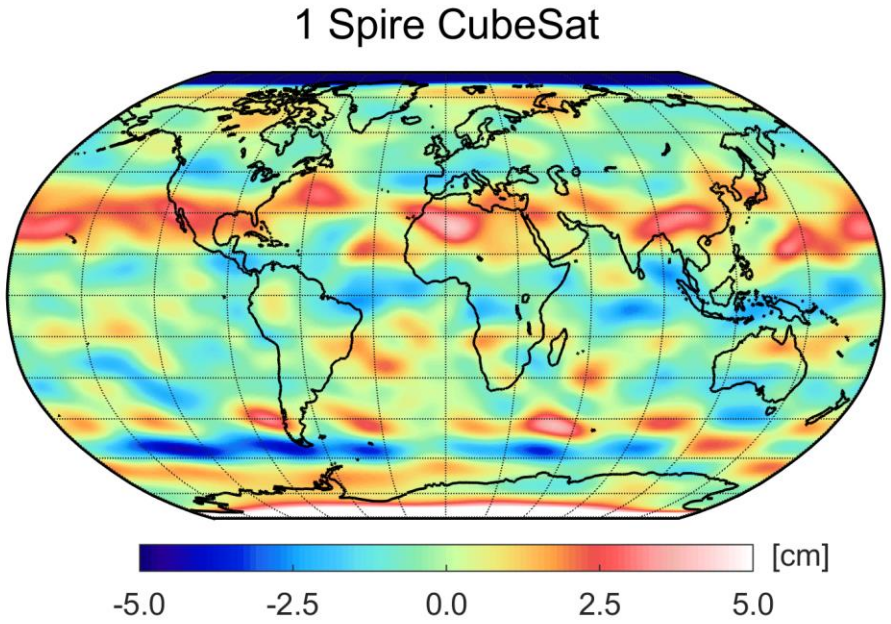
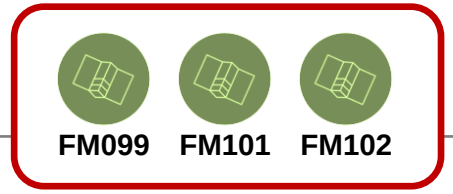
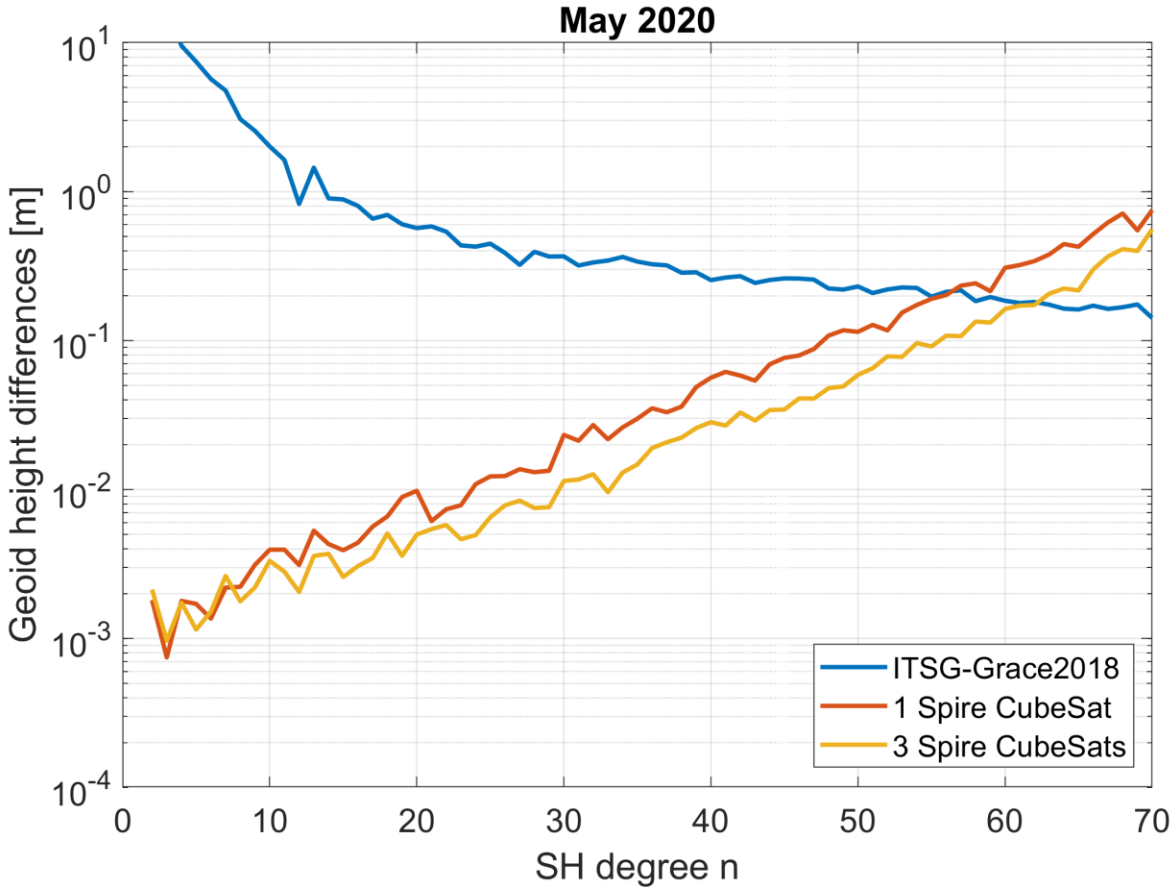


Artifacts in Est/West-direction are correlated with locations of yaw flips

Spire gravity fields



- Difference degree amplitudes



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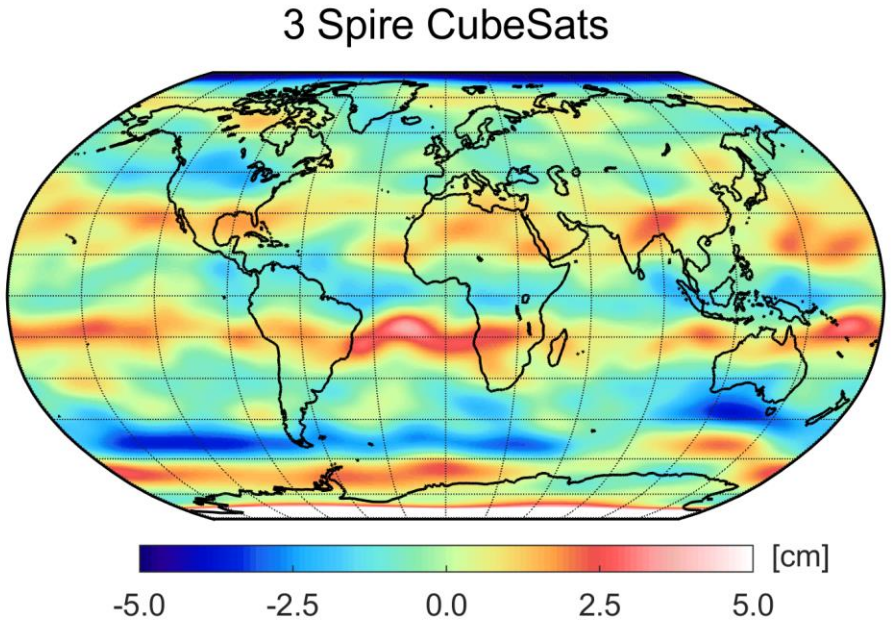
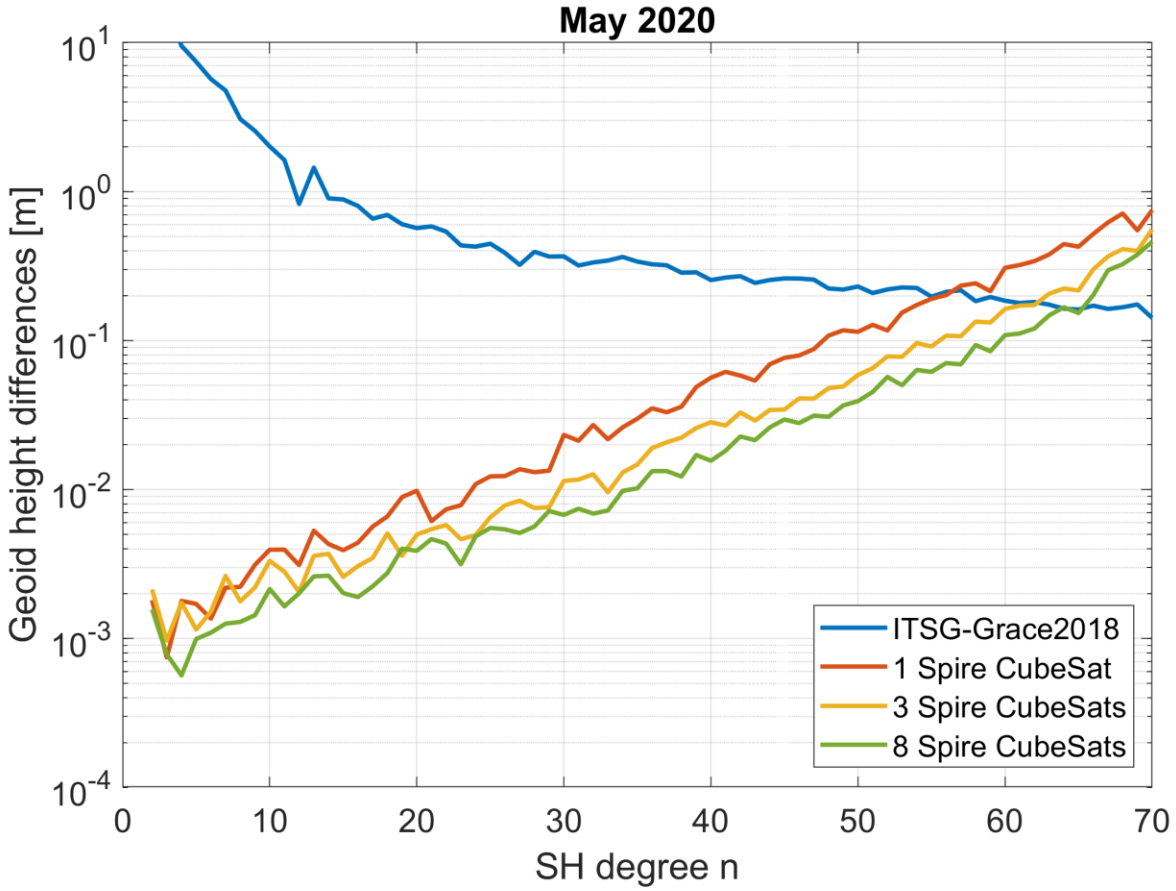


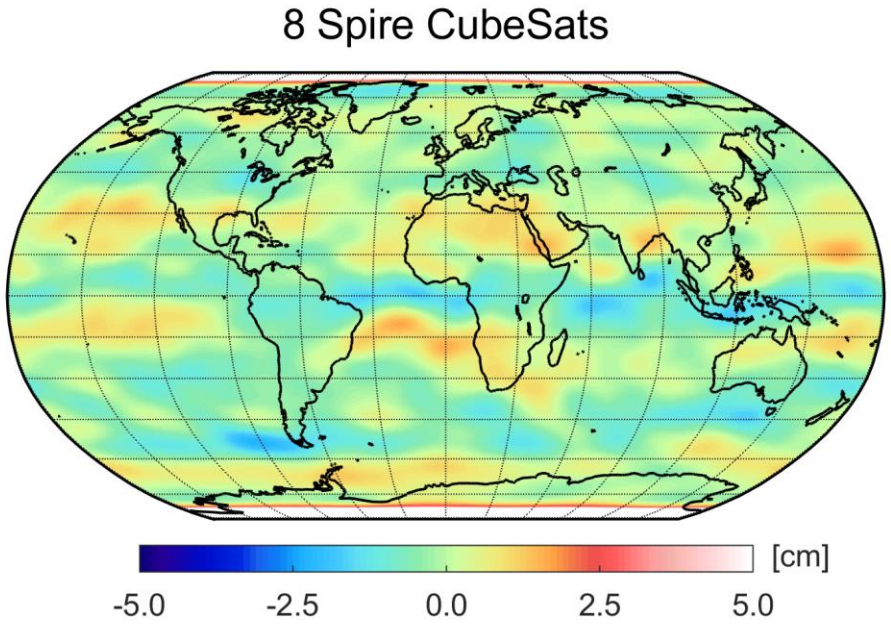
Spire gravity fields

FM099 FM101 FM102 FM103 FM104 FM106 FM107 FM108

- Difference degree amplitudes



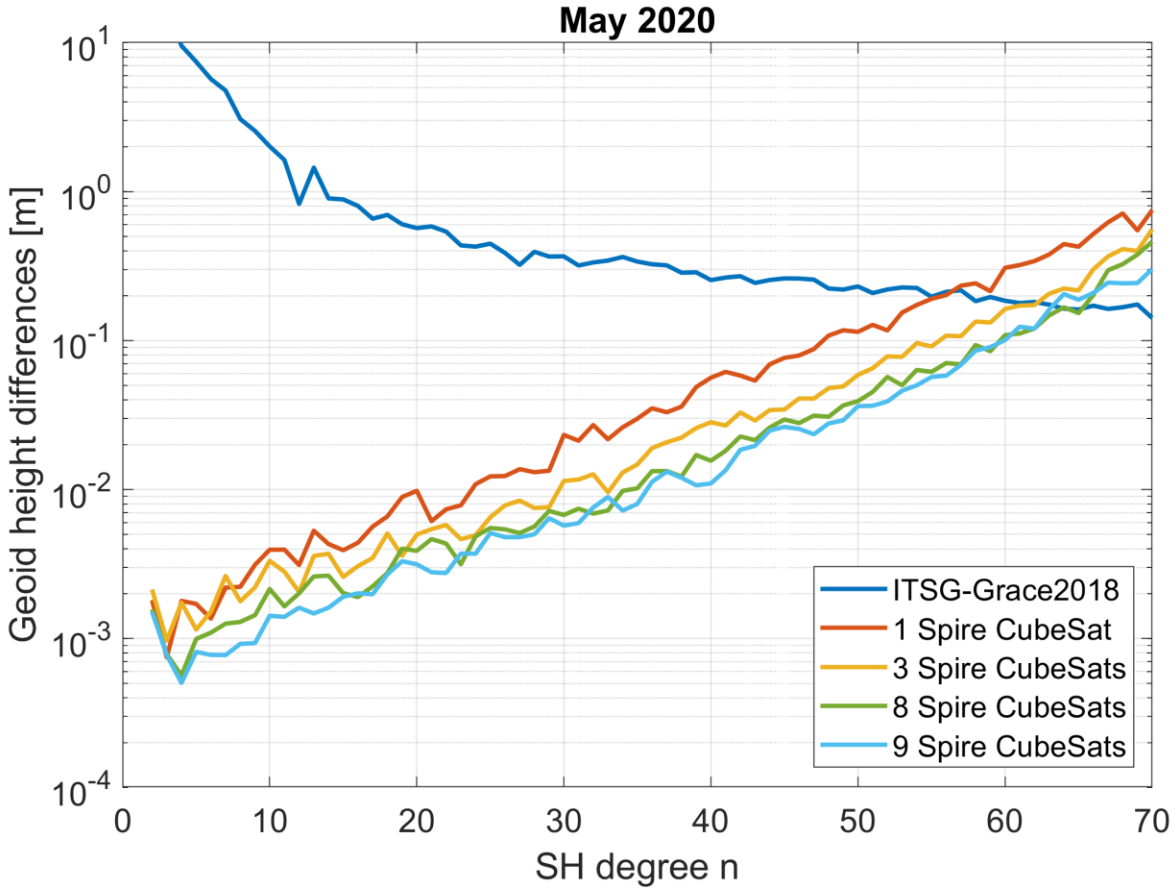
- Geoid height differences



Spire gravity fields

FM099 FM101 FM102 FM103 FM104 FM106 FM107 FM108 FM115

- Difference degree amplitudes



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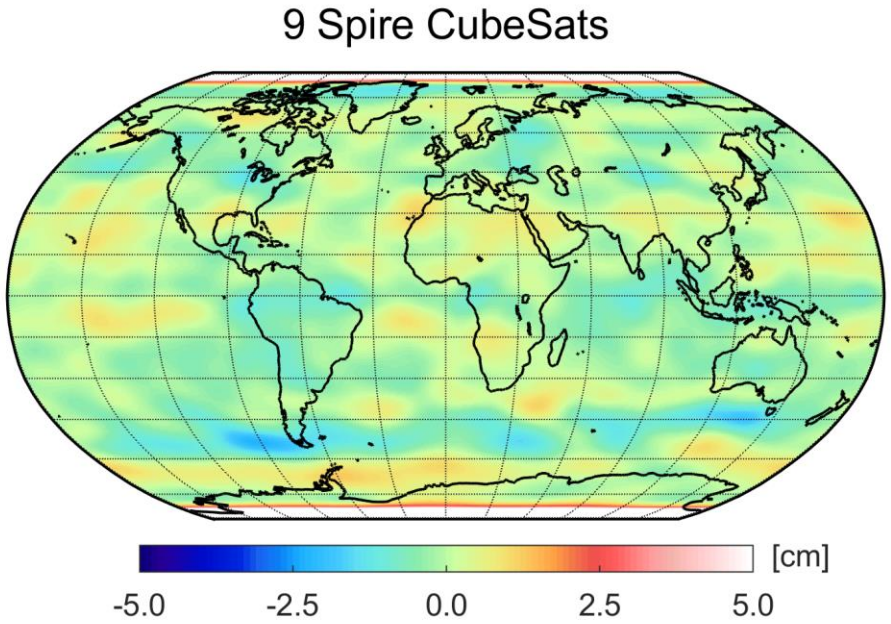

Spire gravity fields

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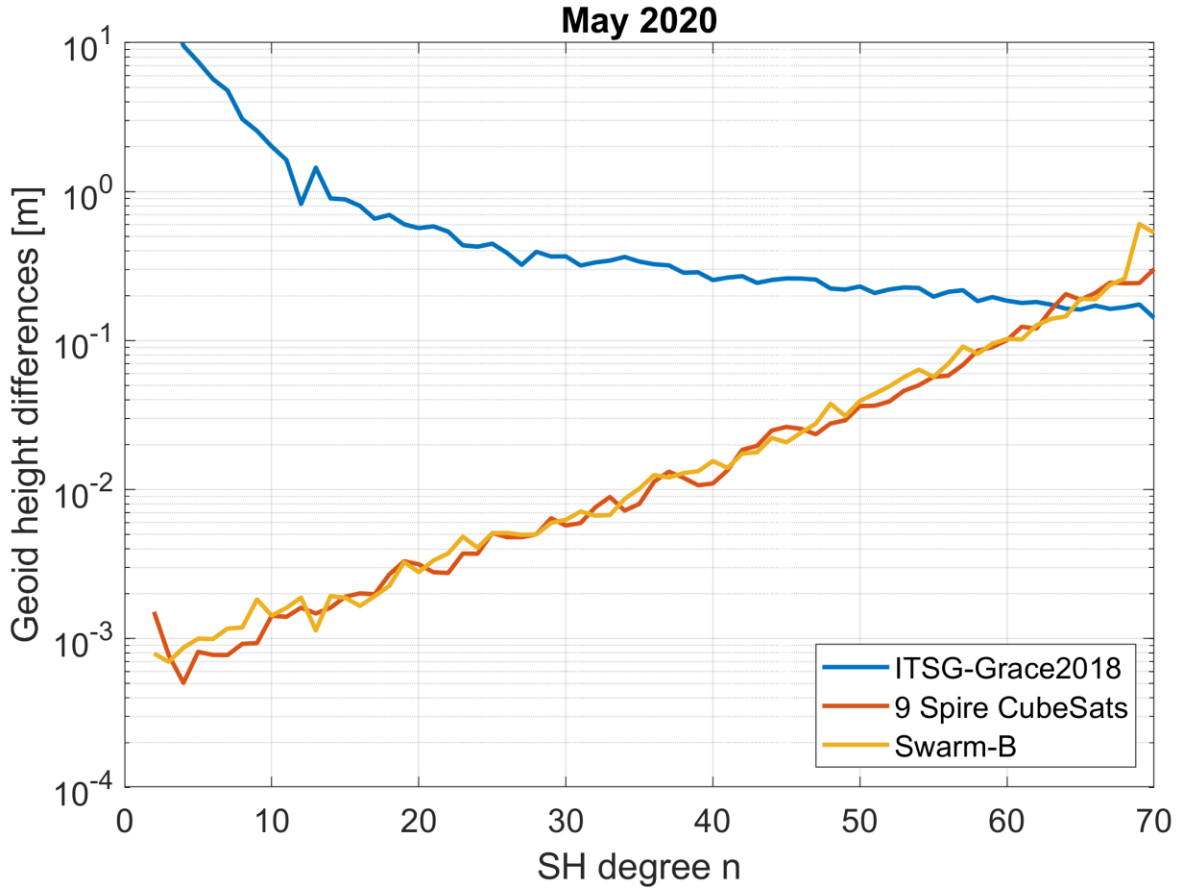
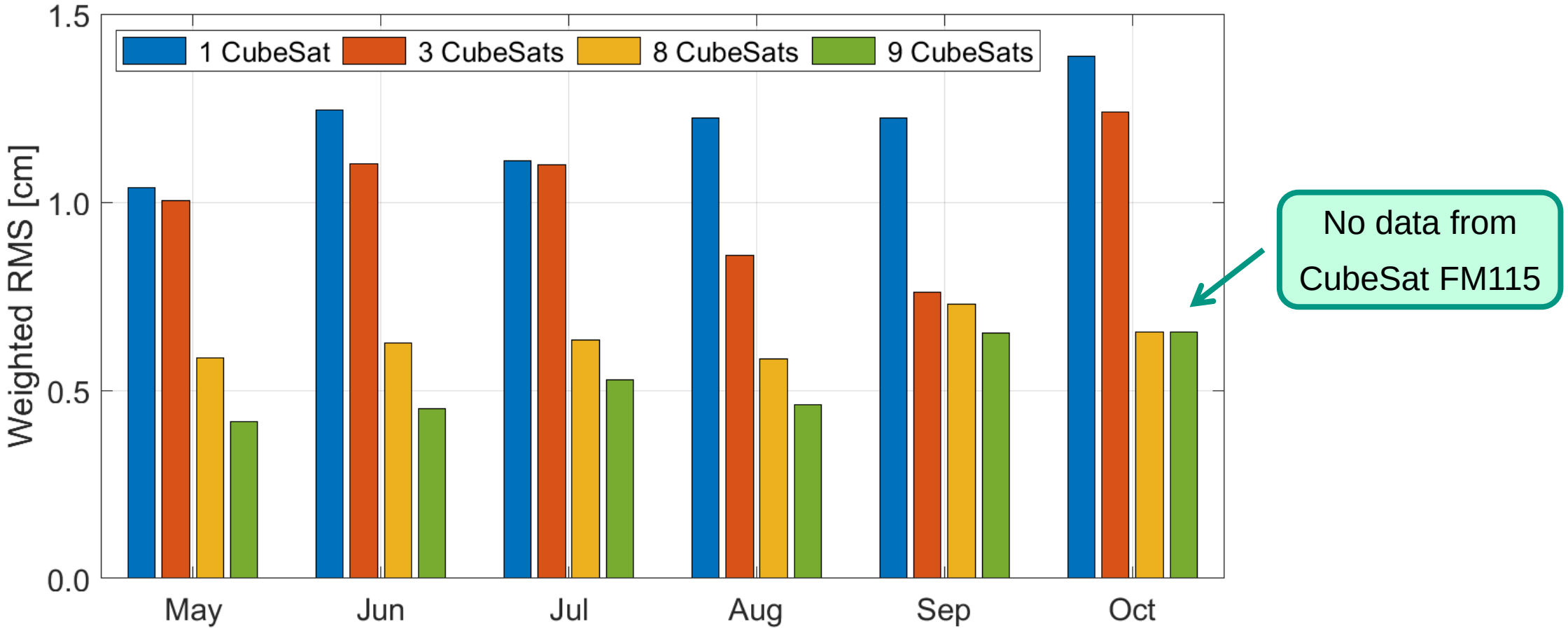
- Difference degree amplitudes



Solutions based on 9 CubeSats can reach a quality level comparable to Swarm-B

Spire gravity fields

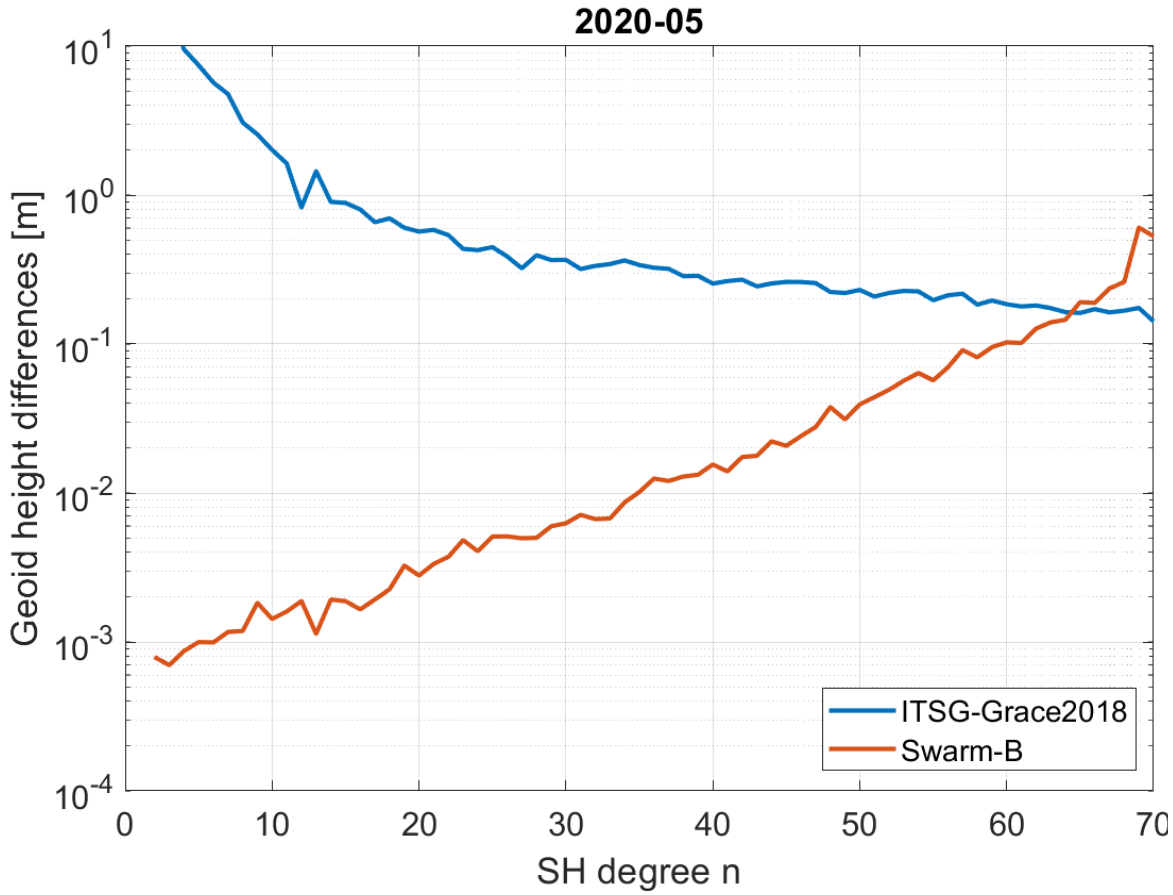
- RMS values of geoid height differences



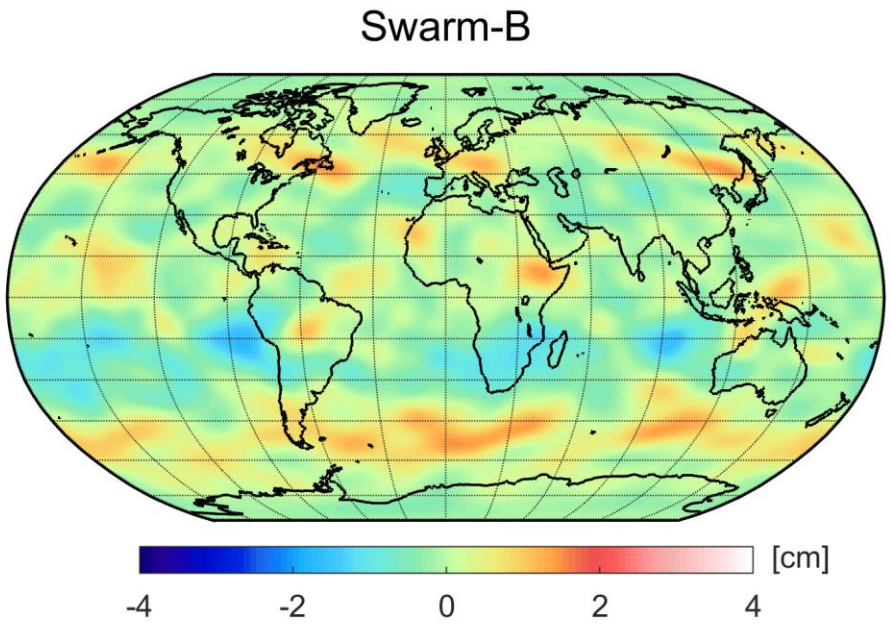
Swarm−Spire combinations

Swarm−Spire combinations

- Difference degree amplitudes

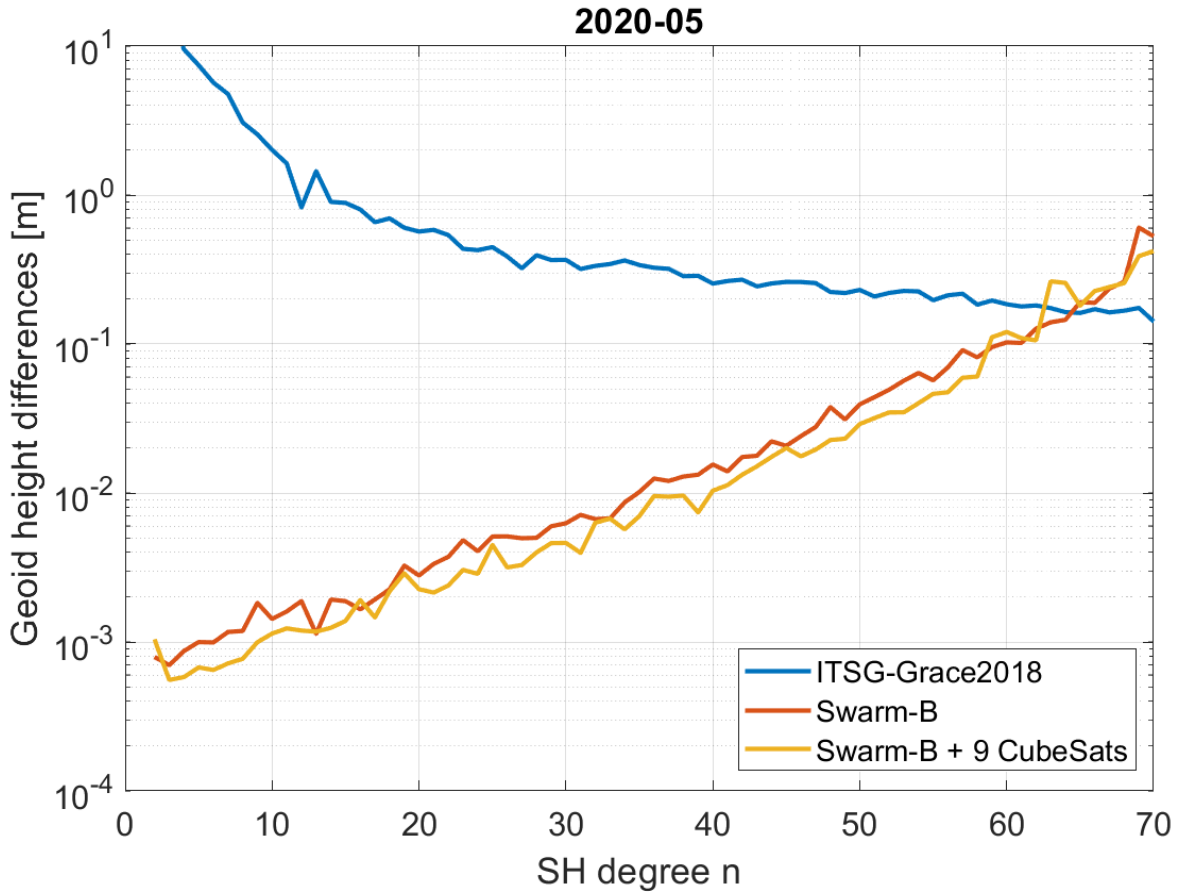


- Geoid height differences

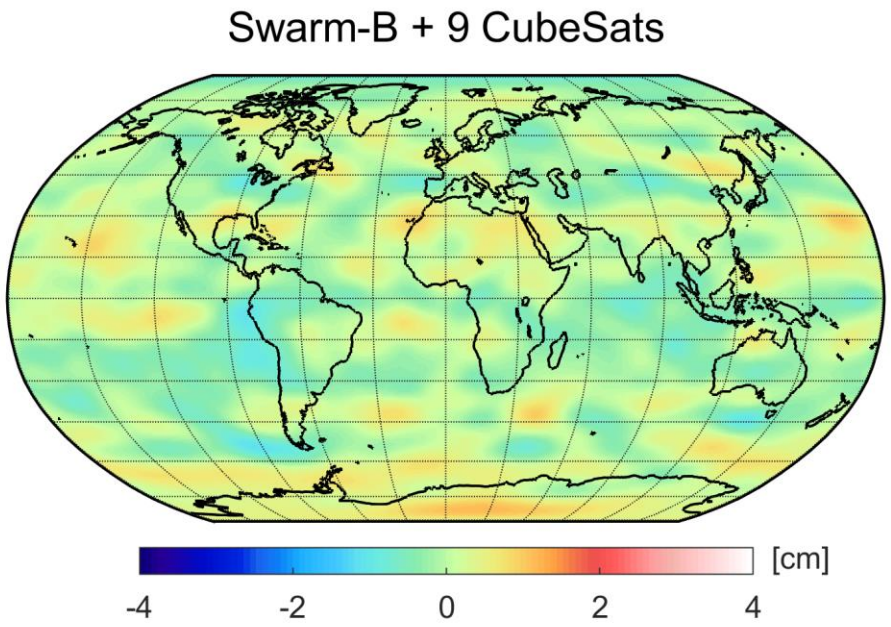


Swarm−Spire combinations

- Difference degree amplitudes



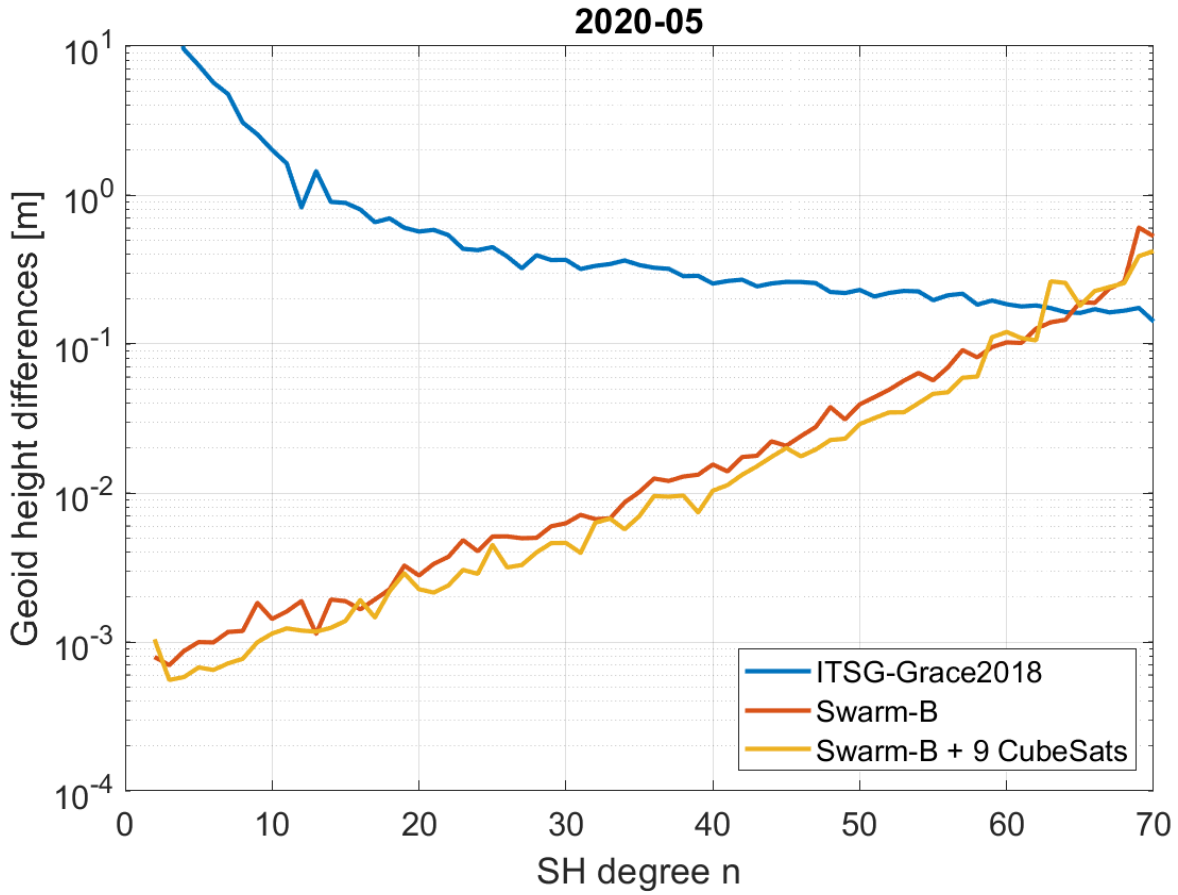
- Geoid height differences



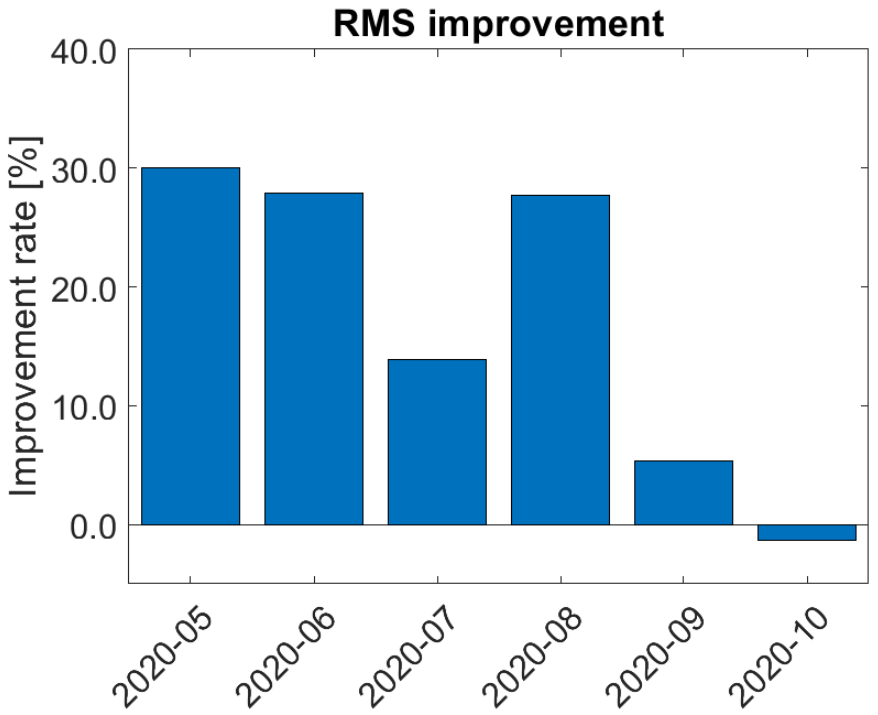
RMS improvement: ~ 30%

Swarm−Spire combinations

- Difference degree amplitudes



- Geoid height differences



Summary and outlook

Take home messages

1) GPS data of Spire CubeSats allow to recover monthly gravity fields
2) Individual CubeSat solutions cannot compete with scientific missions
3) Accumulation of CubeSat solutions significantly increases the quality
4) Solutions based on 9 CubeSats can improve a Swarm-B model

Next steps

- Process Spire data of further CubeSats and longer time spans
- Detailed analysis on the impact of low-inclined CubeSats
- Feasibility to increase the temporal resolution (< 1 month)

Thank you for your attention

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We acknowledge the support from Spire Global and the provision of Spire data by ESA