Constellations and formations of small satellites in NGGM concepts

October 28, 2020

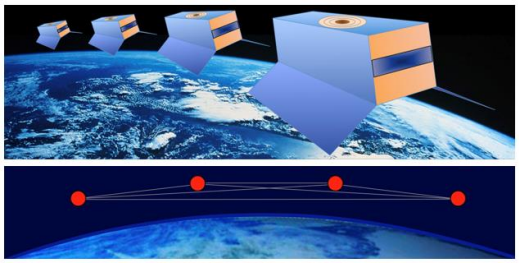
Nikolas Pfaffenzeller, Roland Pail (Technical University of Munich)

GRACE Science Team Meeting 2020

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Motivation

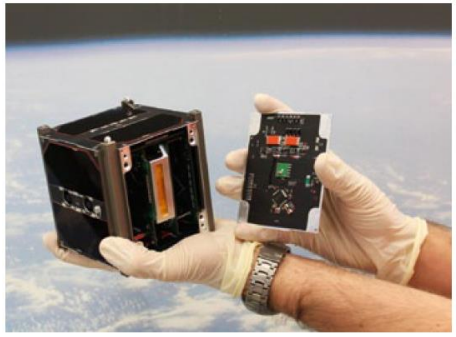
- High costs for construction and launch of gravity field satellite missions
- Aims of NGGMs:
  - increase of spatio-temporal resolution
  - reduction of temporal aliasing



- Miniaturization of satellites (CubeSats) and of (gravity-relevant) instrument components enable future concepts, e.g. Tom Yunck, 2019 a, b

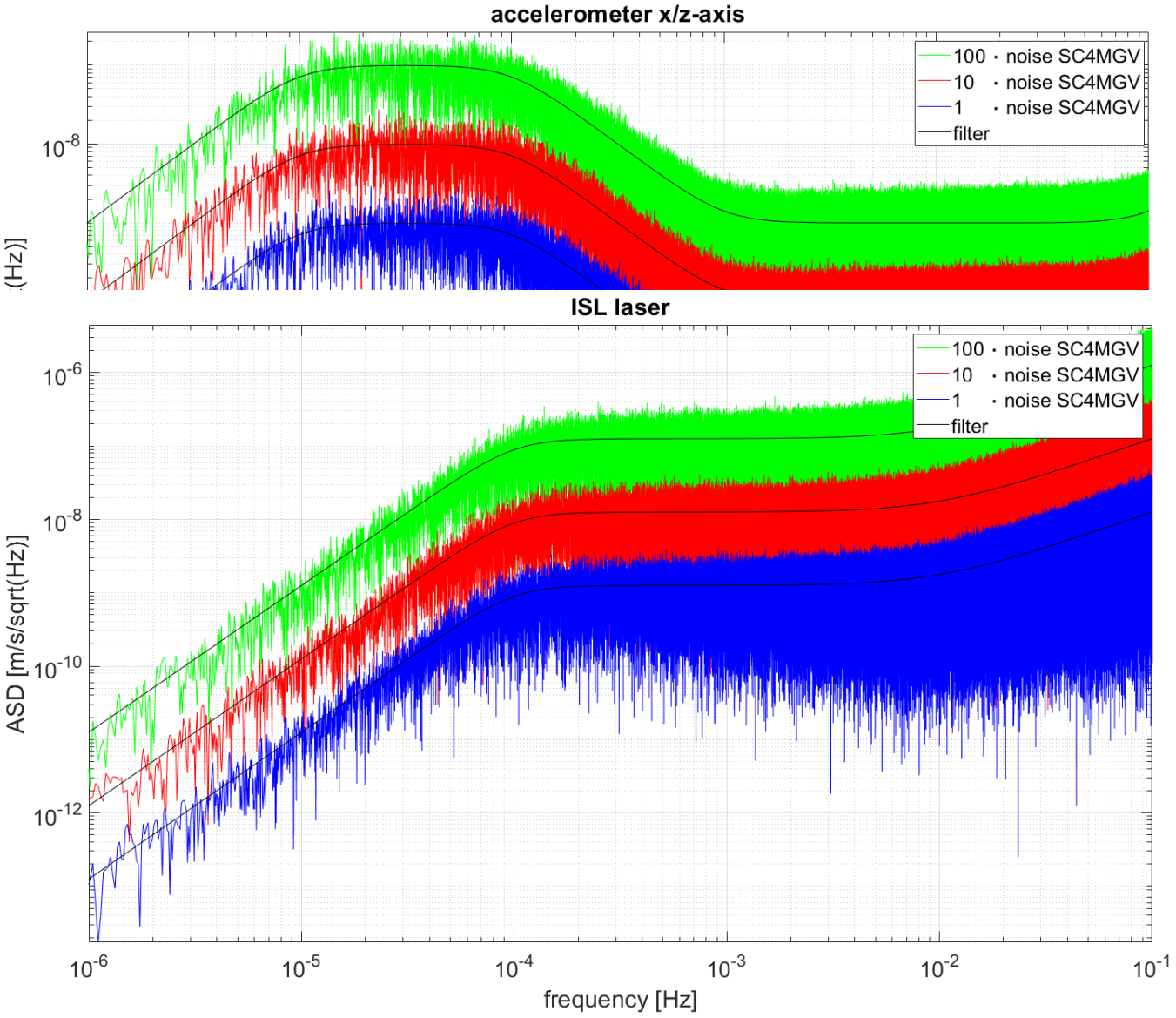
→ What is the impact of different satellite formations and constellations on gravity field solutions?

→ What is the impact of instrument errors on gravity field solutions?



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Gravity field processing



- Full scale numerical closed loop simulations
- Simulated instrument errors

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Simulations

Investigation period: 1 month

Variation of the

- Number of satellites
- Number of inter-satellite links (single, multi ISL)
- Instrument performance (noise level)
- Orbit parameters
- Solution approach (Co-Parametrization of short periodic temporal gravity fields = “Wiese”) Wiese et al. 2011



Single inter-satellite links = links between adjacent satellites (1-2, 2-3, …)
Multi inter-satellite links = links from each respective satellite to all other satellites

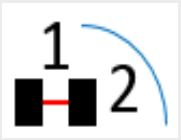
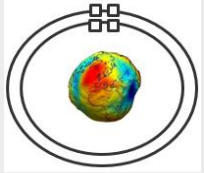
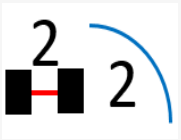
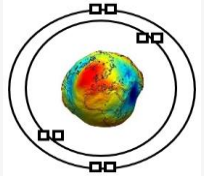
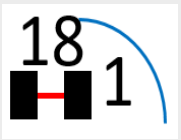
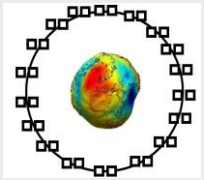
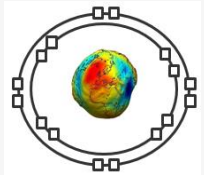
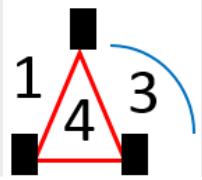
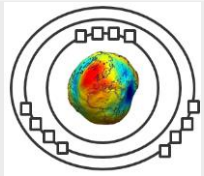


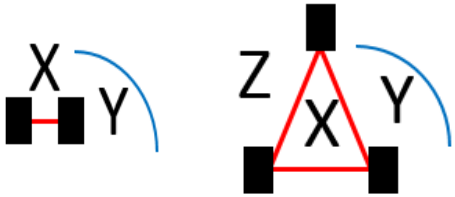
Temporal aliasing models

HIS signal + errors of AO and difference of two ocean tide models (FES2004 – EOT08a) used as errors

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Configurations

case	Altitude [km]	Inclination [°]	Inital mean anomaly
	334 344	89 70	
	439 410	89 70	
	439	89	
	439 410	89 70	
	370 407 445	89 80 70	

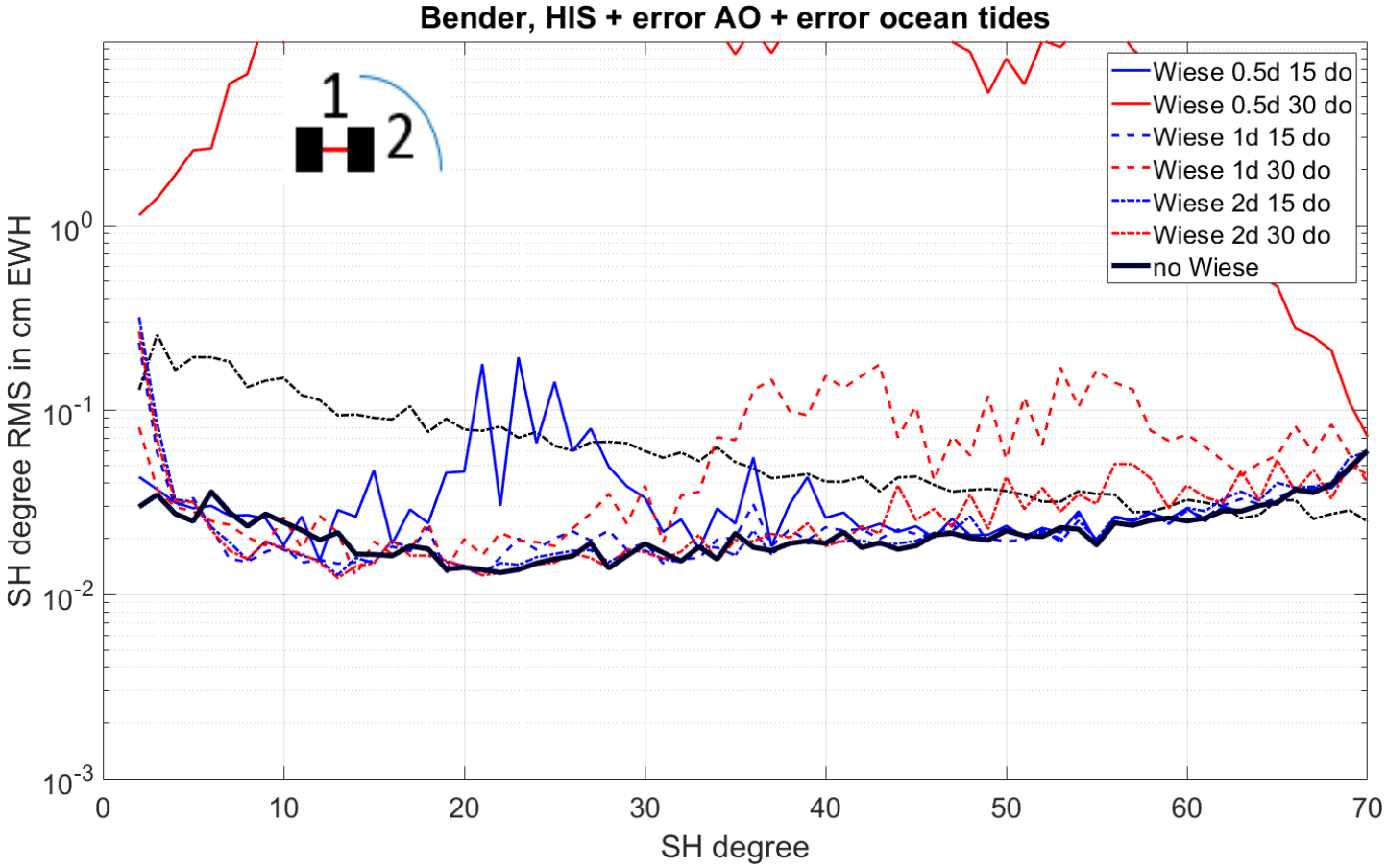


X… number of satellite pairs / satellites forming a chain per orbit
forming a chain
Y… number of orbits
Z… number of chains per orbit

- Repeat cycle: 17 days
- Inter-satellite distance: ~ 200 km
- Single and mutli inter-satellite links

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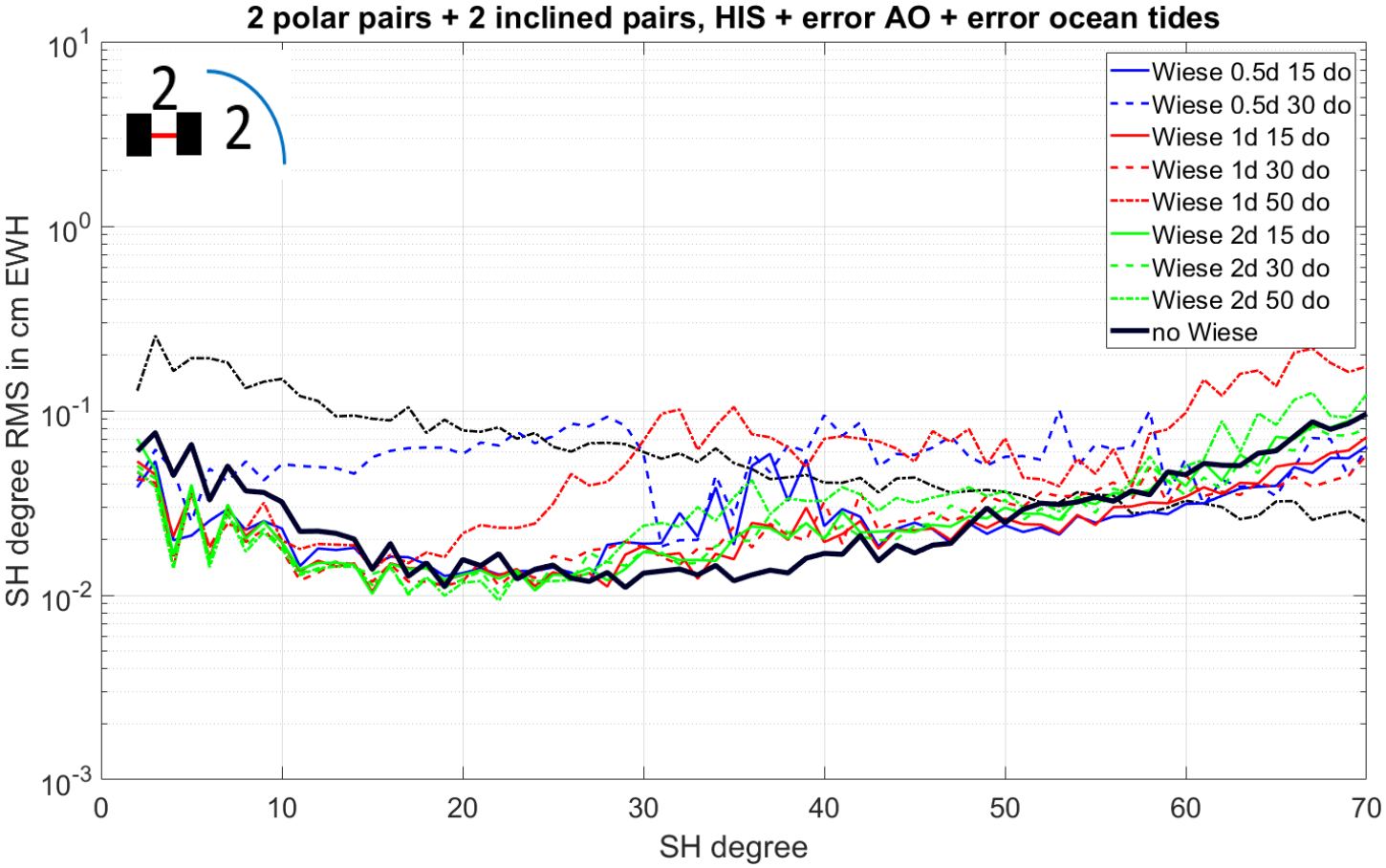
simulation results – (sub)daily gravity field estimates



- Estimation of daily gravity fields only for d/o ~20, for higher d/o 30 degradation
- Estimation of half-daily gravity fields only for very low d/o

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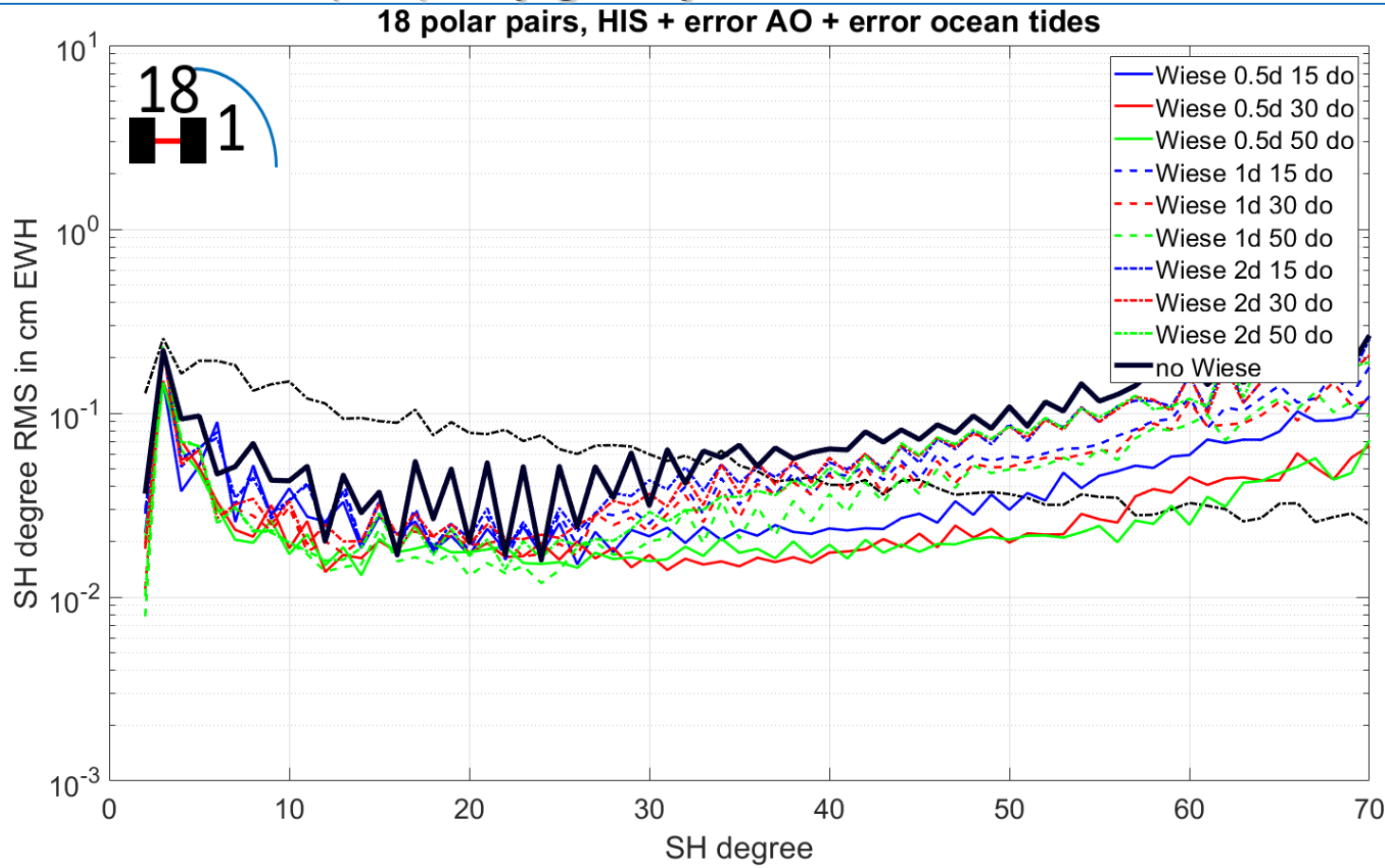
simulation results – (sub)daily gravity field estimates



- Second polar and inclined pair improves the half-daily and daily solutions
- High-quality daily solutions at least up to d/o 30

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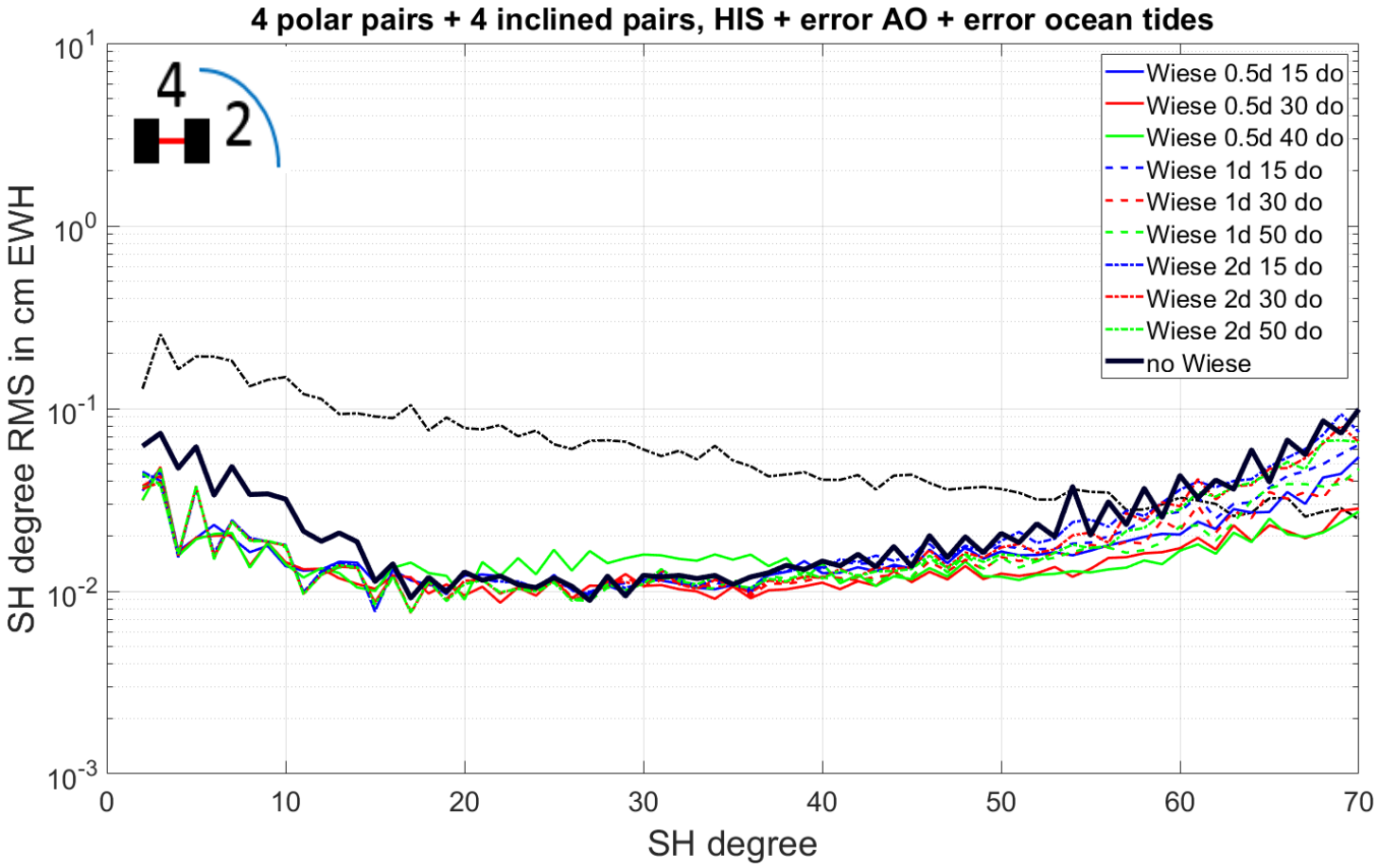
simulation results – (sub)daily gravity field estimates



- Consecutive improvement of overall gravity solution by increasing short periods in co-parametrized estimations (2d → 1d → 0.5 d) in connection with higher spatial resolution (15 do → 30 do → 50 do)
- Generally weaker performance than constellations with inclined pairs

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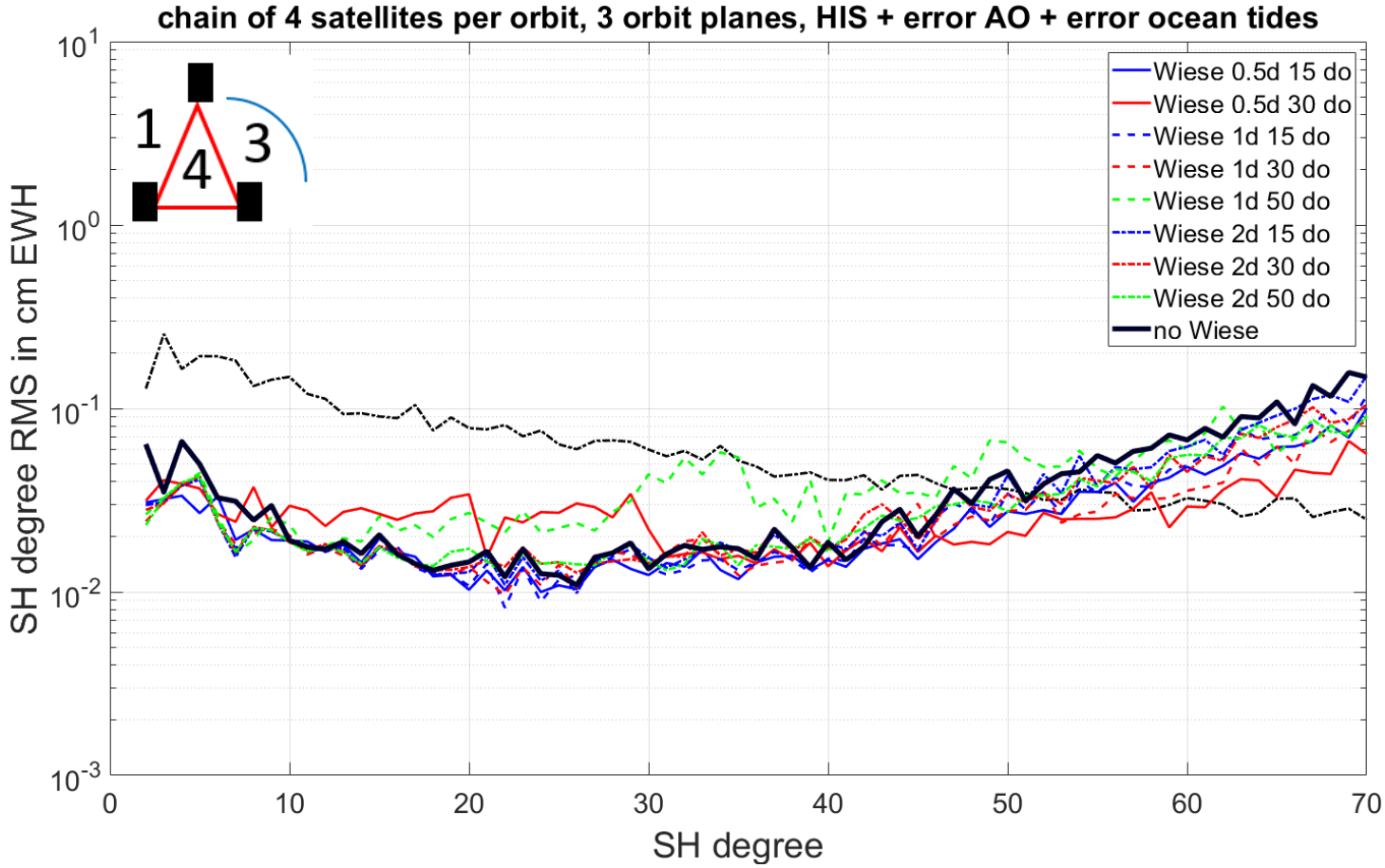
simulation results – (sub)daily gravity field estimates



- Estimation of sub-daily and daily gravity field up to d/o 30 and 50

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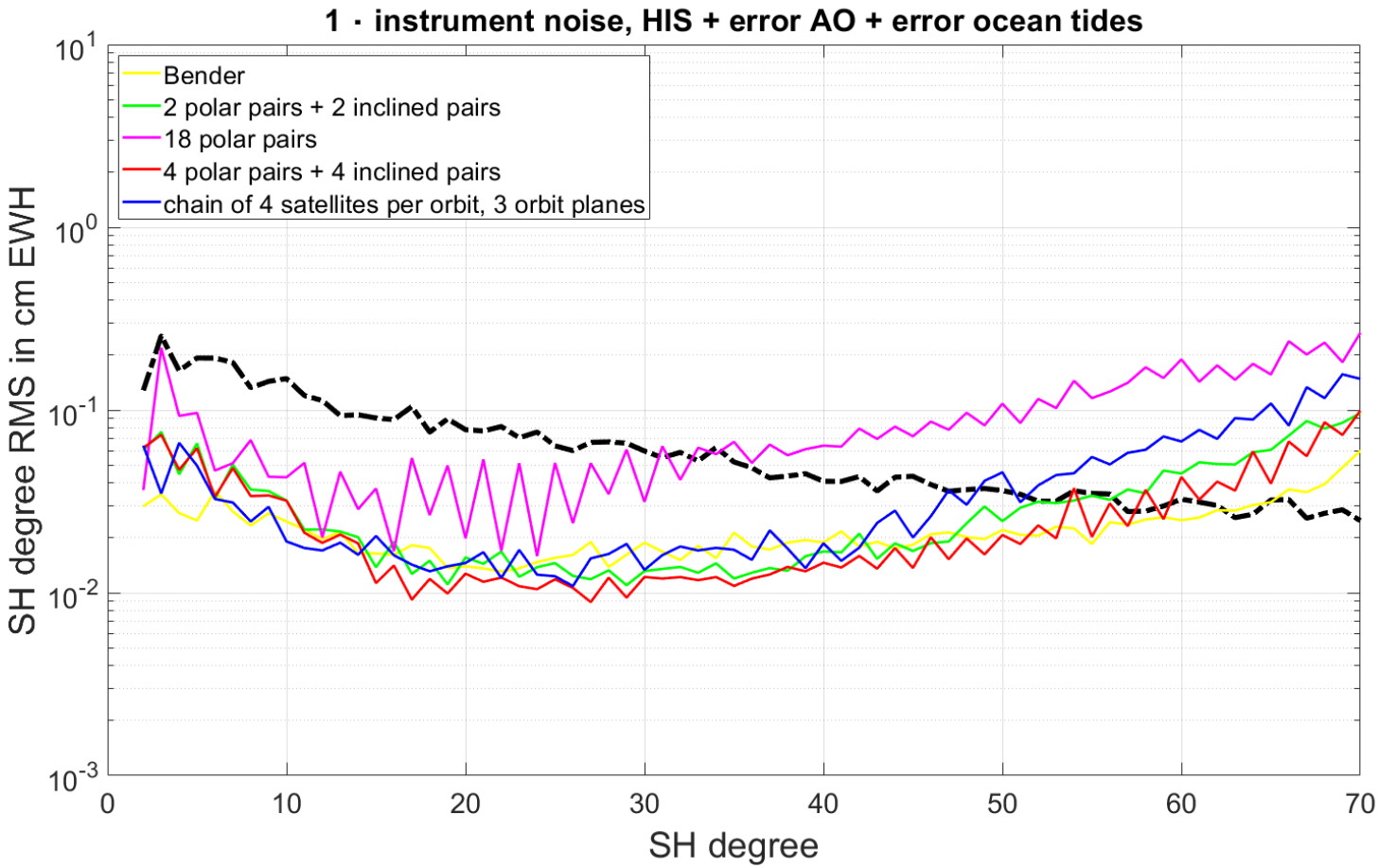
simulation results – (sub)daily gravity field estimates



- Despite observations from three orbits with different inclinations, resolution of (sub-)daily estimates lower compared to distributed multi-pair scenarios

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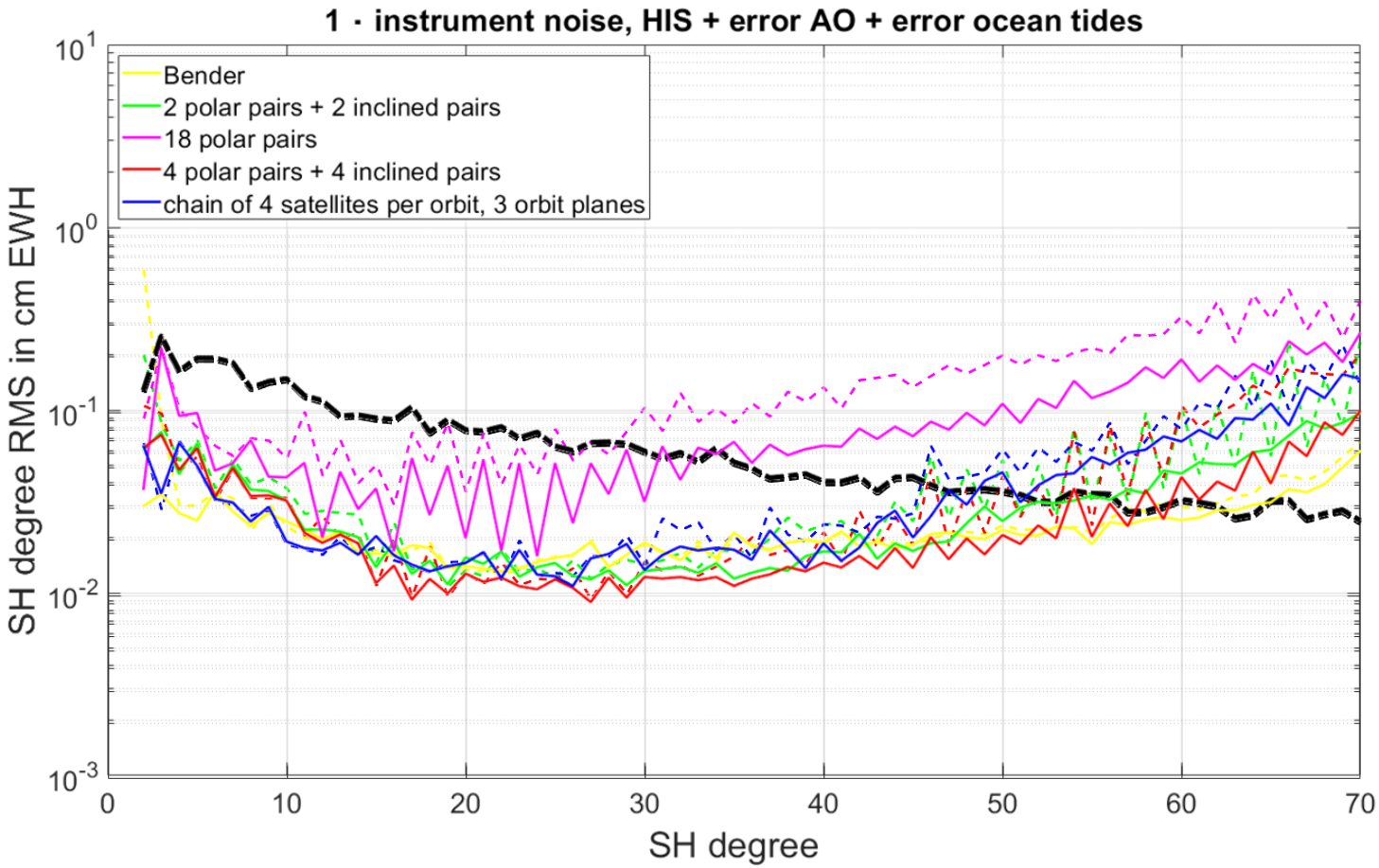
simulation results – comparison of constellations (no Wiese)



- Impact of second (inclined) orbit and spatial coverage (drifting orbits in Bender secenario)

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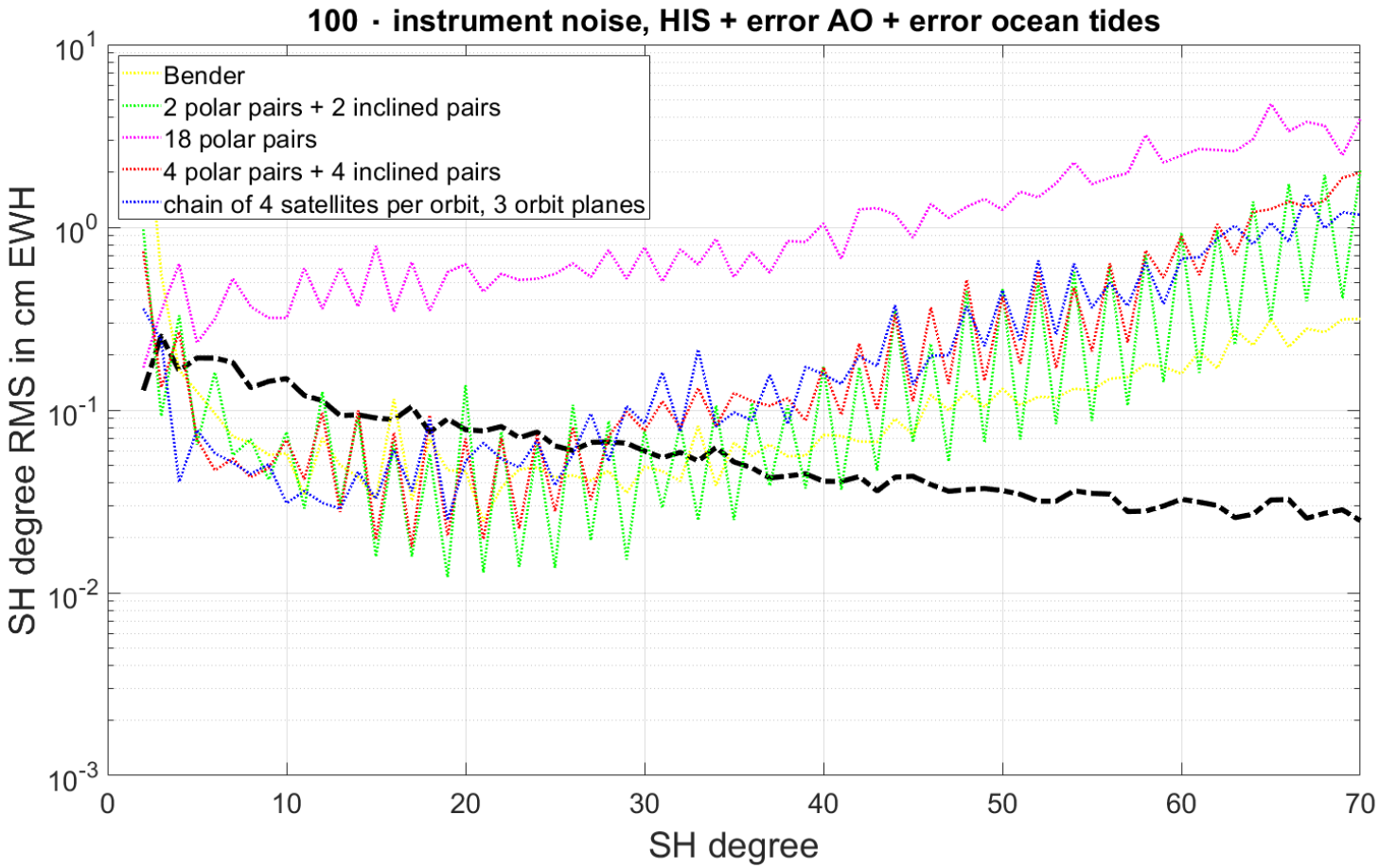
simulation results – impact of different instrument noise level



- Increased instrument noise of factor 10: downgrade different for different constellations

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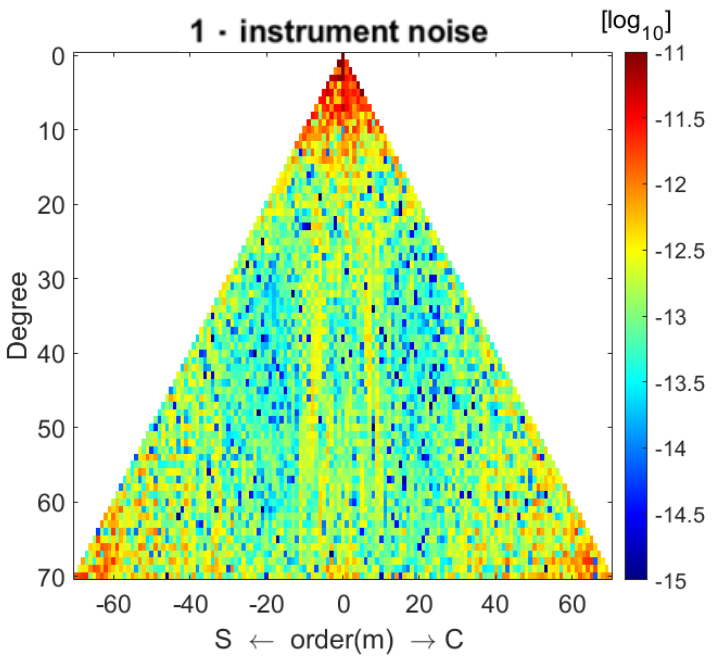
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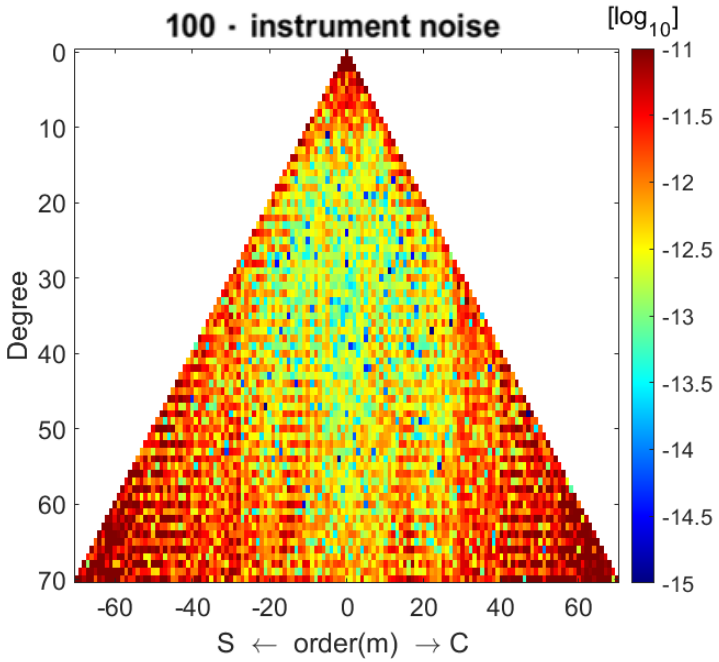


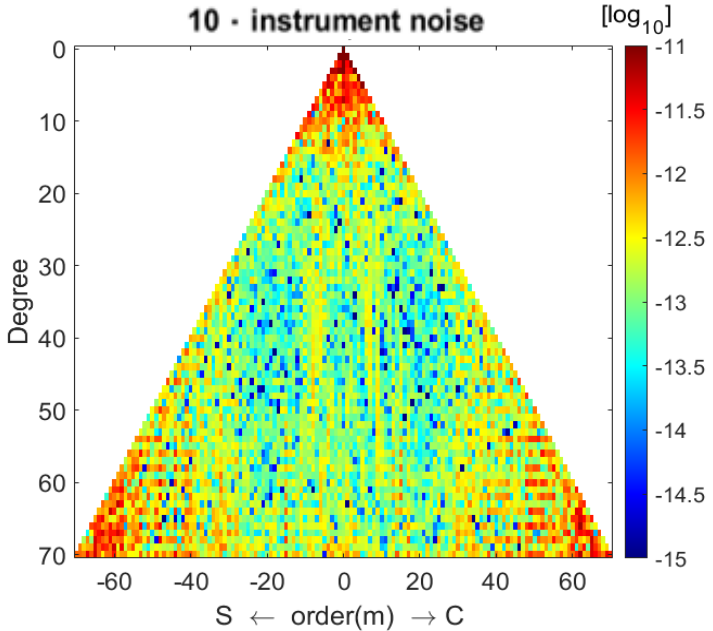
- Instrument noise as dominating error source by increasing instrument noise of factor 100

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Spherical harmonic coefficients of different instrument noise level

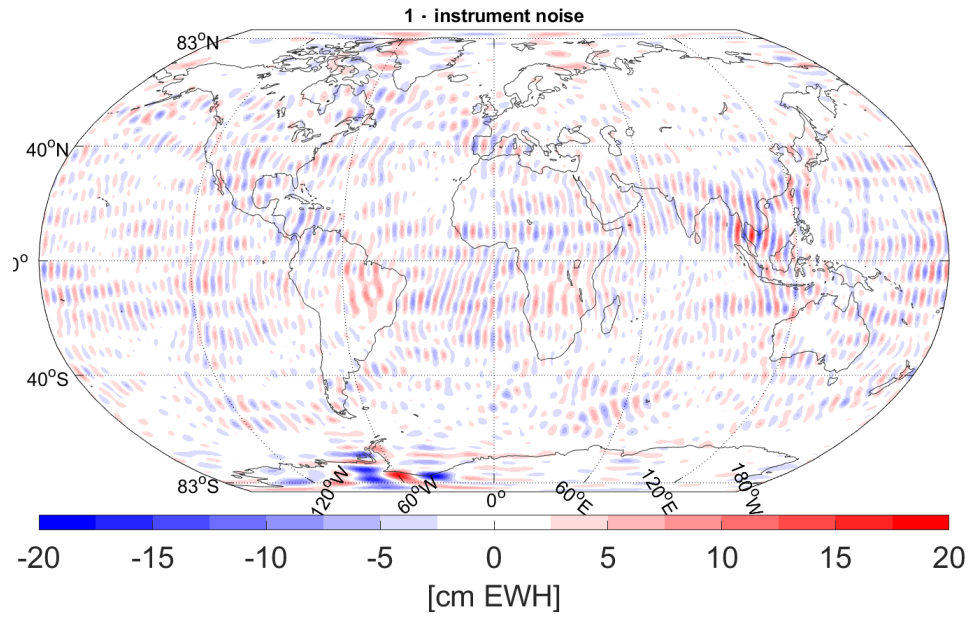


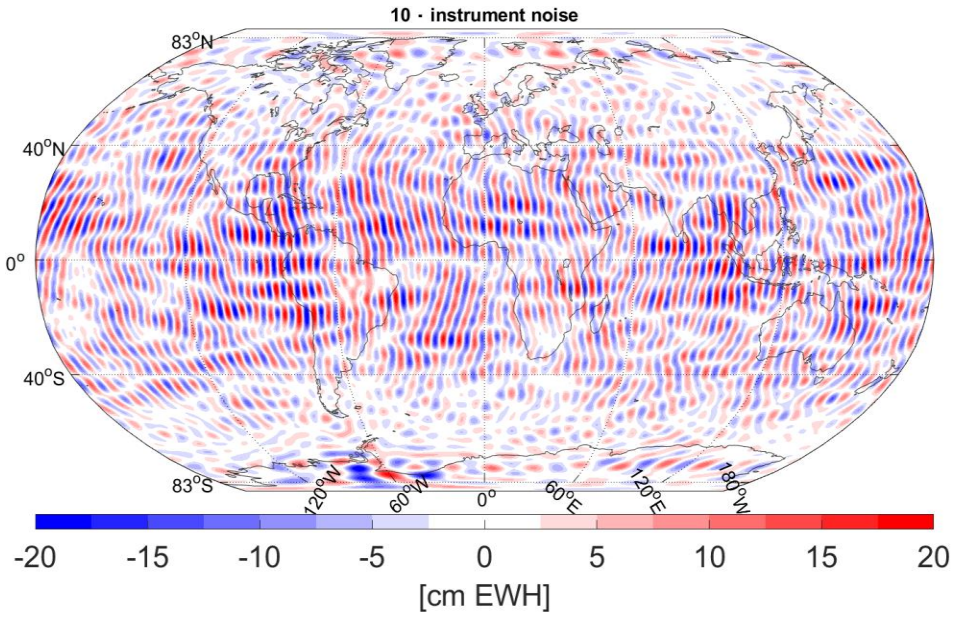


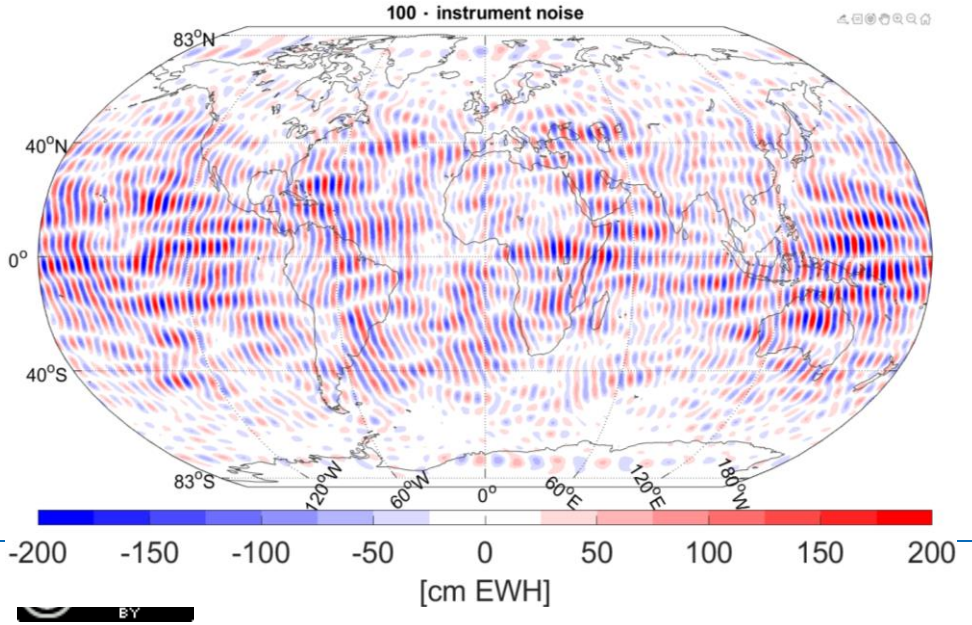


Instrument noise represents in the coefficients of high degree and order

Spatial plot of different instrument noise level







Impact of instrument noise show up as typical North-South stripes

Conclusions

- Co-estimation of short periodic gravity fields down to 0.5 d possible for multi-satellite constellations
- instrument noise starts to become the dominant error source in results when accuracy is reduced by factor > 10
- Influence on improving gravity field solutions
  - Satellite chains (-)
  - Amount of satellite pairs (-)
  - Spatial distribution (+)
  - Observations from different inclined orbit (+)
- Further investigations:
  - Impact analysis of the individual instrument performance
  - Shorter-term gravity field parametrization (6 hours, …)
  - Co-parameterization of ocean tides → high potential due to multiple satellites and increased temporal resolution

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References

- Yunck, T (2019a), The Earth Gravitational Observatory: Smallsat constellation for multi-link low-low SST, Washington, DC
- Yunck, T, A Saltman, S Bettadpur, S Nerem, J Abel, M Widner, C Deccia, G Franklin (2019b), The Earth Gravitational Observatory: Multisat clusters in chain formations, NASA Mass Change Workshop, Washington, DC,

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