Gravity field recovery using co-estimation of background model errors to improve de-aliasing capabilities of the MAGIC double-pair constellation

GFZ Helmholtz-Zentrum POTSDAM

NEROGRAV New Refined Observations of Climate Change from Spaceborne Gravity Missions

HELMHOLTZ-ZENTRUM POTSDAM DEUTSCHES GEOFORSCHUNGSZENTRUM

DFG Deutsche Forschungsgemeinschaft

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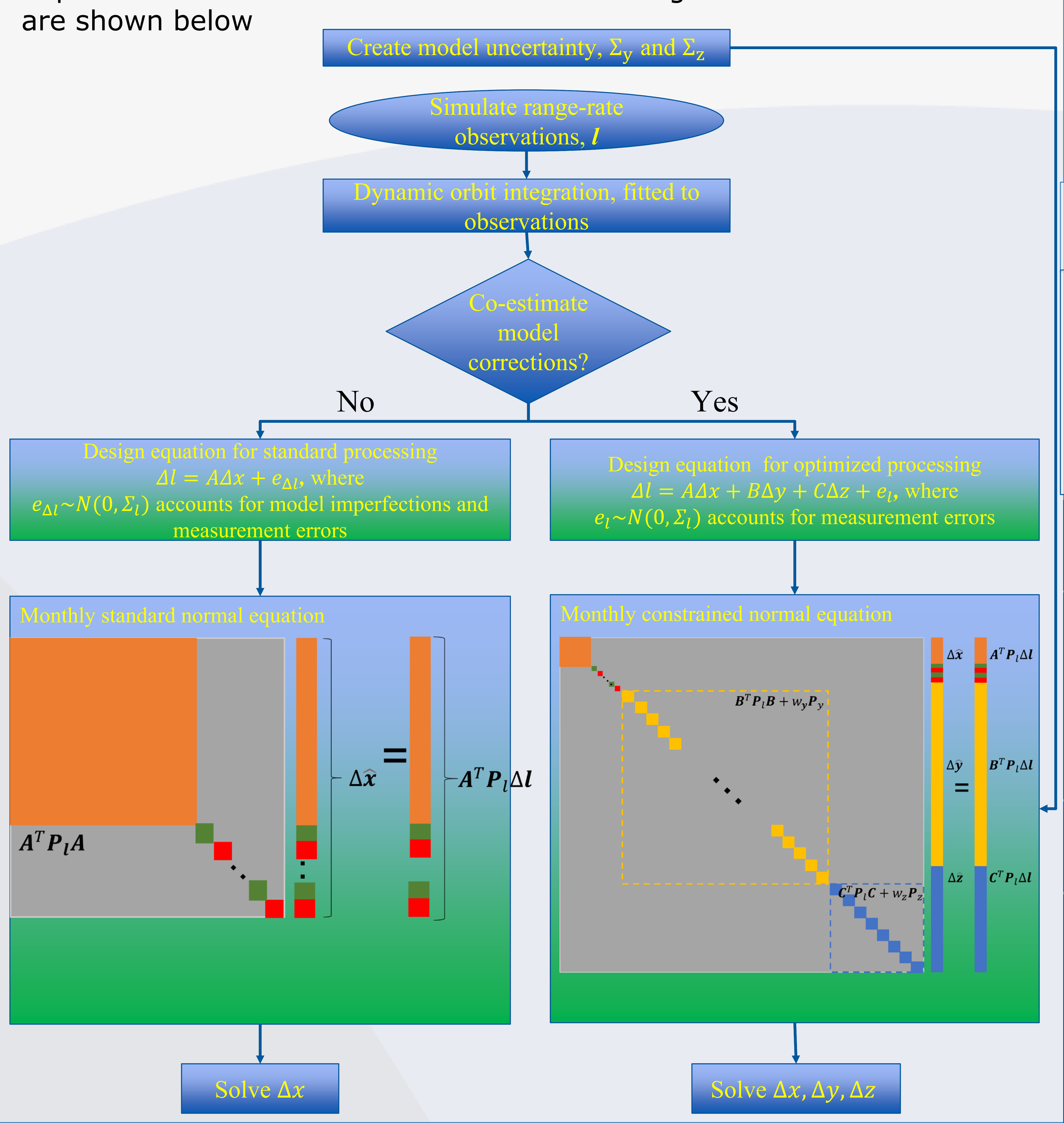
Overview

- Monthly gravity field recovery simulations for the planned MAGIC constellation include errors limiting the spatial and temporal resolution of the estimated gravity field solutions. **Primary error contributions include imperfect ocean tide (OT) and non-tidal atmosphere-ocean (AO) background models.**
- As part of a DFG-funded project, the research unit **NEROGRAV** derived AO and OT uncertainty information [1][2]. These describe the error characteristics of the background models.
- AO and OT background model corrections are co-estimated and constrained with the pre-computed model uncertainties during gravity field estimation.
- Error-specific recoveries were performed to assess the impact of constrained co-estimation of correction parameters on the AO and OT errors. Full-noise recoveries were conducted to investigate its effect during a realistic gravity field recovery scenario.
- Here, we provide a comparison of monthly gravity fields recovered with and without the constrained co-estimation of background model corrections for MAGIC simulations.
- The following scenarios were investigated:

Scenario	Estimated parameters
Case 1	Full-noise using standard processing
Case 2a	Full-noise using optimized processing that co-estimates OT model corrections
Case 2b	OT error-specific using standard processing
Case 2c	OT error-specific using optimized processing that co-estimates OT model corrections
Case 3a	Full-noise using optimized processing that co-estimates non-tidal AO model corrections
Case 3b	AO error-specific using standard processing
Case 3c	AO error-specific using optimized processing that co-estimates AO model corrections
Case 4	Full-noise using optimized processing that co-estimates both AO and OT model corrections

Method

- Differences between the standard and optimized processing that implements the constrained estimation of background model corrections are shown below



Conclusions

- The estimated model corrections absorb errors that enter the gravity field solutions during standard processing.
- Co-estimation of background model corrections reduces gravity field recovery errors by up to 36%.
- The co-estimation of AO model corrections also improves OT error estimation, specifically in polar regions.

Outlook

- Estimating ocean tides requires a sufficiently long simulation period. Although a one-year simulation has improved ocean tide estimation, further reductions are expected when extending the observation period to several years.

Acknowledgements

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References

[1] Sulzbach R., Hart-Davis M., Dettmering D., Thomas M. (2023): Regularized Empirical Variance-Covariance-Matrices for stochastic gravity modeling of 8 major ocean tides. GFZ Data Services. https://doi.org/10.5880/NEROGRAV.2023.003

[2] Shihora, Linus; Balidakis, Kyriakos; Dill, Robert; Dobslaw, Henryk (2022): Atmosphere and Ocean Non-Tidal Dealiasing Level-1B (AOD1B) Product RL07. GFZ Data Services. https://doi.org/10.5880/GFZ.1.3.2022.003

Simulation Results: OT Corrections

- Figure 1 shows the degree error amplitudes for full-noise and OT error-only simulations. The constrained co-estimation of OT model corrections with known uncertainties yields significantly smaller errors for OT error-only scenarios. The effect is dampened for full-noise scenarios due to the presence of AO and instrument errors.

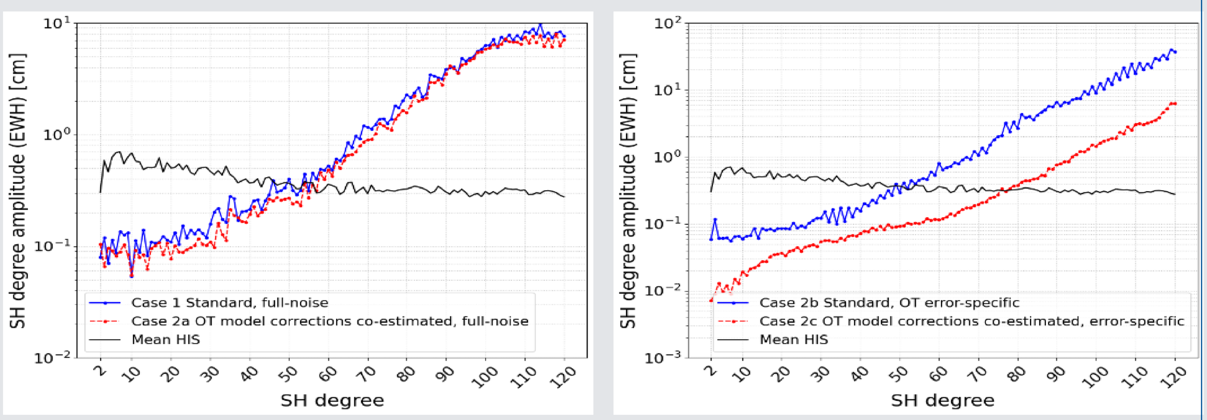

Figure 1: SH degree amplitudes of the monthly residuals based on simulations including full-noise and OT error-only scenarios.

- In Figure 2, the difference between the absolute errors for standard and optimized processing is shown in terms of dimensionless SH coefficients and EWH. Blue denotes areas where errors are reduced, and red indicates areas with increased errors. For the error-only scenario, errors are reduced by 85%.

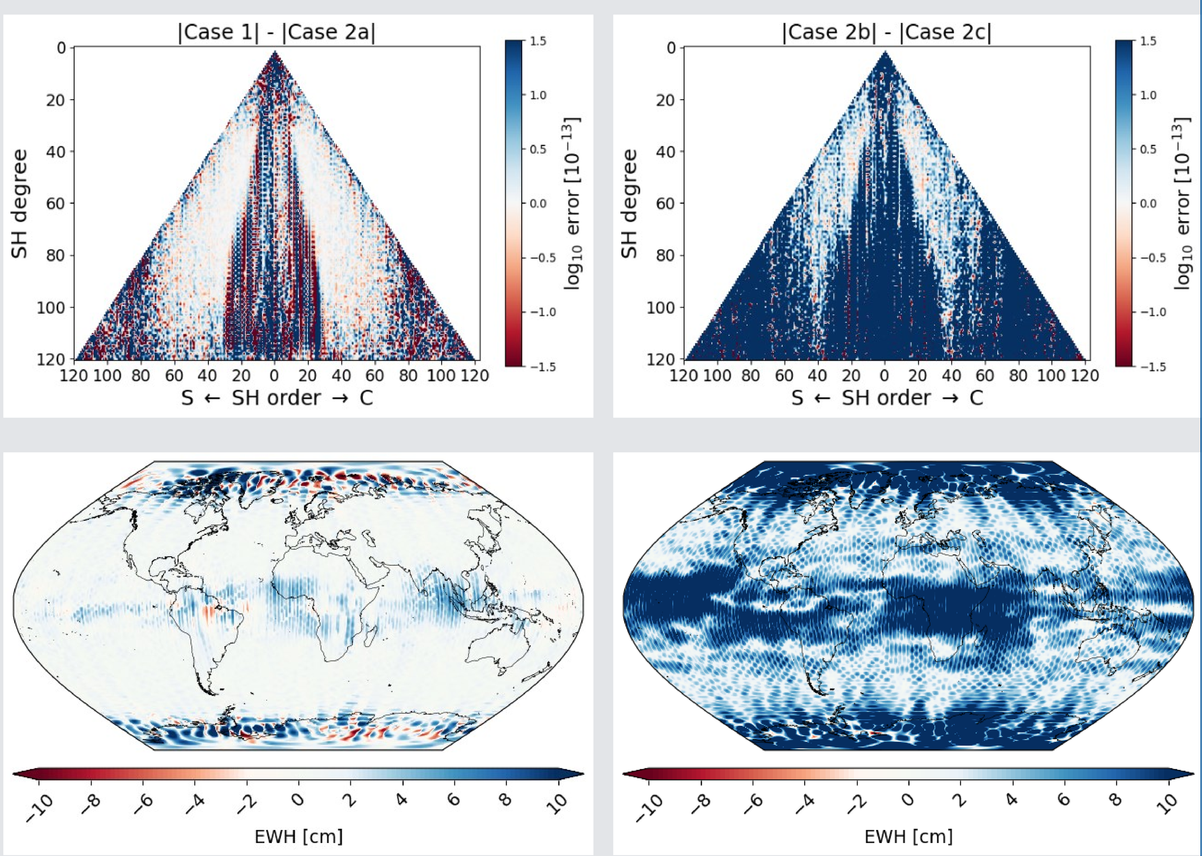

Figure 2: Dimensionless triangle and spatial plots for full-noise and OT error-only scenarios are shown on the left and right, respectively. These plots show the difference between the absolute errors for standard and optimized processing.

- Figure 3 shows the half peak-to-peak amplitudes over 24 hours in cm EWH computed for January 1st 2002, for the sum of the eight major tidal constituents. Estimated ocean tides from a one-year simulation reduce OT errors by 19%.

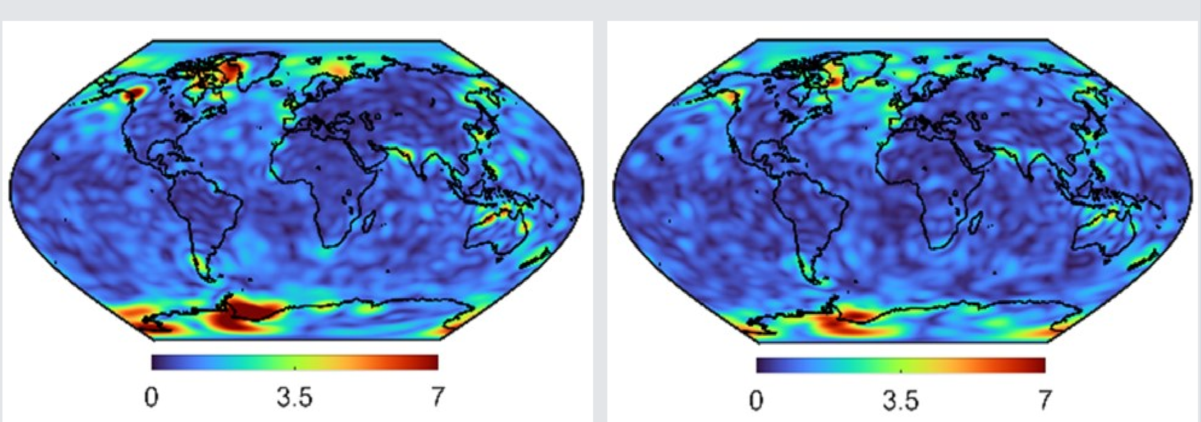

Figure 3: EOT11a-FES2014 (left) and EOT11a-updated FES2014 (right) in terms of half peak-to-peak amplitudes over 24 hours for the sum of the eight major tidal constituents.

Simulation Results: AO Corrections

- Figure 4 shows the degree error amplitudes for full-noise and AO error-only simulations. The constrained co-estimation of AO model corrections with known uncertainties yields significantly smaller errors for both full and AO error-only scenarios.

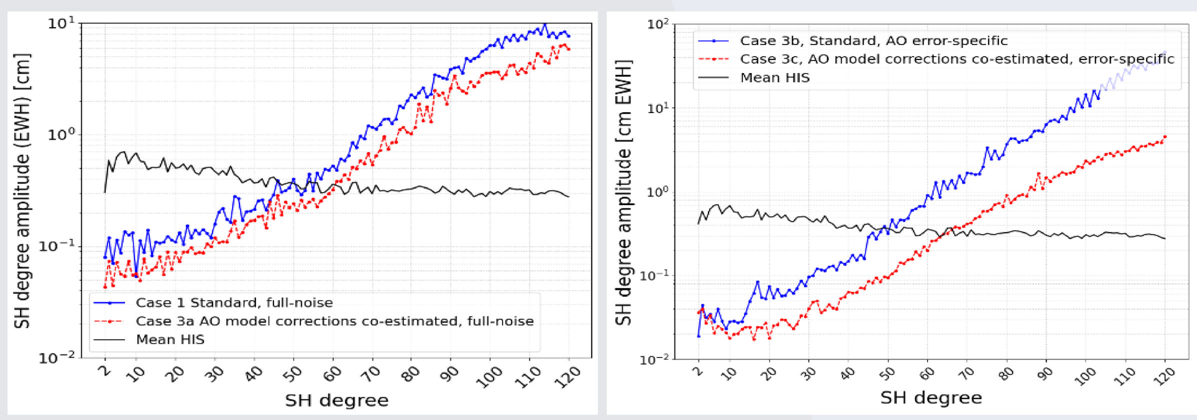

Figure 4: SH degree amplitudes of the monthly residuals based on simulations, including full-noise and AO error-only scenarios.

- In Figure 5, the difference between the absolute errors for standard and optimized processing is shown in terms of dimensionless SH coefficients and EWH. Blue denotes areas where errors are reduced, and red indicates areas with increased errors. For the error-only scenario, errors are reduced by 88%.

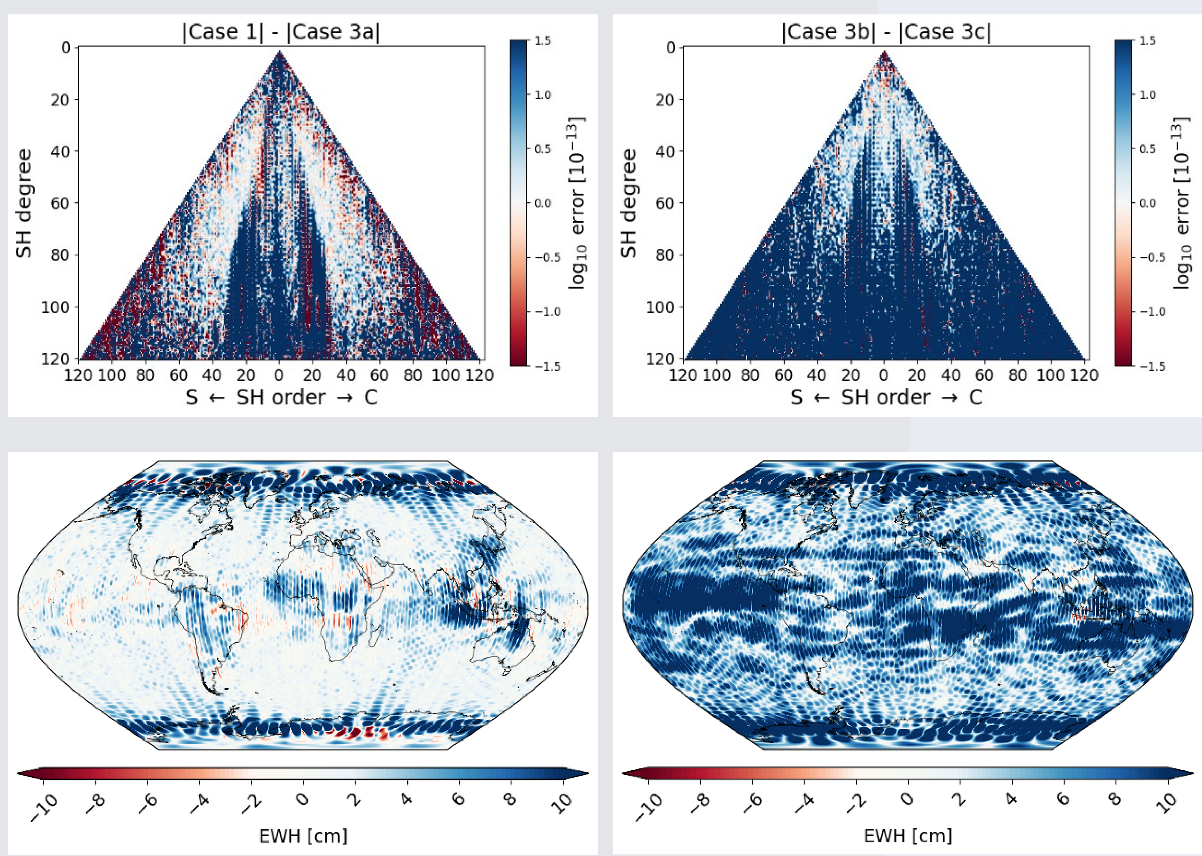

Figure 5: Dimensionless triangle and spatial plots for full-noise and AO error-only scenarios are shown on the left and right, respectively. These plots show the difference between the absolute errors for standard and optimized processing.

- Figure 6 shows the AO model errors, AOe07, and estimated corrections for the AO error-only scenario for January 1st 2002 at 06:00 on the left and right. Corrections are correctly estimated during recovery since the estimated correction is approximately the negative of the error.

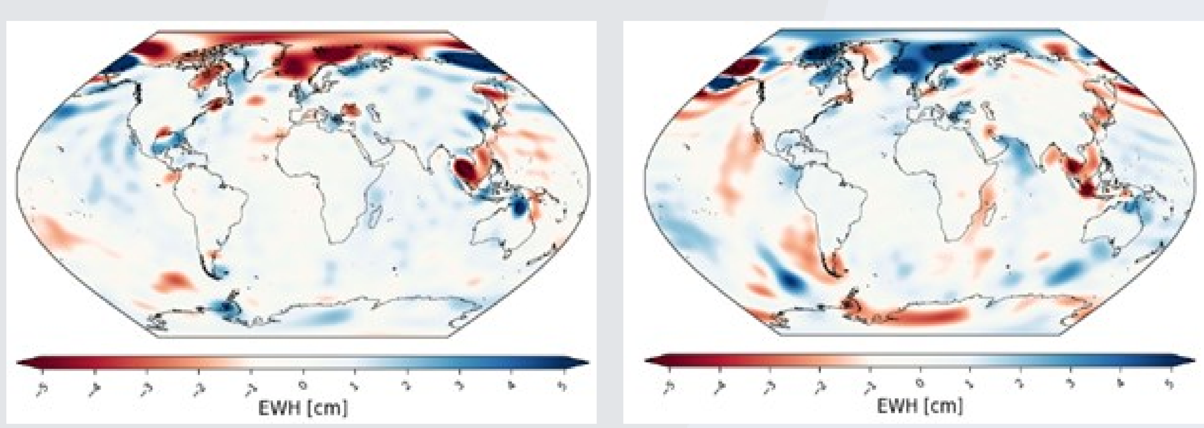

Figure 6: AO error model (left) and AO estimated corrections (right) for January 1st 06:00.

Simulation Results: AO+OT Corrections

- Figure 7 Left shows the degree error amplitudes for each month in 2002 for a full noise simulation during which both AO and OT corrections were co-estimated subject to their respective uncertainty constraints. On the right, the accumulated errors are compared to the mission requirements (green circles), and it can be seen that the optimized method fulfils the mission requirements.

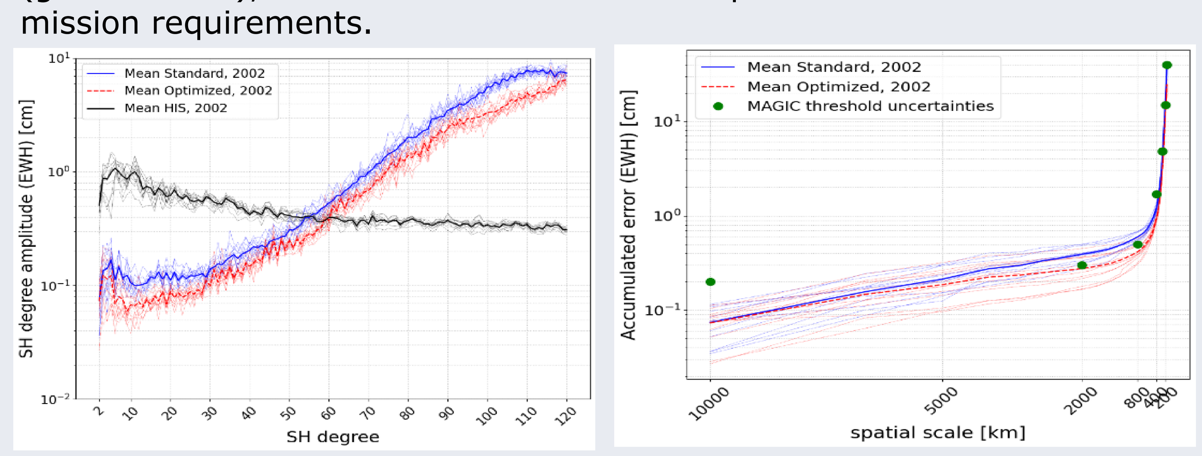

Figure 7: Mean monthly residuals, calculated over one year, for the standard and optimized processing methods in blue and red.

- The temporal coefficient RMS for each degree n and order m at time t, given by $\sqrt{1/T\sum_t\left(C_{HIS}(n,m,t)-C_{est}(n,m,t)\right)^2}$, was calculated over $T=12$ months, and the values obtained for the standard and optimized processing schemes are shown in Figure 8.

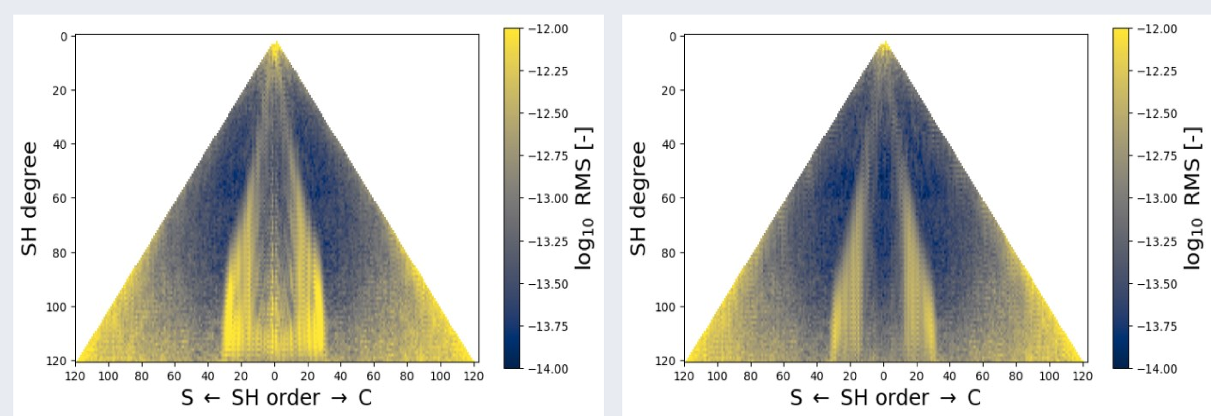

Figure 8: Temporal RMS for the standard (left) and optimized (right) processing strategies in terms of dimensionless coefficients.

- A quantitative assessment of the retrieved MAGIC gravity fields was done through latitude-dependent weighted RMS values (Figure 9). On average, a 32% error reduction is observed.

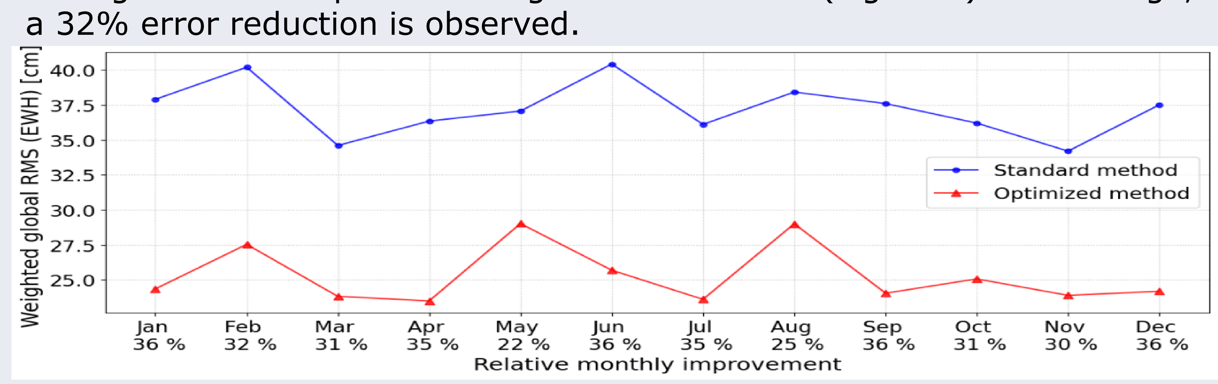

Figure 9: Global wRMS values in terms of cm EWH.

- The co-estimation of AO model corrections further reduces OT errors. Figure 10 shows the half peak-to-peak amplitudes over 24 hours in cm EWH computed for January 1st 2002 for the sum of the eight major tidal constituents. Without AO corrections, the error reduction is 19%, and with AO corrections, it is 27%.

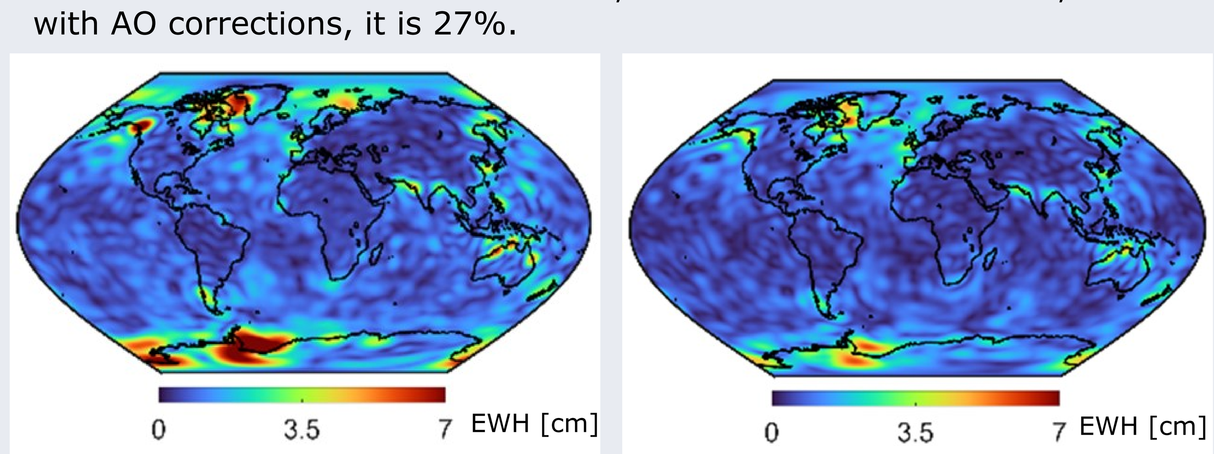

Figure 10: EOT11a-FES2014 (left) and EOT11a-updated FES2014 (right) in terms of half peak-to-peak amplitudes over 24 hours for the sum of the eight major tidal constituents.