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Reducing filter effects in GRACE-derived polar motion excitations

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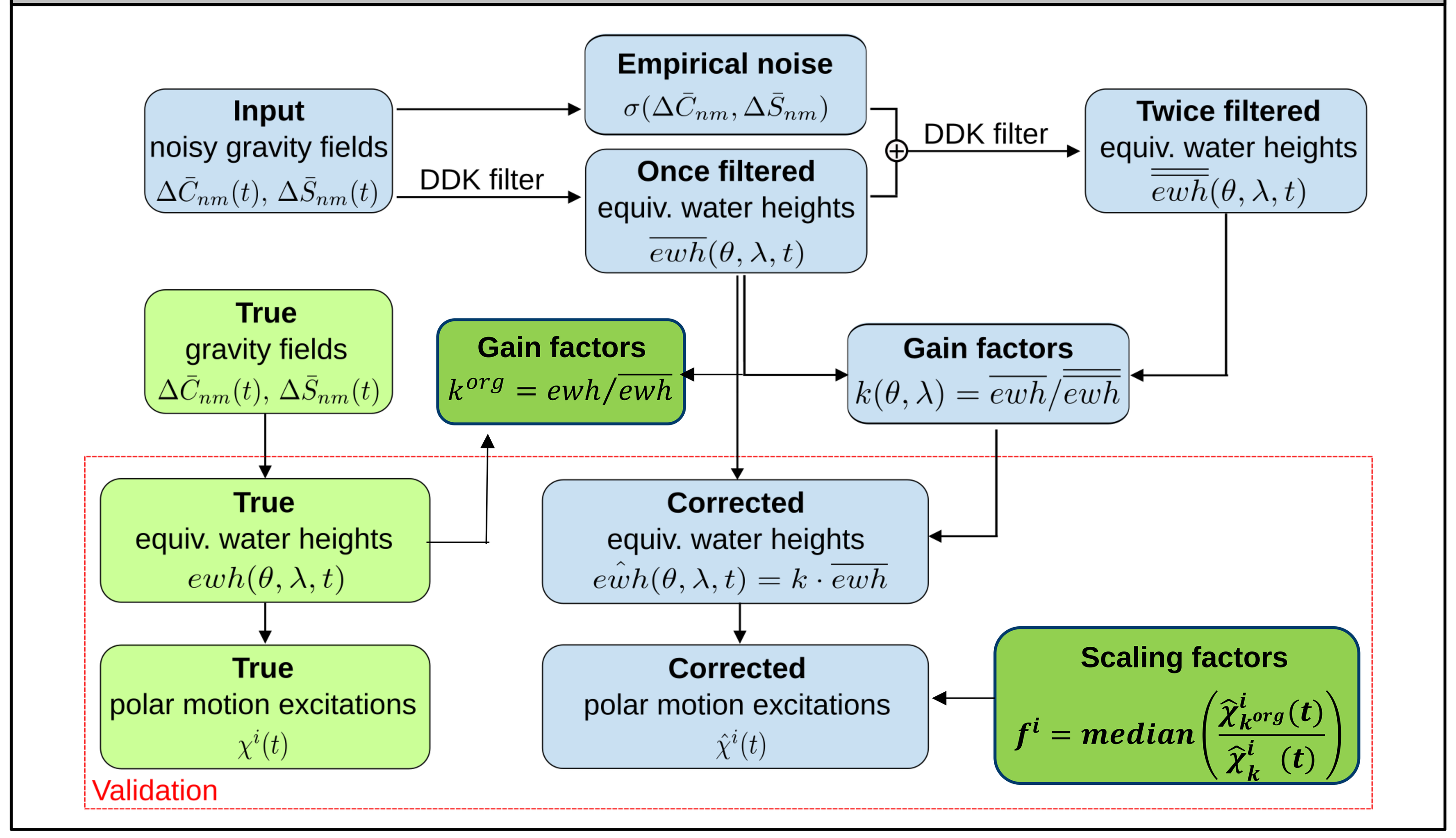
Introduction Polar motion is caused by mass redistribution and motion within the Earth system. The GRACE (Gravity Recovery and Climate Experiment) satellite mission observed variations of the Earth's gravity field which are caused by mass redistribution. Therefore GRACE time variable gravity field models are a valuable source to estimate individual geophysical mass-related excitations of polar motion. Since GRACE observations contain erroneous meridional stripes, filtering is essential in order to retrieve meaningful information about mass redistribution within the Earth system. However filtering reduces not only the noise but also smooths the signal and induces leakage of neighboring subsystems into each other. We present a novel approach to reduce these filter effects in GRACE-derived equivalent water heights and polar motion excitation functions which is based on once and twice filtered gravity field solutions. The advantages of this method are that it is independent from geophysical model information, works on global grid point scale and can therefore be used for mass variation estimations of several subsystems of the Earth.

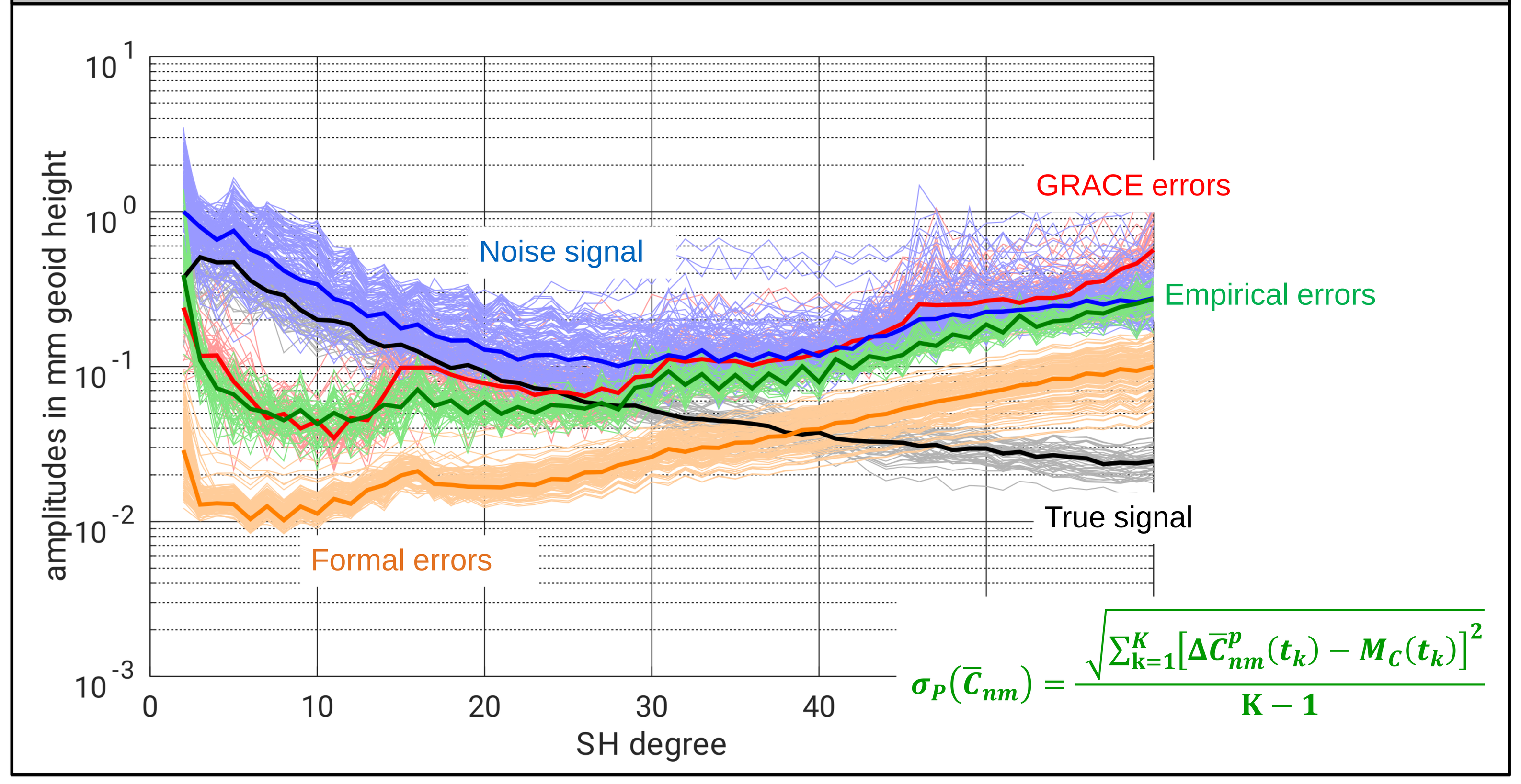
Reduction of filter effects

Based on the methods published by Landerer and Swenson (2012) and Vishwakarma et al. (2016) we developed a filter effect reduction approach that is independent from geophysical model information and that works for several subsystems of the Earth.

Filter effect reduction approach on global grid point scale



Empirical noise determination from GRACE solutions: GFZ, CSR, JPL RL06 and ITSG-Grace2018



References

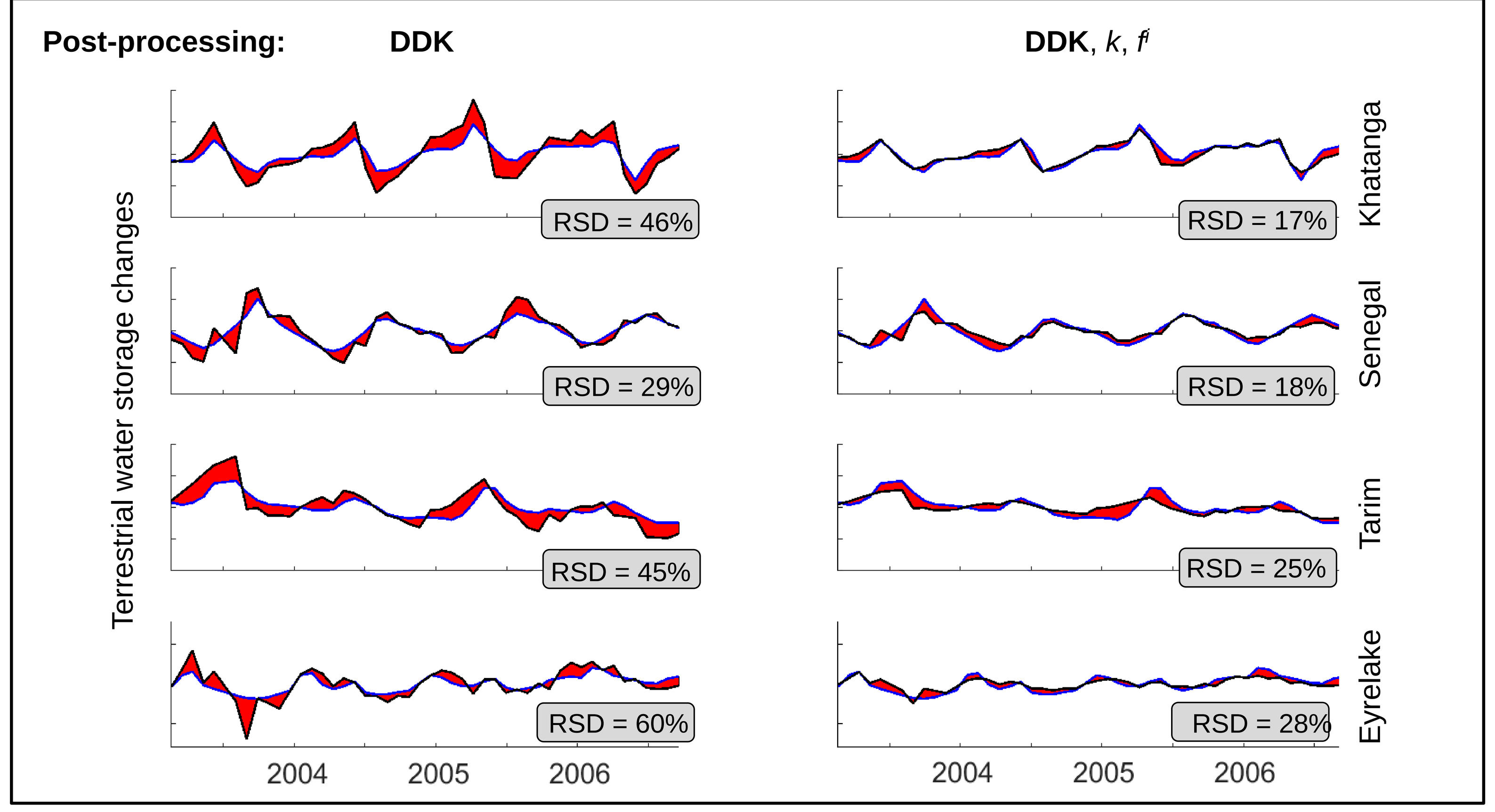
Landerer F.W. and S.C. Swenson (2012): Accuracy of scaled GRACE terrestrial water storage estimates. Water Resour. Res., 48, W04531.

Vishwakarma B.D., B. Devaraju, and N. Sneeuw (2016): Minimizing the effects of filtering on catchment scale GRACE solutions. Water Resour. Res., 52, 5868-5890.

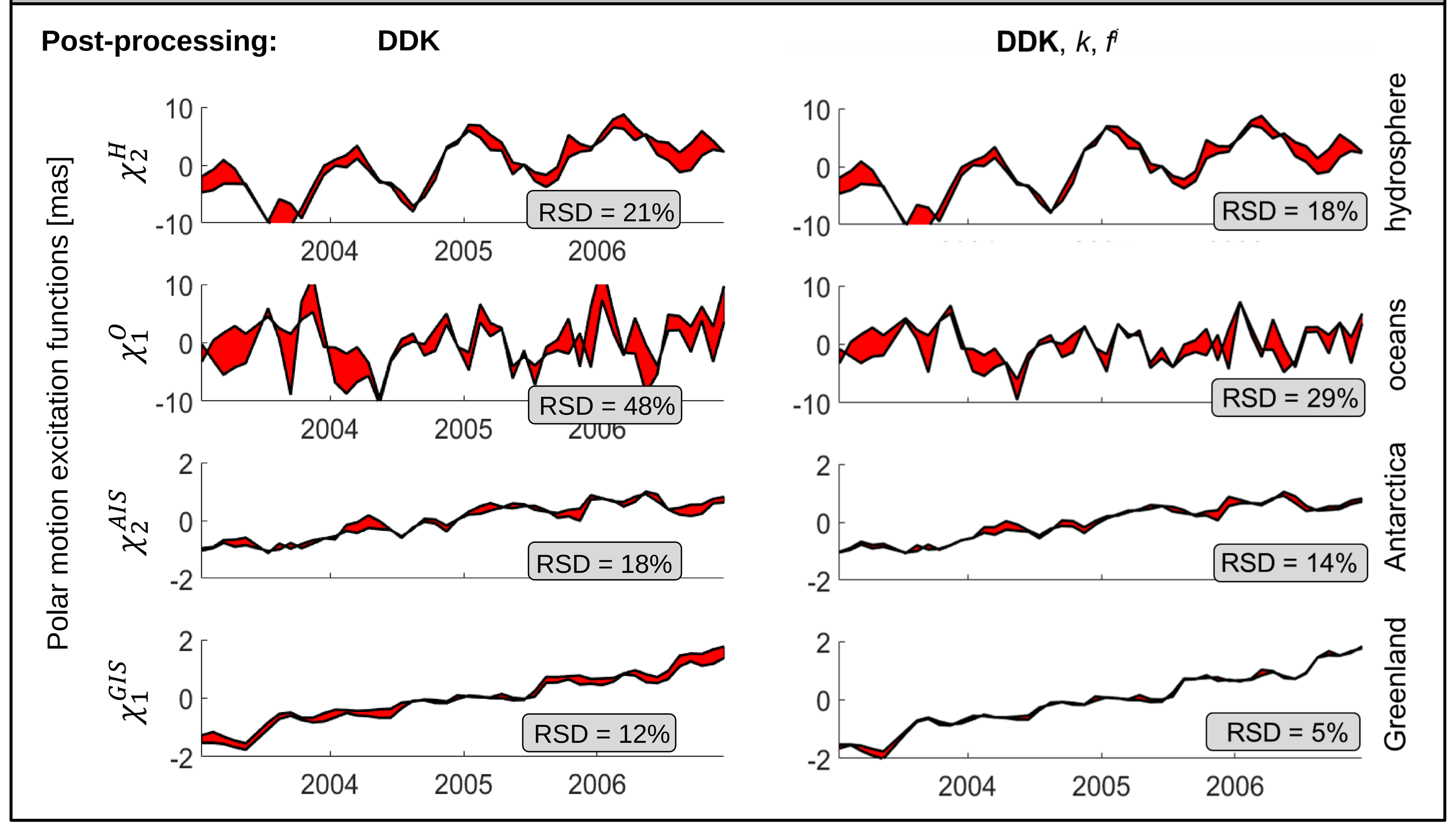
Simulation environment

To validate our approach we use four years of the full-scale closed-loop simulation data described in Flechtner et al. (2016). The observations there are based on a realistic orbit scenario and error assumptions for instruments and background models. We use GRACE-like gravity field solutions up to degree and order 60.

Comparison of terrestrial water storage changes: True vs. filtered time series



Comparison of polar motion excitations: True vs. filtered time series

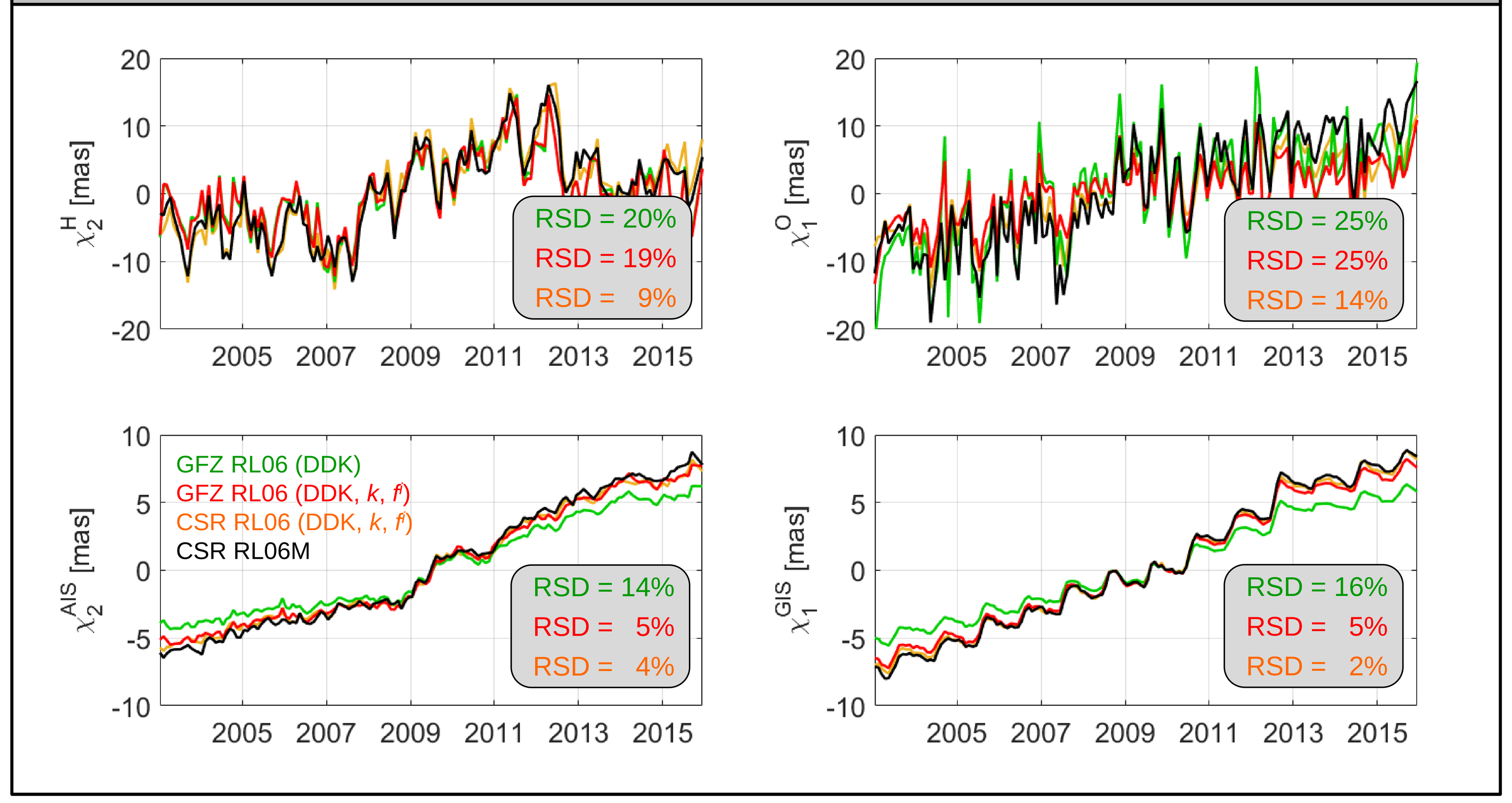


Acknowledgement These studies are performed in the framework of the project CIEROT (Combination of geodetic space observations for estimating cryospheric mass changes and their impact on Earth rotation) founded by the German Research Foundation (DFG).

Application to real GRACE gravity field solutions

We applied our filter effects reduction approach to the GRACE gravity field solutions: GFZ RL06 and CSR RL06 and compare our results for individual polar motion excitations with results of the GRACE mascon solution CSR RL06M and with ocean model solutions.

Validation of our approach with the GRACE mascon solution CSR RL06M



Validation of our approach with the ocean models ECCO and ESMGFZ

	χ_1^O				χ_2^O			
	ECCO		ESMGFZ		ECCO		ESMGFZ	
	correlation	RSD	correlation	RSD	correlation	RSD	correlation	RSD
GFZ RL06 (DDK)	0.53	46%	0.60	32%	0.57	34%	0.68	27%
GFZ RL06 (DDK, k, f^i)	0.54	31%	0.60	27%	0.60	32%	0.67	27%
CSR RL06 (DDK, k, f^i)	**0.62**	**28%**	0.77	22%	**0.72**	**27%**	0.69	27%
CSR RL06M	0.70	29%	**0.89**	**19%**	0.69	29%	**0.80**	**22%**

Conclusions:

- Our filter effect reduction approach is independent from geophysical model information and can be used for mass estimations of several subsystems of the Earth.
- Uncertainties in polar motion excitations derived from GRACE gravity field models can be decreased from 12 – 48% to 5 – 29%.
- Improved accordance with the GRACE mascon solution CSR RL06M, especially in Antarctica and Greenland (9 and 11 percentage points).
- Agreement with ocean model results can be improved by up to 15 percentage points.

References

Flechtner et al. (2016): What can be expected from the GRACE-FO laser ranging interferometer for Earth science applications? Surveys in Geophysics, 37(2), 453-470.

Göttl F., M. Murböck, M. Schmidt, F. Seitz (2019): Reducing filter effects in GRACE-derived polar motion excitations. Earth, Planets and Space, 71.

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