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Minimizing filter effects in GRACE-derived effective angular momentum functions

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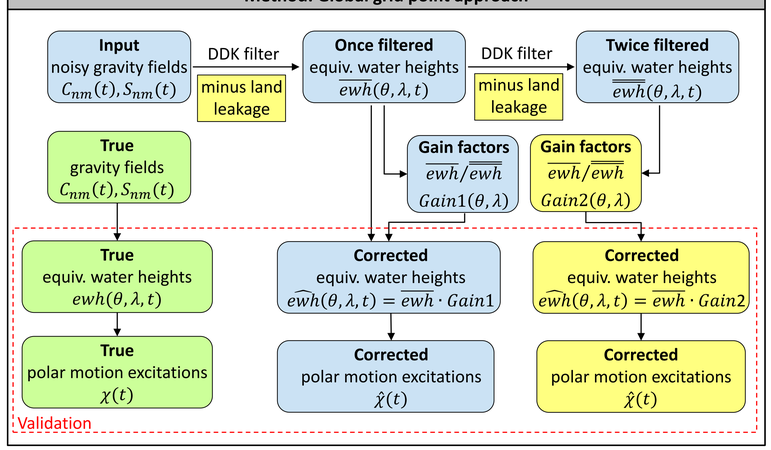
Introduction Variations of Earth rotation are caused by the redistribution and motion of masses within the Earth system. Between 2002-2017, the satellite mission GRACE has observed variations of the Earth's gravity field which are caused by mass displacements. GRACE-derived time variable gravity field models can be used to determine effective angular momentum functions which describe mass-related excitation mechanisms of Earth rotation. Since, GRACE level 2 products are contaminated by noise filtering is essential to retrieve meaningful information about mass redistribution within the Earth system. However, filtering does not only attenuate noise but also signal and it induces, beside the limited degree and order of the spherical harmonic coefficients, that neighboring subsystems leak into each other. Therefore, the separation of integral mass variations into contributions of individual subsystems of the Earth still remains a challenge. We developed two new approaches to minimize the filter effects: (1) on a global grid point basis and (2) on the level of effective angular momentum functions. An advantage especially of the second approach is that it provides significant improvements for all subsystems. Thus in contrast to other filter minimizing methods an equal treatment of the different subsystems is possible.

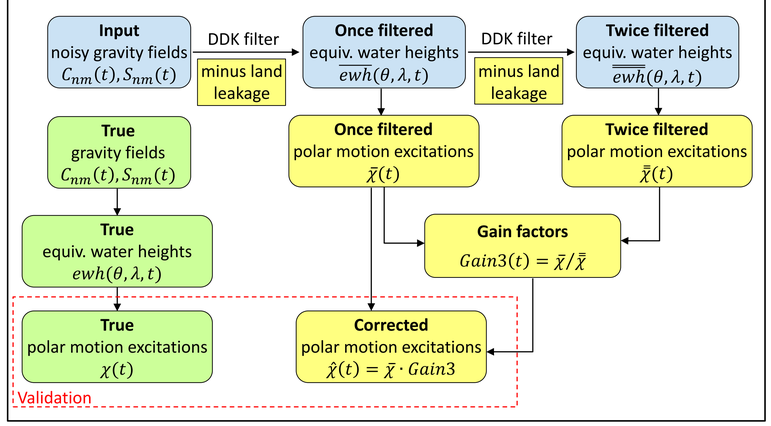
Minimization of filter effects

Following the methods for filter effect minimization of Landerer and Swenson (2012) and Vishwakarma et al. (2016) we developed two new approaches to minimize the filter effects: (1) on a global grid point basis and (2) on the level of effective angular momentum functions. Both methods are independent of geophysical model information. The scaling factors depend only on once and twice filtered GRACE gravity field models.

Method: Global grid point approach



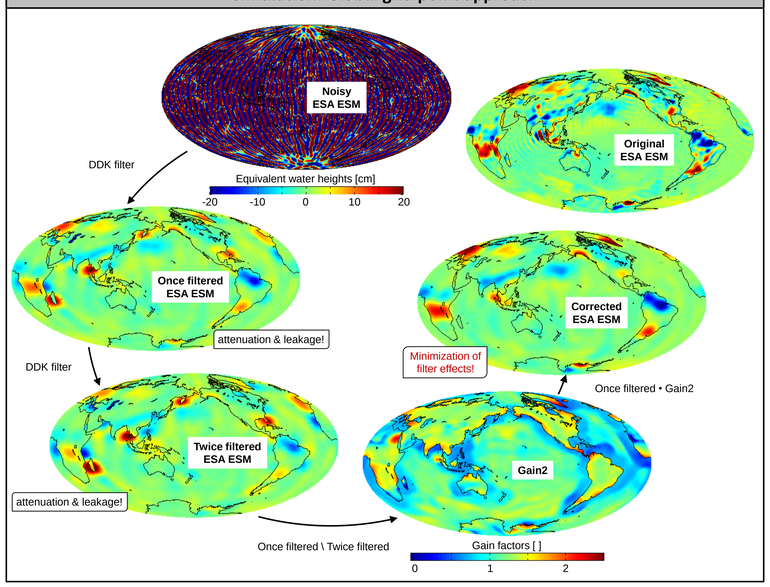
Method: Effective angular momentum function approach



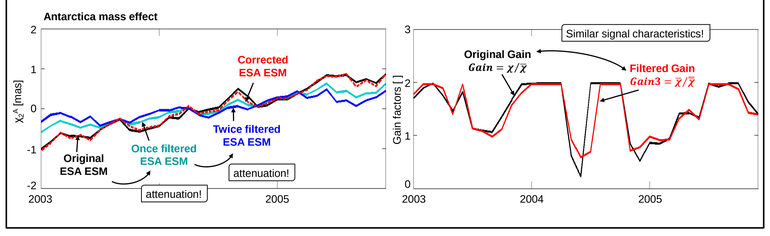
Simulation Environment:

ESA ESM data (Dobslaw et al. 2015) of the oceans, continental hydrosphere and cryosphere are used to perform closed-loop simulations. To ensure spectral consistency with GRACE time variable gravity field models we use only the spherical harmonic coefficients up to degree and order 60. Furthermore, the temporally high-resolution ESA ESM data are converted into monthly solutions like the GRACE gravity field models. In order to consider GRACE type noise in the closed-loop simulation environment, we add realistic noise derived from GRACE CSR RL05 filtered and unfiltered gravity field models.

Simulation: Global grid point approach

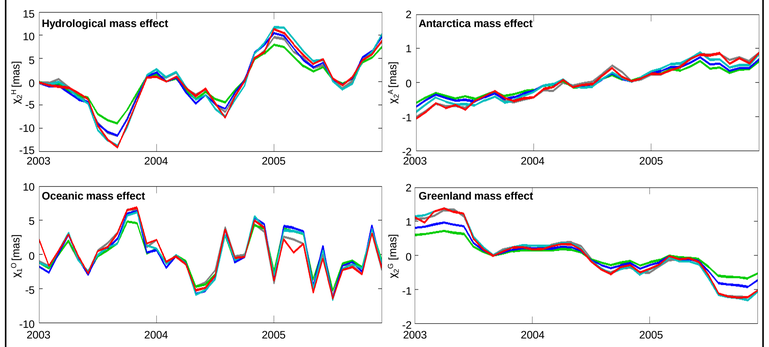


Simulation: Effective angular momentum approach



Validation of simulated effective angular momentum functions

Effective angular momentum functions derived from the original ESA ESM data (grey) and the noisy ESA ESM data by applying only the DDK filter (green) or by using one of the filter effect minimization methods: Gain1 (blue), Gain2 (cyan) and Gain3 (red).



Root mean square (RMS, [mas]) differences and relative standard deviations (RSD, [%]) with respect the original ESA ESM solutions.

	χ_1^H		χ_1^O		χ_1^A		χ_1^G	
	RMS	RSD	RMS	RSD	RMS	RSD	RMS	RSD
Fil1	0.85	13	0.95	15	0.05	16	0.36	24
Gain1	0.65	10	0.90	14	0.05	14	0.21	14
Gain2	0.87	13	0.84	13	0.04	13	0.09	6
Gain3	**0.57**	**9**	**0.74**	**11**	**0.03**	**8**	**0.08**	**6**

	χ_2^H		χ_2^O		χ_2^A		χ_2^G	
	RMS	RSD	RMS	RSD	RMS	RSD	RMS	RSD
Fil1	1.19	10	1.19	11	0.23	23	0.33	25
Gain1	**0.81**	**7**	1.73	16	0.18	18	0.20	15
Gain2	1.27	11	1.17	11	0.14	13	0.06	5
Gain3	0.89	8	**1.14**	**11**	**0.05**	**5**	**0.06**	**4**

Conclusions:

- Destriping and filtering of GRACE gravity field models cause uncertainties of 10 – 25 % in GRACE-derived polar motion excitations.
- These erroneous filter effects can be reduced well by using the global grid point approach, especially for Greenland (6 %) and Antarctica (13 %).
- It is important to reduce the land leakage effects onto the oceans before the determination of the global grid point gain factors.
- The effective angular momentum approach yields the best results for all subsystems, the uncertainties due to destriping and filtering can be decreased to 4 – 11 %.

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References

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