Revisiting the sea level closure budget over 2004-2014 from a GRACE perspective

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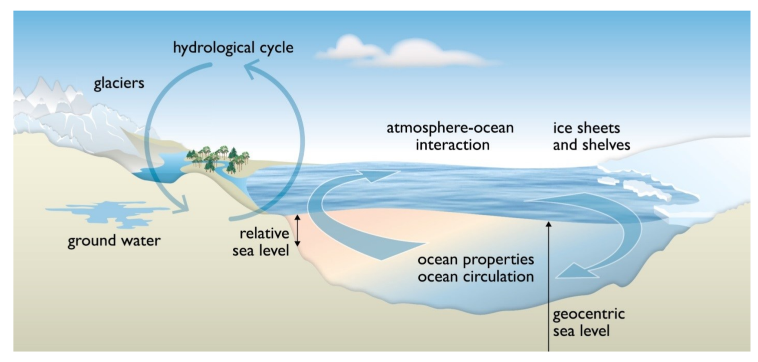
Abstract

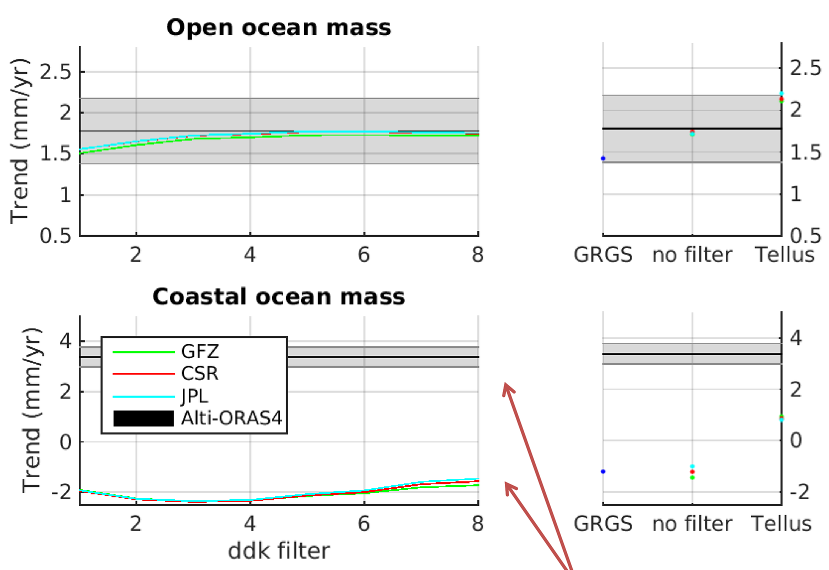
Based on the sea level budget closure approach, this study investigates the consistency of observed Global Mean Sea Level (GMSL) estimates from satellite altimetry, observed Ocean Thermal Expansion (OTE) estimates from in-situ hydrographic data (based on Argo for depth above 2000m and oceanic cruises below) and GRACE observations of land water storage and land ice melt for the period **January 2004 to October 2014**

The consistency between these datasets is a key issue if we want to constrain missing contributions to sea level rise such as the deep ocean contribution. Numerous previous studies have addressed this question by summing up the different contributions to sea level rise and comparing it to satellite altimetry observations (see for example Llovel et al. 2015, Dieng et al. 2015.

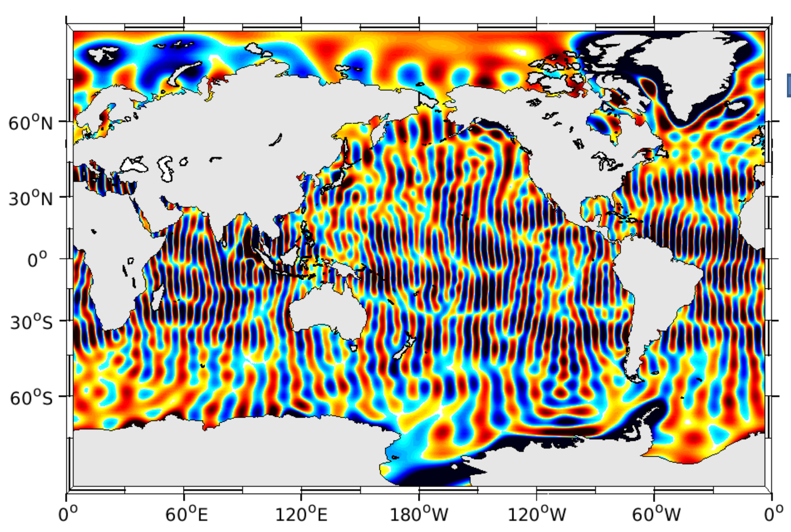
Here we propose a novel approach which consists in correcting GRACE solutions over the ocean (essentially corrections of stripes and leakage from ice caps) with mass observations deduced from the difference between satellite altimetry GMSL and in-situ hydrographic data OTE estimates. We check that the resulting GRACE corrected solutions are consistent with original GRACE estimates of the geoid spherical harmonic coefficients within error bars and we compare the resulting GRACE estimates of land water storage and land ice melt with independent results from the literature. We test the sensitivity of the method to different deep ocean contribution to GMSL and propose a best estimate



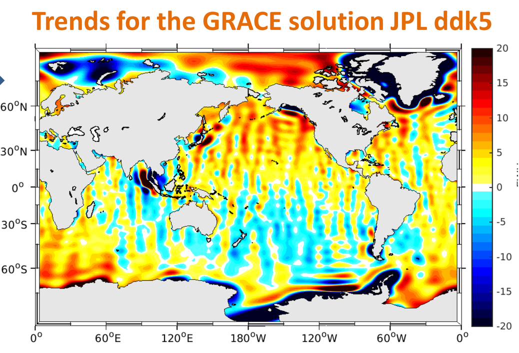
Spurious signal in the ocean prevents from estimating an accurate ocean mass with GRACE

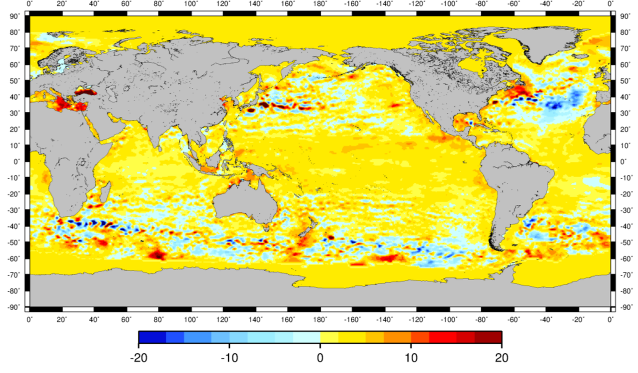


Leakage problem

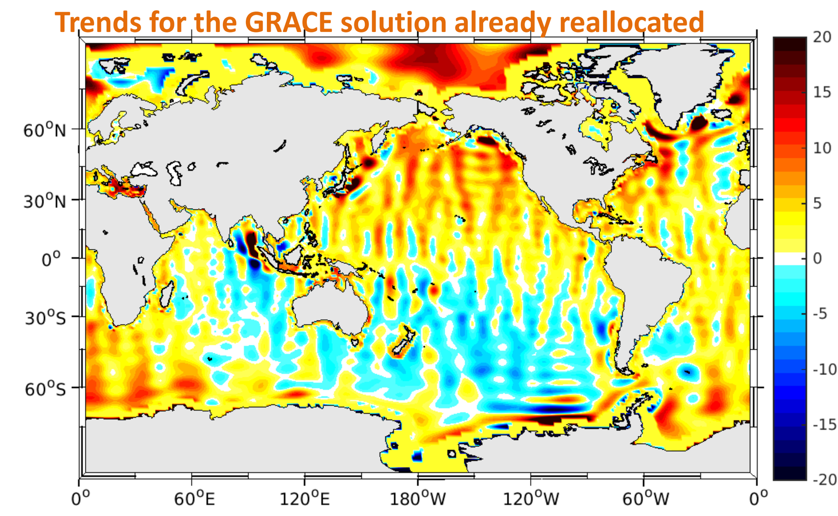


Stripes corrections by ddk filter



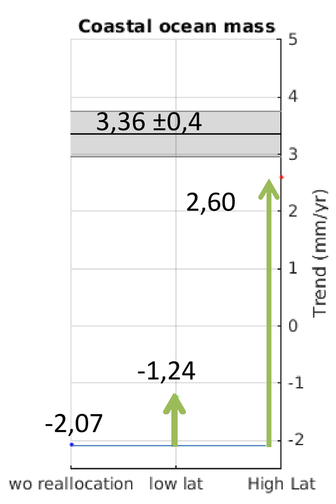


Leakage correction by reallocating mass



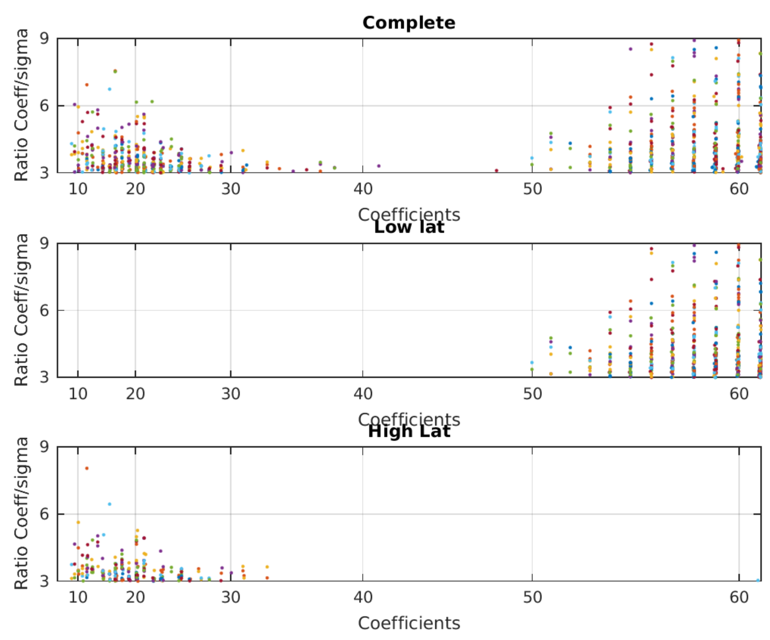
We force the ocean signal in GRACE solution to fit to Observations within the observability of GRACE

1) Two main sources of leakage:



1) At high latitudes along the coast of Greenland and Antarctica
2)At low latitudes near the epicenter of major earthquakes

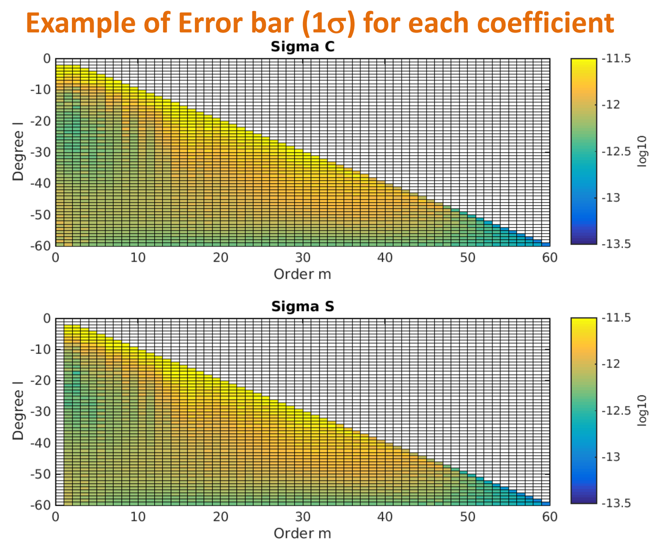
Left figure shows the Trend for the coastal ocean after reallocating the mass



Right Figure shows the ratio between differences in SHE and their sigma associated
Each dot corresponds a coefficient at a date violating the error bar (3 sigma)

2) Reallocation constraints

- Total Water conservation.
- Compliant with GRACE observations
  Differences between new Spherical harmonic expansion and original one should be within the error bar
- Reallocation occurs in leakage zones



The error associated for each coefficient at **each date** is estimated as the maximum among:

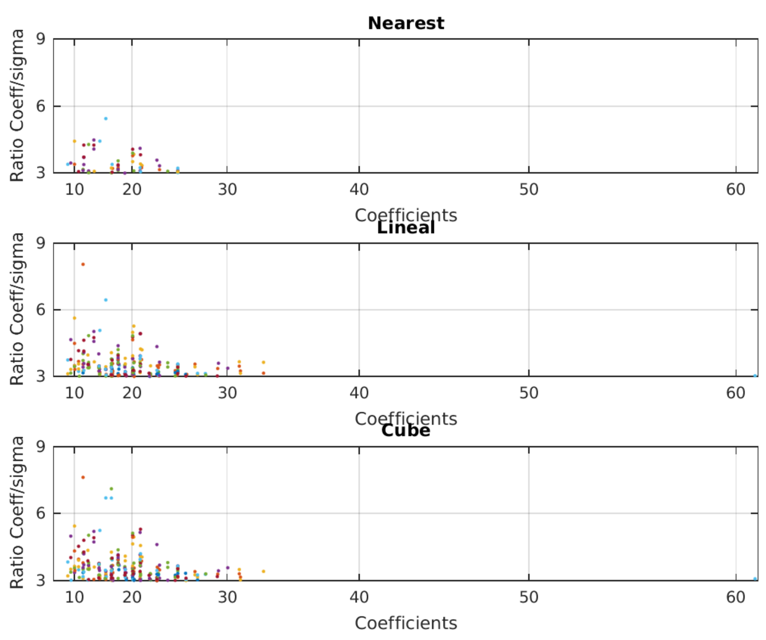
- formal error shown in JPL ddk5 and GFZ ddk5 and
- Differences between JPL ddk5, GFZ ddk5 and CSR ddk5

3) How to reallocate the water from the ocean?

Nearest: Each ocean mass is reallocated at the nearest sea front

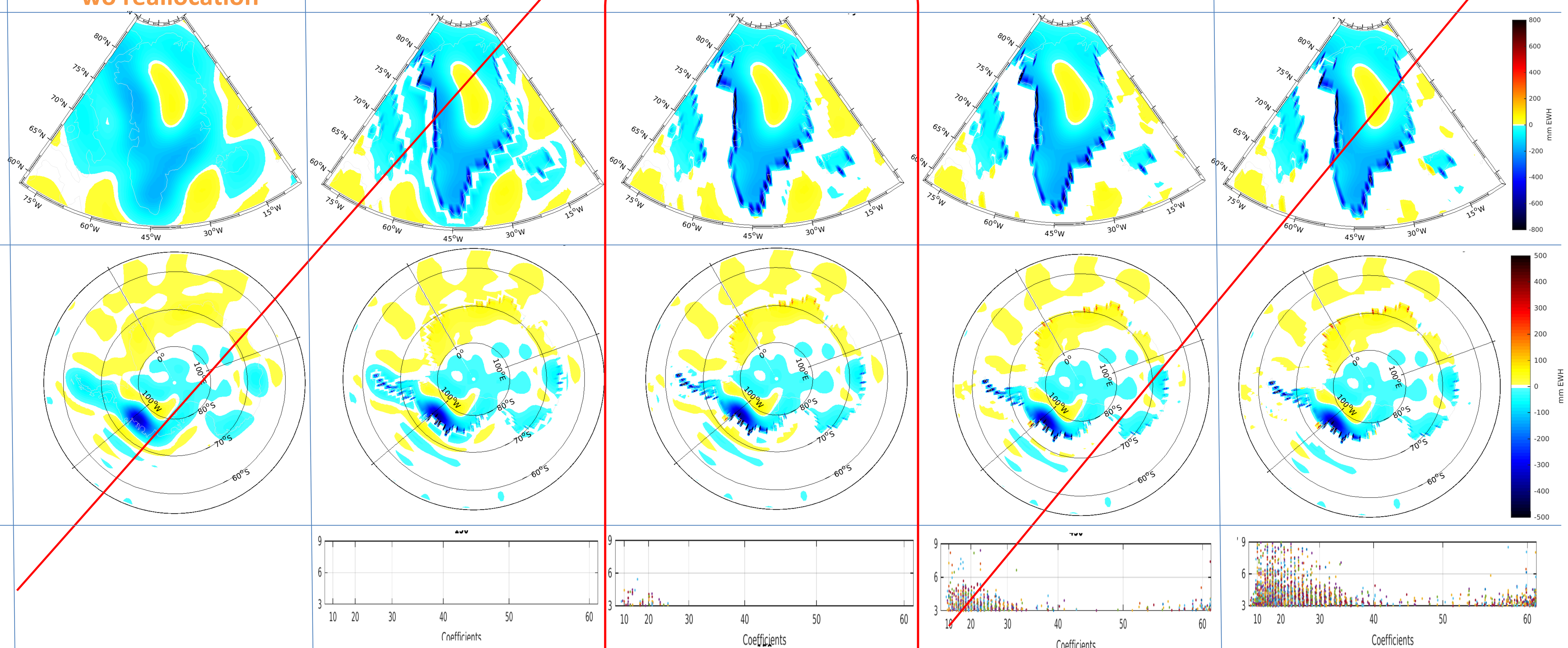
Linear: Each ocean mass is reallocated within a 300km inversely proportional to the distance

Cube: same as lineal but to the cube of the distance



And we test this method with four different mass allocation distances

Results



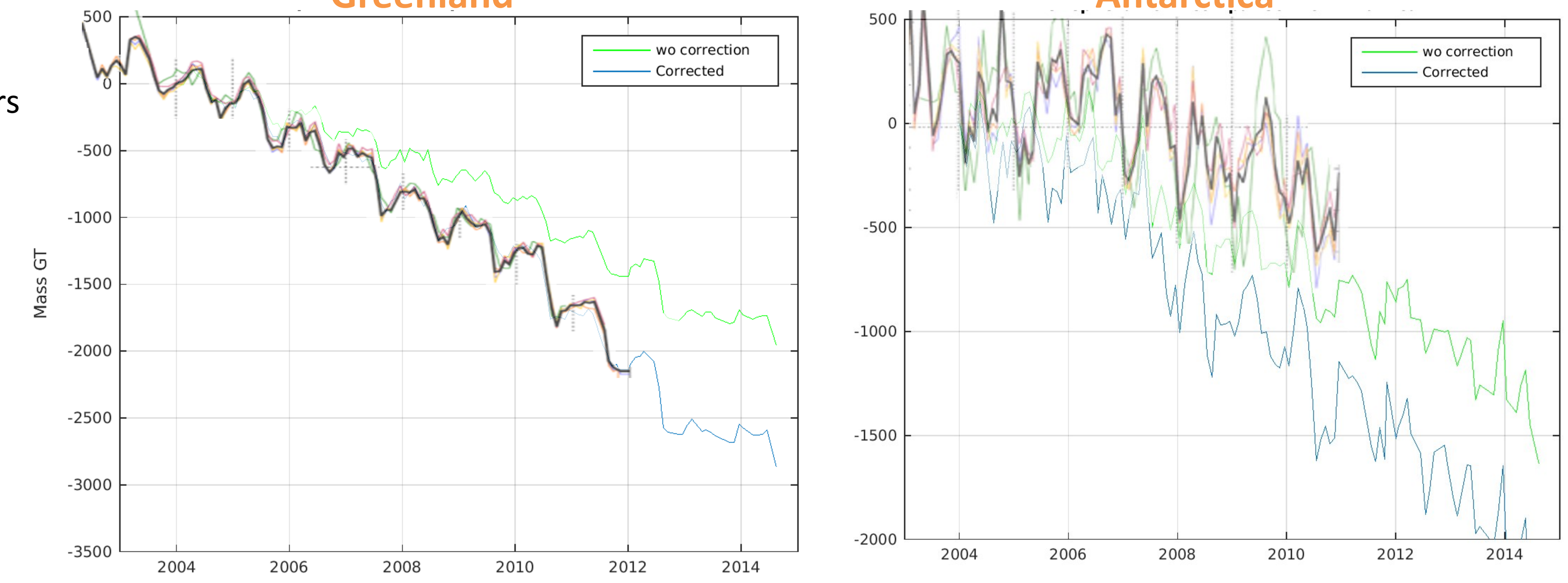
	Original wo reallocation	150 km	300 km	450 km	600 km
Coastal Ocean	**-2,07**	**1,42**	2,60	2,65	2,68
Open Ocean	1,77	1,77	1,77	1,70	1,61
GOM	**1,13**	**1,72**	1,92	1,86	1,80
GL	**-0,53**	-0,72	-0,79	-0,78	-0,77
Antarctica	**-0,39**	-0,54	-0,56	-0,54	-0,52

Not compliant with Altimetry and steric observations — Compliant with GRACE and Altimetry and steric — Not compliant with GRACE

Further analysis

- Downscaling from 1 degree to 0.5 degree and from SHE order 60 to 80
- Improve ocean observations using altimetry observations for Arctic ocean
- Improving land distribution in the emerged lands (First line of coast vs glaciers
- Specific treatment for the low latitudes and earthquakes
- Improving of the Antarctica solution. GIA
- Sensibility of the method to different s GIA model

Shepherd 2012 6 GRACE solutions comparison



This on-going method provides un independent solution, which will be, by definition, compliant with:

- **Sea level rise by satellite altimetry and Ocean Expansion**
- **Greenland, Antartica mass loss estimated by GRACE**
- **Water storages and glaciers ice melt estimated by GRACE**

The 6 solutions used the same GIA model and our solution used A.G. Whar 2013

Data used

GRACE solutions already filtered at www.icgem.gfz-potsdam.de/ICGEM/
GRGS solution: http://grgs.obs-mip.fr/grace/variable-models-grace-lageos/grace-solutions-release-03
Tellus Ocean solutions: http://grace.jpl.nasa.gov/data/get-data/monthly-mass-grids-ocean/ + Global Ocean Mass evolution
GIA: A, G., J. Wahr, and S. Zhong (2013)

AVISO+ altimetry DUACS
ORA-S4 : ftp://ftp.icdc.zmaw.de/EASYInit/ORA-S4/monthly_1x1/