Ocean tides in the GRACE CSR RL5 monthly averaged gravity fields.

and other stuff

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Abstract

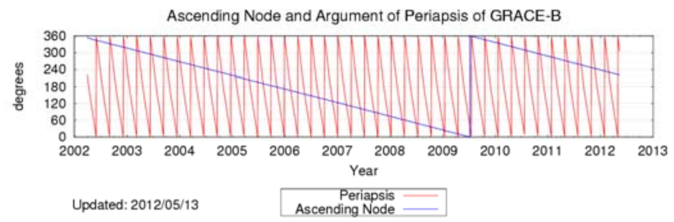
The The GRACE gravity field satellite mission maps the Earth's gravity fields and its variations with unprecedented accuracy during its 11-year lifetime. Unless ocean tide signals and their load upon the solid earth are removed from the GRACE data, their long period aliases obscure more subtle climate signals which GRACE aims at. In this analysis the results of Knudsen and Andersen [2002, 2007] have been revised using actual post-launch orbit parameter of the GRACE mission.

Tidal errors may affect the GRACE data up to harmonic degree around 40 and they will not cancel in the GRACE monthly averaged temporal gravity fields. The S2 and the K2 terms have alias frequencies much longer than 30 days, so they remain almost unreduced in the monthly averages. In this analysis the tidal residuals are extracted using the CSR-RL05 monthly geoid variations from GRACE data over the period from January 2003 to August 2013 made available by UTCRS.

Revision of tidal alias frequencies

The tidal alias frequencies are revised using the actual drift of the ascending node which is -48.60 deg/year and results in a sampling of 0.49844 days.

The revised tidal alias frequencies are shown in the table below.



From CSR: http://www.csr.utexas.edu/grace/operations/configuration.html

Table showing tidal alias frequencies and their monthly averaged reductions

Constituent	Frequency	Alias	Reduced
M2	0.5175	13.5	0.10
S2	0.5000	160	0.94
N2	0.5274	9.1	0.08
K2	0.4986	1594	1.00
K1	0.9973	0.9969	0.01
O1	1.0758	0.9969	0.01
P1	1.0028	0.9969	0.01
Q1	1.1195	0.9969	0.01

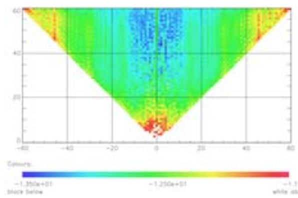
The estimation

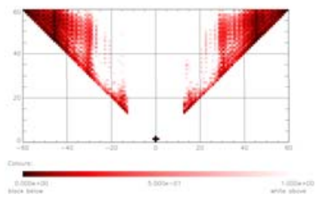
A joint estimation of mean, trend, acceleration, annual cycle, annual cycle trend, S2 and K2 tidal residuals is carried out using the harmonic coefficients for each harmonic degree and order up to degree and order 60

A filtering of the coefficients is applied. This filtering is based on std.dev. of the coeff.s. (shown below left)

Filter for m>12 if std.dev.>2e-13: f=(2e-13/std.dev.)**2 (shown below right)

In addition, to obtain higher accuracy estimates, solutions are computed where a Gaussian smoothing having a width of harmonic degree 25 was applied.



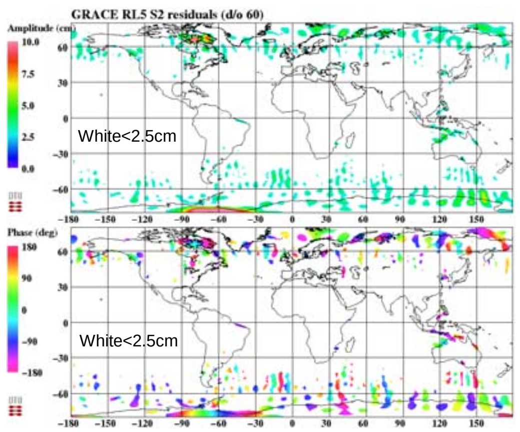


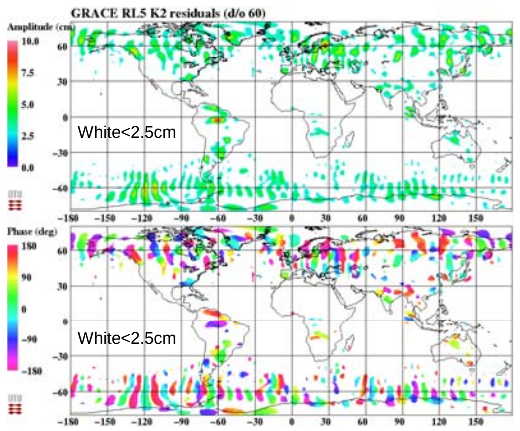
Results

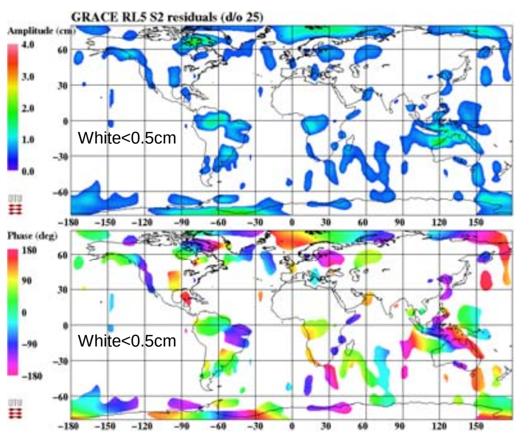
The results show that basically no tidal residuals are left in the monthly averaged CSR RL5 gravity fields to harmonic degree and order 60. Minor residuals are found in the inner Weddell Sea and in the Canadian Archipelago.

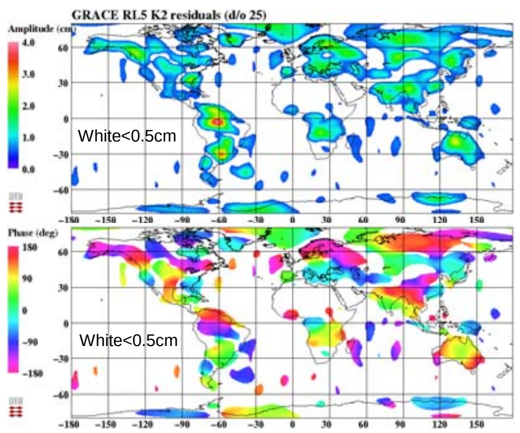
For the smoothed gravity fields where the accuracy level is lowered to around 0.5 cm, Additional, still minor, tidal residuals are found North of Australia and in the Arctic Ocean.

Hence, the GOT 4.8 ocean tide model does a fantastic job removing ocean tides from the GRACE gravity fields. With the enhanced accuracy of the GRACE Follow-On mission, ocean tides may become an issue.









Longer term changes

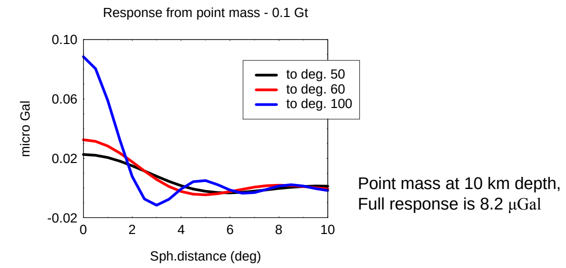
In addition to the tidal residuals associated with the tidal constituents S2 and K2, an annual cycle, a trend and an acceleration were estimated jointly. As mentioned above, this was done using both the full resolution up to harmonic degree and order 60 and using the coefficients where a Gaussian smoothing having a width of harmonic degree 25 was applied to focus more accurately on the variability of the oceans.

Ocean variability

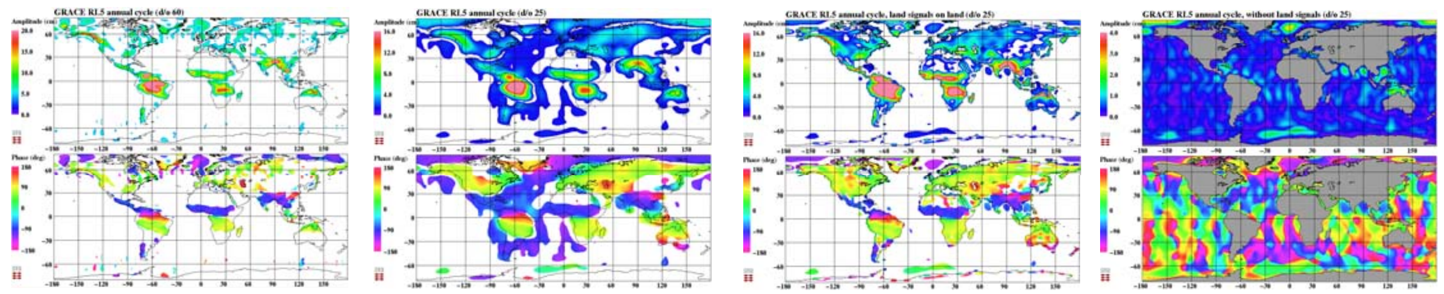
The Gaussian smoothing was applied to enhance the accuracy of the GRACE fields to be able to extract parameters associated with the ocean variability. Though the Gaussian smoothing has negligible side-lopes – which reduces the ringing effects of the truncated series – the additional smoothing smears out signal originating from mass changes on land, over the nearby ocean area. This is seen in Southern Greenland and in Alaska.

To remove land signal from the ocean point masses located on land in a grid are estimated. This a done using the response expanded into Legendre's polynomials and truncated at harmonic degree 60. Subsequently the responses from the point masses were removed.

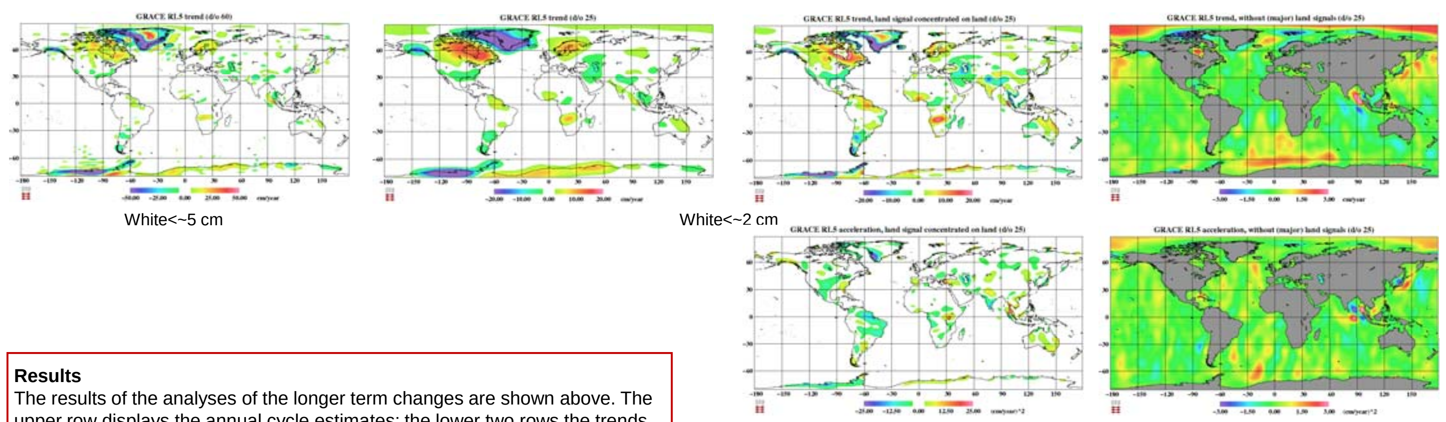
$$\Delta g_P = \frac{Gm_Q}{r_Q^2}\sum_{i=1}^{60}(i-1)\left(\frac{r_Q}{r_P}\right)^i P_i(\cos\theta)\, e^{-(i/25)^2}$$



Point mass at 10 km depth,
Full response is 8.2 μGal



White<4 cm White<1 cm



White<~5 cm White<~2 cm

Results

The results of the analyses of the longer term changes are shown above. The upper row displays the annual cycle estimates; the lower two rows the trends and the accelerations.

- The first column plots show the quantities computed to harmonic degree and order 60. Small signals – heavily affected by noise – have been blanked.
- The second column plots show the quantities computed using the Gaussian smoothed coefficients. Small signals – heavily affected by noise – have been blanked.
- The third column plots show the results where the responses from the estimated point masses on land have been removed. Subsequently, the point masses have been restored on land.
- The last column plots show the results where the responses from the estimated point masses on land have been removed.

The annual cycle

The main features are the seasonal variability in the Equatorial regions, especially in the Amazonas river system. The phases show that the variability peaks in early spring north of the Equator and in fall south of the Equator. At higher latitudes the variability in the Alaska Range peaking in spring is clearly seen.

At the ocean it is very difficult to extract information which is not affected by the noise. Even the filtered annual cycle is dominated by stripes. In the Arctic Ocean, though, as well as in the Weddell Sea some consistent signals peaking in early fall and in early spring, respectively, are found.

The trends

The dominant features in the trends are associated with the melting of the Greenland Ice Sheet and the Post Glacial rebound in Northern Canada and in Scandinavia. Both positive and negative trends in Antarctica may be associated with both ice sheet changes and post glacial rebound. Especially for the ,trends, the concentration of signal from land sources on land successfully removes the contamination of the ocean signal.

Also in this case it is difficult to extract trends in the oceans. Some consistent positive trends are found in the Arctic Ocean. In the southernmost Atlantic Ocean some positive trends may be seen as well.

The accelerations

In Southwestern Greenland the melt of the ice sheet appears to accelerate (which is well-known). The melt of the Alaska glaciers appear on the other hand to decrease. An acceleration in the Western Arctic Ocean may be present.

Discussion

In short: Tides are done for now; more to be done wrt the seasonal and the long term changes.

We are looking forward to the GRACE Follow-On!