Assessing Global Ocean and Continental Mass Change from 17 (18) years of GRACE/-FO and the role of coastal buffer zones

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Ocean Mass Change 04-2002 / 02-2020

Monthly SH solutions (d/o 60)
- ITSG-Grace2018 (shown here)
- CSR RL06
- GFZ RL06
- JPL RL06

Corrections:
- Individual Degree 1 (after Swenson / Bergmann-Wolf)
- C20/C30 from TN-14
- GIA by Caron et al. (2018)
- GAD restored, mean atmospheric pressure over entire ocean subtracted
- 300 km coastal leakage buffer

Method:
- Global integration of buffered kernel
- Joint adjust fit function that includes absolute, linear, annual, semi-annual and 161-day terms; optionally quadratic fit

Result: \(2.52 \pm 0.22 \text{ mm/a} (04-2002/02-2020)\)

Quadratic acceleration: \(0.08 \text{ mm/a}^2\)

Residual contains multi-annual signal with main modes of \(~3\) and \(11\) years.
Continental (Land) Mass Change
2003—2016 analysis shown here; includes glaciers but no Greenland & Antarctica

Monthly SH solutions (d/o 60)
— Same as Ocean

Corrections:
— Same as ocean, but:
— ~300 km coastal leakage buffer extended onto the ocean to integrate out-leaking signal
— Exclude EQuakes and Caspian Sea

Method:
— Global integration over extended land-kernel
— Remove mean ocean in buffer
— Joint adjust fit function (here: no quadratic)

Result (01-2003/08-2016):
Grace: \(-1.21 \pm 0.20\) mmSLE/a
TWSA\textsubscript{ens}: \(-1.18 \pm 0.10\) mmSLE/a

TWSA here is a combined product (Cáceres et al., 2020, under revision; in the ESA CCI SLBC Project, Horwath et al., 2020 tba) that includes glaciers by Marzeion et al. (2012, 2015). TWSA ensemble consists of 4 members /w different irrigation scenarios and climate forcings; its uncertainty (STD) is a low estimate and is expected to be higher with a larger number of model runs. TWSA and Grace both exclude the Caspian Sea here.
This figure shows the effect of the oceanic-side buffer-width on the linear trend of GRACE continental mass change (CMC).

Reddish shaded areas are the 1- and 2σ uncertainty ranges of the individual GRACE-based solutions.

Blue-shaded is the combined uncertainty (1- and 2-STD) of the TWSA ensemble mean.

CMC including the Caspian Sea (surface area only) would lead to a down-shift of ~0.07 mm/a.

The linear behaviour at larger buffer-width is a good indicator for the effect of the mean-OMC correction.

However, this assumes OMC to be identical over buffer and inner ocean kernel (not entirely true, but cannot be assessed with GRACE).
Re-scaling effects from coastal buffer zones
Combined fingerprint effect of the ESA CCI SLBC products (linear trend)

Coastal zones and high-latitudes have lower trends (here: 2003—2016).

We applied a sea-level equation fingerprint solver in a quasi-spectral approach that includes a purely elastic response of the ocean as a consequence of mass change (following Clarke et al. 2005 and Blewitt & Clarke 2003).

Up to degrees 60 (‘observation’) and 360 (‘truth’).

Input: monthly mass change data of glaciers, ice sheets and terrestrial water storage from ESA SLBC_cci

Analysis uses:

— Set of 14 buffer masks / kernels
— For each combination: optional ±65° latitudinal cut-off

→ How big is the error, if we re-scale results from the inner ocean integration kernel to the entire Global Ocean area?
Combined fingerprint effect of the ESA CCI SLBC products

- Global Ocean Mass (blue curve) trend re-scaled from a 300 km buffer is **6.9% higher** than for the un-buffered full-resolution case ('truth'), e.g. a 2.5 mm/a assessed trend from GRACE were only 2.34 mm/a

- A latitudinal cut-off at ±65° together with 300 km buffer leads to **9.1% overestimation**

- Narrow buffers beyond ±65° have negative trends (Greenland coast etc.)

- Continental-mask extended buffer approach overshoots by ~15% (over ocean during the remove process only, not the entire trend)
  - CMC trends on slide 4 would be slightly weaker (less negative) than the TWSA ensemble mean, but still well within uncertainty bounds
Combined fingerprint effect of the ESA CCI SLBC products

- Seasonal signal (phase) of the Global Ocean not much affected
- Amplitude in the inner ocean slightly higher (~0.5 mm @ 300 km)

Fingerprint results based on ESA CCI SLBC data indicate: the annual mean ocean low occurs between day-of-year 80 and 81.
See an animation (~2MB) of the monthly fingerprint variability after removal of the linear trend here:
(colorbar units are millimetres of equivalent water height; colormap by Fabio Crameri)

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