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Interannual Variability in Global Ocean Mass Derived from 18+ Years of GRACE and GRACE-FO Satellite Gravimetry

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The combined 18+ years long time series of observations of the Earth's gravity field from the satellite missions GRACE and GRACE-FO provides us with an unprecedented opportunity to analyse mass change and re-distribution in the Earth system. Furthermore, as the mission continues, we may also gain more insight into those types of variability in the water mass system that act over time scales of several years and possibly even decades.

For our analysis presented here, we updated the previous Ocean Mass Change (OMC) product by the ESA CCI Sea Level Budget Closure project, including (1) corrections for Glacial Isostatic Adjustment, (2) restorement of GAD background fields, (3) subtraction of atmospheric mean fields, and (4) replacement of dedicated low-degree coefficients for centre-of-mass, oblateness (TN14) and C30 (TN14) in the spherical harmonic gravity field solutions. We applied least-squares minimisation of the residual of a multi-parameter functional fit to the OMC series, including i.a. linear trend, semi-/annual signals, and an optional quadratic fit. We analysed the complete residual series based on the four monthly GRACE and GRACE-FO RL06 solutions from CSR/GFZ/JPL and ITSG-Grace2018 after removal of linear trend and seasonal cycles.

The remaining signal shows clear evidence of interannual oscillations and correlates (>0.5) with the Multivariate ENSO index (MEI). By spectral analysis and by an independent simulated-annealing approach, we locate several primary modes of the residual between 130 and 29 months. The phase of the lowest of these partial frequencies approximates that of solar flux data representing the solar cycle and the shortest major mode resembles the frequency of the Quasi Biennial Oscillation. However, minor phase-shifts and a direct physical link in this regard are not yet fully understood. When we include the extra modes in our OMC minimisation approach, it can be shown that recent acceleration in global ocean mass may indeed be smaller than previously anticipated by quadratic fitting while neglecting longer wavelengths.

Furthermore, the extrapolation of the fit including three prominent interannual modes between 29 and 130 months is able to predict recent La Niña related negative ocean mass anomalies. Our findings might support and integrate in similar analyses of the global sea level and other ECVs elsewhere. However, we must emphasise that an analysis of near-decadal oscillations from a sub-20 year lasting data set is yet to become more stable with increasing observation length from GRACE-FO.