New insights from the sea level budget

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Abstract

Balancing the sea-level budget is critical to understanding recent and future climate change as well as balancing Earth's energy budget and water budget. During the last decade, advancements in the ocean observing system — satellite altimeters, hydrographic profiling floats, and space-based gravity missions — have allowed the global mean sea level budget to be assessed with unprecedented accuracy from direct, rather than inferred, estimates.

Extending the understanding of the sea-level budget from global mean sea level to regional patterns of sea level change is crucial for identifying regional differences in recent sea level change. The local sea-level budget can be used to identify any systematic errors in the global ocean observing system. Using the residuals from closing the sea level budget, we demonstrate that systematic regional errors remain. We present a new analysis of the steric component of the budget using the recently released Simple Ocean Data Assimilation reanalysis version 3 (SODA 3).

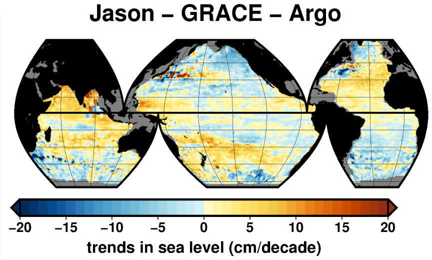

Figure 3. Residual trends in the sea level budget for 2005-2014.

The observational sea level budget

On a bi-monthly basis, the sum of the steric component estimated from Argo and the ocean mass (barystatic) component from GRACE agree total sea level from Jason within the estimated uncertainties with the residual difference having an rms less than 2 mm (Figure 1) [Leuliette 2014]. Direct measurements of ocean warming above 2000 m depth during January 2005 and December 2015 explain about one-third of the observed annual rate of global mean sea-level rise.

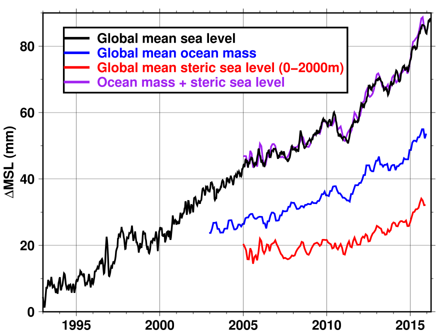

Figure 1. Comparisons of global mean sea level from the NOAA/Laboratory for Satellite Altimetry [Leuliette and Scharroo, 2010], global mean ocean mass from GRACE [Johnson and Chambers, 2013], and steric (density) sea level from Argo [SIO, Roemmich and Gilson, 2009], with seasonal variations removed and 2-month smoothing applied.

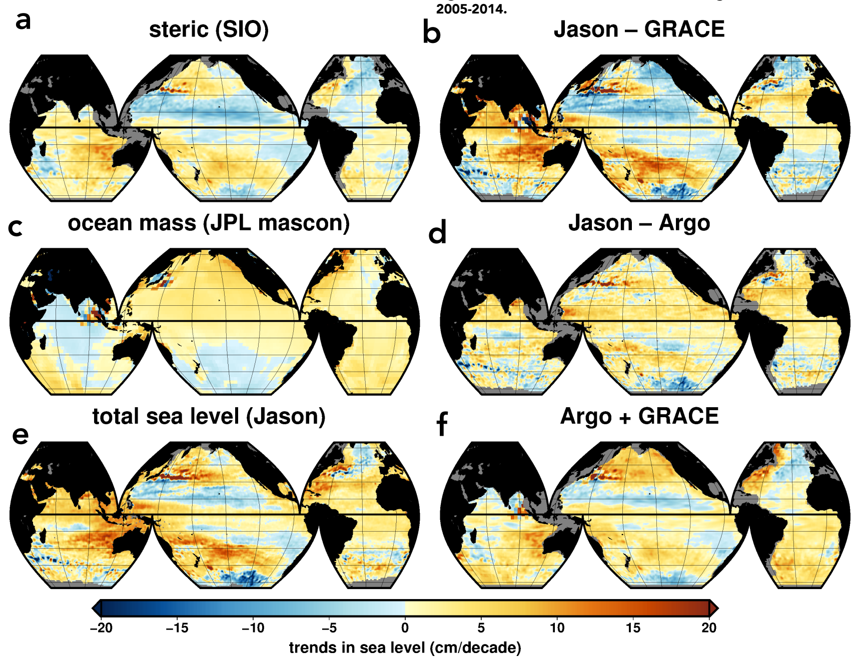

Figure 2. Sea level trends from the ocean observing system (left column) and the inferred trends (right column) from monthly observations from 2005 to 2014. Here, the GRACE trends are from the GRCTellus JPL-Mascons [Wiese 2015 and Watkins et al. 2015]

SODA

The Simple Ocean Data Assimilation ocean/sea ice reanalysis (SODA) uses a simple architecture based on community standard codes with resolution chosen to match available data and the scales of motion that are resolvable. Agreement with direct measurements (to within observational error estimates) as well as unbiased statistics are expected.

SODA Version 3 represents a major change from the previous SODA2. It now uses GFDL MOM5/SIS numerics at finer 1/4°x1/4°x50lev (28km at the Equator down to <10km at polar latitudes) resolution, similar to the ocean component of the GFDL CM2.5 coupled climate model, and includes an active sea ice component. The optimal interpolation filter has also been augmented (relative to previous releases) with bias correction to reduce bias in estimates of long term trends of variables such as heat content.

SODA3.3.1, forced by MERRA2 and spanning the 36-year period 1980-2015, was released on 7 October 2016. Trends in the sea surface height field were created from the monthly fields that had been remapped onto a uniform 1/2°x1/2° Mercator horizontal grid similar to SODA2, but with expanded vertical resolution.

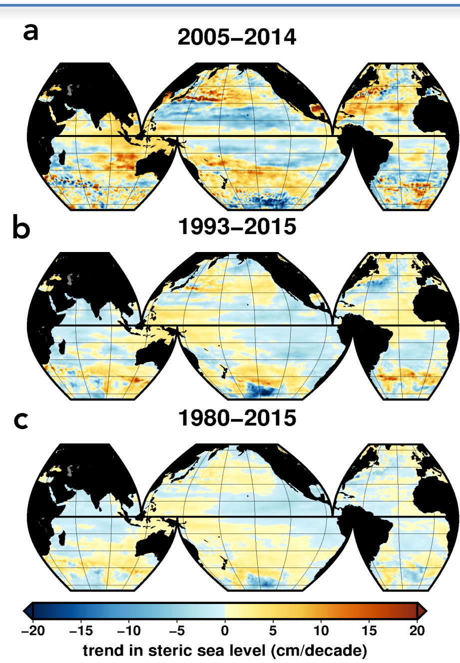

Figure 4. Regional trends in the steric component of sea level from the SODA3.3.1 reanalysis a) the same time period as Figure 2, b) the altimetry era, and c) the entire reanalysis period.

Discussion and conclusions

Expressed in terms of globally-averaged height, contributions to the total budget of global mean sea level are:

$$SL_{total} = SL_{steric} + SL_{mass},$$

where *SLtotal* are variations in total sea level, *SLsteric* is the steric component of sea level, and *SLmass* is the ocean mass/barystatic component.

Using Jason altimetry, steric sea level derived from the upper 2000m of SIO/Roemmich and Gilson Argo monthly fields, and Chambers 2013 GRACE bi-monthly global mean estimates of ocean mass, the global sea level budget can be closed to a few mm rms (Figure 1). Regional trends inferred from the budget (Figure 2) show similar patterns, but significant residuals remain (Figure 3).

The steric trends from the SODA 3.3.1 reanalysis (Figure 4a) for 2005-2014 show a similar pattern to the Argo/SIO trends (Figure 2a), but exhibit higher magnitudes such as those inferred from Jason-GRACE trends (Figure 2b). This suggests that our analysis of the SIO/Argo steric trends may underestimate the regional trends, despite the excellent agreement in the global mean.

Extending the understanding of the regional patterns of sea level change to the entire altimetry era (Figure 4b) and earlier (Figure 4c) will benefit from reanalyses of the historical ocean databases, assimilation of tide gauges, and sea level "fingerprints" [Chepurin Carton, and Leuliette, 2014].

Acknowledgments

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