Asymmetric Decadal Sea Level Trends in the Subtropical Pacific

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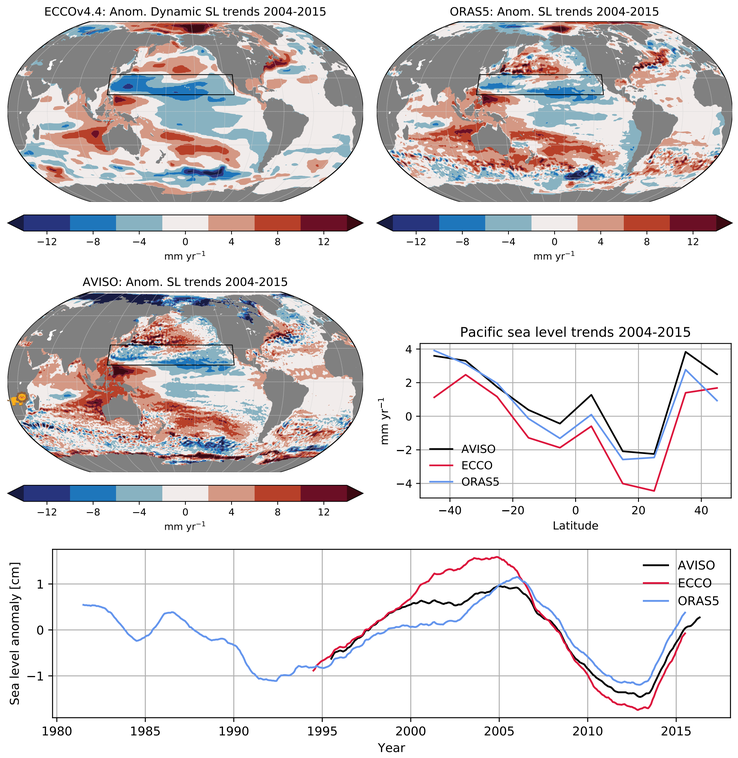
(I) Abstract

Recent sea surface height (SSH) trends in the South Pacific are substantially greater than trends in the Northern Hemisphere. Version 4 of the data-constrained ocean state estimate from the Estimating the Climate and Circulation of the Ocean consortium (ECCO-V4r4) and Ocean Reanalysis System 5 (ORAS5) reproduce the spatial structure in observed SSH trends, which allows for a diagnosis of the forcing and mechanisms that account for meridional asymmetry in the rate of change (Box *II*).

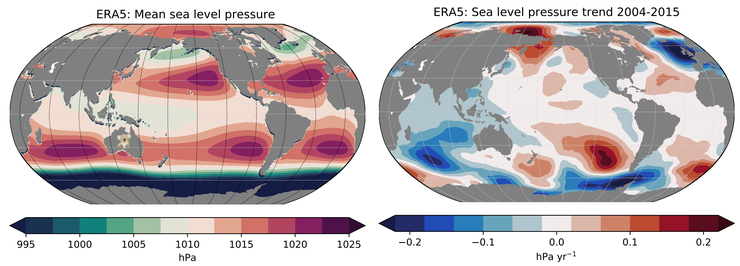
Thermosteric contributions dominate the spatial structure in Pacific SSH trends for years 2004-2015, however, contributions from surface heat fluxes are small (BOX VI). Wind stress trends drive a spin-up of the South Pacific Subtropical Gyre and a northward shift of the North Pacific Subtropical Gyre (BOX III). A reduced gravity model forced with observed winds qualitatively reproduces the meridional seesaw in sea level, suggesting that asymmetric trends in subtropical wind stress drive a cross-equatorial heat transport (Box IV). A reversal in forcing associated with this process could have important implications for near-term rates of coastal sea level change, particularly in Pacific Island communities.

(II) Pacific sea level trends

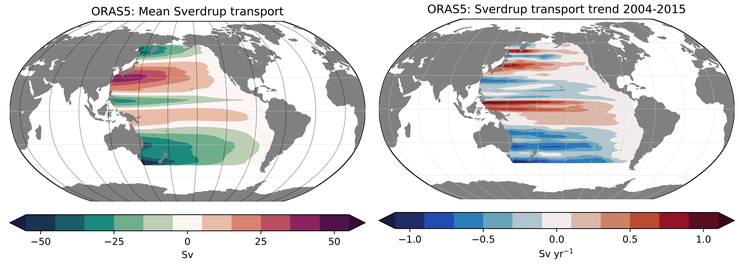


Maps of dynamic sea level trends for years 2004-2015 for ECCO, ORAS5 and AVISO, and Pacific mean trends as a function of latitude. The global sea level trend is removed from the trends shown for all products. Time series of sea level anomalies are shown in the bottom panel for the area indicated by black boxes in the Subtropical North Pacific. A 5-year running-mean filter is applied to the anomalies.

(III) Wind forcing



Maps of ERA5 mean sea level pressure and sea level pressure trends over years 2004-2015.



Maps of the average Sverdrup transports and its trends for years 2004-2015 in the Pacific, calculated from time-mean ORAS5/ERA-Interim wind-stress curl.

(V) Data

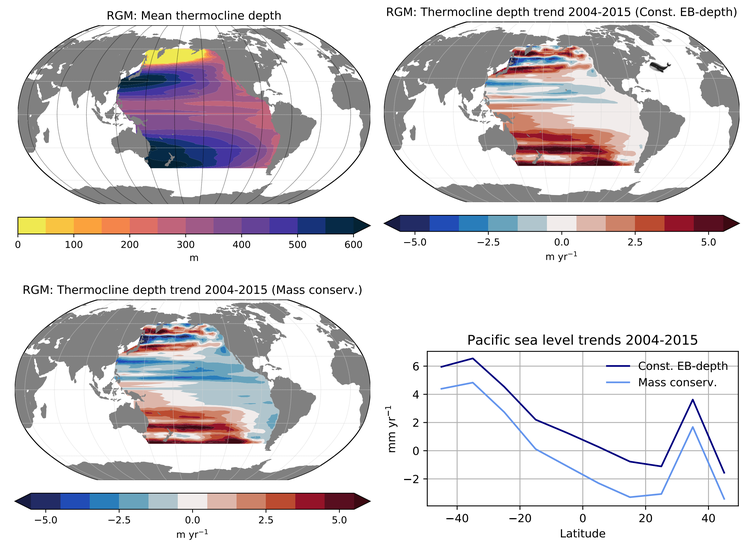
AVISO:
Multimission altimeter monthly sea level height anomaly, gridded with 0.25 degree horizontal resolution. See https://www.aviso.altimetry.fr for additional information.

ECCO-V4r4:
Version 4 Release 4 (V4r4) of the "Estimating the Circulation and Climate of the Ocean" (ECCO) consortium ocean state estimate covers the period 1992-2017. This product is an updated edition to that described by Forget et al. (2015, Geosci. Model Dev.). The ocean model resolution is 1 degree in the horizontal and 50 levels in the vertical. Additional information is provided at https://ecco.jpl.nasa.gov/.

ORAS5:
The European Centre for Medium-Range Weather Forecasts (ECMWF) Ocean Reanalysis System 5 (ORAS5) provides an ocean state estimate for years 1979 to 2017 (Zuo et al., 2017). The ocean model resolution is 0.25 degree in the horizontal and 75 levels in the vertical. For additional information see https://www.ecmwf.int/en/research/climate-reanalysis/ocean-reanalysis.

ERA5:
The ECMWF reanalysis product for atmospheric variables covers the Earth on a 30km grid and resolve the atmosphere using 137 levels from the surface up to a height of 80km. We use monthly data from the first segment of data spanning years 1979-2018. For additional information see https://www.ecmwf.int/en/forecasts/datasets/reanalysis-datasets/era5 .

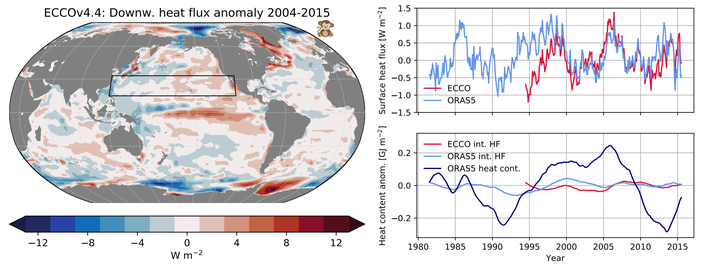
(IV) Reduced gravity model



Maps of mean thermocline depth h from a reduced gravity model (RGM), and thermocline-depth trends for years 2004-2015 assuming constant eastern boundary thermocline thickness h_e (Const. EB-depth) and conservation of mass over the Pacific domain (Mass conserv.), respectively. The lower right panel shows resulting sea level trends as a function of latitude.

The model is driven by the Ekman pumping velocity w_{Ek} calculated from ORAS5/ERA-Interim wind-stress. The thermocline depth is determined by $h = \sqrt{h_e^2 - \frac{2f^2}{g'\beta}\int_x^{x_e} w_{Ek}dx'}$, with f being the Coriolis parameter, β its meridional derivative, the reduced gravity $g' = 0.02\ m^2\ s^{-1}$, x the longitude, and x_e the eastern boundary. Depth h_e is constant along the eastern boundary and either h_e =300 m, or h_e is adjusted each month to conserve mass.

(VI) Heat fluxes



Map of ECCO net downward heat flux anomalies for years 2004-2015. Heat flux anomalies averaged over the Subtropical North Pacific (black box) are shown for ECCO and ORAS5 in the upper right panel. The lower panel shows the time integral of the flux anomalies, i.e., their contribution to the heat content together with ORAS5 total heat content anomaly, a proxy for sea level. All time series are detrended and a 5-year running-mean filter is applied.

Can you spot all six animals?

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