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Causal Mechanisms of Sea Level Variations along the U.S. West Coast

Ian Fenty, Ou Wang, and Ichiro Fukumori
NASA Jet Propulsion Laboratory/California Institute of Technology, Pasadena, CA USA (Ian.Fenty@jpl.nasa.gov)

Tide-gauge records along the U.S. West Coast since the mid-1920's show large ENSO-correlated sea-level variability and a below-average linear trend relative to the global mean over the past three decades. On weekly and longer timescales, sea-level variations in the region are primarily steric, reflecting variations in coastal ocean temperatures rather than that of mass. Previous research into sea-level variability in the region identified coastally-trapped waves forced by nonlocal winds as the main source of long-lasting sea-level variability. Here we offer a rigorous quantification of the contributions of wind-stress and buoyancy forcing anomalies across the entire Pacific Basin on the U.S. West Coast Sea level using a global data-constrained ocean and sea-ice model of the Estimating the Circulation and Climate of the Ocean (ECCO) consortium. Causal relationships are quantified using the model's adjoint and mechanisms are elucidated via perturbation experiments.

By convolving the adjoint sensitivities with atmosphere forcing anomalies we find that long-term (>1 week) sea level variations along the U.S. West Coast are almost entirely due to wind-stress anomalies while buoyancy anomalies, in contrast, contribute virtually nothing. Interestingly, the wind stress anomalies that contribute to sea level variations in the region come from two sectors: i) a coastally-confined region from 0-45N and ii) and the open-ocean Pacific equatorial waveguide (roughly -/+ 10 degrees latitude). Wind stress anomalies in the coastally-confined sector induce coastally-trapped waves which propagate poleward, depress the thermocline, reduce upwelling/air-sea heat loss and, thereby, lead to positive ocean temperature / steric height anomalies. Zonal wind stress anomalies in the equatorial waveguide induce eastward-propagating equatorial Kelvin waves, some energy of which is converted to coastally-trapped waves upon reaching continent, which lead to positive steric height anomalies following the same causal chain.

This study highlights the benefits of applying the complimentary tools of adjoint-based convolution and perturbation experiments to explain the origin of regional sea-level anomalies.