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Unraveling Regional Patterns of Sea Level Change over the Altimeter Era

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Satellite altimeters have measured the global mean and regional patterns of sea level change since 1993 with impressive detail and precision. While the global mean rate of sea level rise has been studied extensively and is readily linked to global water budgets, the regional patterns (or deviations from the global mean) are subject to diverse physical mechanisms that span the gauntlet of internal climate dynamics, and models suggest a nuanced relationship to radiative forcing (greenhouse gases, aerosols, etc.). To date, little attempt has been made to synthesize the regional patterns of sea level change across the global ocean with a common diagnostic framework. Here we combine oceanic and atmospheric observations and leverage ensembles of a state-of-the-art global climate model to unravel the mechanisms governing the basin-scale patterns of sea level change around the world ocean. By applying some bedrock principles of physical oceanography and coupled dynamics, we find a leading role for wind forcing—Ekman and Sverdrup dynamics together yield faithful reproductions of the large-scale structure of sea level change from the tropics to the midlatitudes. We argue that the global pattern of sea level rise since 1993 is set, to leading order, by changes in the wind-driven ocean circulation and their influence on sea surface height via ocean heat divergence. Importantly, wind-driven needn't be synonymous with internal variability—indeed, much of the observed global pattern is recovered by global climate models subject to historical anthropogenic forcings, and single-forcing experiments enable further insight into which forcings are responsible for which regional phenomena. As we move forward into the uncertain future, a better understanding of the causes of regional rates of sea level rise, including distinguishing which features are driven by human activities versus modes of natural variability—or both, is critical for the successful adaptation of humanity and its infrastructure to a rapidly changing climate.