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Low-Frequency Variability in Regional Sea Level: The Roles of Advection, Diffusion and Surface Buoyancy Fluxes

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Attribution of contemporary regional sea level changes has been a major research focus in recent years. Both observational studies and ocean general circulation model investigations have revealed that low-frequency variability in regional sea level can be ascribed mainly to local steric anomalies. However, quantitative understanding of the relative roles of advection, mixing, and air-sea buoyancy fluxes in determining regional steric sea level variability is still lacking. In order to attribute regional steric changes occurring on seasonal and longer time scales, an ocean state estimate produced by the "Estimating the Circulation and Climate of the Ocean" (ECCO) consortium was utilized. The solution was generated by constraining an ocean general circulation model to millions of oceanographic observations via non-linear least squares. The optimized model solution retains dynamical consistency with the governing equations, thus allowing for the formulation of closed property tendency budgets in terms of changes owing to advection, mixing, and air-sea fluxes. Budgets of local steric sea level tendencies (i.e. local rates of change) were the focus of study here.

Steric changes are the main contributor to the seasonal cycle in sea level at low- and mid-latitudes. In all but a few isolated regions seasonal steric changes are predominantly thermosteric in nature. In the tropics, seasonal amplitudes of both advective flux divergence and steric sea level tendency are comparable and advection explains most of the variance in the seasonal steric height. Elsewhere, advection is small and both the amplitude and variance of the seasonal steric sea level can be attributed primarily to surface buoyancy fluxes. Thus, the mean seasonal cycle in sea level is explained at low-latitudes mostly by divergence of advective heat fluxes, at mid-latitudes by air-sea buoyancy fluxes, and at high-latitudes by non-steric processes (i.e. mass redistribution).

On interannual scales, most regional sea level anomalies correspond to steric changes, excepting some shallow areas where bottom pressure fluctuations are more influential. Halosteric changes contribute to the steric anomalies in some regions, most notably the Atlantic. Interannual steric anomalies come primarily from anomalous advective fluxes. At high latitudes, both mixing and advection contribute to steric variance. Surface buoyancy flux anomalies also appear to contribute secondarily in several regions (e.g., Atlantic, eastern South Pacific). Thus while non-steric effects, mixing, and surface buoyancy fluxes can contribute to sea level anomalies in some regions, interannual changes in sea level appear to be mostly attributable to advective fluxes of heat and freshwater.

These results have important consequences for modeling past and future variability in regional sea level. Because interannual sea level changes mostly come from ocean property transports, regional estimates may be most sensitive to factors affecting the ocean circulation. In particular, good estimates of wind-driven transports seem crucial. At high latitudes, proper parameterizations of mixing are also likely to be important. Accurate prescription and/or optimization of air-sea buoyancy fluxes may be less influential, unless the focus is on the seasonal cycle.