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Revisiting the effects of river runoff on sea level along the Atlantic and Gulf coasts of the United States

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Identifying the physical processes responsible for historical changes in coastal sea level is important for anticipating future trends and impacts in the densely-settled coastal zone. Recent studies have sought to understand the drivers of interannual to multidecadal sea level changes along the Atlantic and Gulf coasts of the United States. Ocean dynamics, terrestrial water storage, nonlinear vertical land motion, and melting of land-based ice have all been highlighted as important mechanisms of sea-level change along these coastlines and on these time scales. While long known to exert a dominant control on coastal ocean circulation, the contribution from variable river discharge has been absent from recent discussions of United States sea level. Using tide-gauge measurements from 65 stations and discharge measurements from 41 river gauges, we revisit calculations from the 1970s to quantify the relationship between run off and sea level. We demonstrate that annual sea-level anomalies are significantly correlated with river runoff along the Gulf of Maine, Mid-Atlantic Bight, South Atlantic Bight, and Gulf of Mexico, such that runoff explains 16–46% of the variance in detrended annual sea-level series. Sea level rises by 0.01–0.14 cm for a 1 cubic km annual river flow increase, depending on region. Using conservation of volume and considering the effects of rotation, stratification, and friction, we also present a simple (reduced gravity) geophysical fluid dynamic theory that describes the relationship between variable river runoff and sea-level changes as a function of the total runoff, the latitude-dependent Coriolis parameter, the linear drag coefficient, and the density contrast between fresh river water and salty ocean water. This theory is shown to correctly predict the observed order of sea-level change per unit river runoff anomaly, demonstrating a causal (halosteric) relationship between the two. Our results have implications for understanding differences in regional and global sea level measurements from coastal tide gauges compared to satellite altimetry, which struggles in coastal regions. Although river run off exerts a strong influence of annual-scale sea level trends, a significant relationship between the two variables is not detectable on decadal time scales given the available data records. This could suggest that proxy relative sea level reconstructions (even from estuarine settings) do not record (or are not influenced by) variability in river run off. Future and local-scale flood risk in the coastal zone will in part be dependent on sea-level anomalies caused by run-off, although this factor is frequently overlooked in risk assessment.