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How does sea-level rise influence tides, coastal storms, and river flow interaction? Insights from an urbanized estuary

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Coastal regions influenced by coastal storms and rivers can experience hazardous conditions arising from individual storm or fluvial events, as well as the interaction of coastal and fluvial processes. The overall water levels experienced can arise from the interaction of coastal river discharges influenced by rainfall and antecedent soil moisture conditions, storm surge and wind-waves generated from the coastal storm, and tides that are independent of atmospheric conditions but influence storm surge, wave, and river discharge propagation. Sea level rise, a slow onset event and one manifestation of climate change, may alter these interactions and affect the magnitude, location, duration and/or extent of extreme conditions such as extreme water levels and flooding.

Here, we investigate the interaction of tides, coastal storms, and river discharges, and the possible evolution of this interaction with sea level rise. Our study region is the Napa River Basin and Estuary in San Francisco Bay, California, USA. The Napa River watershed extends from the city of Calistoga in the northern end of the watershed to the city of Napa at the southern, tidally influenced end, and the river drains into a shallow sub-embayment of the San Francisco Bay. The region comprises many communities that are susceptible to flooding along the bay shoreline and along inland rivers and creeks that drain to the Bay.

We applied a coupled watershed and coastal model framework to estimate river and estuary water levels and flooding extent from a moderate coastal storm and a wide range of river discharges, during spring and neap tide conditions. Napa river discharges corresponding to 2-year to 200-year recurrence intervals were derived using a watershed model driven by regional precipitation and soil moisture conditions. These discharges were used as a driver in a coastal ocean model of the San Francisco Bay that included tides, storm atmospheric conditions, and detailed regional bathymetry. The coastal storm's atmospheric conditions were chosen to match historical conditions that generated 25-year return period nontidal water levels at the Golden Gate. This work is part of a larger study of the interaction of coastal storms, sea level rise, and coastal infrastructure in San Francisco Bay, and contributes to the development of a joint watershed and coastal flood forecast system for San Francisco Bay.

Results indicate an increase in peak river flow rate in the upmost reaches of the river under wet soil moisture conditions, leading to higher peak water levels than those produced under dry soil moisture conditions. Peak water levels were higher in the lower reaches of the river during spring tide conditions than neap tides, and dissipated upstream, with faster dissipation as river discharge increased. With sea-level rise, peak water levels increased along the stretch of the river, and extended further upstream with increasing river discharge, and with spring tides. Analysis of change in peak water levels along the river indicates that the increase in water levels in the coastal-and river impacted stretches was greater than the effect of sea-level rise alone.