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A global analysis of the future morphology of estuaries under sea-level rise

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Sea level will rise 1-2 m in the next century, while sediment supply to estuaries is decreasing globally. The effect of rising sea level on the morphology of estuaries is unknown. If sediment supply is sufficient, estuaries may adapt through sedimentation in channels, on sand bars and saltmarsh formation. However, if sea-level rise outpaces formation of new land, the present-day intertidal area and habitat may drown because of sediment starvation. We developed a model based on theory and data for equilibrium morphology and hydrodynamic conditions along estuaries, depending only on the tidal amplitude at the estuary mouth and the estuary outline taken from imagery. This allowed us to calculate the sensitivity of 30 estuaries from all around the world to rising sea level. We varied estuary planform size and tidal amplitude in our model to test effects of sea-level rise using the following scenario sets: (1) widening of the estuary planform shape when salt marshes inundate, (2) a range of increases and decreases in tidal amplitude at the mouth, either of which can occur due to shifting amphidromic points offshore and reduced friction for the tidal wave inside the estuary, (3) a combination of the previous two scenarios. Results were validated with geological data on past planform sizes of systems that evolved under early to mid-Holocene sea-level rise, which is in the same order of the future expected sea-level rise. The results show that the breakdown and reworking of salt-marshes on sandy substrates would deliver part of the sediment required for adaptation to sea-level rise, but at the cost of intertidal and supratidal habitat loss. An increased tidal amplitude typically reduces the required sediment for adaptation because it will increase the equilibrium channel volume. Moreover, we found a novel relation between sensitivity to future change in tidal amplitude and the characteristic channel convergence length and depth of the estuary. Estuaries with relatively deep channels and with a weak channel convergence are most sensitive: their channel volume increases more with tidal amplitude increase and decreases more with tidal amplitude decrease than for other systems. The results are promising for further exploration of the vulnerabity to sea-level rise caused by changing estuary shape and changing tidal regimes.