Consolidation and Stratification within a Muddy, Partially Mixed Estuary: A Comparison between Idealized and Realistic Models for Sediment Transport in the York River Estuary, Virginia

Danielle Tarpley, Courtney Harris, and Carl Friedrichs
Virginia Institute of Marine Science Gloucester Point Virginia, United States.
drtarpley@vims.edu, ckharris@vims.edu, carl.friedrichs@vims.edu

The York River estuary is a partially mixed semi-diurnal tidal tributary of the Chesapeake Bay with salinities ranging from 0 to 26 psu and an ~0.8 m tidal range. Sediment within many estuaries, including the York River, Virginia, is dominated by mixtures of mud. Due to its cohesive nature, estimating sediment fluxes for mud is a complex problem that can be addressed using numerical models such as the Community Sediment Transport Modeling System (CSTMS), which incorporates suspended sediment transport, erosion, and deposition within the hydrodynamic Regional Ocean Modeling System (ROMS). One version of the CSTMS accounts for cohesive processes via consolidation and swelling of the sediment bed, which changes the critical shear stress of the seafloor in response to sedimentation. Additionally, the effects of sediment-induced stratification can be included within the model via adjusting the vertical momentum equation to include the combined water-suspended sediment density. We will examine the degree to which these processes, i.e. bed consolidation and sediment–induced stratification, influence fine-grained sediment transport in the York River, VA using both an idealized, and a more realistic model implementation.

Initial investigation into the relative impacts of bed consolidation and swelling, and sediment-induced stratification on spatial and temporal sediment distribution was done with an idealized two-dimensional estuary designed to mimic the primary features of the York River. This represented a longitudinal section, and accounted for a freshwater source, tides and estuarine circulation, but neglected across-channel variation. Results showed that when bed consolidation and sediment-induced stratification were neglected, the model produced unrealistic amounts of erosion and deposition. The incorporation of bed consolidation alone lowered the amount of erosion and deposition but values remained high. Sediment-induced stratification alone produced more realistic values but higher than observed in the York River. Only the combination of bed consolidation and sediment-induced stratification produced reasonable estimates of erosion and deposition along the estuary. Thus, while sediment-induced stratification had a higher impact, it is the combination of the two processes that produced the most realistic scenario.

Will this hold true in a more realistic numerical representation of the York River estuary? To determine the answer, a full three-dimensional model of the York River, which included hydrodynamics, physical forcings, and sediment transport, was used. The boundary conditions were forced with localized tidal elevation, salinity, and wind measurements. Relative to the idealized model, the impacts of sediment-induced stratification and bed consolidation may be muted due to additional driving forces incorporated in the three-dimensional model.