Hydrodynamic modeling of turnover times in Mobile Bay, Alabama and their sensitivity to tides, fluvial discharge, and meteorological forcing

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Residence, exposure, and flushing times are examples of hydrodynamic timescales, and generally describe the physical mass transport within a water body. The response and spatial variability of these measures to tides, fluvial discharge, and local meteorology are investigated through hydrodynamic model simulations of Mobile Bay, Alabama using a two-dimensional depth integrated Advanced Circulation (ADCIRC) model. Mobile Bay is a shallow (mean depth 3 m), drowned river-valley, micro-tidal (mean range 0.4 m) estuary located on the northeastern coast of the Gulf of Mexico. Hydrodynamic model output is coupled with a Lagrangian particle tracking model to predict the trajectories of more than 30,000 discrete particles distributed throughout the study area. Hydrodynamic timescales are estimated and analyzed based on these results. Spatially-averaged timescales generally range from 4 to 130 days, with large standard deviations (± 30 days), depending on the magnitude of fluvial discharge and local meteorology. Spatially averaged timescales can be accurately predicted using a power law regression ($R^2 > 0.99$) and simple freshwater fraction methods, but only if meteorological forcing is neglected. The wide, long, and shallow Bay responds quickly to meteorological forcing, thus changing the average and spatially variable timescale values. The meteorological forcing is found to account for as much as 55% of the variability in hydrodynamic timescales as compared to cases with fluvial discharge and tides only. Flushing of the Bay is found to transition from tidally-enhanced to river dominated for $Q > 1000$ m^3 s^{-1}. Synthesized results suggest average to excellent flushing throughout much of Mobile Bay, and relatively poor flushing along the eastern shoreline, the mid-section of Bon Secour Bay, and in some areas of the Mobile-Tensaw Delta.

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