The frictional nature of tidal propagation in channelized estuaries, with applications to a tidal marsh in Delaware

Ryan Mieras[1], James T. Kirby[1], Fengyan Shi[1]

Duration asymmetries of tidal propagation in frictionally dominated estuarine environments primarily arise through four sources of nonlinearity. In the momentum equation, the friction term is quadratic and depends on time-varying channel depth. In continuity, time-varying channel depth again plays a role in nonlinearity, as does the variable width of the estuary with rising and falling tides. A field study was conducted on the main channel of a brackish tidal marsh (Brockonbridge Marsh, BM) opening to the Delaware Bay, in Kent County, Delaware. Surface elevation was measured using five pressure gauges and an Aquadopp Profiler (ADCP), which were moored at six locations, spanning 2.5 km inland from the channel mouth. Analysis of the tidal signals shows a fast rising tide, accompanied by a much more slowly falling ebb tide, which is indicative of an estuary dominated by tidal variations in channel depth, rather than variations in estuary width. This suggests the wave crest diffuses landward faster than the trough. During a multi-day surge event that occurred during data collection, this asymmetry becomes even more pronounced (Figure 1). A simple scaling analysis reveals that friction tends to dominate inertia by 1 to 2 orders of magnitude throughout most of the tidal cycle. As a result, the governing equations reduce to a single, nonlinear diffusion equation, yielding a solution in the form of a diffusive wave with a time-varying diffusion coefficient (Friedrichs and Madsen, 1992). Several idealized marshes were created, with length scales matching the marsh in the field study, having flats and a single bisecting channel. A quasi-3d numerical model (NearCoM) is used to simulate tidal propagation through these idealized marshes while adjusting certain parameters such as friction values and marsh platform slopes. Comparisons are made between each idealized case and are further compared to their respective diffusive wave solutions, assuming time-averaged, x-independent length and depth parameters. Additionally, a model is carried out using a high-resolution, 2 meter Digital Elevation Model (DEM) of the BM, with the same friction factors used for the idealized cases. Finally, the high-resolution model results are compared with the ideal case whose marsh platform slope most closely represents the BM, which has a negatively sloping platform in the landward direction.

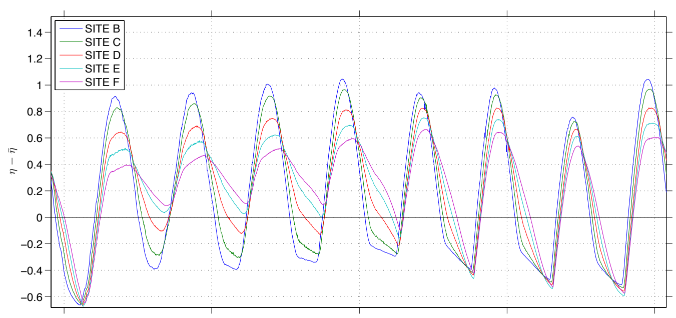

Figure 1. Measured water levels during (3/25 – 3/27) and shortly after (3/27 – 3/29) the surge event, less their respective means, with distance landward increasing from Site B to Site F

(1) Center for Applied Coastal Research, Department of Civil and Environmental Engineering, University of Delaware, Newark, DE 19716