Modeling sediment transport and residence times in the shallow coastal bay complex of the Virginia Coast Reserve

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MORPHOLOGY AND ECOLOGY OF SHALLOW COASTAL BAYS

Morphological evolution and ecosystem dynamics in shallow coastal bays are largely governed by:

- sediment redistribution in response to storms and sea-level rise
- dynamics of marsh and lagoon-bottom plants
- circulation and particle residence times

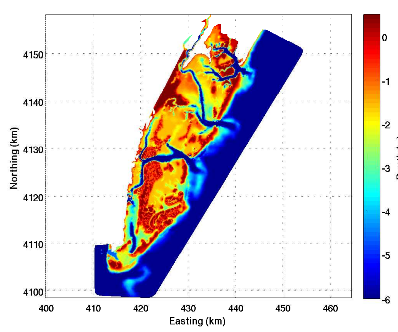

Figure 1. Bathymetry of the Virginia Coast Reserve-Long Term Ecological Research site (VCR). The system lacks a significant fluvial source of freshwater and sediment (e.g., Fagherazzi and Wiberg, 2009), and is relatively unaffected by human activities.

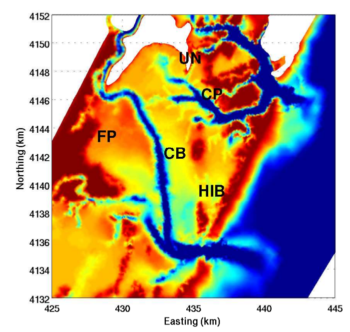

Figure 2. Locations of data collection at the Hog Island Bay:Upshur Neck, Chimney Pole, Hog Island, Central Bay, and Fowling Point.

Goal: Modeling hydrodynamics and sediment transport at the VCR (Fig.1) as a step towards evaluating their impacts on the ecological processes.

METHOD

- Field observations in Hog Island Bay, centrally located within the VCR (Fig.2)
- A 3-D unstructured grid finite-volume coastal ocean model (FVCOM, Qi et al., 2009)

MODEL-DATA COMPARISON OF FLOW

FVCOM was validated with 1-week observations of water flow during a moderate storm (wind speed reaching 10-m/s) (Fig.3). Modeled suspended sediment concentrations on day 2 reached 20 mg/L (Fig.3e) at the measurement site, in general agreement with measured values.

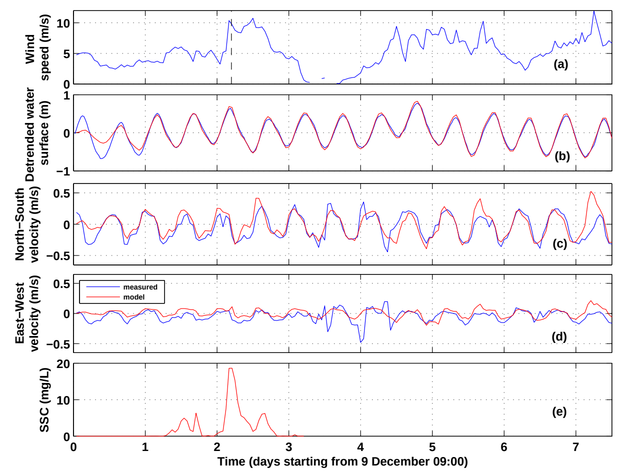

Figure 3. (a) Wind speed, (b) water level, (c) N-S velocity, (d) E-W velocity, and (e) suspended sediment concentration (blue–measured, red–modeled). Sediment model was run for days 1-3.5. Model was ramped up over day 0-1.

SEDIMENT RESUSPENSION

During high-tide, suspended sediment concentration within the model domain calculated by accounting for waves (Fig.4) is more than one-order of magnitude larger than suspended sediment concentration within the domain calculated by neglecting waves.

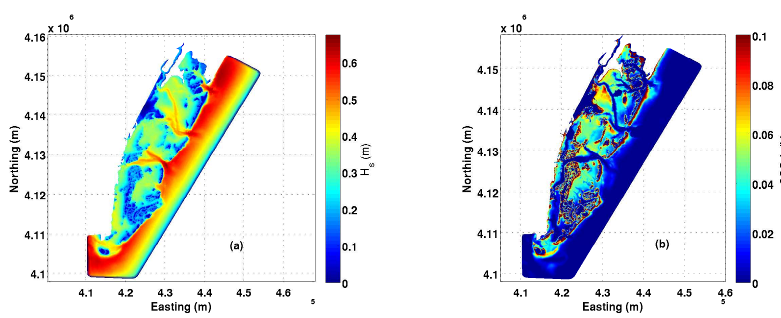

Figure 4. (a) Significant wave height, and (b) near-bed suspended sediment concentration at the peak of the storm during high-tide (corresponding to the time indicated by the dashed line in Figure 3a).

MODEL-DATA COMPARISON OF WAVES

In the absence of wave data in 2002 experiment, performance of the wave model in FVCOM is tested with observations in 2009 (Fig.5).

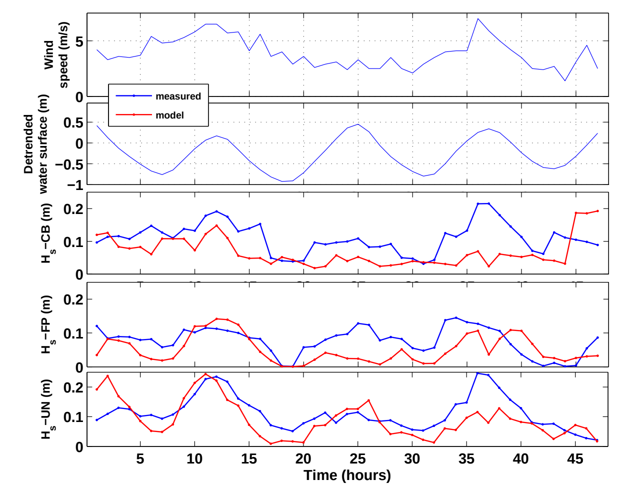

Figure 5. (a) Wind speed, (b) water level, and (c-e) significant wave height at Central Bay, Fowling Point, and Upshur Neck, respectively.

PARTICLE RESIDENCE TIMES

With the Lagrangian particle-tracking module, particle residence within three bays with varying bathymetry, coastline geometry, and nitrogen input to the system, is examined.

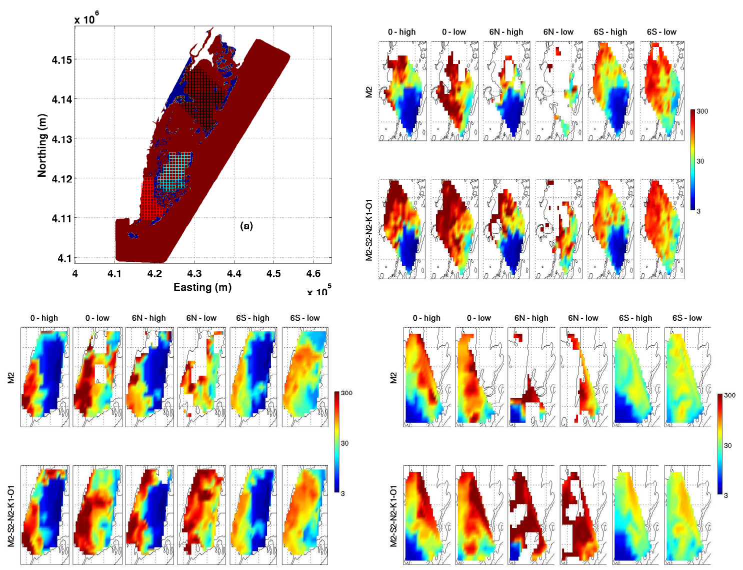

Figure 6. (a) Particle release locations, (b-d) residence times in Hog Island Bay, South Bay and Magothy Bay for varying release times, wind and tidal forcing.

TIDE-INDUCED TEMPERATURE MIXING

Variation of temperature is of interest due to its effect on the survival of *seagrass* in the system. Model domain is forced at the open boundary with the monthly-averages (1990-2008) of ocean temperature measured offshore. Setting the January-average as the initial temperature within the whole domain, the model is run for one year with tides only, i.e., zero wind.

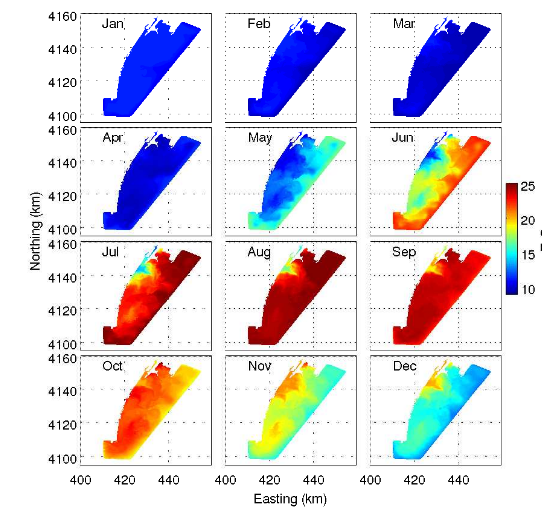

Figure 7. Water temperature variation throughout one year due to varying monthly-averaged temperature introduced at the open boundary

SUMMARY

- Waves largely govern the sediment resuspension.
- Residence time of particles within the system vary greatly depending on the location and tidal phase of particle release, and wind conditions. Realistic wind conditions rather than constant wind could reduce the number of particles that get stuck in boundaries.
- Temperature nudging at the opean ocean boundary will be combined with heat flux calculations.

References

Fagherazzi, S., P.L. Wiberg, 2009:JGR(114)

Qi, J., C. Chen, R.C. Beardsley, W. Perrie, G.W. Cowles, Z.Lai, 2009: Ocean Mod.(28)

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