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Modeling marsh-estuary interactions in the Rhode River, Maryland

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Abstract

Biogeochemical processes on the fringes of estuaries are relatively unconstrained, especially in terms of estuary-marsh exchanges and carbon budgets. A three-dimensional biogeochemical simulation can be a valuable tool to augment the sparse observations on these exchanges and can provide insights into the carbon fluxes associated with them. The Finite Volume Community Ocean Model (FVCOM) coupled with the Integrated Compartment Model (ICM) for water quality is being adapted to simulate the physical and biological characteristics of the Rhode River, MD, a sub-estuary of Chesapeake Bay. Concurrent measurements of biogeochemical parameters and ongoing long-term observations are being used to inform the modeling effort. The model includes a module to simulate the drag imposed by marsh grasses that, along with the unstructured grid and the FVCOM wetting and drying treatment, provides a realistic representation of intertidal marsh hydrodynamics. A chromophoric dissolved organic matter (CDOM) module is being developed for inclusion into the water quality model. The DOM module explicitly defines CDOM independent of non-chromophoric DOM (NCDOM) allowing a dynamic simulation involving UV/visible light and microbial interactions in the water column and diagenesis of DOM in the sediments

Model Domain

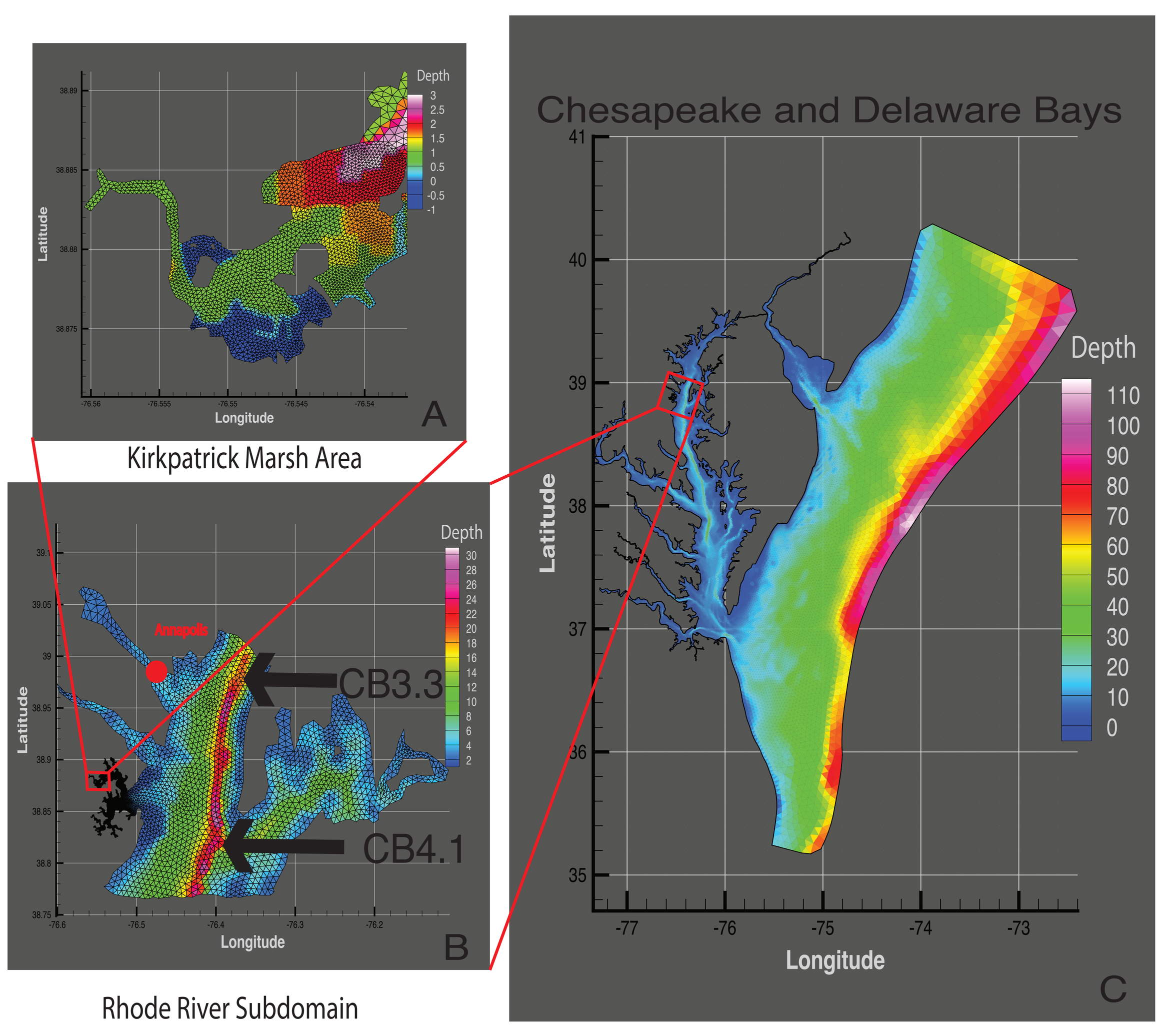

Figure 1. The nested grid approach showing A) the Kirkpatrick Marsh study site where concurrent measurements of physical and biological variables are being taken B) the nested Rhode River subgrid in the upper mid channel of Chesapeake Bay and C) the large scale Chesapeake Bay circulation model domain

Model Validation

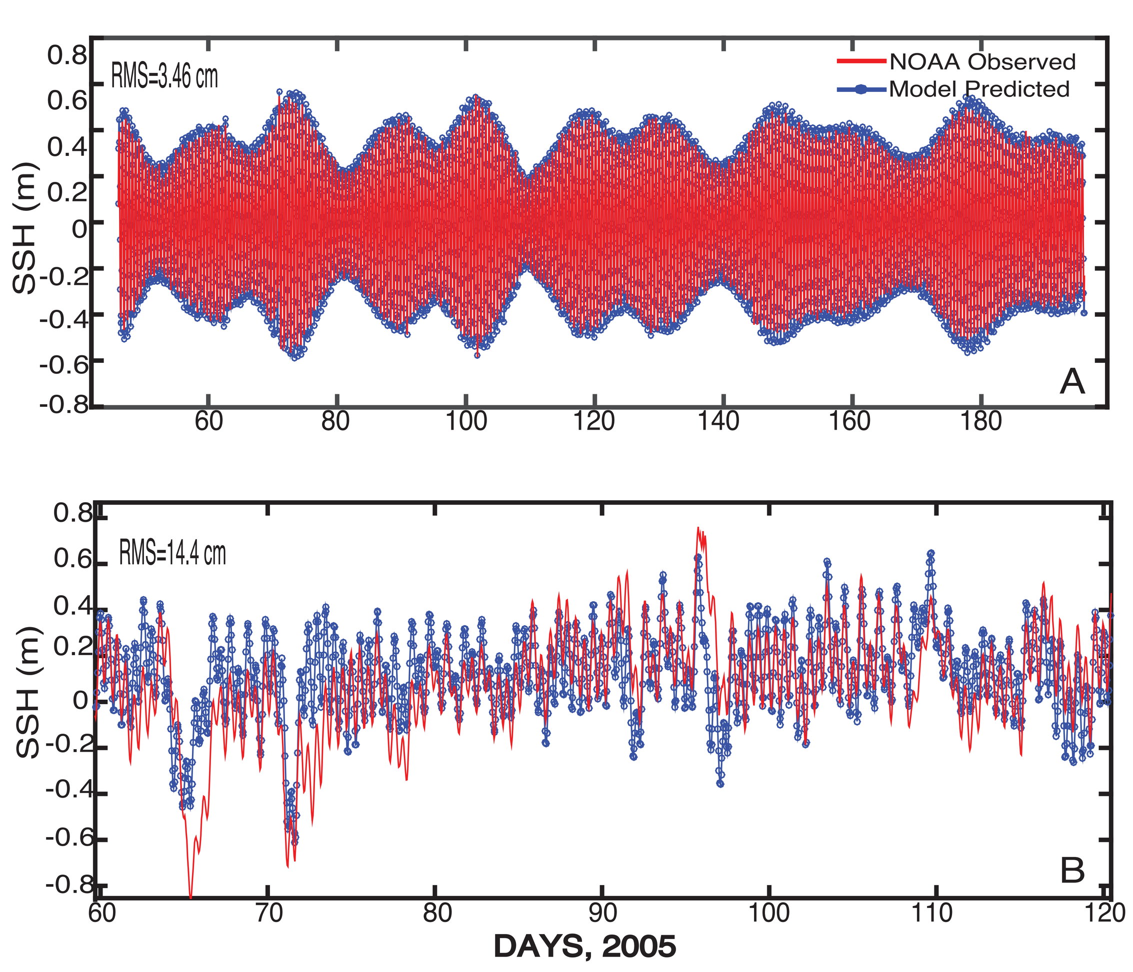

Figure 2. A comparison of modeled and observed Sea Surface height for two NOAA tidal stations (www.noaa.gov) A) High pass filtered (34 hour cut off) from Chesapeake Bay Bridge Tunnel and B) Raw sea surface height from Annapolis, MD.

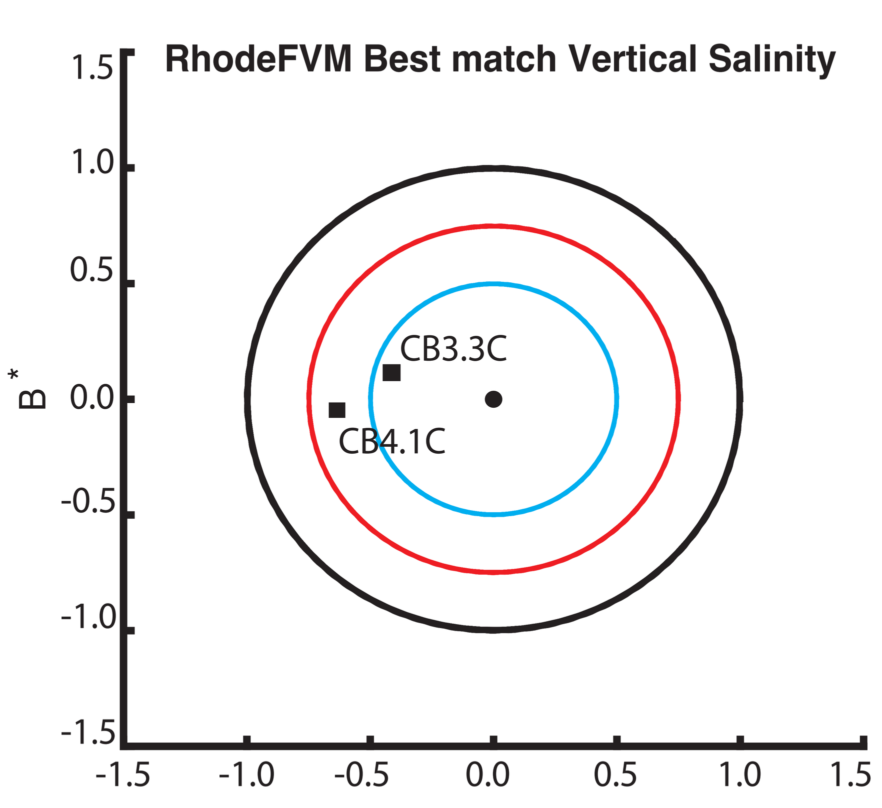

Figure 3. A target diagram comparing the model predicted and observed vertical salinity structure for 2 mainstem Chesapeake Bay water quality monitoring stations. The model error is around 50% (blue circle) of the standard deviation for the two stations sampled in the mainstem of the bay (see figure 1B). The negative values of unbiased RMSE indicate the model solution is dampened relative to the real solution.

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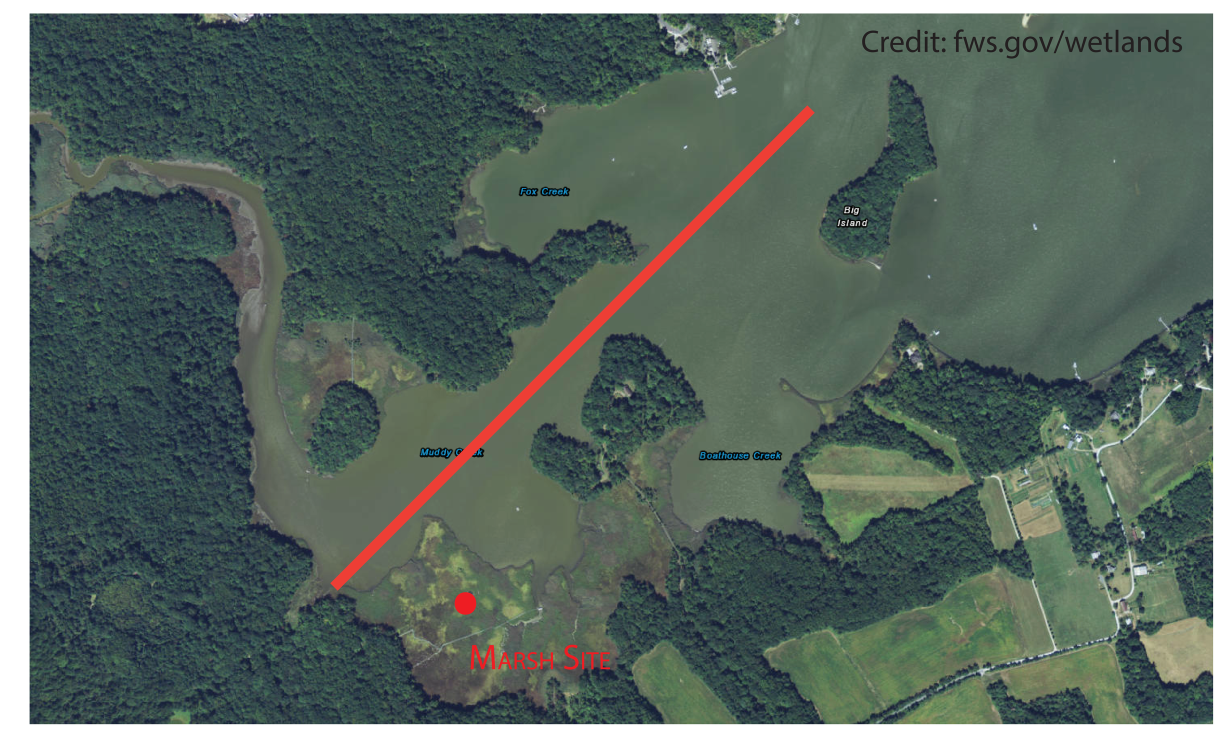
Kirkpatrick Marsh Study Site

The Kirkpatrick Marsh is an irregularly flooded intertidal mesohaline marsh located in the Rhode River sub-estuary of Chesapeake Bay. The marsh-estuary system has been observed to produce organic matter fluxes that are highly variable in time and space and large in magnitude. Understanding the processes that govern carbon dynamics in marshes is important when considering the coastal carbon budget. FVCOM provides the capability to model the marsh flooding and drying process while affording fine scale resolution (Chen et al., 2003). ICM coupled to a sediment diagenesis model uses the FVCOM hydrodynamic solution to model the transport of water quality variables (Kim and Khangaonkar, 2012). The offline coupled model system gives the robustness yet flexibility required for this highly variable ecosystem. RhodeFVM will attempt to simulate these ephemeral carbon fluxes and provide valuable insights into the total carbon budget of the marsh-estuary system



Results

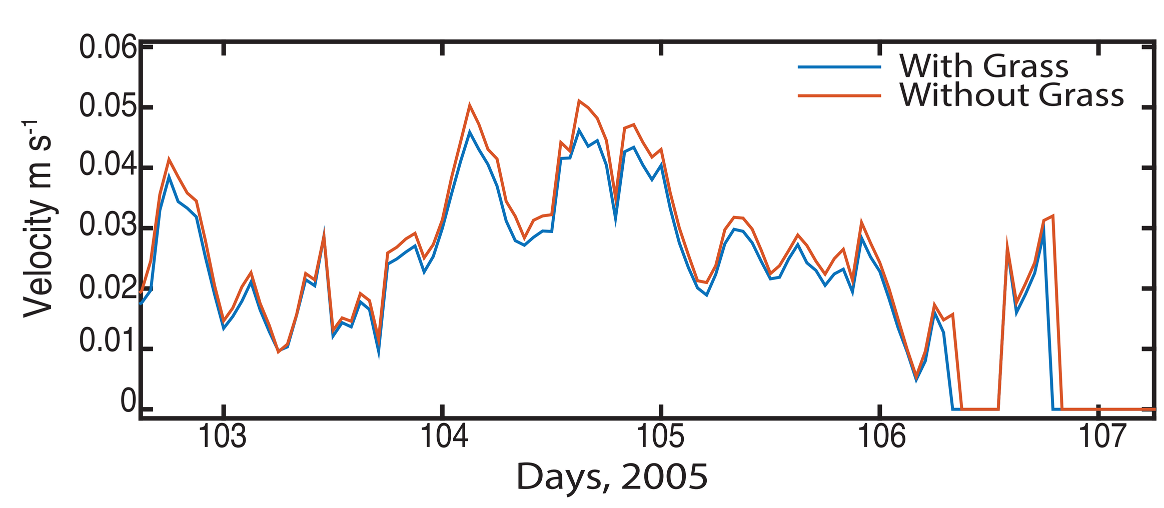


Figure 4. Current velocity in the marsh area over 5 days with and without marsh grass imposed drag. For the two month period modeled (Figure 2B) there was a ~5% mean reduction in current velocity in areas with marshgrass. This equates to a difference of 16090 m^3 of water through a grid cell with cross sectional width of 7.9 m. Zero velocity represents a dry marsh.

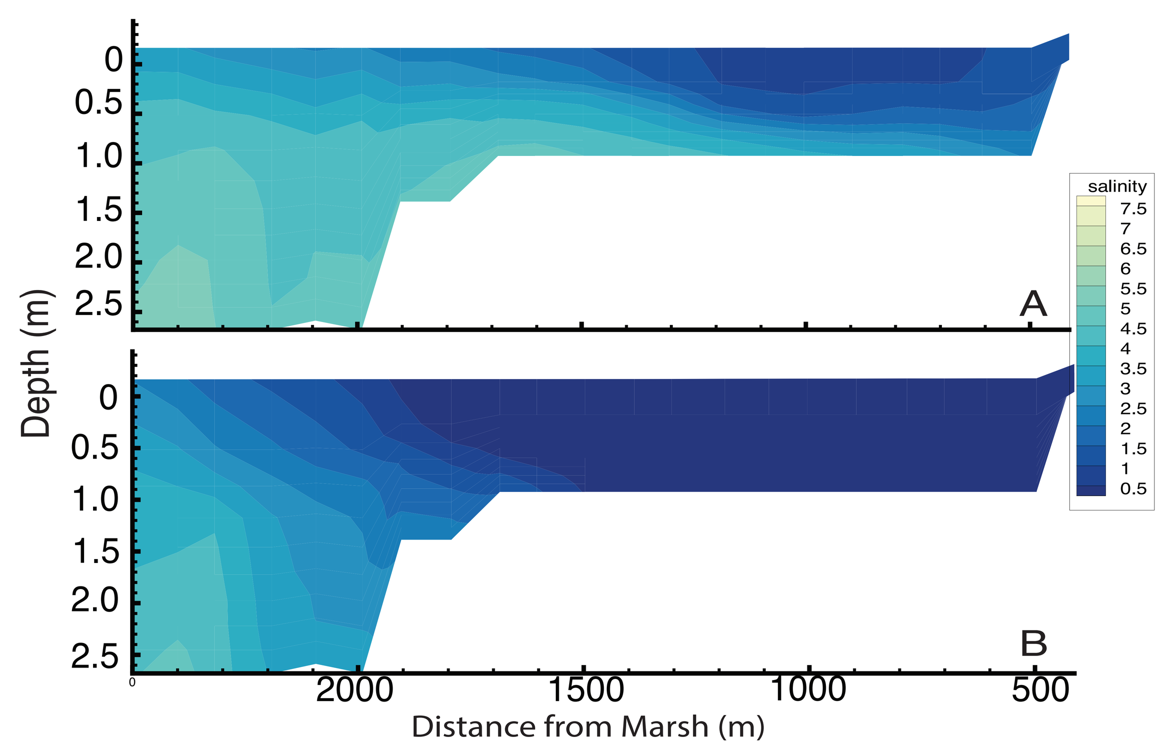


Figure 5. Transects of modeled vertical salinity in the Rhode River (see figure 8) A) modeled wind forcing from North American Regional Reanalysis (NARR) and B) constant northerly wind of the same magnitude as A

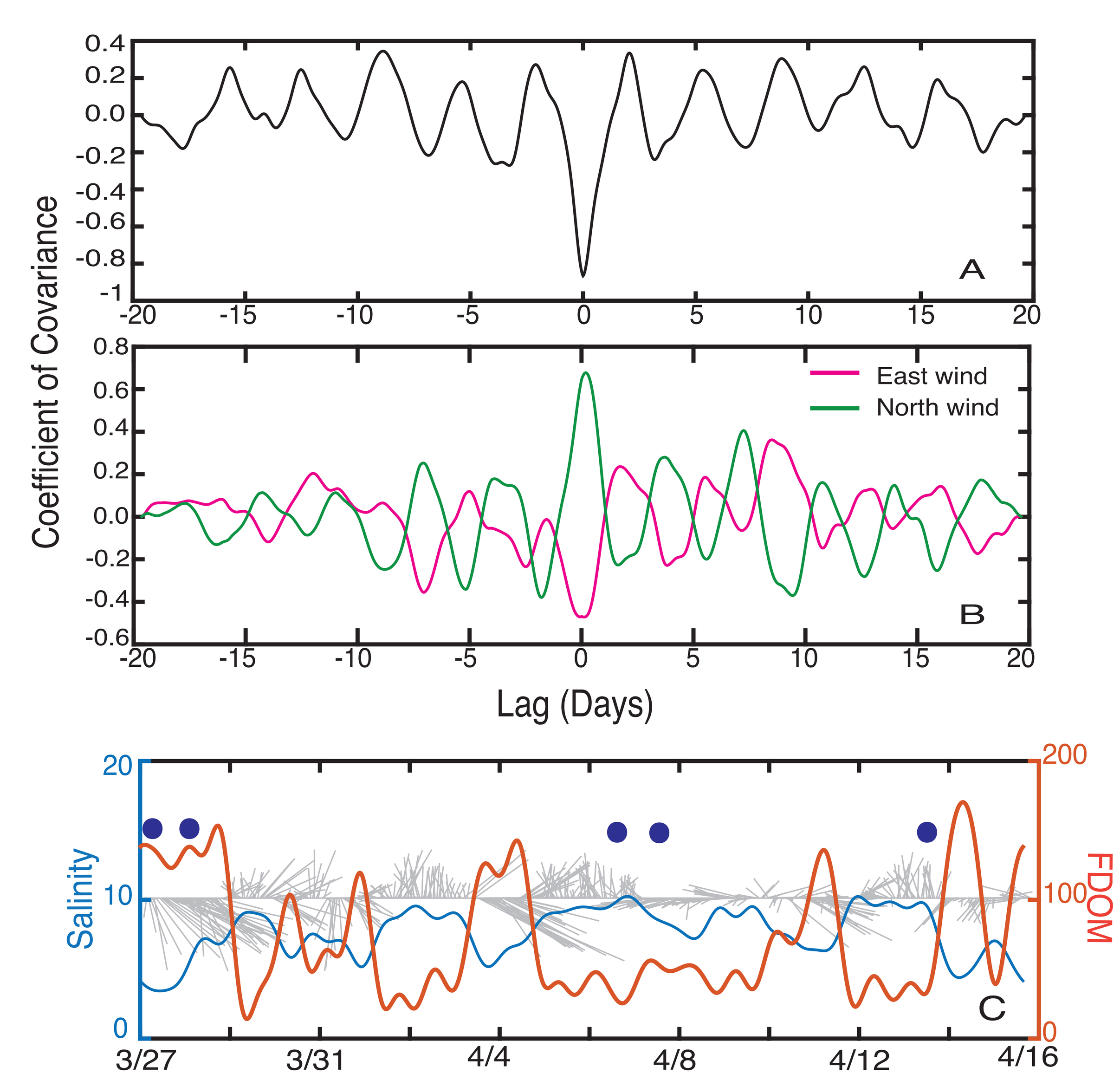


Figure 6. Observational data obtained from Kirkpatrick Marsh weir from March 27-April 16 2015. A) The covariance of salinity and flourescent dissolved organic matter (FDOM) B) The cross-covariance of north and east winds observed at Tolchester Beach and salinity observations in the marsh weir. C) The low pass filtered (34 hour cutoff) FDOM and salinity concentrations measured at the marsh weir with wind from Tolchester Beach, MD for comparison. The blue dots represent days where precipitation was greater than 3.0 mm at Annapolis, MD.

Biogeochemical Modeling Approach

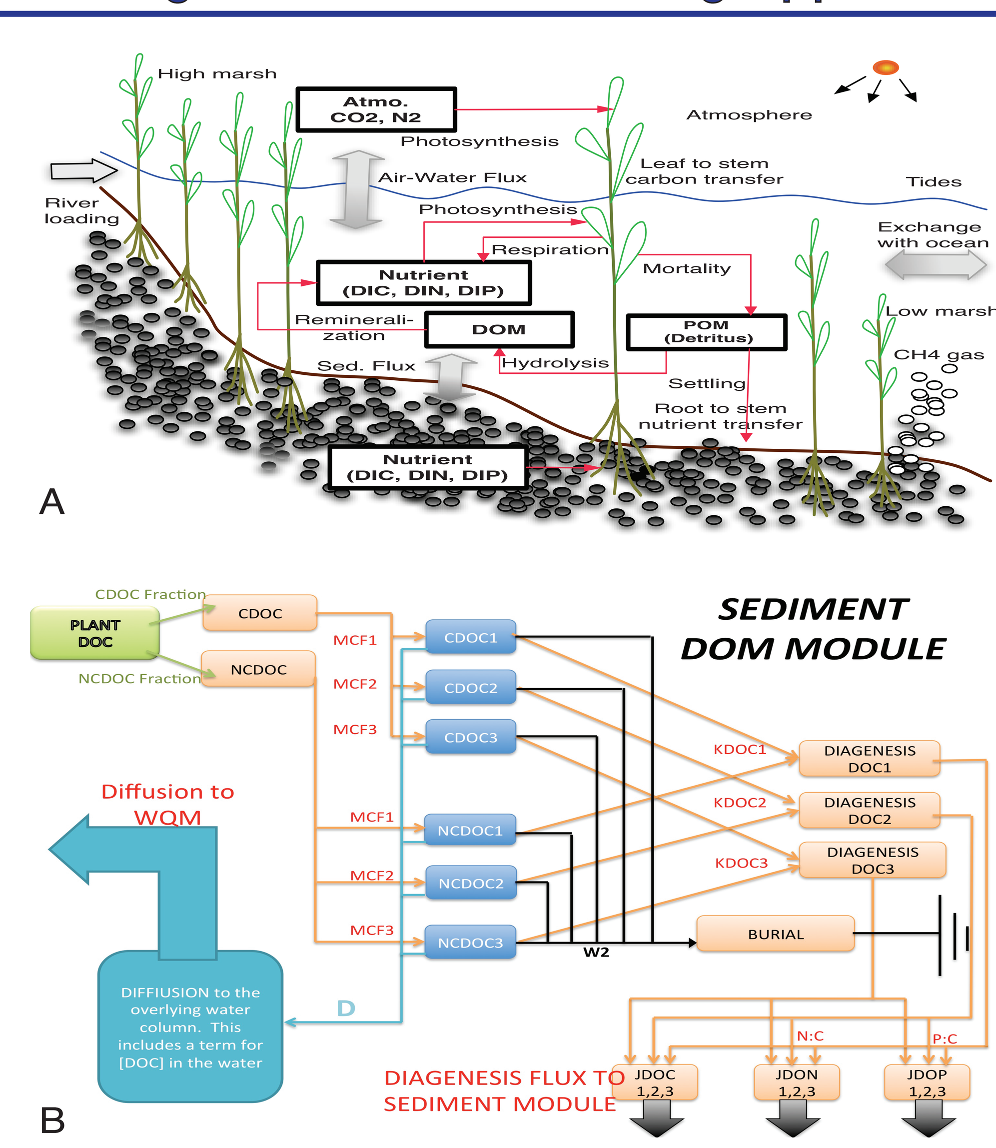


Figure 7. A) Schematic of the marsh-estuary water quality exchange model and B) The sediment DOM module.

Conclusion

Salinity is highly variable on subtidal scales. Model results and observations suggest that wind direction and magnitude influence the salinity intrusion and stratification into the shallow water of the Kirkpatrick Marsh area. In estuaries, density gradients primarily due to salinity differences set up the mean flow. Quantifying how physical factors determine the mean flow and flow variation in shallow water is necessary for accurately modeling tracers as they are advected through these systems.

Future work includes continued tuning of the physical model and development of the colored dissolved organic matter biogeochemical model. The modeling effort will further utilize comprehensive measurements in the Rhode River to better inform the model and characterize the dynamic processes that govern carbon fluxes at the terrestrial and marine interface.

References

Chen, Changsheng, Hedong Liu, and Robert C. Beardsley. "An unstructured grid, finite-volume, three-dimensional, primitive equations ocean model: application to coastal ocean and estuaries." Journal of Atmospheric and Oceanic Technology 20, no. 1 (2003): 159-186.

Kim, Taeyun, and Tarang Khangaonkar. "An offline unstructured biogeochemical model (UBM) for complex estuarine and coastal environments." Environmental Modelling & Software 31 (2012): 47-63.

Wang, Taiping, Tarang Khangaonkar, Wen Long, and Gary Gill. "Development of a Kelp-Type Structure Module in a Coastal Ocean Model to Assess the Hydrodynamic Impact of Seawater Uranium Extraction Technology." Journal of Marine Science and Engineering 2, no. 1 (2014): 81-92.

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