Controls on suspended particle properties and water clarity along a partially-mixed estuary, York River, Virginia, USA

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The Chesapeake Bay and its associated tidal tributaries, which together form one of the United States' largest and most important estuaries, are among the many coastal systems where degraded water clarity is a major concern. Despite long-term decreases in sediment input, water clarity over the last 20 years has continued to deteriorate in the Bay and its tributaries (Williams *et al*., 2010). Analysis of long-term monitoring data (Wang *et al*., 2010) found that the concentration of total suspended solids (TSS), the regulatory indicator of 'suspended sediment pollution', is about as likely to be positively or negatively correlated to sediment loads from the watershed. At the same time, locally suspended sediments are related to water clarity given that the diffuse light attenuation coefficient (K_d) is always positively correlated to TSS. This suggests that even though the suspended sediment in the water column is degrading water clarity, recent sediment input is not determining its concentration.

Gallegos *et al*., (2011) documented a decade-long change in the Chesapeake Bay in the relationship between surface diffuse light attenuations (K_d) and Secchi disks depth, a visual measurement of the depth at which a standard pattern on a 20cm diameter disk is no longer visible from the surface, which he attributed to the decrease in Secchi disk depths. Secchi depth is more sensitive to scattering of light, and the model for attenuation presented by Gallegos *et al*. (2011) suggested that the most likely explanation for the change in the product of Secchi depths and K_d is due to the increase in the concentration of suspended non-algal organic matter, however no data was available to support his claim. Here it is proposed that the apparent disconnect between water clarity and input of sediment into the Bay and its estuarine tributaries is related to the interaction between organic solids and inorganic sediment. The objective of this study was to investigate the influence of common suspended particle properties (size, concentration, composition) on apparent and inherent optical properties in an estuarine system, specifically K_d as well as beam attenuation (C).

This project focused on observations collected along the York River Estuary, a major tidal tributary of the lower Chesapeake Bay. Vertical profiles through the water column of particle properties (settling velocity, concentration, size, organic content, and density) and physical parameters (salinity, turbidity, light attenuation, and acoustic backscatter) were collected using the Coastal Hydrodynamics & Sediment Dynamics (CHSD) water column profiler (Cartwright *et al*., 2013). The profiler is equipped with a pump sampler, two Acoustic Doppler Velocimeters (ADVs), a Sequoia Laser In-Situ Scattering and Transmissometry instrument (LISST-100X), and a CTD (conductivity, temperature and depth probe) equipped with a YSI 6136 turbidity sensor, and a high-definition particle imaging camera system (PICS). The pump allows water samples to be collected so that suspended solids can be analysed for organic content. The ADVs provide estimates of mass concentration of suspended particle matter, bottom current velocities, turbulence, and bulk settling velocity (Fugate and Friedrichs, 2002). The LISST measures the suspended particle size distribution in 32 logarithmically spaced size classes over the range 2.5 to 500μm, and the PICS system provides direct measurements of particle settling velocities and sizes of particles greater than 30μm (Smith and Friedrichs, 2011). Observations of the diffuse light attenuation (K_d) were measured by either a hyperspectral Trios radiometer or LI-COR sensor system (Kirk, 1994). In addition to observations of K_d, LISST optical transmission was used to estimate beam attenuation coefficient (C) following Lund-Hansen (2010).

Preliminary results averaged from along-estuary slack water sampling cruises in the York River in June 2013 and September 2014 are displayed in Fig. 1. Similar spatial and temporal trends are seen in both the inherent (beam attenuation, C) and apparent (diffuse light attenuation, K_d) optical properties (Fig. 1A). The data show an up estuary increase in K_d, c, and TSS and an up estuary decrease in percent organic content. Additionally, these initial results from the York indicate importance of these small, more organic particles on optical properties. Data revealed significant, negative correlations between particle area and organic matter content (i.e. the smaller particles in suspension are more organic). Additional data will be collected in order to further explore preliminary trends.

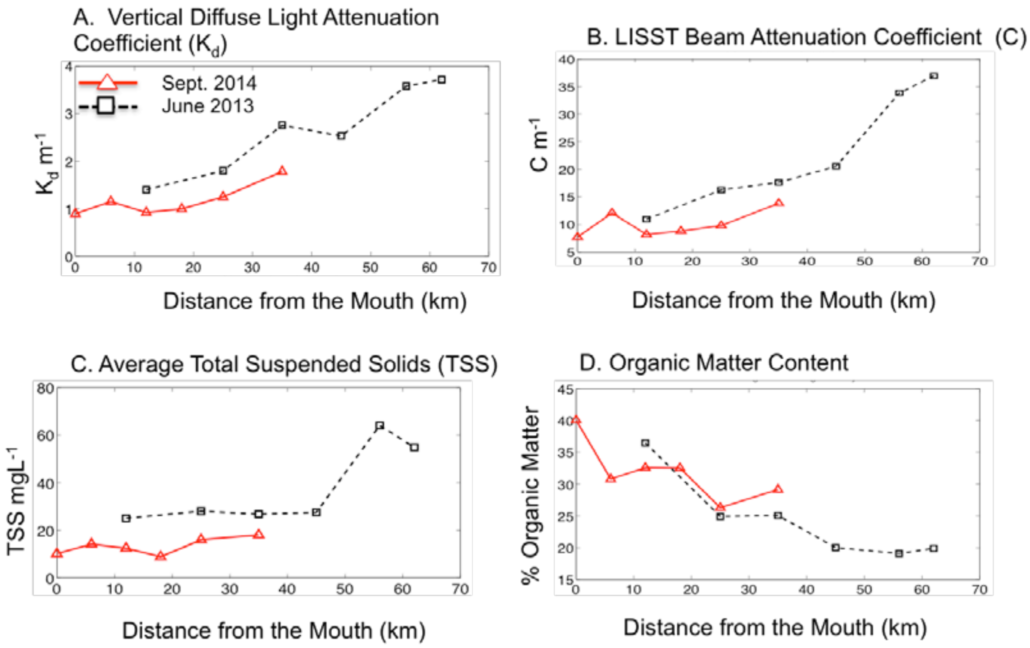

Fig. 1: Averaged K_d (A), C, (B), TSS (C), and Percent Organic Matter (D) from along-estuary slack water sampling cruises in the York River in June 2013 and September 2014.

References

Cartwright G.M., C.T. Friedrichs and S.J. Smith. 2013. A test of the ADV-based Reynolds-flux method for *in situ* estimation of sediment settling velocity in a muddy estuary. Geo-Marine Letters 33:477-484. doi:10.1007/s00367-013-0340-4.

Fugate D.C. and C.T. Friedrichs. 2002. Determining concentration and fall velocity of estuarine particle populations using ADV, OBS, and LISST. Continental Shelf Research 22:1867-1886.

Gallegos C.L., J.P. Werdell and C.R. Mclain. 2011. Long-term changes in light scattering in Chesapeake Bay inferred from Secchi depth, light attenuation, and remote sensing measurements. Journal of Geophysical Research 116, doi:10.1029/2011JC007160.

Kirk J.T.O. 1994. Light and photosynthesis in aquatic ecosystems. Cambridge University Press, Cambridge.

Lund-Hansen L.C. 2010. Suspended matter, Chl-a, CDOM, grainsizes, and optical properties in the Arctic fjord-type estuary, Kangerlussuaq, West Greenland during summer. Estuaries and Coasts 33:1442-1451.

Smith S.J. and C.T. Friedrichs. 2011. Size and settling velocities of cohesive flocs and suspended sediment aggregates in a trailing suction hopper dredge plume. Continental Shelf Research 31(10S):S50-S63.

Wang B.A., L.C. Linker and R.A. Batiuk. 2010. Monitored and modelled correlations of sediment and nutrients with Chesapeake Bay water clarity. JAWRA Journal of the American Water Resources Association 49(5):1103-1118.

Williams M.R., S. Filoso, B.J. Longstaff and W.C. Dennison. 2010. Long-term trends of water quality and biotic metrics in Chesapeake Bay: 1986-2008. Estuaries and Coasts 33(6):1279-1299.