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Resiliency of the western Chesapeake Bay to total suspended solid concentrations following storms and accounting for land-cover

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A B S T R A C T

The effect of storms on water quality in the Chesapeake Bay has been studied in a patchwork fashion at various sites for short periods of time. In this paper, we use a relationship between MODIS-Terra red light reflectance and total suspended solid (TSS) concentrations in order to develop a fourteen-year time period of TSS estimates during which effects of storms and land cover can be studied over a large portion of the Bay. Exponential fits were most appropriate, resulting in viable reflectance-TSS relationships for the five major Western Shore rivers and the Mainstem of the Bay. Other tributaries were less well-disposed for such relationships due to lack of a large range of TSS concentrations, shallow river beds, or low number of data points. Treating the entire Chesapeake as a single entity and modeling a single reflectance-TSS relationship for the entire estuary produced poorer models with less significance compared to treating each channel separately. Over 2800 rain events were studied in the Lower Western Shore between 2000 and 2014. We found some evidence that higher rainfall amounts correspond to a lower distribution of TSS concentrations 1 day following the event in forested watersheds. At rainfall events of <50 mm, maximum TSS within one day of the storm was highly variable, suggesting that rainfall amounts alone cannot explain variation in TSS levels. Finally, we found value in the use of prediction intervals around TSS estimates, a statistical procedure uncommonly used heretofore with satellite-based estimates but which can help to determine if results are significant or not.

1. Introduction

The Chesapeake Bay is the nation's largest estuary, home to one of its most productive ecosystems, and is an icon of American heritage and history (Kemp et al., 2005). It extends across a large swath of the mid-Atlantic coast, from the mouth of the Susquehanna River near Havre de Grace, Maryland, to its juncture with the Atlantic Ocean near Virginia's Norfolk metropolitan area (Fig. 1). However, nutrient and total suspended solids (TSS) have exceeded Clean Water Act regulations in recent decades, resulting in sediment-driven water clarity impairment and light attenuation. This inhibits solar energy from reaching submerged aquatic vegetation (SAV) and oyster reefs and the associated fish nurseries, some of the most crucial components of the ecosystem (Jordan et al., 1997; Focazio et al., 1998; Gellis et al., 2009). In this paper, we use satellite data to study the effect of storms and land cover on TSS levels.

Uncoordinated research on storm-effects in the Bay has been performed in a patchwork way at limited study sites and times. Some studies found TSS and nutrients increased following storms, but this is not universal and depends on sediment size, organic/mineral content, compaction, invertebrate mucus secretions, land slope, and water velocity (Ward, 1985; Gellis et al., 2009; Sutton et al., 2009). Furthermore, wet weather is not alone in increasing TSS levels, as dry, windy weather can lead to increased erosion and wave-caused resuspension acting on normally submerged river beds (Stevenson et al., 1985; Ward and Twilley, 1986). Storm-induced TSS concentrations are not necessarily runoff-based but may be wind or tidal-driven bottom resuspension, particularly in areas without buffering features like SAV beds (Ward et al., 1984; Stevenson et al., 1985; Ward, 1985). The settling periods for post-storm TSS levels before a return to normal conditions can be less than 24 h for smaller events, but as high as weeks for large hurricanes (Ward et al., 1984; Stevenson et al., 1985; Liu and Wang,

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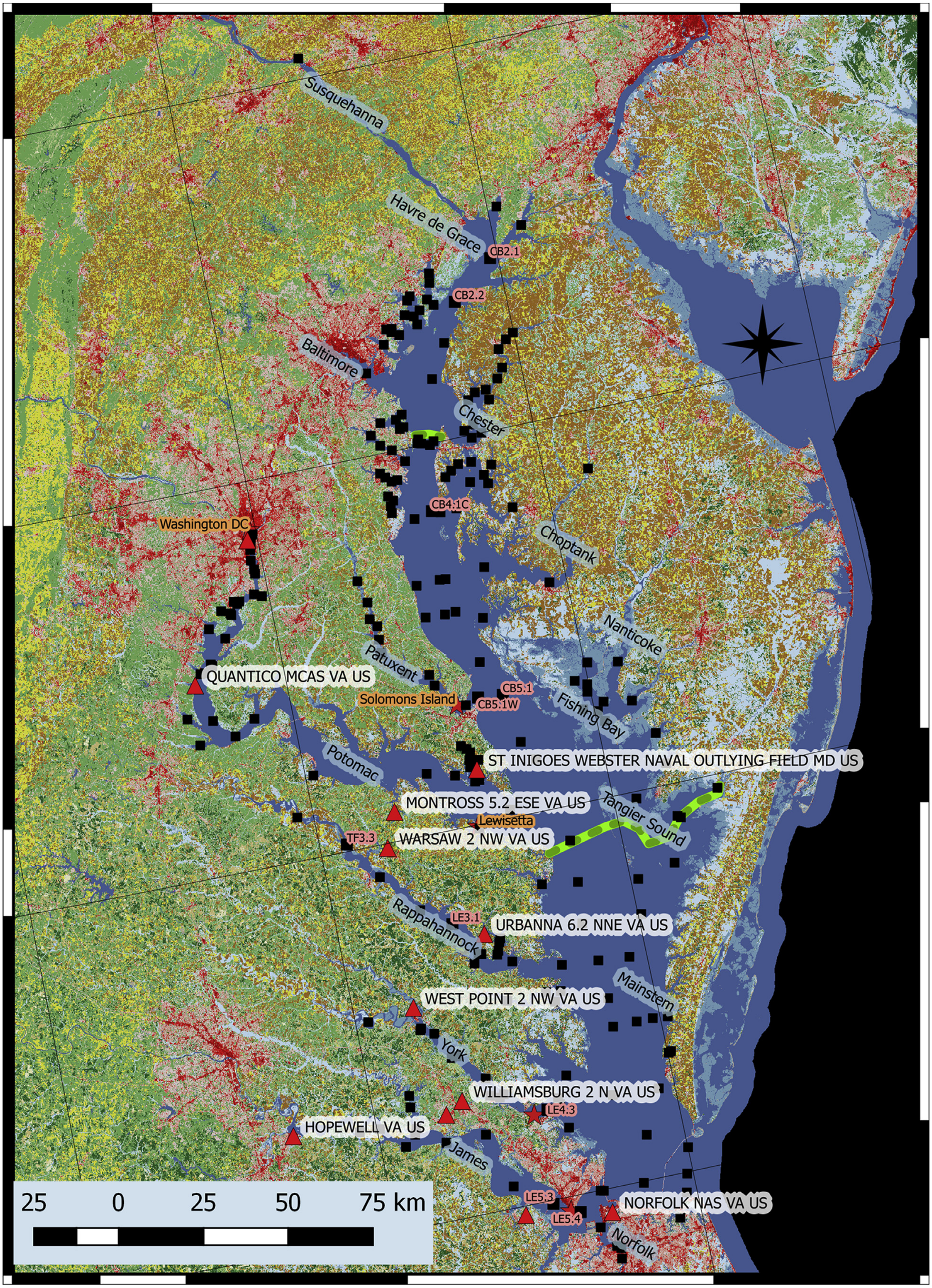

Fig. 1. Study area in the Chesapeake Bay, where black squares represent the CBP stations and the extent of the study area upstream each channel. CBP stations identified in the paper are labeled in pink. Location and name of NOAA rain gages are represented by red triangles/white text bubbles. Light blue text labels indicate channel names. Orange text labels indicate NOAA "tides and currents" stations. The lower green dash is the Virginia-Maryland border; the upper green dash is the Bay Bridge. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)