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Analysis of suspended particulate matter concentrations in Weeks Bay, Alabama using Landsat imagery

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Objective

To model in situ observed SPM and SPIM concentrations within Weeks Bay with corresponding radiometer data simulated to represent the Rrs values observed by the Landsat-8 satellite. The creation of an algorithm for the retrieval of SPM and SPIM concentrations will provide a low cost methodology for future SPM and SPIM research.

Background

- A primary concern in the Weeks Bay estuary is the threat of increased sediment transport within the watershed due to a rapid increase in development. The watershed of Weeks Bay has experienced substantial urban growth throughout its recent history. There was a 42.87% population increase between 1990 and 2000 and a 29.80% increase between 2000 and 2010 (U.S. Census Bureau 2000; U.S. Census Bureau 2010; Forstall 1995). From 1990 to 2000, the Weeks Bay watershed experienced an increase in urban/built-up land cover by 92.47% (Cartwright, 2002).
- The use of satellite sensors to remotely sense visible and near-infrared reflectance allows for suspended particulate matter (SPM) and suspended particulate inorganic matter (SPIM) concentrations to be monitored on a repetitive synoptic scale.
- Many studies have demonstrated the effectiveness of using combinations of various band reflectance data to observe suspended sediment (Chen et al., 2011; Han et al., 2006; Kaba et al., 2014; Miller et al., 2004; Zhao et al., 2011).
- The Landsat satellites, while designed for land surface studies, have often been selected to study suspended sediment in smaller bodies of water due to the superior spatial resolution of 30 meters for bands 1-5 and 7 (Jenson, 2006).
- Due to the complexity of Case-2 waters, established bio-optical models are often site specific due to local variations in environmental conditions (Merritt, 2016).

Methods

- In situ water samples were collected on four days between May and September 2016. Collection corresponded to Landsat 8 passes over Weeks Bay.
- The following was collected at each sample location: GPS coordinates, three surface water samples, and a GER 1500 Radiometer was used to determine water surface reflectance in the region from 300 to 1050 nm. At each site location, two sets of scans were taken. Each set of scans included a reference scan of a 99% spectralon reference panel, three consecutive scans of the target surface water, and a scan of the sky
- Raw GER 1500 radiometer data was processed into Landsat-8 reflectance values
- Water samples were filtered for SPM within 24 hours of collection to limit the deterioration of organic particulate matter. SPM concentrations in mg/L were determined using the glass-fiber filter method (Guy and Norman, 1970). Filtration was done using Whatman GF/F 47 mm glass microfiber filters (pore size 0.7μm).
- Previously presented algorithms for relating remote sensing reflectance (Rrs) and SPM/SPIM concentrations were evaluated for the Weeks Bay estuary in Alabama. Each model was first tested exactly as published in the literature. The previously developed models were then adjusted by keeping the defined independent parameters, and altering the coefficients by running regressions with the Weeks Bay SPM/SPIM data.
- Once the previously developed models were tested, many additional possible reflectance parameters were tested as potential variables in a Weeks Bay SPM/SPIM retrieval algorithm. These reflectance parameters included single bands, the natural logs of single bands, band ratios, band combinations, and combinations of the previously listed. Both linear and nonlinear models were tested for each reflectance parameter.

Discussion & Conclusions

- The reflectance parameters produced much more significant results when being related to SPIM, opposed to SPM.
- The best performing SPIM model was the third order polynomial equation utilizing Ln(Band 4)/Ln(Band 3) as the predictive variable as given in the following equation:

  $$SPIM = -84393 x^3 + 266348 x^2 - 279970 x + 98029$$

  Where SPIM is the concentration of SPIM measured in mg/L, and x is the combination of Landsat-8 Rrs values such that

  $$x = (\ln(\text{Band } 4))/(\ln(\text{Band } 3))$$

  This model resulted in the lowest RMSE (12.50% or 1.59 mg/L), and highest R^2 (R^2=0.6504).
- In the event that the nonlinear equation is over fit to the noise of the specific sample set used, a linear model may more accurately determine SPIM concentrations from reflectance. the best performing model was the equation utilizing Band 4/Band 3 as the predictive variable as given in the following equation:

  $$SPIM = -20.644x + 30.374$$

  Where SPIM is the concentration of SPIM measured in mg/L, and x is the combination of Landsat-8 Rrs values such that

  $$x = (\text{Band } 4)/(\text{Band } 3).$$

  This model resulted in the lowest RMSE (17.48% or 2.23 mg/L), and highest R^2 (R^2=0.2619).
- Despite the significant p-values and Pearson correlation coefficients of the reported SPIM retrieval algorithms, none have R^2 values that stand up to those of the models published in the literature. Published SPM/SPIM retrieval algorithms typically report an R^2 value of 0.75 or greater.

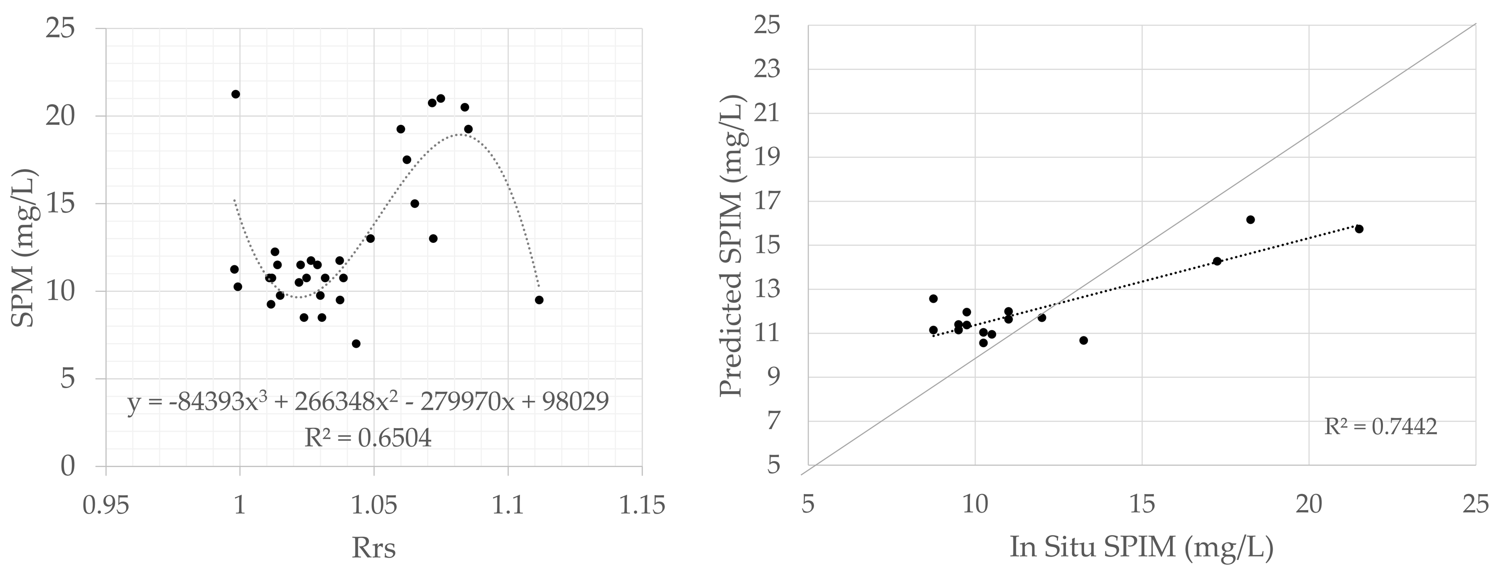

Figure 2 – Development (left) and validation (right) plots for SPIM = -84393*x³ + 266348*x² - 279970*x + 98029 where x =(Ln(Band 4))/(Ln(Band 3))

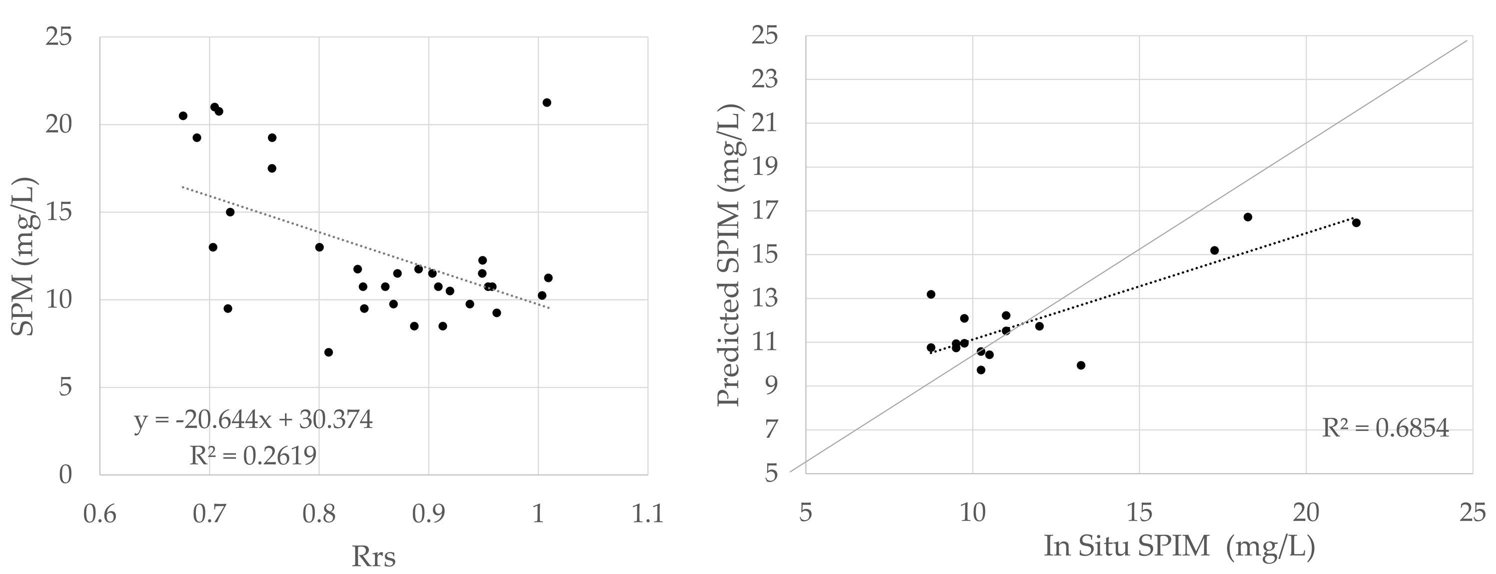

Figure 3 – Development (left) and validation (right) plots for SPIM= -20.644x + 30.374 where x =Band 4/Band 3

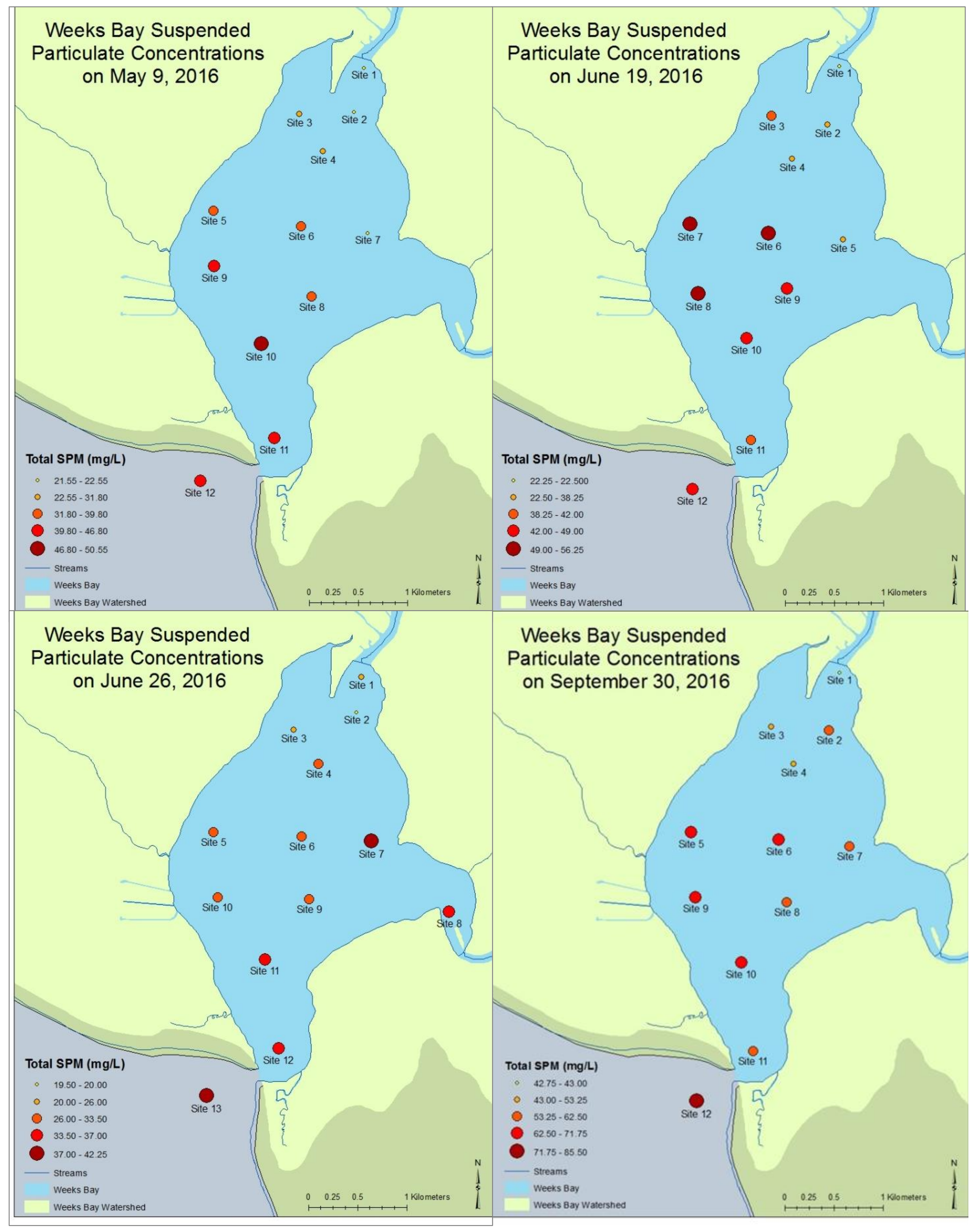

Figure 1- Spatial variability of total SPM concentrations for each field collection trip

Future Work

- Create sediment concentration maps for both future and historic Landsat-8 imagery, allowing for a number of questions on sediment transfer to be investigated.
- It may be beneficial for additional sampling to range evenly over each season, in order to account for seasonal meteorological differences.
- Future research may investigate the influence of meteorological influences such as precipitation, wind speed, and wind direction.

Acknowledgements

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