**Plum Island Estuary Water Resources II**

*Employing Remote Sensing Techniques to Quantify Sediment Supply and Evaluate Marsh Vulnerability in the Plum Island Estuary*

**VPS Title:** Particulate Matters: Investigating suspended sediment in Plum Island Estuary

**Project Team**

***Project Team*:**

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***Advisors & Mentors*:**

Cedric Fichot (Boston University)

Sergio Fagherazzi (Boston University)

***Past or Other Contributors*:**

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**Project Overview**

***Project Synopsis*:**

In an increasingly urban environment, salt marshes, such as the Plum Island Estuary (PIE) in Massachusetts, offer not only traditional ecosystem services, such as carbon sequestration and water quality improvement, but also social services in the form of educational and recreational opportunities. Sea level rise (SLR) threatens the equilibrium between sediment supply and erosion that ensures the marsh’s survival. Quantifying sediment supply is therefore a good metric for evaluating a marsh’s vulnerability. Using satellite imagery and *in situ* data, the team created maps of sediment supply that help inform management decisions and provide high resolution information to researchers regarding the resilience of Plum Island Estuary.

***Abstract*:**

The Plum Island Estuary (PIE) in Massachusetts is New England’s largest salt marsh. This dynamic ecosystem plays an important role in the surrounding communities by providing ecosystem services and acting as a center for education, research, and recreation. However, marshes around the world are threatened by sea level rise. As the equilibrium between sediment supply, erosion rates, and vegetation growth is unbalanced by rising waters, marshes are liable to recede. Because sediment is so crucial, researchers use sediment budgets as a metric to assess PIE’s vulnerability to rising seas; however, established data collection methods are limited in scope. The project employed five years of imagery from Landsat 8 Operational Land Imager and three years of imagery from Sentinel-2 Multispectral Instrument, in conjunction with *in situ* data, to generate and refine a local algorithm that derives suspended sediment concentration from remote sensing reflectance. This information was used to generate a time series analysis, and a hydrodynamic model was used to analyze transport patterns and possible sediment sources, particularly the Merrimack River via coastal connectivity. Results of these analyses demonstrated that sediment in the estuary comes primarily from riparian rather than oceanic sources, making it unlikely that the Merrimack is a major sediment source. The use of remote sensing techniques will provide our partners at the US Geological Survey, US Fish and Wildlife Service, and Long Term Ecological Research Network, Plum Island Ecosystems LTER with higher spatial and temporal resolution data, which will allow for the development of more effective management practices.

**Keywords:**

Remote sensing, Landsat 8 OLI, Sentinel-2 MSI, salt marsh, suspended sediment concentration, suspended sediment flux, remote sensing reflectance, sea level rise

***National Application Area Addressed:*** Water Resources

***Study Location:*** Plum Island Estuary, MA

***Study Period:*** April 2013 – July 2018

***Community Concern:***

* Salt marshes are critical for resilience in coastal communities; they provide protection against storm surge and floods, purify water, control erosion, and sequester large amounts of carbon.
* Plum Island Estuary is a popular destination for recreation, research, education, and outreach activities, making it a valuable social resource for nearby communities.
* A sediment budget, including possible sediment sources, will help decision-makers efficiently identify high-risk parts of the marsh that could benefit the most from limited conservation funds.

***Project Objectives:***

* Improve Sentinel-2 Multispectral Instrument (MSI) atmospheric corrections by adding gains
* Refine the algorithm for deriving suspended sediment concentration (SSC) from remote sensing reflectance developed during the previous term of this project and apply semi-analytical methods to sediment concentration quantification
* Create a time series showing the variation in sediment dynamics from 2013 - 2018
* Evaluate the Merrimack River as a possible source of sediment to the estuary
* Quantify suspended sediment flux in PIE using the Delft3D hydrodynamic model

***Previous Term:*** 2018 Spring (MA) – Plum Island Estuary Water Resources

**Partner Overview**

***Partner Organizations:***

|  |  |  |  |
| --- | --- | --- | --- |
| **Organization** | **POC (Name, Position/Title)** | **Partner Type** | **Boundary Org?** |
| **USGS, Woods Hole Coastal and Marine Science Center** | Dr. Neil Ganju, Research Oceanographer | End User | Yes |
| **US Fish and Wildlife Service, Parker River National Wildlife Refuge** | Nancy Pau, Biologist | Collaborator | No |
| **Long Term Ecological Research Network, Plum Island Ecosystems LTER** | Dr. Anne Giblin, Lead Principal Investigator | Collaborator | No |

***Decision Making Practices & Policies***:

Plum Island Estuary is a protected area under the 1972 Wetlands Protection Act, which prohibits the alteration of any wetland without a permit. It is located within the Great Marsh Area of Critical Environmental Concern, an area nominated by the community and then designated by the Massachusetts Secretary of Energy and Environmental Affairs as having unique ecological value. Long Term Ecological Research Network, Plum Island Ecosystems LTER (PIE LTER) is the primary steward of the region. Massachusetts is a ‘home-rule’ state, meaning that local decision-making is prioritized over state level authority. The variety of stakeholders that control different parts of the estuary can make implementing policy difficult and complicates efforts to coordinate management. The PIE LTER focuses on solving empirical problems, such as sediment flux in the estuary, that influence policy in nearby areas. Currently, sediment flux is measured at a small number of point locations by the United States Geological Survey (USGS) in collaboration with Dr. Sergio Fagerhazzi (Boston University) and Nancy Pau (United States Fish and Wildlife Service, USFWS). Dr. Neil Ganju (USGS) uses this information in vulnerability assessments of the marsh, which are used to determine management procedures, allocate funds judiciously, and guide future research.

***Project Benefit to End User***:

Relying on *in situ* data to assess SSC is labor-intensive and limited in temporal and spatial scope. Deriving SSC from remote sensing data provides greater geographic coverage and allows for more frequent observations. The capacity to obtain detailed SSC information relatively quickly from years of remote sensing data allows our end user and collaborators to understand the sediment dynamics of the estuary more completely, improving their ability to effectively allocate management resources. This project also provides a template for the establishment of similar remote sensing projects led by our partners, building remote sensing capacity for these organizations.

**Earth Observations & End Products Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameter** | **Use** |
| **Landsat 8 OLI** | Remote sensing reflectance (Rrs) | Remote sensing reflectance at all wavelengths derived from Landsat 8 OLI Collection 1 Level 1 data were used to calculate suspended sediment concentration. |
| **Sentinel-2 MSI** | Remote sensing reflectance (Rrs) | Remote sensing reflectance at all wavelengths derived from Sentinel-2 MSI Level 1C data were used to calculate suspended sediment concentration. |

***Ancillary Datasets:***

Boston University (C. Fichot) *in situ* measurements of Rrs – Algorithm development and validation

Boston University (C. Fichot and S. Fagherazzi) *in situ* measurements of SSC – Algorithm development and validation

PIE LTER (H. Garritt) pressure and climate data – Atmospheric correction

PIE LTER (C. Hopkinson) *in situ* measurements of SSC – Algorithm validation

NOAA Office of Coast Survey Portsmouth Harbor to Boston Harbor Nautical Chart 13274 – Develop depth mask to eliminate bottom reflectance

***Modeling:***

Delft3D Model (POC: Sergio Fagherazzi, Boston University) – Quantify suspended sediment flux based on the suspended sediment concentration

***Software & Scripting:***

SeaDAS – Atmospheric correction

MATLAB – Algorithm development, bathymetry mask creation, statistical analysis

R – Algorithm development, statistical analysis

Esri ArcGIS Pro – Geospatial analysis, map production, bathymetry mask creation

Google Earth Pro – Bathymetry mask creation

ACOLITE – Retrieve turbidity from Rrs

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Product** | **Earth Observations Used**  | **Partner Benefit & Use** | **Software Release Category** |
| **Suspended Sediment Flux Map** | Landsat 8 OLI, Sentinel-2 MSI | Suspended sediment flux map derived from Landsat 8 sediment concentration data from 11/8/16 in conjunction with the Delft3D model will help our partners get a clear picture about the amount of sediment exchange in the Plum Island Estuary, which can be used in vulnerability assessments of the area. | Options:N/A |
| **Time Series of Surface-Water SSC with Environmental Variable Correlations** | Landsat 8 OLI, Sentinel-2 MSI | A time series of SSC will assist our partners in understanding rates of accretion and erosion throughout the marsh over the last five years and allow them to see where SSC varies most. Correlating SSC with wind, tide, and river discharge will enhance understanding of what drives SSC variation. | N/A |
| **Imagery Acquisition and Processing Tutorial (Atmospheric Corrections, Mask, Time Series)** | N/A | A tutorial of the methods used in this analysis will allow the end user to continue the study as desired. | N/A |
| **Maps of SSC** | Landsat 8 OLI, Sentinel-2 MSI | Individual maps of SSC in the estuary on various days at low and high tidal levels will help our partners understand how tidal level affects SSC. | N/A |

**Project Handoff Package**

**Transition Plan:**

The team held a virtual handoff via WebEx and the National Teleconference Line during Week 10 of the term. All maps, imagery, data, deliverables, and project materials were sent by the Center Lead via NASA Large File Transfer to our project partners following approval by the National Program Office.

**Team POC:** Henrik Westerkam, HWesterkam@clarku.edu

**Partner POC**: Dr. Neil Ganju, nganju@usgs.gov

**Handoff Package:**

* Project Summary
* Technical Paper
* Presentation
* Project Video
* Poster
* Shapefiles
* Model Output Package
* SSC GeoTIFF Analysis Results
* Suspended Sediment Flux Maps
* Time Series of Surface-Water SSC
* Imagery Acquisition and Processing Tutorial

**References:**

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Morris, J., Sundareshwar, P. V., Nietch, C., Kjerfve, B., & Cahoon, D. R. (2002). Responses of coastal wetlands to rising sea level. *Ecology, 83(10),* 2869-2877.

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