**NASA DEVELOP National Program**

**Massachusetts - Boston**

*Project Summary – Spring 2018*

**Plum Island Estuary Water Resources**

*Utilizing NASA Earth Observations to Assess Marine Sediment Fluxes and Determine Marsh Vulnerability in the Plum Island Estuary*

**VPS Title:** Piece of the PIE: Evaluating Sediment Flux in the Northeast’s Largest Salt Marsh

**Project Team**

***Project Team*:**

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***Advisors & Mentors*:**

Cedric Fichot (Boston University)

Sergio Fagherazzi (Boston University)

**Project Overview**

***Project Synopsis*:** Salt marshes provide coastal communities with important ecosystem services, including storm surge protection and improved water quality. The health of these valuable ecosystems is threatened by sea level rise. One such ecosystem, Plum Island Estuary in northern Massachusetts, is a site of existing research relating marsh resilience to the effects of a changing climate. Using satellite imagery from NASA Earth observations, paired with *in situ* data, sediment concentration and distribution in the estuary was evaluated. Sediment supply is essential for the marsh’s continued resilience, and this work will inform future conservation policy.

***Abstract*:** Salt marshes provide valuable ecosystem services, including protection from coastal storms, erosion control, carbon sequestration, improved water quality, and ecological diversity. Plum Island Estuary (PIE), the largest salt marsh in the northeast United States, is a two thousand year-old ecosystem located thirty-five miles north of Boston, Massachusetts. As sea level rises, the structure and health of this marshland ecosystem depends on sediment availability. Current research in the estuary, performed by the United States Geological Survey (USGS) and the Woods Hole Marine Biological Laboratory (MBL), uses point-measurements of sediment fluxes. However, these isolated data points can be misleading when attempting to understand system-wide changes. Landsat 8 Operational Land Imager (OLI) and Sentinel-2 MultiSpectral Instrument (MSI) imagery from 2013 to 2017 were compared to *in situ* data measurements. An algorithm was generated to calculate total suspended sediment concentration and distribution in the estuary. In dynamic ecosystems like salt marshes, utilizing remote sensing to quantify and visualize sediment supply assists end users in generating current and future vulnerability assessments of PIE to sea level rise.

**Keywords:**

Salt marsh, Plum Island Estuary, Landsat 8 OLI, Sentinel-2 MSI, sea level rise, suspended sediment concentration, ecosystem services

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

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

***Study Period:*** May 2013 – December 2017

***Community Concern:***

* Salt marsh conservation plays a crucial role in coastal resilience by protecting inland ecosystems from storm surge, maintaining water quality, and acting as a reservoir for flood waters.
* Modeling sediment fluxes could help explain the formation of ponds throughout the marsh.
* Altering the structure of the salt marsh due to net changes in sediment levels could affect the system’s viability as a habitat for species of fish and migratory birds, as well as impact the spread of invasive species such as Phragmites (*Phragmites australis*) and Pepperweed (*Lepidium latifolium*).
* Resources allocated to the restoration and conservation of salt marshes are limited, and more data on the long-term viability of salt marsh units are needed to target those sites most negatively affected by sea level rise.

***Project Objectives:***

* Use NASA Earth observations to develop an accurate methodology for estimating total suspended sediment concentration (SSC) and distribution in the water
* Determine the SSC of PIE from satellite imagery
* Map sediment fluxes throughout the estuary to determine areas most vulnerable to low accretion rates or erosion resulting from sea level rise and other risk factors
* Create a time series of SSC in the water column

**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, Interim Director, Ecosystems Center | Collaborator | No |

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

Plum Island Estuary has been legally protected from development since 1972 under the Massachusetts Wetlands Protection Act. Since 1998, Plum Island Ecosystems Long Term Ecological Research Network (PIE LTER) has been responsible for ecological monitoring of the area. PIE LTER is a collaboration between various partners, including the USGS, US Fish and Wildlife Service (USFWS), and academic researchers. The USGS, in collaboration with Dr. Fagherazzi (Boston University) and Nancy Pau (USFWS), currently uses point-measurements of sediment fluxes *in situ* at different locations throughout PIE marshes. These data are used by the Parker River National Wildlife Refuge to develop rapid assessment metrics, which can be applied by the USFWS and other conservation organizations to assess salt-marsh persistence on a regional scale. The data also allow the USGS to conduct region-wide vulnerability assessments that help focus future research, management, restoration, and acquisition funds where they are most needed.

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

The methodology developed in this project will enable the USGS to use Landsat and Sentinel data to assess the availability and fluxes of marine sediments in a coastal bay. This will be a powerful large-scale supplement to current *in situ* data measurements, which can be used to benefit the conservation and restoration of PIE, as well as other marshes in the future. The methodology developed herein can also be tested in the future for other bays along the east coast of the United States. The results will allow for better-informed decisions regarding adaptive management practices as sea level rise threatens coastal ecosystems.

**Earth Observations & End Products Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameter(s)** | **Use** |
| **Landsat 8 OLI** | Remote-sensing reflectance (Rrs), SSC | High-resolution maps (30 m) of suspended sediment concentration were used with the outputs of a hydrodynamic model to derive sediment fluxes in and out of PIE. |
| **Sentinel-2 MSI** | Remote-sensing reflectance (Rrs), SSC | High-resolution maps (10-20 m) of suspended sediment concentration were used with the outputs of a hydrodynamic model to derive sediment fluxes in and out of PIE. |

***Ancillary Datasets:***

Boston University (C. Fichot) *in situ* measurements of Remote-Sensing Reflectance (Rrs) – Algorithm development and product validation

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

Boston University (S. Fagherazzi) *in situ* measurements of surface-water currents – Model product and validation

USGS (N. Ganju) *in situ* measurements of SSC – Model product and validation

***Modeling:***

Delft3D Model (POC: Sergio Fagherazzi, Boston University)

***Software & Scripting:***

SeaDAS – Remote sensing data re-projection for Landsat 8 OLI and Sentinel-2 MSI

ACOLITE – Atmospheric correction for Landsat 8 OLI and Sentinel-2 MSI

Esri ArcGIS Pro – Generating maps of suspended-sediment concentration

R – Statistical analysis and graphs

MATLAB – Data projection, statistical analysis, and graphs

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Product** | **Earth Observations Used** | **Partner Benefit & Use** | **Software Release Category** |
| **Surface-water SSC Maps** | Landsat 8 OLI, Sentinel-2 MSI | This information provides the partners with valuable information about the spatio-temporal variability of surface-water SSC in PIE. These products directly inform them about the sensitivity of these variables to environmental forcing, and will be used to derive the sediment-flux products described below. | N/A |
| **Maps of suspended-sediment exchange (fluxes in and out of the PIE)** | Landsat 8 OLI, Sentinel-2 MSI | These maps provide valuable information about the vulnerability of the Plum Island salt marsh and inform future management strategies to increase the resilience of this environment to climate change. | N/A |
| **Data Acquisition & Analysis Tutorial** | N/A | A tutorial of the methods will ensure further analysis of satellite imagery can be completed by the end user if necessary. | N/A |

**Project Handoff Package**

**Transition Plan:**

Following the term, all relevant project materials, data, maps, tutorials, and deliverables will be sent by email to all project partners: Dr. Neil Ganju, Nancy Pau and Dr. Anne Giblin. These materials will be sent by the Center Lead once all final drafts are approved by the National Program Office. A virtual hand-off event with the partners will occur during Week 9 or 10 of the term, during which the team will summarize the results and conclusions of the project, as well as give any suggestions for future work.

*Project Continuation Plan*: This term will hand off *in situ* data in addition to a tutorial outlining the applied methods of data collection, atmospheric correction, and modeling of SSC. Preliminary results include SSC calculated from satellite images and a comparison to existing *in situ* data. The summer term will focus on incorporating additional NASA Earth observations and a greater volume of *in situ* data to improve the accuracy and validity of the models and results. The next term can extend this analysis to include estimations of dissolved organic carbon (DOC). All project materials will be archived with the Center Lead.

**Team POC:** Zachary Bengtsson, zachbengtsson@gmail.com

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

**Handoff Package:**

* Project Summary
* Presentation
* Project Video
* Poster
* Technical Paper
* Shapefiles
* Map package
* Tutorial (data collection & methods)

**References:**

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