**Apostle Islands Water Resources**

*Mapping Sediment Plumes and Algal Blooms Using Earth Observations at the Apostle Islands National Lakeshore*

**Project Team**

***Project Team:***

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**Project Overview**

***Project Synopsis:*** Sediment plume and algal bloom occurrence may be increasing within western Lake Superior and the Apostle Islands National Lakeshore due to changes in local precipitation patterns. The dynamics of these phenomena, however, are not currently well-understood. The Apostle Islands Water Resources team partnered with the National Park Service and the University of Minnesota Duluth, Large Lakes Observatory to compare the efficacy of multiple satellite sensors to detect sediment plume and algal bloom occurrence, extent, and duration within western Lake Superior. This project will aid partners in understanding plume and bloom dynamics, which would inform future management and mitigation practices within this federally protected area.

***Abstract:***

Perceived increases in the occurrence of sediment plumes and algal blooms following storm events have raised concerns about water quality within western Lake Superior. Increases in algal productivity and suspended sediment concentration may have negative impacts on wildlife, human health, and recreation. These phenomena are of critical concern for the Water Resources Division of the National Park Service (NPS). Researchers at the NPS and the University of Minnesota Duluth, Large Lakes Observatory (UMD LLO) first identified algal blooms in western Lake Superior in 2012. They currently only incorporate Moderate Resolution Imaging Spectroradiometer (MODIS) Earth observations in a limited capacity, but to this point they have not utilized MODIS in conjunction with *in situ* data. The Apostle Islands Water Resources team partnered with the NPS and UMD LLO to develop a methodology utilizing Aqua MODIS, Terra MODIS, and Sentinel-3 Ocean and Land Colour Instrument (OLCI) observations to better understand the dynamics of sediment plumes and algal blooms within western Lake Superior during summer months (June to August) from 2011 to 2019. Results saw success in incorporation of remote sensing technology for the detection of sediment plumes and the potential for the remote detection of algal blooms with expanded field data collection. The use of Earth observations will aid project partners in implementing effective mitigation strategies and improving public communication surrounding issues of water quality within the Apostle Islands National Lakeshore.

***Keywords:***

chlorophyll-a, turbidity, transmissivity, Aqua/Terra MODIS, Sentinel-3 OLCI, western Lake Superior, water quality, remote sensing

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

***Study Location:*** Apostle Islands National Lakeshore (WI, MI, and MN)

***Study Period:*** 2011 to 2019 (June to August)

***Community Concerns:***

* Sediment plumes and algal blooms disrupt ecological systems by altering the physical and chemical properties of water quality, specifically the availability of dissolved oxygen, light, and nutrients.
* Increased frequency and severity of sediment plumes and algal blooms may negatively impact water quality parameters and thus affect the ecosystem, tourism, and quality of water for both aquatic life and human use.
* The National Park Service (NPS) is concerned about the impact of these phenomena on tourism and wildlife, which to this point have only been qualitatively understood.
* The University of Minnesota Duluth, Large Lakes Observatory (UMD LLO) is interested in quantifying these phenomena within the western portion of the lake.

***Project Objectives:***

* Assess the feasibility of monitoring sediment plume and algal bloom presence, extent, and duration using remote sensing in the Apostle Islands National Lakeshore
* Determine which ESA and NASA Earth Observing satellites are appropriate for monitoring sediment plumes and algal blooms
* Analyze the most effective indices for remote detection of sediment plumes and algal blooms using transmissivity and chlorophyll-a as proxies for water quality
* Apply top performing remote sensing indices to generate a model to map sediment plumes in the western arm of Lake Superior

**Partner Overview**

***Partner Organizations:***

|  |  |  |  |
| --- | --- | --- | --- |
| **Organization** | **POC (Name, Position/Title)** | **Partner Type** | **Boundary Org?** |
| **National Park Service, Water Resources Division** | Dr. Brenda Moraska Lafrancois, Midwest Region Aquatic Ecologist | End User | No |
| **University of Minnesota, Duluth Large Lakes Observatory** | Dr. Bob Sterner, Director | End User | No |

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

The Apostle Islands National Lakeshore consists of 21 islands, nearly 164 shoreline miles, and 31,437 acres that the NPS is tasked with protecting and managing. Researchers at the NPS and the UMD LLO have collaborated to collect vital *in situ* data of current conditions and phenomena in western Lake Superior, including chlorophyll-a concentrations and transmissivity since 2012. The UMD LLO operates a research vessel, The Blue Heron, which collects frequent water quality measurements in the off-shore waters of Lake Superior as part of a long-term monitoring study. The Blue Heron, however, cannot collect near-shore water samples which, in conjunction with off-shore samples, are vital for a complete understanding of water quality over time. Listed as a federally protected area under the National Park Service Organic Act of 1916, the scenery, natural and historic objects, and wildlife within the Apostle Islands National Lakeshore must be conserved for the enjoyment of future generations. This will require the National Park Service to adopt strategies to mitigate the detrimental effects of storm-driven sediment plumes and algal blooms to protect ecological health and recreation in response to changing precipitation patterns.

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

Our project partners at the NPS and UMD LLO are currently interested in the dynamics of sediment plumes and algal blooms and the role of storm events. Having a better understanding of these phenomena will allow for informed future mitigation efforts and effective public communication. Our project will enhance the detection of sediment plume and algal bloom trends over space and time; prior to 2012, there are no well-documented algal bloom events in western Lake Superior. The application of remotely sensed imagery will contextualize current sediment plume and algal bloom data, creating a framework for the interpretation of these phenomena in a historic context.

**Earth Observations & End Products Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameters** | **Use** |
| **Aqua MODIS** | Transmissivity | High temporal resolution (1-2 day) imagery used to analyze sediment plume presence and extent over time. |
| **Terra MODIS** | Transmissivity | High temporal resolution (1-2 day) imagery used to analyze sediment plume presence and extent over time. |
| **Sentinel-3 OLCI** | Chlorophyll-a | High temporal resolution (2 days) imagery used to analyze algal bloom presence and extent over time. |

***Ancillary Datasets:***

* UMD LLO Water Quality Sampling Locations– *in situ* water quality measurements for western Lake Superior used to determine presence and absence of an algal bloom for visual evaluation
* NPS List of Storm Events– used to focus study periods on dates when sediment plumes and algal blooms were likely to occur

***Modeling:***

* Random Forest Regression (POC: Dr. Catherine Jarnevich, USGS Fort Collins Science Center) – explored the linear relationship between field-collected and remotely sensed data

***Software & Scripting:***

* Google Earth Engine Application Programming Interface (API) – large-scale image analysis
* R-Studio 1.2.5001– statistical analyses and figure generation
* Microsoft Excel - statistical analyses and figure generation
* Esri ArcGIS Pro – image processing and end product generation

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Products** | **Earth Observations Used**  | **Partner Benefit & Use** | **Software Release Category** |
| **Chlorophyll-a and Transmissivity Maps** | Aqua MODIS Terra MODIS Sentinel-3 OLCI | Chlorophyll-a and transmissivity maps provided partners with a visualization of the changes in algal bloom and sediment plume extent in the study area. | N/A |

**Project Handoff Package**

***Transition Plan:*** The team hosted a short seminar in Week 10 via video conference to relay the results of our project to partners, Dr. Brenda Moraska Lafrancois and Dr. Bob Sterner. Our handoff package was sent to our partners through an emailed Google Drive link.

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***Handoff Package:***

* Chlorophyll-a and Transmissivity Maps
* Presentation
* Technical Paper

**References**

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