NASA DEVELOP National Program
2019 Fall Project Proposal

Colorado – Fort Collins
Apostle Islands Water Resources
Mapping Sediment Plumes and Algal Blooms using Earth Observations at the Apostle Islands National Lakeshore

Project Overview

Project Synopsis: This project will use Landsat and Sentinel imagery to provide partners at the National Park Service (NPS) with maps and temporal trend analyses of sediment plume and algal bloom extent. The team will utilize several spectral indices and modeling techniques to generate these maps for the Apostle Lakes National Lakeshore and the surrounding region along Lake Superior. The team will also provide partners with a written tutorial outlining a repeatable methodology for future analyses. These end products will be used by project partners to better understand sediment plume and algal bloom dynamics, which they will communicate to the public, and to inform future management and mitigation practices.

Community Concern: There is a perceived increase in flood-driven sediment plumes and nearshore algal blooms in western Lake Superior, particularly at Apostle Islands National Lakeshore. Project partners are concerned that algal blooms might increase in numbers due to changes in regional precipitation patterns and increases in extreme precipitation events. While sediment plumes can happen at any time, large ones are often observed after large rainstorms. In this area, algal have been observed to bloom following large sediment plume events; however the dynamics between the two are not clear. Sediment plumes are much larger and more easily identified using satellite imagery than algal blooms in this area tend which tend to last anywhere from one day to one week long. Partners at the National Park Service and the University of Minnesota are interested in better understanding these phenomena, as well as their development over time. Understanding these events is important to maintaining water quality, ecosystem health, and tourism and will better inform management options as well as communication to the public

Source of Project Idea: The Water Resources Division of the National Park Service requested a project to address the needs described in this proposal. The Fort Collins node science advisors met with the NPS and University of Minnesota partners to work out the details for the project described here.

National Application Areas Addressed: Water Resources
Study Location: WI, MI, MN
Study Period: January 1984 – January 2019

Advisors: Dr. Paul Evangelista (Colorado State University, Natural Resource Ecology Laboratory), Dr. Catherine Jarnevich, (USGS, Fort Collins Science Center), Nicholas Young (Colorado State University, Natural Resource Ecology Laboratory), Tony Vorster (Colorado State University, Natural Resource Ecology Laboratory)

Partner Overview

Partner Organizations:

Organization	POC (Name, Position/Title)	Partner Type	Boundary Org?
National Park Service, Water Resources Division	Brenda Moraska Lafrancois, Midwest Region Aquatic Ecologist	End User	No

University of Minnesota, Duluth Large Lakes Observatory	Dr. Bob Sterner, Director of Large Lakes Observatory and Professor of Biology	End User	No

End-User Overview

End User's Current Decision-Making Process: Partners at the National Park Service NPS and the University of Minnesota currently monitor tributaries and nearshore waters predominantly through water quality sampling. These organizations are making decisions about how to respond to algal blooms in real-time, how to manage and mitigate future algal blooms, and how to accurately communicate changes in lake conditions, including potential shifts in water clarity and bloom frequency, with the public. Analysis of Moderate Resolution Imaging Spectroradiometer (MODIS) satellite imagery suggests possible temporal trends in sediment plume occurrence in the Apostle Islands. Other imagery has been used to visually identify specific algal bloom events, but formal remote sensing analyses have not been conducted, particularly to examine trends over time.

End User's Capacity to Use NASA Earth Observations:

National Park Service, Water Resources Division, Midwest Region – Our partners at the NPS utilizes MODIS data to monitor water quality within the Apostle Islands National Lakeshore, but has limited capacity to conduct formal remote sensing studies or to incorporate other sensors. This project will increase their capacity to utilize NASA Earth observations to understand and communicate how this system has changed over time.

University of Minnesota, Duluth Large Lakes Observatory – Our points of contact at the university are familiar with Earth observations and have utilized MODIS to observe sediment plume events. However, they are less familiar with employing other sensors to analyze events over time and are interested in how they can utilize them to address research gaps. This project will build their capacity to incorporate NASA Earth observations into their research and public outreach when looking at sediment plumes and algal blooms.

Project Communication & Transition Overview

***In-Term Communication Plan*:** The team will communicate with partners and collaborators three times throughout the term via teleconference meetings. These three meetings will include an introduction meeting in week2, mid-project update week 6, and closing handoff in week 10. The Center Lead and Project Lead will be the primary points of contact with the partner organizations.

***Transition Plan*:** At the end of the term, the team will host a web-based seminar to disseminate project results. A handoff package will be sent to the end users via email. As part of the handoff package, the end-users will receive 1) Sediment Plume and Algal Bloom Maps, 2) Temporal Trend Analysis including a time series, 3) Tutorial, and 4) Technical Report. There is no software release required for this project.

Earth Observations Overview

Earth Observations:

Platform & Sensor	Parameters	Use
Landsat 5 TM	Chlorophyll-a, surface reflectance	This dataset will provide the temporal (16 days) and spatial (30 m^2) resolution needed to derive spectral indices for mapping sediment plumes and algal blooms.
Landsat 8 OLI	Chlorophyll-a, surface reflectance	This dataset will provide the temporal (16 days) and spatial (30 m^2) resolution needed to derive spectral indices for mapping sediment plumes and algal blooms.

Aqua MODIS	Chlorophyll-a, surface reflectance	The frequent (1-2 day) temporal resolution will be valuable for monitoring blooms and plumes in this project.
Terra MODIS	Chlorophyll-a, surface reflectance	The frequent (1-2 day) temporal resolution will be valuable for monitoring blooms and plumes in this project.
Sentinel-2 MSI	Chlorophyll-a, surface reflectance	This dataset will provide the spatial (10-60 m^2) resolution needed to derive spectral indices for mapping sediment plumes and algal blooms.

Ancillary Datasets:

- University of Minnesota Water Quality Sampling Locations – field data to inform modeling process
- NPS List of Storm Events – inform when sediment plumes and algal blooms were likely to occur

Modeling:

- Random Forest (RF) (POC: Dr. Catherine Jarnevich, USGS Fort Collins Science Center)
- Generalized Linear Model (GLM) (POC: Dr. Catherine Jarnevich, USGS Fort Collins Science Center)

Software & Scripting:

- Esri ArcGIS – Image processing and end product generation
- R – Statistical analyses and raster processing
- Google Earth Engine Application Programming Interface (API) – Large-scale image analysis
- ACOLITE – image processing, chlorophyll, and turbidity algorithms

Decision Support Tool & End Product Overview

End Products:

End Product	Partner Use	Datasets & Analyses	Software Release Category
Sediment Plume and Algal Bloom Maps	The partners will use maps of sediment plumes and algal bloom conditions during several discrete events to understand the extent of these events and interactions between plumes, blooms, and storm events.	Spectral indices will be derived from Landsat 5, Landsat 8, MODIS, and Sentinel-2 imagery to create maps delineating the extent of sediment plumes and algal blooms.	N/A
Temporal Trend Analysis	An analysis of temporal trends in sediment plume presence and algal bloom occurrence at key sites will allow partners to more accurately communicate changes in lake conditions with the public and to increase their understanding of these events.	Spectral indices will be derived from Landsat 5, Landsat 8, MODIS, and Sentinel-2 imagery to conduct an analysis of temporal trends. A timelapse will be created to show how events change over time.	N/A
Mapping Sediment Plumes and Algal Blooms via Google Earth Engine Tutorial	The tutorial will enable end users to replicate this study in future years.	Tutorial will describe the steps to generate the maps and analysis described above.	N/A

***End-User Benefit*:** Providing partners with better documentation of the spatial extent and duration of previous sediment plume and algal bloom events, identifying longer-term trends in sediment plume presence and algal bloom occurrence, and exploring potential interactions between sediment plumes and algal blooms will help clarify remote sensing options for use in future plume or bloom events and research.

Project Timeline & Previous Related Work

Project Timeline: 1 Term: Fall 2019

Related DEVELOP Work:

2019 (ARC) – America Samoa Water Resources: Evaluating the Impacts of Land Cover and Water Quality Changes in American Samoa to Improve Watershed Management

2019 (ARC/JPL) – Belize Water Resources: A Google Earth Engine Dashboard for Assessing Coastal Water Quality in Belize's Coral Reefs to Identify Sustainable Development Goals (SDGs) for Achieving Sustainable Use of Natural Resources

2019 (CO) – Rocky Mountain Water Resources II: Employing NASA and ESA Earth Observations to Monitor Alpine Lake Algal Productivity in Rocky Mountain National Park

2018 (ARC) – Lake Michigan Water Resources II: Utilizing Multispectral Satellite Imagery to Monitor and Predict the Displacement of *Cladophora* Along the Milwaukee County Shoreline

Notes & References:

References:

Dogliotti, A. I., Ruddick, K. G., Nechad, B., Doxaran, D., & Knaeps, E. (2015). A single algorithm to retrieve turbidity from remotely-sensed data in all coastal and estuarine waters. *Remote Sensing of Environment*, *156*, 157-168.

Hauser, C. (2018). Algae Bloom in Lake Superior Raises Worries on Climate Change and Tourism. New York Times, August 29, 2018. https://www.nytimes.com/2018/08/29/science/lake-superior-algae-toxic.html

Nechad, B., Ruddick, K. G., & Park, Y. (2010). Calibration and validation of a generic multisensor algorithm for mapping of total suspended matter in turbid waters. *Remote Sensing of Environment*, *114*(4), 854-866.