**NASA DEVELOP National Program**

**2019 Summer Project Proposal**

**Colorado – Fort Collins**

**Rocky Mountain Water Resources II**

*Employing NASA Earth Observations to Monitor Alpine Lake Algal Productivity in Rocky Mountain National Park*

**Project Overview**

***Project Synopsis*:** This project will provide partners at the USGS Fort Collins Science Center (FORT) and National Park Service (NPS) Rocky Mountain National Park (RMNP) with improved maps of alpine lake algal productivity as well as an automated Google Earth Engine (GEE) tool designed for monitoring of algal blooms. To do this the team will utilize the Landsat and Sentinel series along with several spectral modeling techniques that will incorporate *in situ* data provided by partners and collaborators. In addition to chlorophyll-a maps, the team will devise written and video tutorials designed to outline the modeling process for the partners. These chlorophyll-a maps and tutorials will be used by the partners to improve their on-the-ground monitoring efforts of algal productivity and increase their decision-making ability concerning habitat management of fragile alpine lake systems.

***Community Concern:*** Since the 1960s, the 140 alpine lakes of RMNP have experienced an increase in nitrogen and phosphorus concentrations. This has subsequently resulted in increased algal productivity in many of these lakes. High algal productivity negatively affects water quality through eutrophication and the creation of anoxic events. This issue of increased algal biomass is increasingly important for RMNP because alpine lakes serve a crucial ecological function within the park as well as also as a main economic and aesthetic driver. Since 2005, RMNP has collaborated with the USGS FORT to develop monitoring protocols for algal biomass and nutrient deposition in these alpine systems. These agencies are currently investigating the recent trends of algal biomass in relationship to the increasing water temperature changes. Currently, there are significant difficulties in collecting sufficient monitoring data due to the remote setting of the alpine lake systems.

***Source of Project Idea:*** Dr. Jill Baron and Dr. John Mack were initially introduced to the Colorado – Fort Collins NASA DEVELOP Node through conversations with the node’s Science Advisor Dr. Paul Evangelista. These discussions lead to a NASA DEVELOP project in Fall 2016 at the Colorado Node which produced coarse approximations of chlorophyll-a. NPS and USGS officials are interested in building off of the Fall 2016 project to create an automated monitoring system that incorporates higher resolution imagery.

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

***Study Location:*** Rocky Mountain National Park, CO

***Study Period:*** 2016 – 2019 (June – August)

***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:***

|  |  |  |  |
| --- | --- | --- | --- |
| **Organizations** | **POC (Name, Position/Title)** | **Partner Type** | **Boundary Org?** |
| **USGS, Fort Collins Science Center** | Dr. Jill Baron, Research Ecologist Senior Scientist | End User | No |
| **National Park Service, Rocky Mountain National Park** | Dr. John Mack, Chief of Resource Management | End User | Yes |

***End-User Overview***

***End User’s Current Decision-Making Process:***Intensive monitoring by the USGS takes place in RMNP lakes on a weekly basis throughout the year to quantify physical, chemical, meteorological, and biological characteristics. While RMNP staff has utilized NASA Earth observations in the past, they do not currently have an automated means by which to incorporate remotely sensed data into their regular decision-making process.

***End User’s Capacity to Use NASA Earth Observations:***

*USGS, Fort Collins Science Center –* Researchers at the Fort Collins Science Center have collaborated with NPS RMNP in developing monitoring protocols for algal biomass and nutrient deposition in these alpine systems. Our point of contact has limited spatial analysis experience and limited familiarity using NASA Earth observations to build monitoring tools. This project will further build the end user’s capacity and influence decision making in regards to their long-term ecological research and monitoring.

*National Park Service, Rocky Mountain National Park* – This federal organization office encompasses a broad array of academic researchers who have been tasked with conserving the scenic, natural, and historic elements of the park. Our point of contact has limited spatial analysis experience and limited familiarity using specific NASA Earth observations for monitoring efforts. This project will further build the end user’s capacity, as well as the NPS Rocky Mountain National Park collectively.

***Project Communication & Transition Overview***

***In-Term Communication Plan*:** The team will communicate with partners and collaborators on a biweekly basis via teleconference meetings. 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 and to hand off deliverables. End of project term deliverables include chlorophyll-a maps, a video tutorial on using the monitoring tool, and a written tutorial on methods, which will be shared via email. A software release will be required for the chlorophyll-a monitoring tool, and the Project Lead or Center Lead will provide partners with training resources once the tool is released.

**Earth Observations Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameters** | **Use** |
| **EO-1 Hyperion** | Spectral vegetation indices | This dataset will provide 220 unique spectral channels ranging from 0.357 to 2.576 micrometers with a 10 nm bandwidth at a temporal resolution of 200 days and spatial resolution of 30 m data to derive environmentally significant spectral predictors from for random forest modeling. |
| **Landsat 8 OLI** | Chlorophyll-a | This dataset will provide temporal (8-day composite) and spatial (500 m) resolution surface spectral reflectance data to derive environmental significant spectral predictors from for random forest modeling. |
| **Sentinel-2 MSI** | Surface reflectance, normalized difference vegetation index, normalized difference moisture index, tasseled cap brightness, greenness, and wetness | This dataset will provide the temporal (16 days)  and spatial (30 m) resolution needed for  environmental predictive variables employed via a spectral classification modeling approach to  Investigate focal species presence. |
| **Sentinel-1 C-SAR** | Synthetic Aperture Radar  backscatter values,  surface roughness | This dataset will provide high temporal resolution (6 days) imagery used to detect changes in vegetation growth. |

***Ancillary Datasets:***

National Agriculture Imagery Program (NAIP) – 1m imagery for training dataset and validation

USGS Fort Collins Science Center Field Data – Field validation dataset

Colorado Department of Transportation’s Colorado lake shapefiles – Defining study area

***Modeling:***

Random Forest (RF) (POC: Dr. Catherine Jarnevich, USGS Fort Collins Science Center)

Boosted Regression Trees (BRT) (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 API – Large-scale image analysis, GUI tool generation

**Decision Support Tool & End Product Overview**

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Product** | **Partner Use** | **Datasets & Analyses** | **Software Release Category** |
| **Chlorophyll-a Maps** | Maps of alpine lake algal productivity will increase the partner’s decision-making ability concerning the habitat management of fragile alpine lake systems. | Random Forests generated maps using both spectral data from EO-1 Hyperion, Landsat 8 OLI, Sentinel-2 MSI, and Sentinel-1 C-SAR and field data will delineate algal presence within RMNP lakes. | N/A |
| **Chlorophyll-a Monitoring Tool** | The Google Earth Engine tool will be used to monitor algal blooms as a means for improving partner strategic field monitoring and future decision-making. | This product will be an  interactive Google Earth  Engine user interface designed to allow partners to evaluate algal blooms as a means to monitor and quantify the impact in RMNP. | III |
| **Methodology Toolset** | The toolset will enable end users  to replicate this study for future  years by outlining the modeling process. | The toolset will cover data  collection and processing,  fitting statistical models to the  data, and interpretation of  model output. | N/A |

***End-User Benefit*:** The integration of our end products organizational workflows will allow the USGS and NPS to more efficiently and effectively monitor algal bloom status. This collaboration will allow for quicker and cost-effective decision making about habitat management.

**Project Timeline & Previous Related Work**

***Project Timeline:*** 1 Term: 2019 Summer

***Related DEVELOP Work:***

Spring 2017 (ARC) – Lake Erie Water Resources: Utilizing Satellite Multispectral and Airborne Hyperspectral Imagery to Identify Annual and Seasonal Trends of Harmful Algal Blooms and Resulting Water Quality in Lake Erie’s Western Basin

Fall 2016 (CO) – Rocky Mountain National Park Climate: Monitoring Algal Productivity to Inform Spatiotemporal Alpine Lake Dynamics in Rocky Mountain National Park

Spring 2015 (ARC) – Lake Erie Water Resources: Utilizing NASA Satellite Data to Model Indicators of Harmful Algal Blooms in the Maumee River Watershed of Lake Erie

Summer 2014 (LaRC) – New England Water Resources: Historical Tracking of Harmful Algal Blooms Utilizing Landsat Missions from 1999-2013

Summer 2014 (GA) - Water Resources: Developing a Cyanobacteria Detection Tool for Georgia Inland Waters Using NASA Landsat 8 OLI Data for Water Quality Protection and Restoration

**References:**

Baron, J. S. (2006). Hindcasting nitrogen deposition To determine an ecological critical load. *Ecological Applications*, *16*(2), 433–439. https://doi.org/10.1890/1051-0761(2006)016[0433:HNDTDA]2.0.CO;2

Barrett, D. C., & Frazier, A. E. (2016). Automated method for monitoring water quality using Landsat imagery. *Water 2016, 8(6), 257;* https://doi.org/10.3390/w8060257

Beck, R.., Zhan, S., Liu, H., Tong, S., Yang, B., Xu, M., & Su, H. (2016). Comparison of satellite reflectance algorithms for estimating chlorophyll-a in a temperate reservoir using coincident hyperspectral aircraft imagery and dense coincident surface observations. *Remote Sensing of Environment*, *178*, 15–30. https://doi.org/10.1016/j.rse.2016.03.002

Berry, J. A., Frankenberg, C., & Wennberg, P. (2013). New Methods for Measurements of Photosynthesis from Space. *Unpublished* *Report by Keck Institute for Space Studies,* http://resolver.caltech.edu/CaltechAUTHORS:20190213-140402585

Breiman, L. (2001). Random Forests. *Machine Learning*, *45*(1), 5–32. https://doi.org/10.1023/A:1010933404324

Compton, J. E., Harrison, J. A., Dennis, R. L., Greaver, T. L., Hill, B. H., Jordan, S. J., … Campbell, H. V. (2011). Ecosystem services altered by human changes in the nitrogen cycle: A new perspective for US decision making. *Ecology Letters*, *14*(8), 804–815. https://doi.org/10.1111/j.1461-0248.2011.01631.x

Dörnhöfer, K., & Oppelt, N. (2016). Remote sensing for lake research and monitoring - Recent advances. *Ecological Indicators*, *64*, 105-122. <https://doi.org/10.1016/j.ecolind.2015.12.009>