**Lake Anna Water Resources**

*Using NASA Earth Observations to Identify Algal Event Risk Factors in Lake Anna and Help Inform Future Management Practices*

**Project Team**

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**Project Overview**

***Project Synopsis:***

NASA DEVELOP has partnered with the Virginia DEQ to assist in the detection and monitoring of harmful algal blooms along with cyanobacteria and risk factors associated with them. Our study area was focused on Lake Anna between the years 2016 and 2022. We used Earth observations to identify various water quality factors, such as chlorophyll-a, cyanobacteria, turbidity, nutrients, and surface temperature as they influence algal blooms. Using Earth observations alongside the DEQ *in situ* datasets allows us to detect algal bloom trends and enhance future management strategies.

***Abstract:***

Lake Anna is a man-made reservoir and popular recreation destination that spans over 13,000 acres—9,600 public and 3,400 private—in the Piedmont region of Virginia. Harmful algal blooms (HABs) pose a variety of community and ecological concerns to Lake Anna and are exacerbated by anthropogenic factors such as excess nutrient levels. NASA DEVELOP has partnered with the Virginia Department of Environmental Quality (DEQ) to help monitor cyanobacteria and nutrient pollution indicators across Lake Anna. The project utilized a combination of Earth observations (EO) and *in situ* ancillary data to identify and monitor algal bloom trends. Landsat 8 Operational Land Imager (OLI), Landsat 9 OLI-2, Sentinel-2 Multispectral Instrument (MSI), and Sentinel-3 Ocean and Land Color Instrument (OLCI) were used to analyze water quality variables such as chlorophyll-a, turbidity, surface temperature, and cyanobacteria. Our ability to validate satellite retrievals was limited by the availability of comprehensive *in situ* data and records of historic harmful algal bloom events. Additionally, deficient spatial resolutions along with geographically complicated coastal boundaries accentuated the spatial constraints faced in our analysis. Across the Earth observations we examined, our results indicate conditions conducive to the formation of HABs within the upper reaches of Lake Anna. Yet, spatially dependent limiting factors may also influence where these phenomena develop. When used in concert with existing *in situ* datasets, NASA Earth observations provide relevant stakeholders with more comprehensive analyses with which to engage in enhanced monitoring and watershed management.

***Key Terms:***

cyanobacteria, harmful algal blooms, phycocyanin, NDCI, NDTI, Sentinel, Landsat, Google Earth Engine

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

***Study Location:*** Lake Anna, VA

***Study Period:*** June 2016 – April 2023

***Community Concerns:***

* Certain species of cyanobacteria, and less frequently algae, in HABs produce toxins which can cause a range of health consequences for the human respiratory, gastrointestinal, and nervous systems.
* Cyanotoxins can also harm aquatic life, and beyond that, excessive algal growth disrupts aquatic ecosystems by blocking out sunlight and depleting life-sustaining oxygen as blooms die off.
* The ecological and public health impacts of persistent HAB events can also contribute to loss of recreation and subsistence opportunities, impaired landscape aesthetics, property devaluation of adjoining sites, and the contamination of drinking water supplies.

***Project Objectives:***

* Assess utility of EOs as a tool for monitoring cyanobacteria and HAB risk factors
* Analyze trends in cyanobacteria concentrations using chlorophyll-a, phycocyanin, & turbidity as proxies
* Explore trends in HABs risk factors, including nutrient runoff potential and lake surface temperature
* Explore where HABs are likely to occur throughout Lake Anna
* Create reproducible methodologies to enhance water resource management strategies for Lake Anna

**Partner Overview**

***Partner Organization(s):***

|  |  |  |
| --- | --- | --- |
| **Organization** | **Contact (Name, Position/Title)** | **Partner Type** |
| **Virginia Department of Environmental Quality** | Dr. Tish Robertson, Water Quality Assessment Scientist | End User |

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

The DEQ is responsible for establishing water quality standards and facilitating HAB monitoring statewide. They regularly work in conjunction with the Virginia Department of Health (VDH), which issues HAB advisories, as well as local citizen groups like the Lake Anna Civic Association (LACA), which engage in their own algae monitoring and mitigation efforts. Since 2018, DEQ has responded to reports of harmful cyanobacteria blooms in Lake Anna. While DEQ can create HAB “hot spot” maps using data from monitoring and Geographic Information Systems to inform management decisions in Lake Anna, it currently does not use NASA Earth Observation data due to lack of expertise and capacity. They have the capacity to use this data to help inform when and how the department mobilizes monitoring resources as well as help inform watershed management decisions.

**Earth Observations & End Products Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameter(s)** | **Use** |
| **Landsat 8 TIRS** | Surface Temperature | This sensor was used to map surface temperature across the body of the lake. |
| **Landsat 9 TIRS-2** | Surface Temperature | This sensor was used to map surface temperature across the body of the lake. |
| **Sentinel-2 MSI** | NDCI/NDTI | This sensor was used to detect chlorophyll-a concentrations and turbidity, as well as generate a floating algal index in turbid waters, throughout Lake Anna’s boundaries. |
| **Sentinel-3 OLCI** | Phycocyanin | This sensor was used to investigate cyanobacterial presence through the detection of associated phycocyanin pigmentation. |

***Ancillary Datasets:***

* Virginia DEQ - *in situ – P*rocessed in ArcGIS Pro to create Kriging maps and run PCA analysis.
* USDA Cropland Data Layer - Determine primary sources of agriculture feeding excess nutrients into the lake.
* National Watershed Boundary Dataset – Determine the boundary of our watershed study area.
* 2019 Virginia Census Counties & County Equivalents - Lakes/Reservoirs Water Quality Standards

***Software & Scripting:***

* Google Earth Engine – Download and process image collections
* ESRI ArcGIS Pro (3.0) - Process *in situ* data and create maps
* R – Run principal component analysis
* Acolite – Process floating algal index algorithm

***End Product(s):***

|  |  |  |
| --- | --- | --- |
| **End Product(s)** | **Earth Observations Used** | **Partner Benefit & Use** |
| **NDTI Maps** | Sentinel-2 MSI | Visualization of turbidity trends may be used as a proxy for algal blooms as chlorophyll blocks sunlight penetration |
| **NDCI Maps** | Sentinel-2 MSI | Visualization of chlorophyll concentration will allow partners to identify generalized algal growth trends, and potential underlying issues, across Lake Anna |
| **Surface Temperature Maps** | Landsat 8-9 TIRS/TIRS-2 | Will allow the partners to visualize trends in surface temperature across the lake body and over time, as well as serve as a point of comparison for other HABs-related parameters |
| **PCA** | N/A | Will aid partners in the determination of limiting factors across the Lake |
| **Time Series Analysis** | Sentinel-3 OLCI | Partners may examine and extrapolate historical and phenological records of HABs in the southern basin of Lake Anna |
| **Kriging Maps** | N/A | Partners will be able to compare distribution of various water quality parameters to other HABs indicators |
| **Cyanobacteria Concentration Maps** | Sentinel-3 OLCI | Will provide insights into cyanobacterial presence across the relatively unmonitored southern half of Lake Anna |
| **Nutrient Loading Map** | N/A | Will enable partners to visualize sub-watersheds of concern and their associated contributions to the Lake |

***Product Benefit to End User:***

This project utilized a variety of Earth observation systems along with *in situ* and ancillary datasets to provide multiple maps and analyses about the study area to the end users. Our partners can choose to incorporate these remote sensing datasets and Earth observations into their ongoing study of Lake Anna. This project can be useful for future efforts to identify nutrient loading sources, detect algal bloom hot spots, and coordinate future *in situ* sampling efforts and monitoring locations.

**References**

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