**Highland Lakes Water Resources**

*Using NASA Earth Observations to Improve Detection Systems for Harmful Algal Events in the Highland Lakes**in Central Texas*

**Project Team**

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**Project Overview**

***Project Synopsis:***

In the Highland Lakes chain near Austin, Texas, recent cyanobacteria harmful algal events (HAE), which include blooms and proliferations, have caused canine deaths and present risks to ecosystems, public health, water supply, and recreation opportunities. Current monitoring efforts by the City of Austin and the Lower Colorado River Authority (LCRA) rely on field-based water quality sampling faced with resource (cost and time) limitations. This project will partner with these organizations to improve algal event monitoring and mitigation by establishing an early warning system through the use of NASA Earth observations and *in situ* data.

***Abstract:***

Beginning in 2019, harmful algal events in Austin, Texas, caused canine deaths in the Lady Bird Lake and Lake Travis reservoirs. These reservoirs are part of the larger Highland Lakes chain, managed by the Lower Colorado River Authority (LCRA) and the City of Austin Department of Watershed Protection (CoA DWP), which fulfill municipal, commercial, and agricultural water demands. Given the recent increase in favorable algal event conditions in central Texas, the LCRA and CoA DWP partnered with NASA DEVELOP to improve algal event early-warning systems through the application of remote sensing and machine learning. An Earth observation-based algal monitoring system will assist the responsible agencies in predicting algal conditions and communicating hazards to the public. The NASA DEVELOP team utilized Landsat 8 Operational Land Imager (OLI) and Sentinel-2 Multispectral Instrument (MSI) data to produce products including chlorophyll-a concentrations, cyanobacteria detections, turbidity, and water surface temperature. Chlorophyll-a concentrations were retrieved with a pre-trained machine learning model (mixture density network) and spectral indices, while the other products were derived from spectral indices. In situ field data were used to validate and quantify uncertainties for each product. The validations show strong correlations for chlorophyll-a and water surface temperature. Time series analyses of chlorophyll-a concentrations show peaks in the severe drought years (2015 and 2016). This project's resulting products enable monitoring of environmental proxies relevant to algal event presence in the Highland Lakes chain and will ultimately support water management, decision making, and risk communication.

***Key Terms:***

machine learning, remote sensing, chlorophyll-a, cyanobacteria, turbidity, water surface temperature, Landsat 8 OLI, Sentinel-2 MSI

***National Application Areas Addressed:*** Water Resources, Ecological Forecasting

***Study Location:*** Highland Lakes, TX

***Study Period:*** January 2019 - July 2021

***Community Concerns:***

* The presence of cyanobacteria events and cyanotoxins can have negative impacts on the environment, public health, and the economy; the Highland Lakes serve municipal, commercial, and agricultural water supply needs and are local outdoor recreation hubs.
* Canine deaths in Lady Bird Lake (2019 and 2020) and Lake Travis (2021) have been traced back to the presence of cyanobacteria-produced neurotoxins, including anatoxin-a and dihydroanatoxin-a.
* Increased frequency of extreme heat and drought conditions in Central Texas, generally favorable to algal events, suggest that such events will intensify in coming years.

***Project Objectives:***

* Analyze historic algal event imagery to determine where high concentrations of toxic algae are likely present and help local users and management agencies select locations for future field sampling efforts
* Combine Earth observations and *in situ* data to provide a tool for monitoring harmful algal events in the Highland Lakes through monitoring of various environmental proxies
* Create a user-friendly graphical user interface that enables simple functionality for monitoring of satellite-derived algal event drivers

**Partner Overview**

***Partner Organizations:***

|  |  |  |  |
| --- | --- | --- | --- |
| **Organization** | **POC (Name, Position/Title)** | **Partner Type** | **Boundary Org?** |
| **City of Austin, Department of Watershed Protection** | Dr. Brent Bellinger, Aquatic Ecologist | End User | Yes |
| **Lower Colorado River Authority** | Lisa Benton, Senior Aquatic Biologist | End User | Yes |
| **The University of Texas at Austin, Department of Molecular Sciences** | Dr. Schonna Manning, Research Assistant Professor  Molecular Biosciences | Collaborator | No |
| **Austin Water Utility** | Teresa Lutes, P.E., Managing Engineer | Collaborator | No |

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

The LCRA and the City of Austin have been collecting *in situ* water samples and routinely monitoring surface water temperature and hydraulic flow in the Highland Lakes for decades. Since the surge of cyanotoxin presence in 2019, they have implemented a more robust formal algae monitoring program, which includes more frequent sampling, measurement of specific pigments, metagenomic community analysis, and evaluation of toxins. These data have been used to monitor for favorable conditions for harmful algal events, but limitations such as cost and lab delays result in insufficient monitoring coverage from field sampling alone. Water quality in the Highland Lakes is regulated by the LCRA, which manages land use and development and prohibits effluent discharge.

**Earth Observations & End Products Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameters** | **Use** |
| **Landsat 8 Operational Land Imager (OLI)** | Chlorophyll-a; cyanobacteria detection; turbidity; water surface temperature; surface reflectance | Contributed to chlorophyll-a concentration retrievals (mixture density network machine learning and FLHV index), cyanobacteria detection (Broad Wavelength Algae Index), turbidity quantification (Normalized Difference Turbidity Index), and water surface temperature. |
| **Sentinel-2 Multispectral Imager (MSI)** | Chlorophyll-a; cyanobacteria detection; turbidity; surface seflectance | Contributed to chlorophyll-a concentration retrievals (mixture density network machine learning and FLHV index), cyanobacteria detection (Broad Wavelength Algae Index), and turbidity quantification (Normalized Difference Turbidity Index). |

***Ancillary Datasets:***

* LCRA Water Quality Data – *In situ* physical and chemical parameters for monitoring algal growth and validating models
* CoA DWP Water Quality Data – *In situ* physical and chemical parameters for monitoring algal growth and validating models

***Modeling:***

* Mixture Density Network (MDN) machine learning (POC: Dr. Nima Pahlevan, NASA Goddard Space Flight Center, SSAI) – Provided chlorophyll-a concentrations using deep learning techniques

***Software & Scripting:***

* Python 3.7.0 notebook interface via Google Colaboratory and Jupyter Notebook – Used for organizing and running scripts
* Google Earth Engine Python API – Used for retrieving, processing, and displaying Earth observation imagery and charts
* Heroku app – Used for deploying Python notebook as accessible website tool, keeping code hidden

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Product** | **Earth Observations Used** | **Partner Benefit & Use** | **Software Release Category** |
| **Lake Algae Monitoring Dashboard (LAMDA)** | Landsat 8 OLI, Sentinel-2 MSI | This interactive tool will offer end users the ability to monitor recent changes in the lakes that can contribute to algal events. | III |
| **Historical Algal Event Products** | Landsat 8 OLI, Sentinel-2 MSI. | These products will provide insight to environmental trends related to algal events. Time series charts of chlorophyll-a, turbidity, and temperature will be provided alongside maps summarizing spatial averages. This will be useful for planning field sampling campaigns. | N/A |

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

The availability and processing ease of continually-updating remote sensing datasets allow end users to move beyond traditional field-based methods for water quality monitoring, which has previously been focused on data collection typically at a limited number of sites and at bi-monthly intervals. Supplementing *in situ* monitoring with remote sensing observations will provide more frequent and comprehensive information important for monitoring conditions related to algal events. Users will be equipped to monitor near real-time changes of environmental proxies through satellite imagery and charts. The use of machine learning has provided confident chlorophyll-a concentrations, which will help the end users better understand which sites are chlorophyll-a hotspots. Furthermore, observing turbidity and temperature patterns and/or trends through spectral indices will help the end users understand the hydraulic system as well as observe any environmental connections. Overall, these Earth observation-based products will expand the end users’ observational toolkit for decision making around lake management and protection.

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