Employing Remote Sensing Techniques to Understand Seasonal Changes in Water Quality in the Muskingum Watershed Conservancy District

Committee Members:

Joseph Ortiz, Ph.D. – Major Advisor, Environmental Remote Sensing

Timothy Gallagher, Ph.D. – Minor Advisor, Geochemical Processes

David Singer, Ph.D. – Reader, General Earth Sciences

Spencer Williams

Impetus

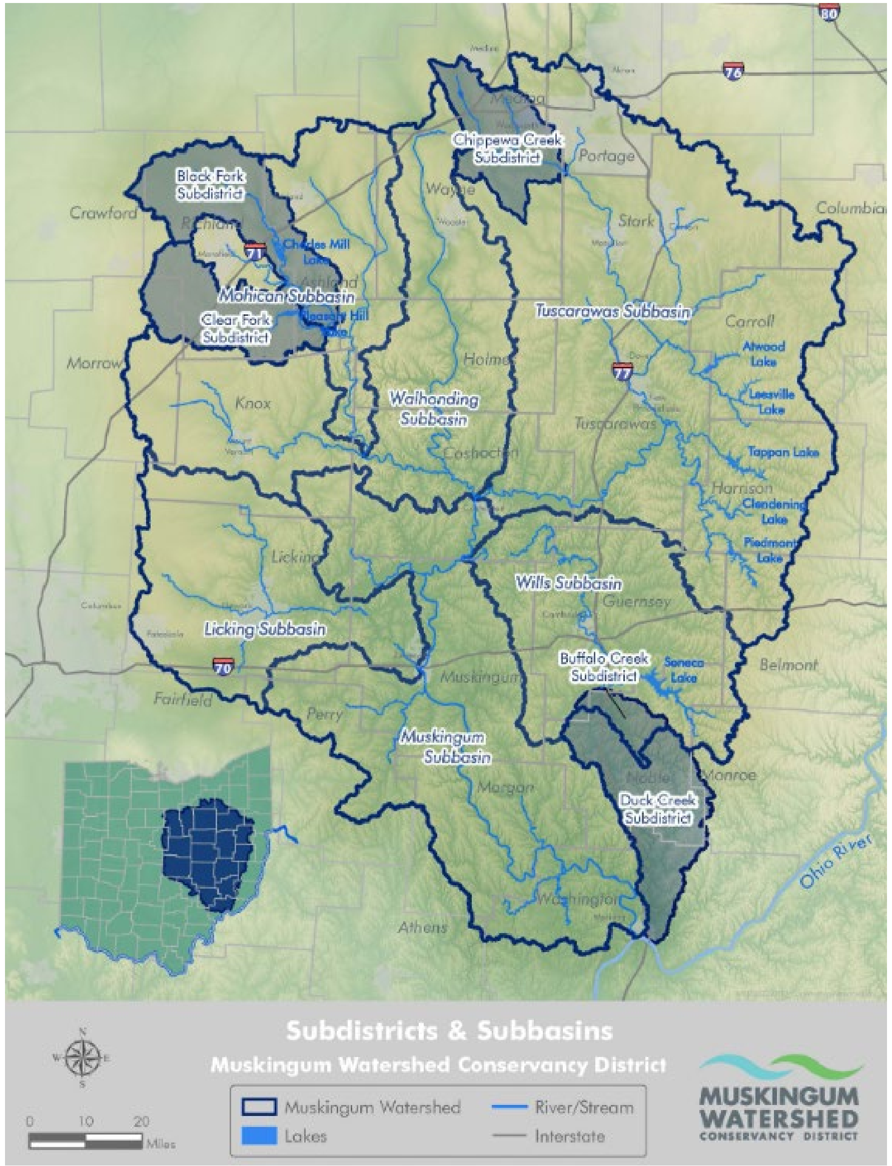
- Anthropogenic activities such as industrial, agricultural and poorly regulated mining practices can negatively impact water quality.

- Multiple studies confirm the degeneration of water quality due to agricultural and industrial practices in the Midwest.

- I will evaluate past and present utilization of land surrounding the Ohio Muskingum Watershed Lakes to characterize land use impacts on water quality.

Muskingum Watershed Conservancy District

- Established in 1933
- 20% of Ohio
- Largest wholly encompassed watershed
- 16 damns & 10 permanent reservoirs



(MWCD, 2023)

Objectives

- Assess land use/land cover surrounding the MWCD lakes to quantify impact on water quality.
- Identify effects of land use/land cover on nitrogen and phosphorus, sediment load and algae composition.
- Use satellite imagery to monitor MWCD lakes using multispectral instrumentation.
- Differentiate suspended solids from cyanobacterial pigments and pigment degradation products.
- Employ land use/cover maps with field-sampled water quality validation measurements

Outline

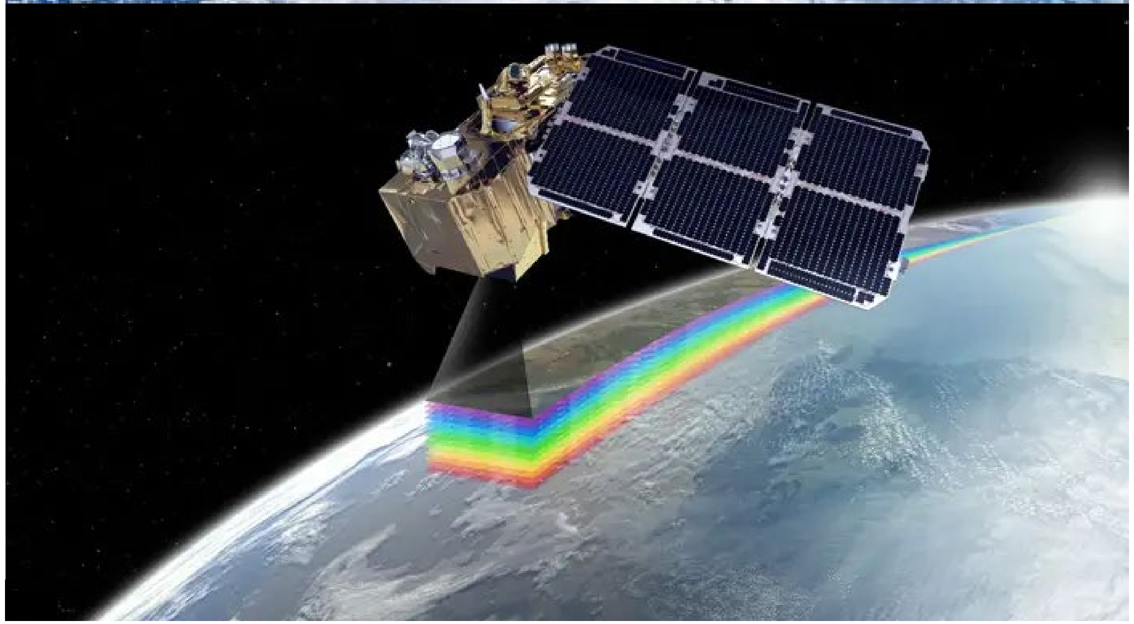
- Methodology
- Analysis
- Preliminary Results
- Discussion of Results
- Conclusions

Methods

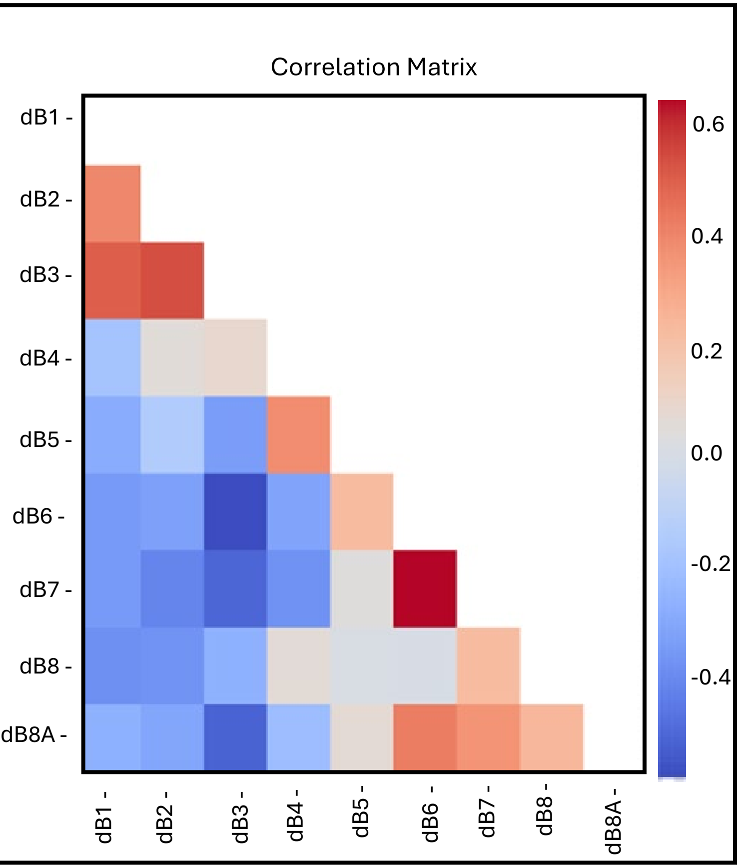
- Collected Water Samples
- Sonde data (temperature, turbidity, pH,
- Hyperspectral field measurements
- Event 38 E-400 drone equipped with a MicaSense RedEdge-P multispectral camera system
- Sentinel - 2 A/B (MSI) Image Analysis
- KSU Varimax Rotated Principal Component Analysis
- Statistical analysis

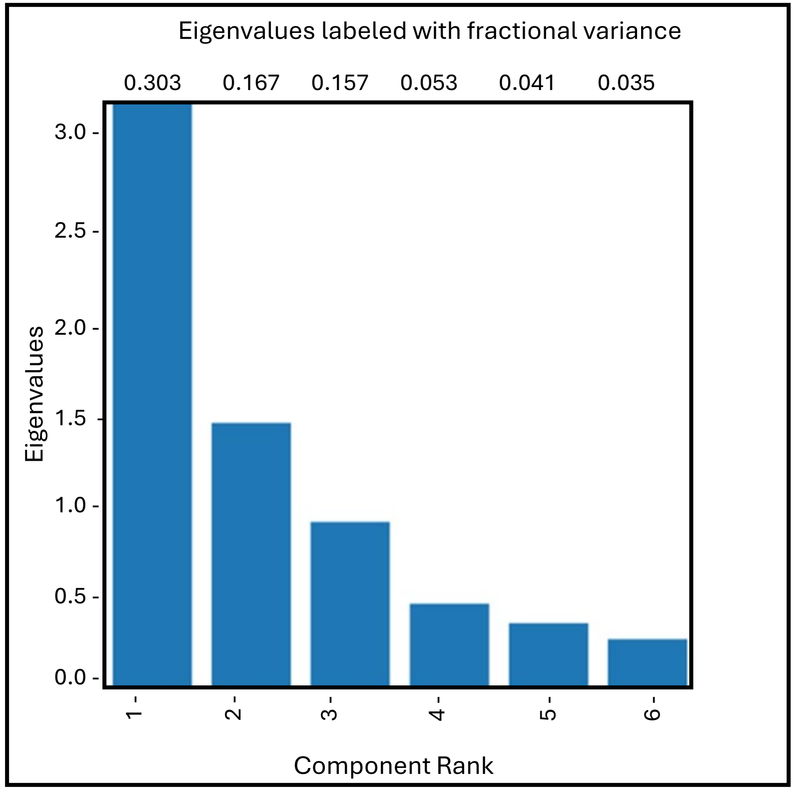
Sentinel – 2 A/B Multi-Spectral Instrument

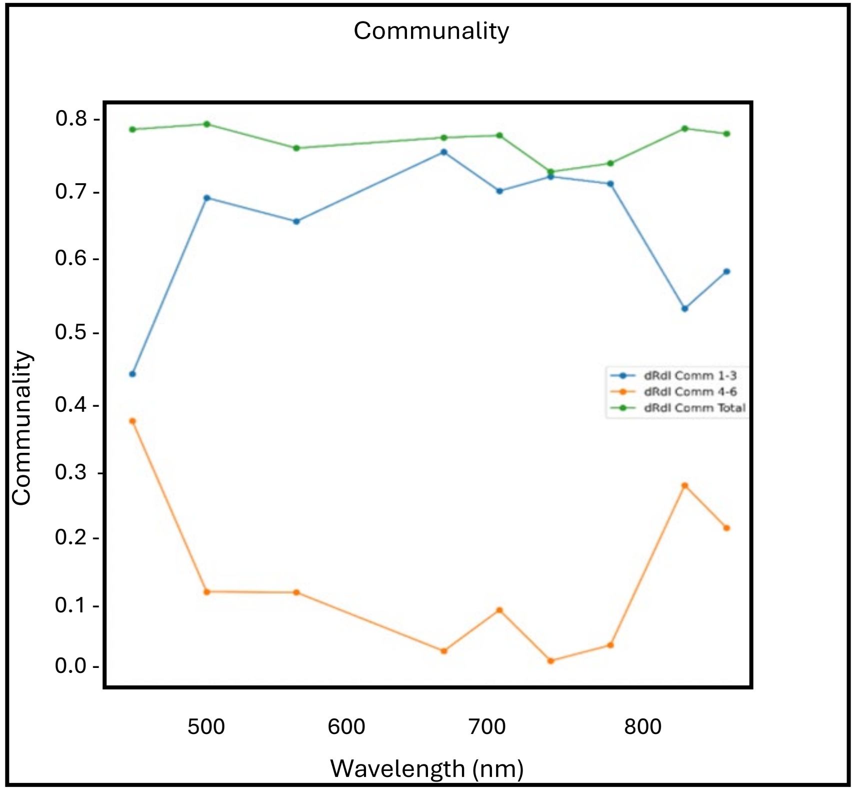
- 290km orbital swath/High resolution
- Monitors vegetation, soil and water cover
- The payload consists of visible, near infrared & shortwave infrared sensors
- 13 spectral bands in all
- 4 bands in 10m spatial resolution
- 5 Day temporal resolution



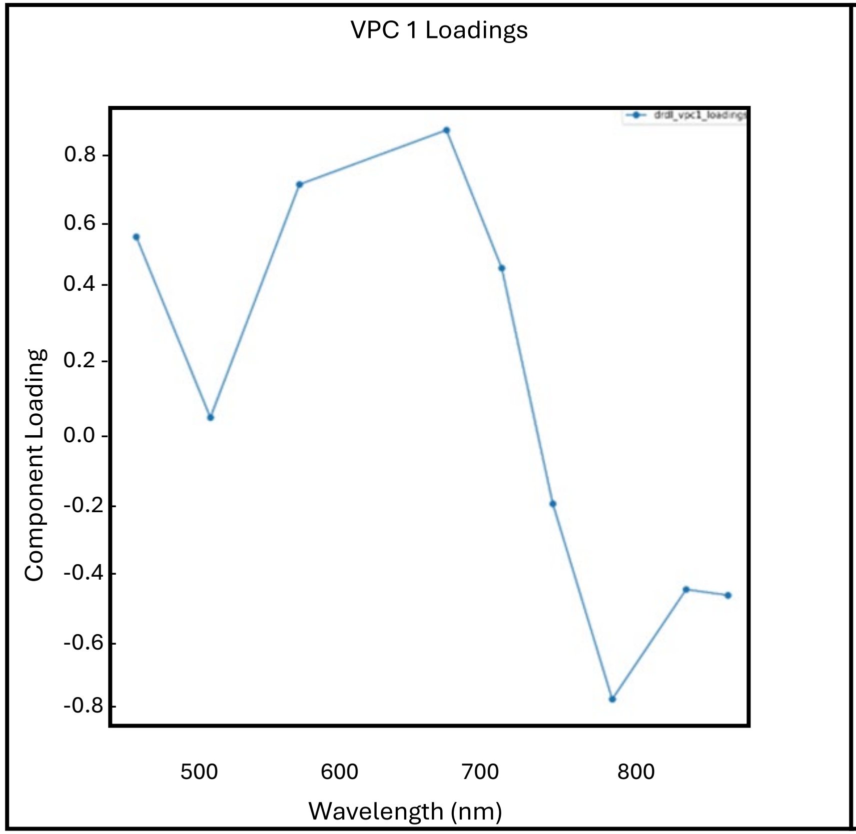
KSU Varimax Rotated Principal Component Analysis





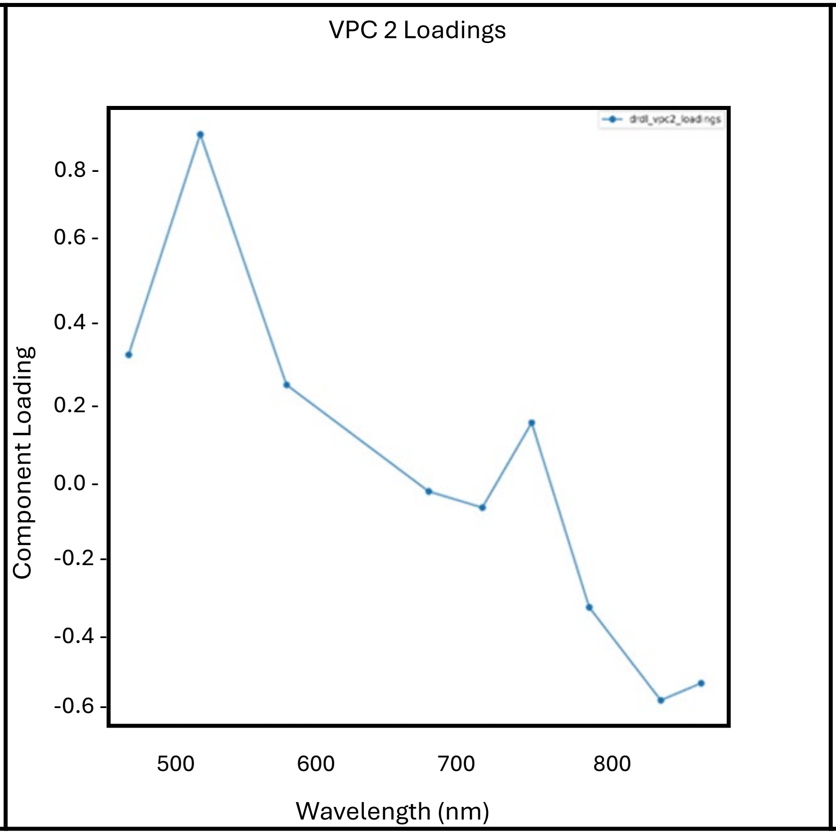


We Examine the Red Edge Response (670nm-720nm) Positioned between the Visible and Near Infrared Bands



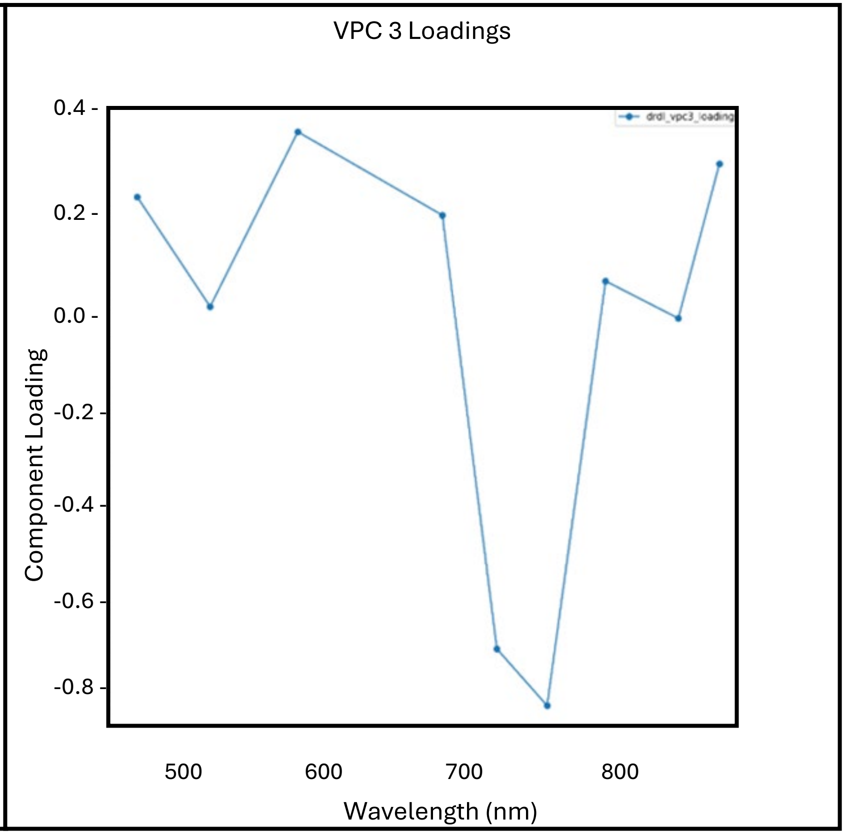
Phycocyanin

(cyanobacteria pigment)



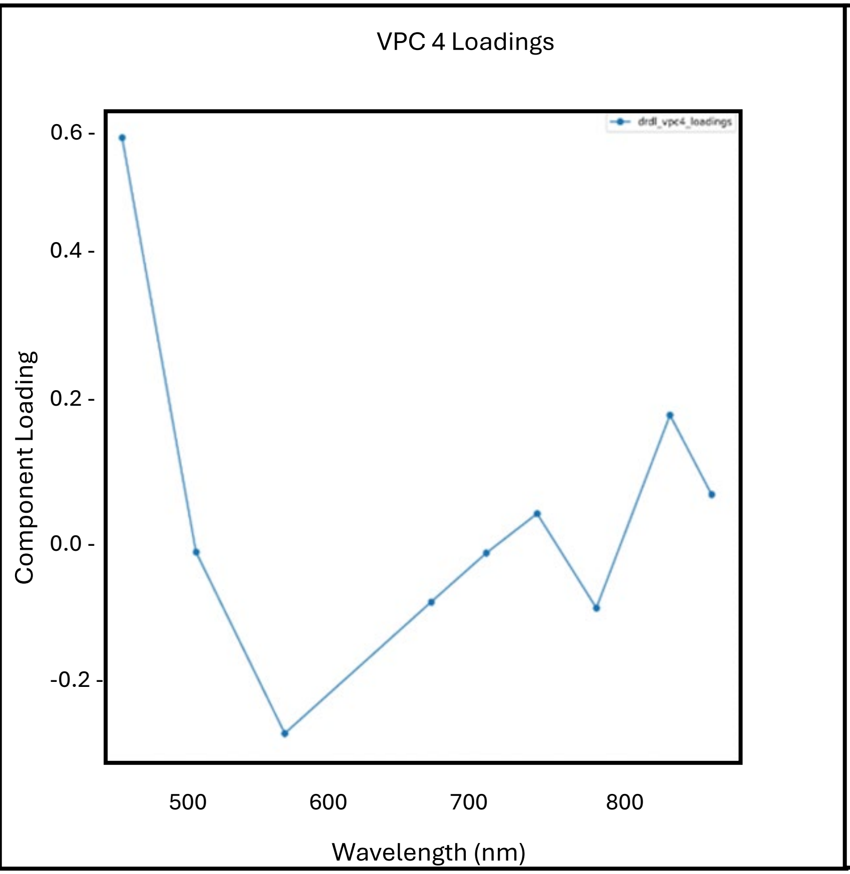
Nostoxanthin Carotenoid

(cyanobacteria pigment)



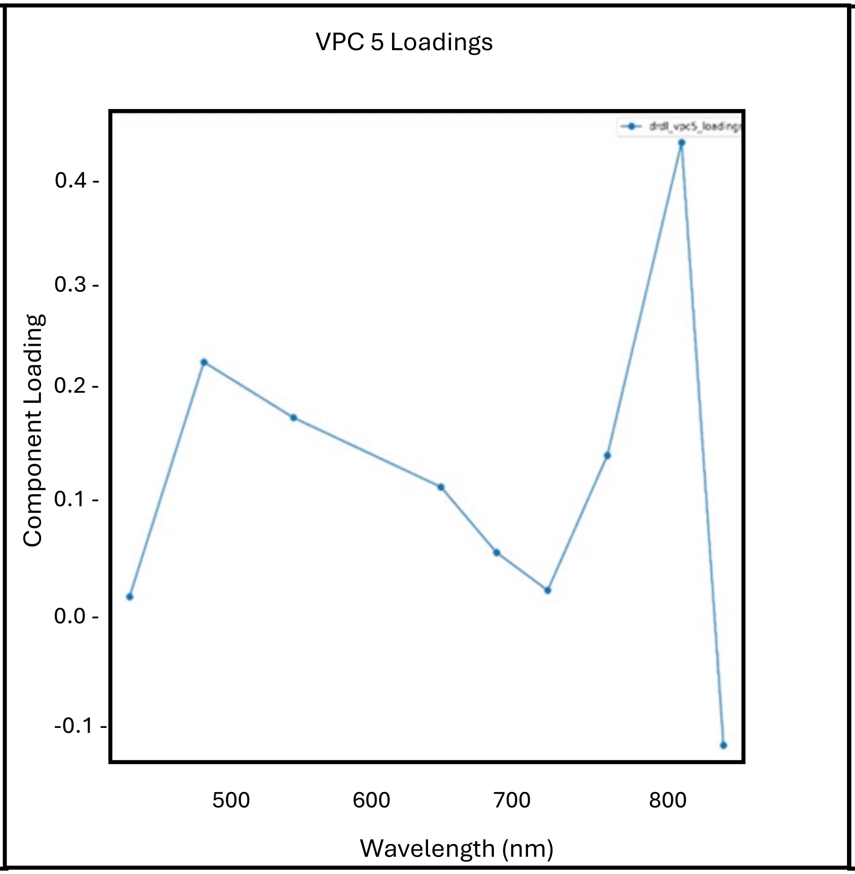
Chlorophyllide

(degradation product of chlorophyll)



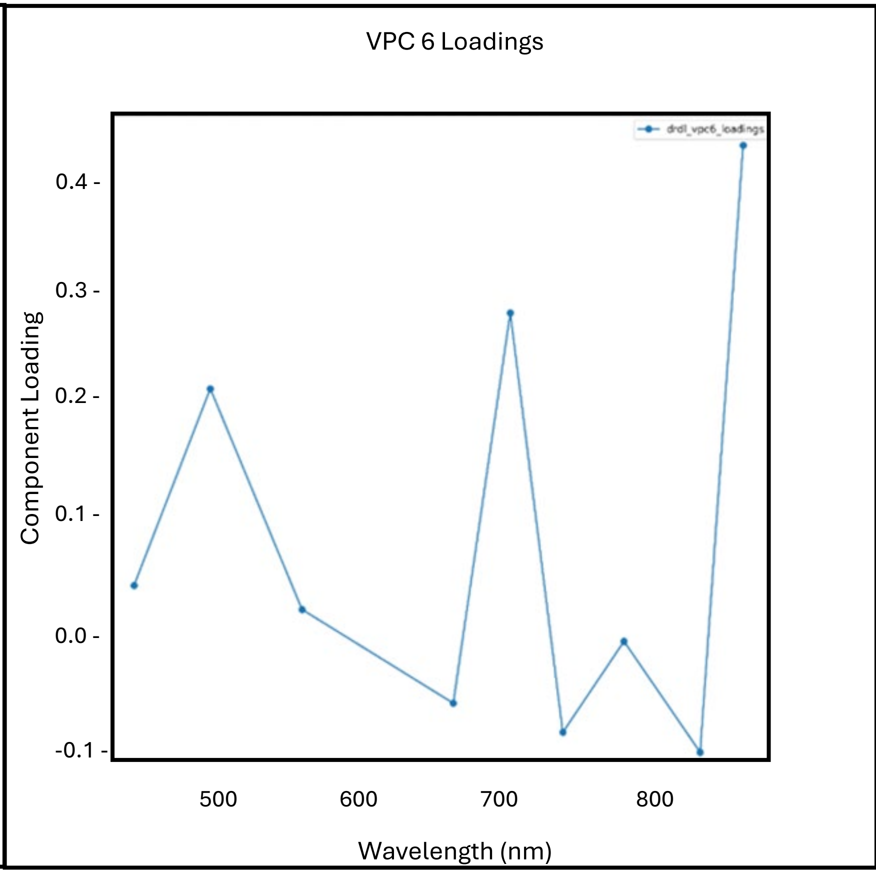
Fucoxanthin

(diatom accessory pigment)



Cyanophyta Carotenoid

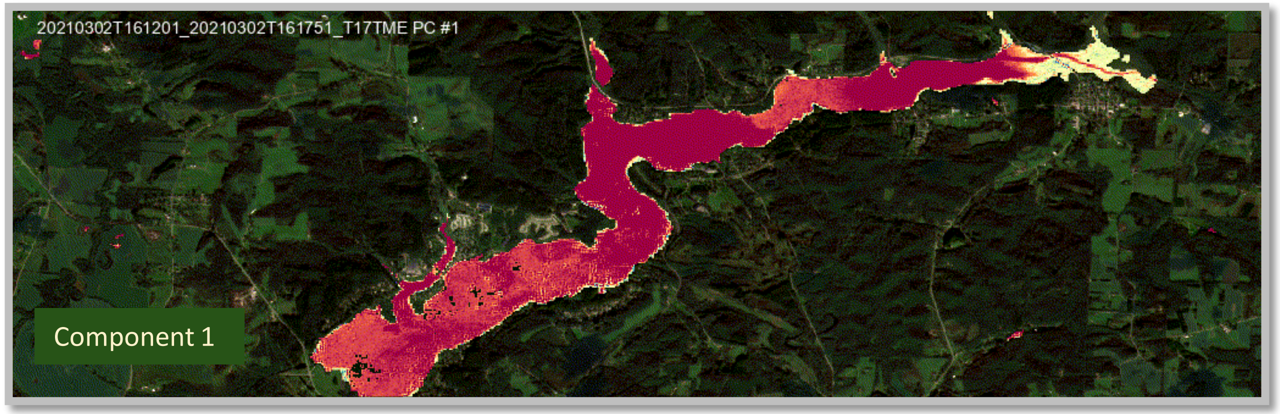
(cyanobacteria)

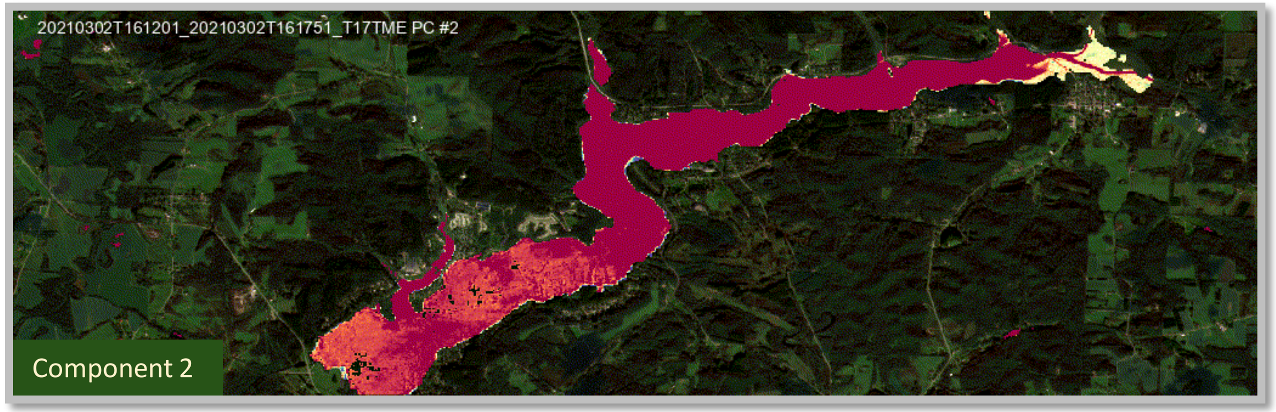


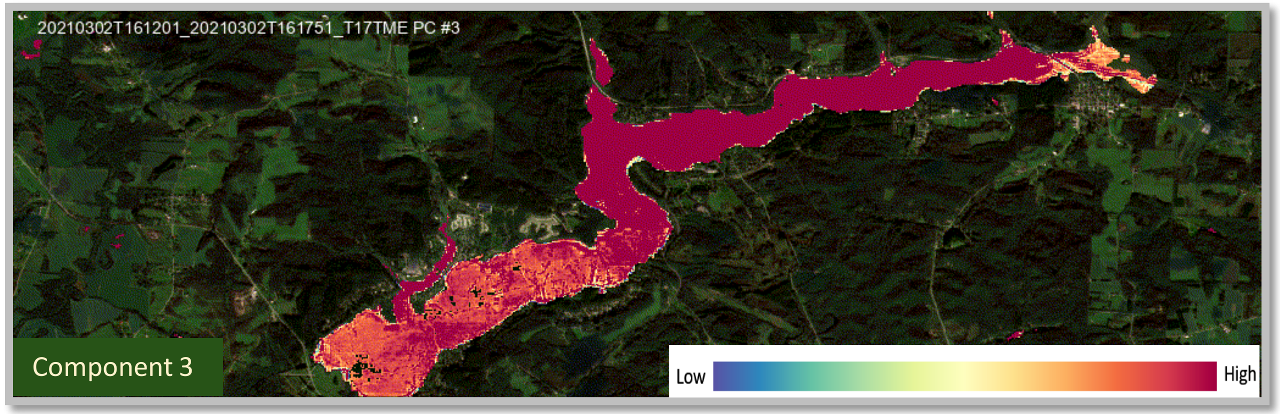
Iron Oxide Feature?

Atwood Lake Animated gifs representing Sentinel-2 A/B Satellite Imagery

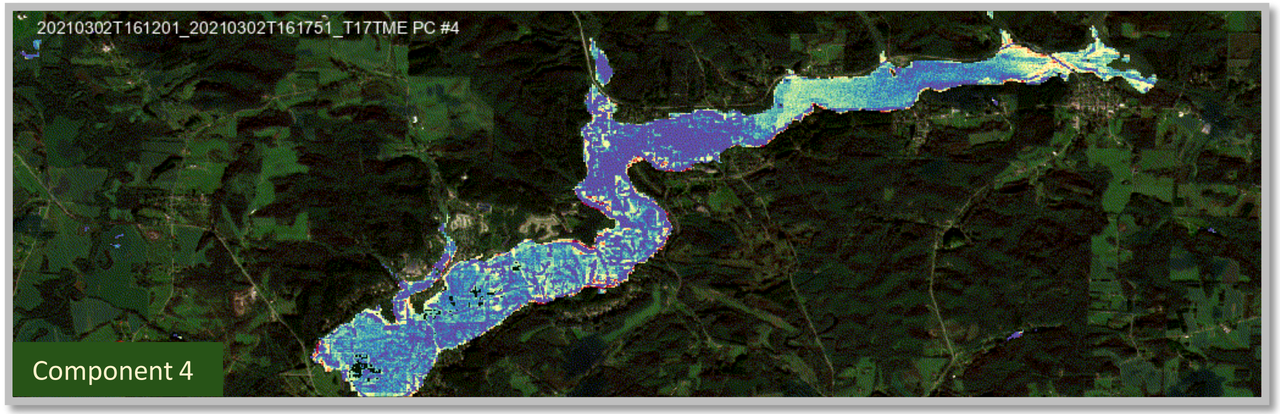
- 6 components in all
- 22 images over a 2 year period
- All images taken under 20% cloud coverage

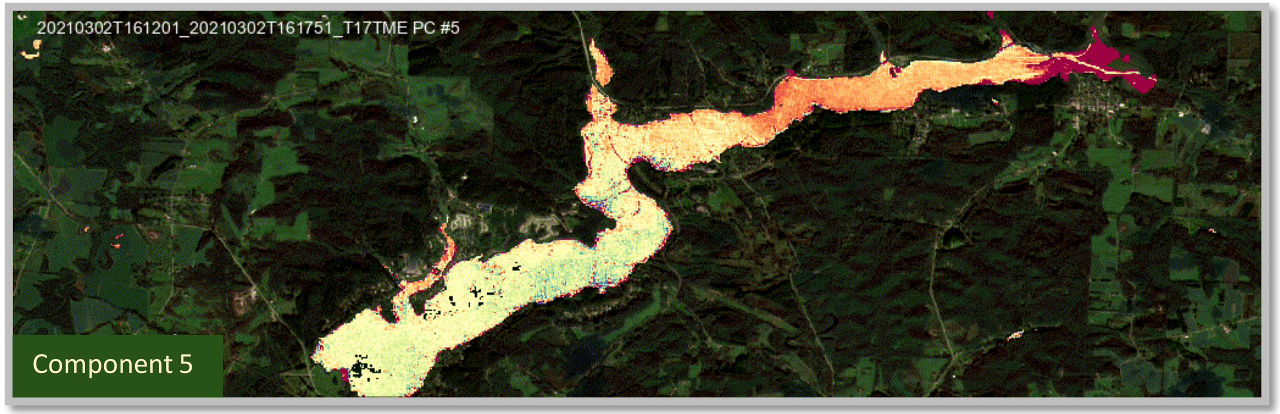


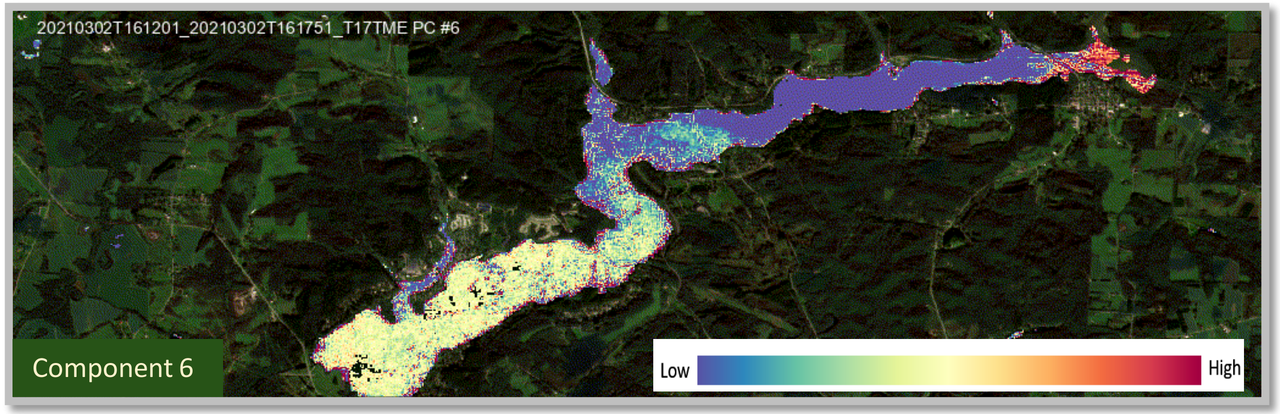




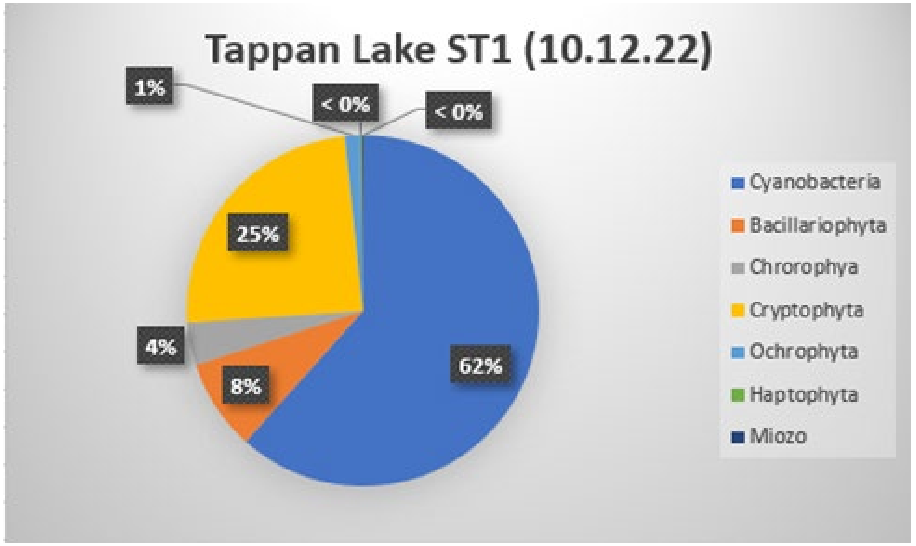
Atwood Lake Animated gifs representing Sentinel-2 A/B MSI Satellite Imagery

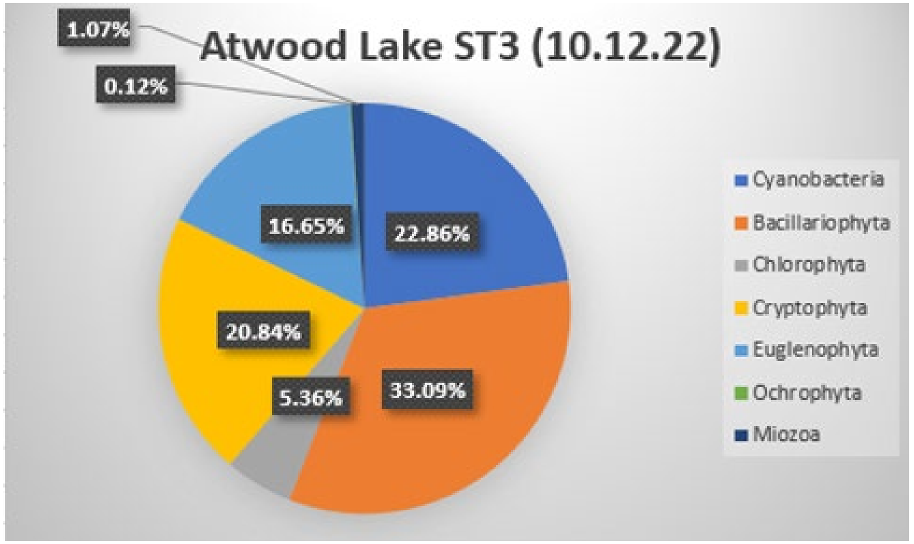


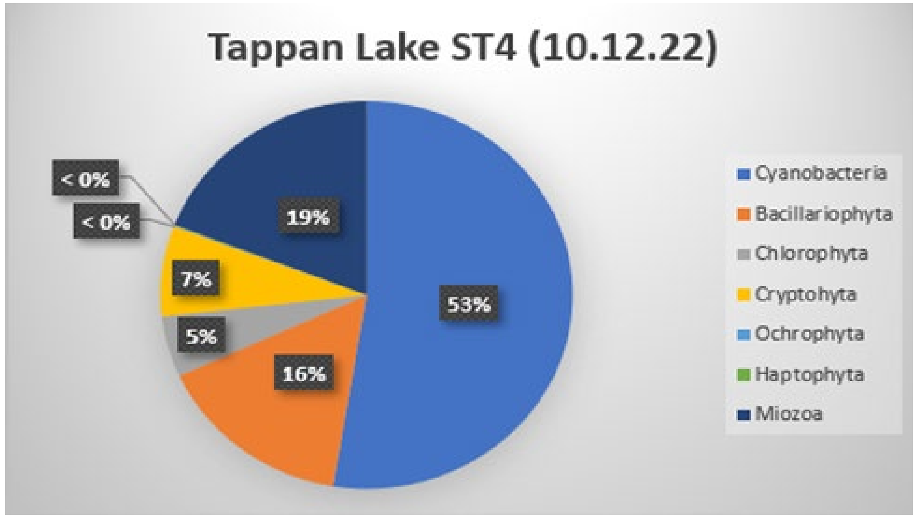


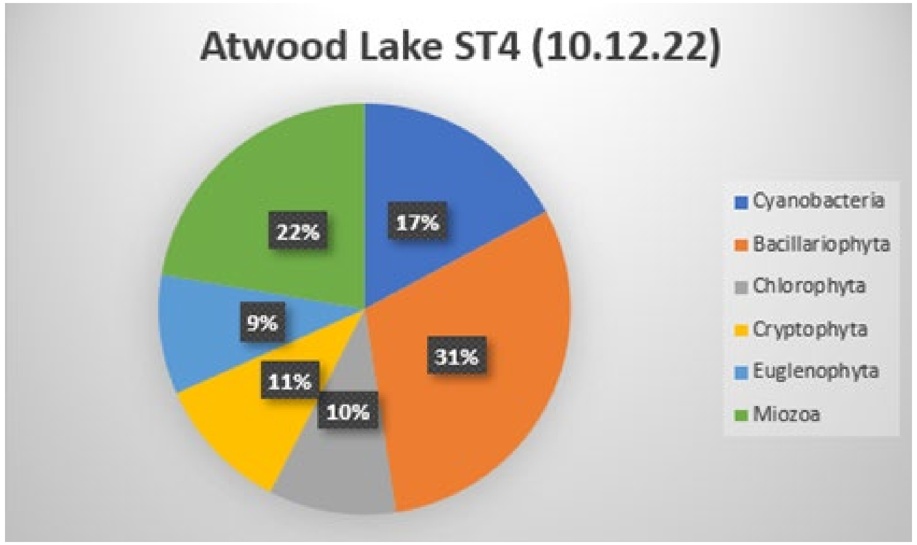


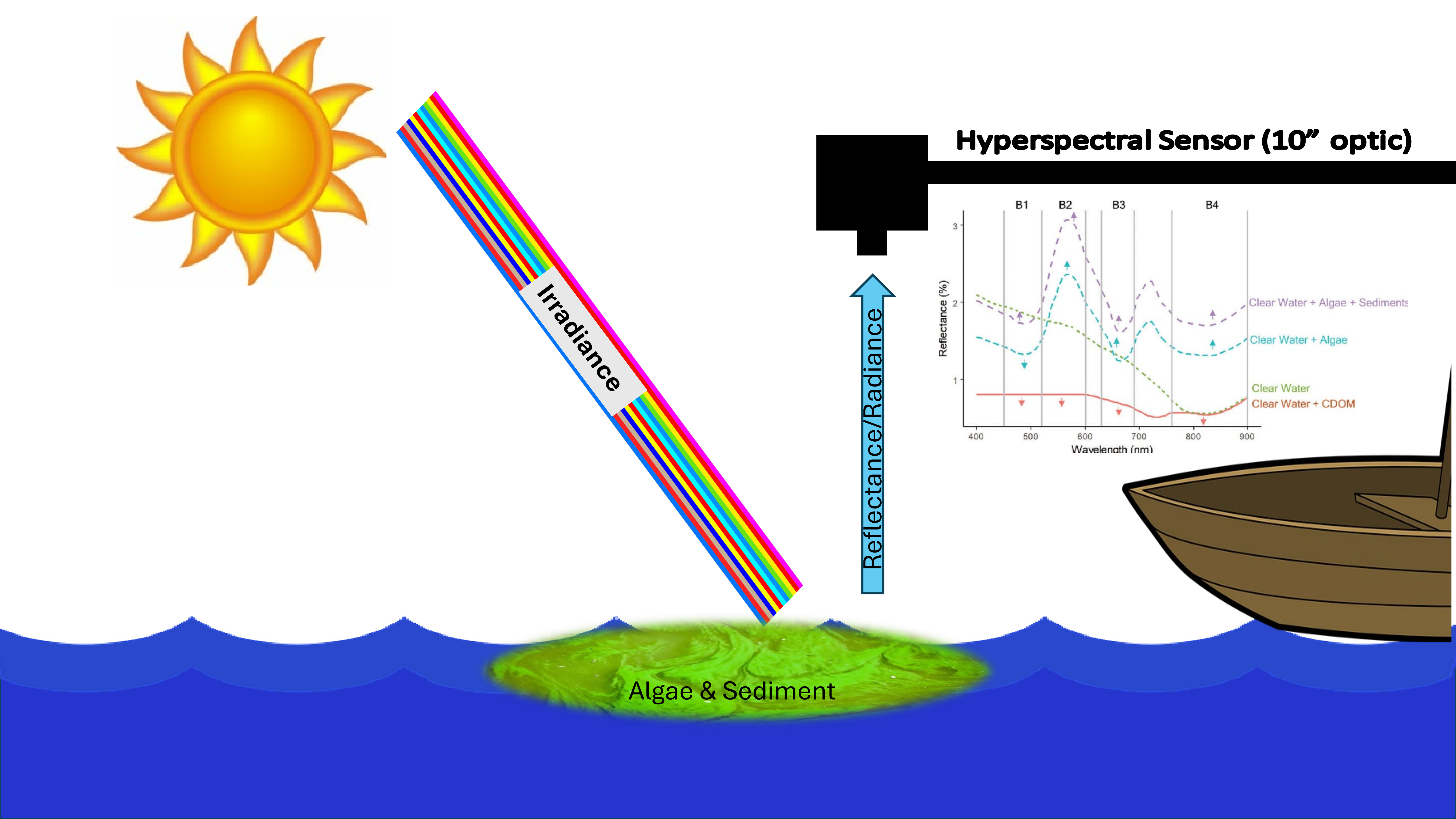
Algal Distribution calculated from Cell Count (biovolume) Concentrations



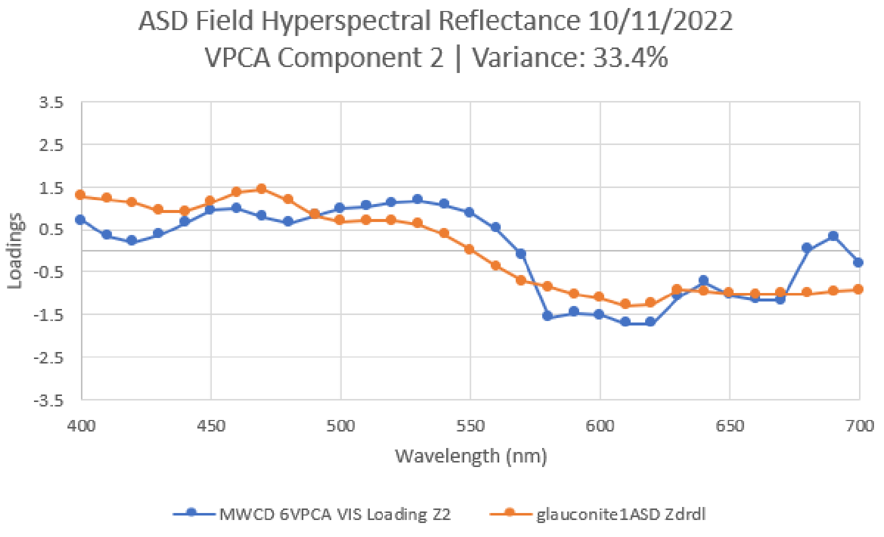


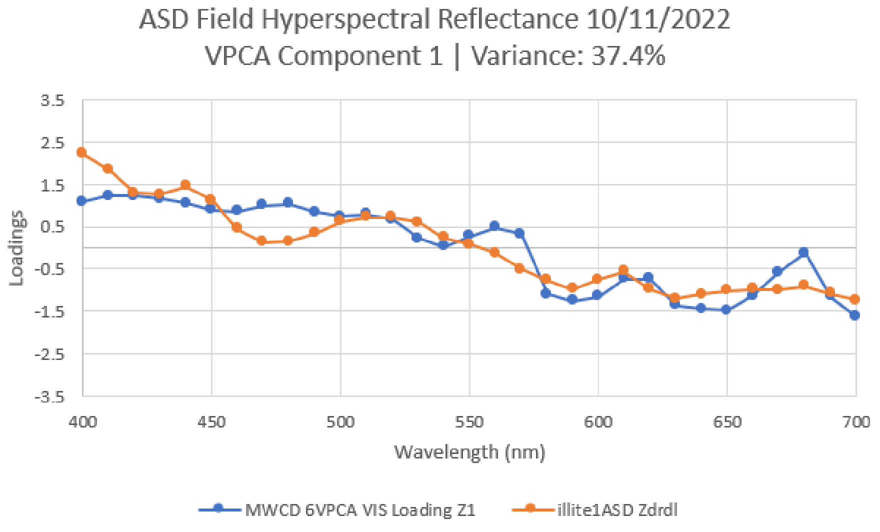


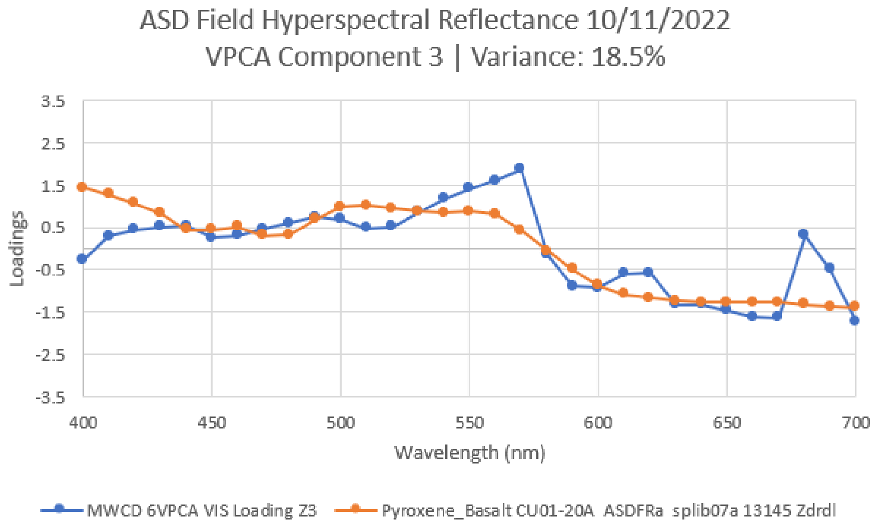


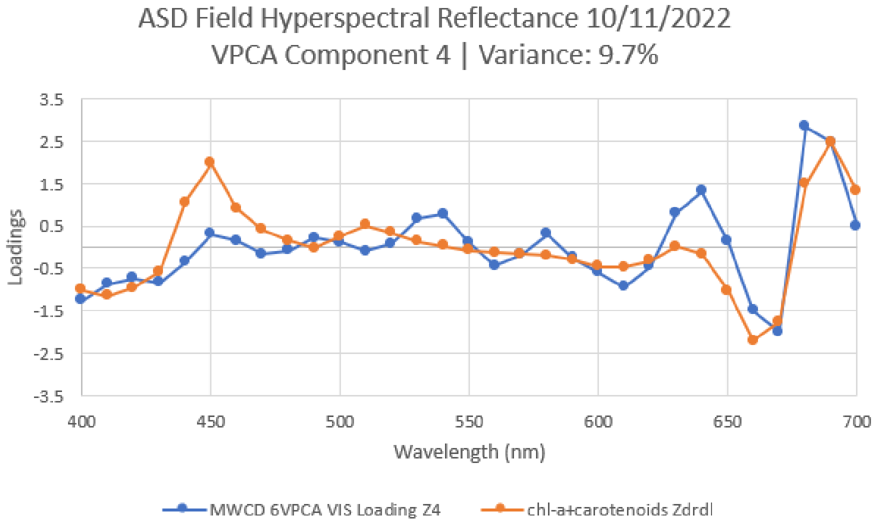


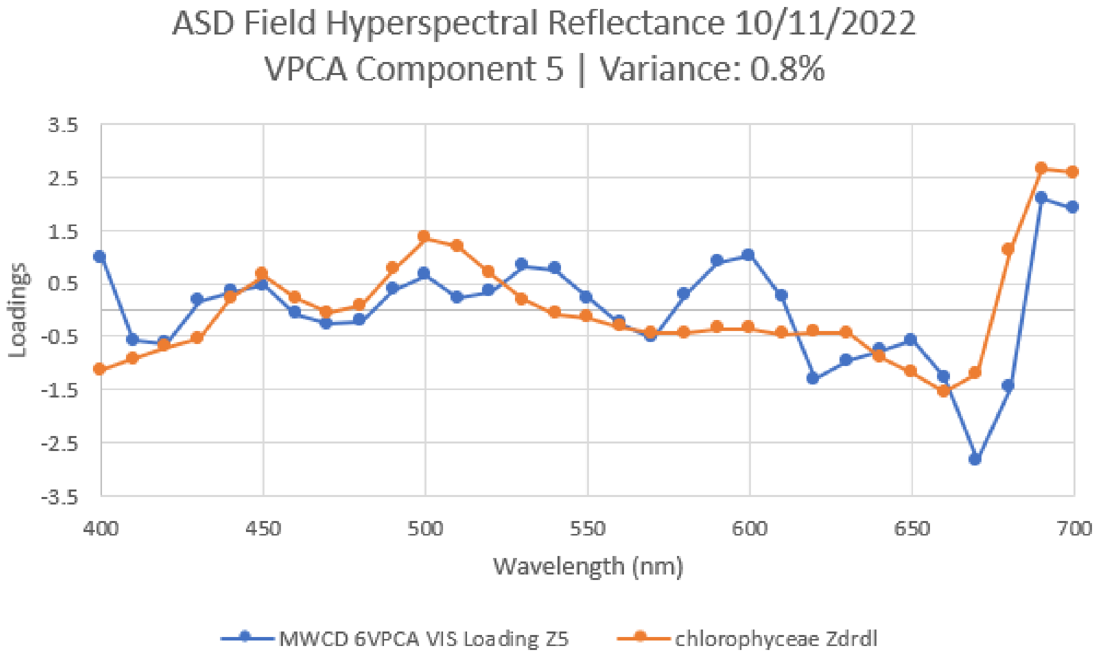
Hyperspectral Sensor (10" optic)
Irradiance
Reflectance/Radiance
B1
B2
B3
B4
Reflectance (%)
Wavelength (nm)
Clear Water + Algae + Sediments
Clear Water + Algae
Clear Water
Clear Water + CDOM
Algae & Sediment

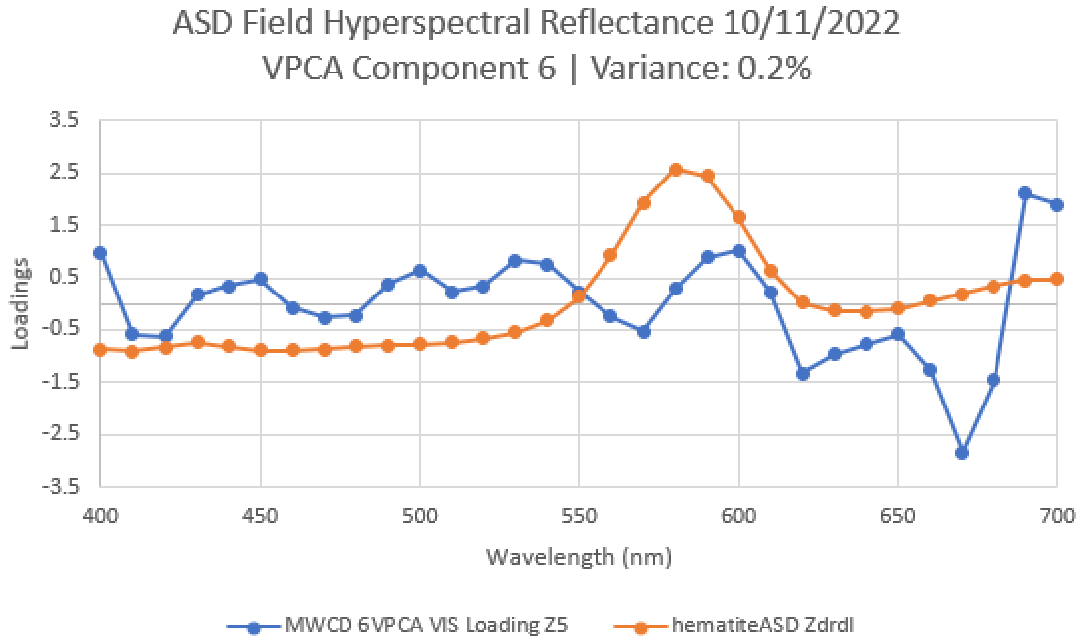

ASD Field Hyperspectral Reflectance 10/11/2022
VPCA Component 2 | Variance: 33.4%
Loadings
Wavelength (nm)
MWCD 6VPCA VIS Loading Z2
glauconite1ASD Zdrdl


ASD Field Hyperspectral Reflectance 10/11/2022
VPCA Component 1 | Variance: 37.4%
Loadings
Wavelength (nm)
MWCD 6VPCA VIS Loading Z1
illite1ASD Zdrdl

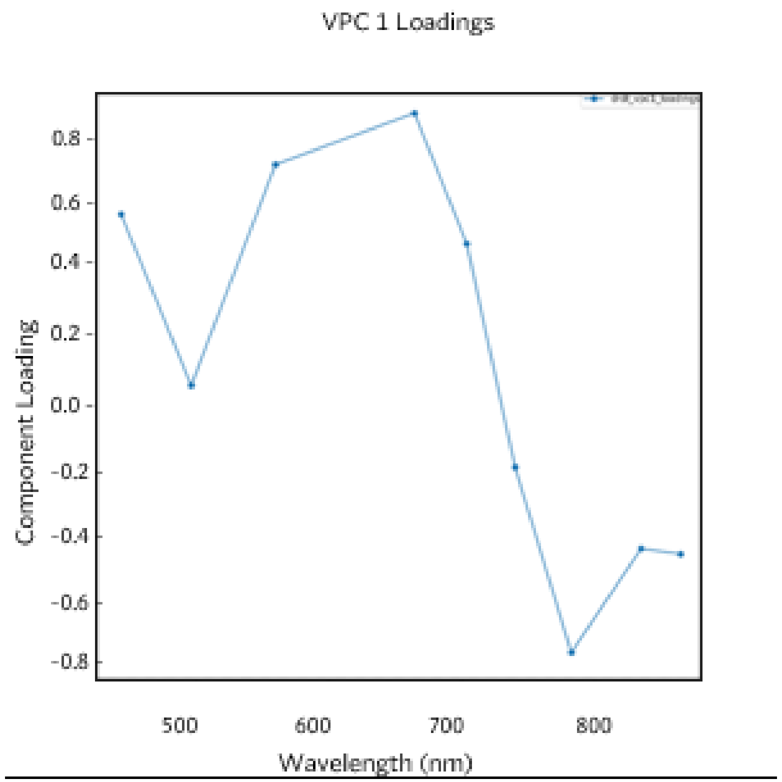

ASD Field Hyperspectral Reflectance 10/11/2022
VPCA Component 3 | Variance: 18.5%
Loadings
Wavelength (nm)
MWCD 6VPCA VIS Loading Z3
Pyroxene_Basalt CU01-20A ASDFRa splib07a 13145 Zdrdl


ASD Field Hyperspectral Reflectance 10/11/2022
VPCA Component 4 | Variance: 9.7%
Loadings
Wavelength (nm)
MWCD 6VPCA VIS Loading Z4
chl-a+carotenoids Zdrdl


ASD Field Hyperspectral Reflectance 10/11/2022
VPCA Component 5 | Variance: 0.8%
Loadings
Wavelength (nm)
MWCD 6VPCA VIS Loading Z5
chlorophyceae Zdrdl


ASD Field Hyperspectral Reflectance 10/11/2022
VPCA Component 6 | Variance: 0.2%
Loadings
Wavelength (nm)
MWCD 6VPCA VIS Loading Z5
hematiteASD Zdrdl

Satellite Imagery vs. ASD Field Data



Sentinel-2 Satellite Component 1
Phycocyanin (cyanobacteria)

ASD Field data Component 1

		Unstandardized B	Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.	Correlations Partial	Statistics VIF
Model 1	(Constant)	2.155E-18	.069		.00	1.00		
	Illite	.925	.071	.925	13.108	<.001	.925	1.000
Model 2	(Constant)	-2.058E-16	.060		.00	1.00		
	Illite	1.024	.068	1.024	15.079	<.001	.944	1.243
	Dolomite	-.244	.068	-.244	-3.302	.003	-.529	1.243
Model 3	(Constant)	-1.011E-16	.055		.000	1.000		
	Illite	.924	.074	.924	12.550	<.001	.924	1.745
	Dolomite	-.195	.063	-.195	-3.079	.005	-.510	1.286
	Kaolinite	.169	.066	.169	2.546	.017	.440	1.415

Preliminary Summary

- Spectral data indicates that the Tappan and Atwood reservoirs are dominated by photosynthetic phytoplankton community and suspended sediment.
- Cell count data reveals that Tappan Lake is dominated with cyanobacteria and Atwood Lake has a more even distribution of algae present with diatoms taking slight precedence.
- Cyanobacterial pigments and pigment degradation products found in the lakes during our Fall sampling period could be the result of prior Summer bloom activity because cyanobacteria are often found in warmer waters.
- Many primary pigments have a characteristic red edge response of intensive reflectance peaks between 670nm and 720nm.
- Weather events and spatial and temporal differences in sensors may cause inconsistencies between data retrieved from satellite imagery and ASD measurements collected in the field.
- The presence of iron oxide minerals are likely linked to extensive coal mining operations in the MWCD.

Acknowledgments

- KSU Department of Earth Sciences
- Herbert W. Hoover Foundation Grant
- Muskingum Watershed Conservatory
- U.S. Army Corps of Engineers