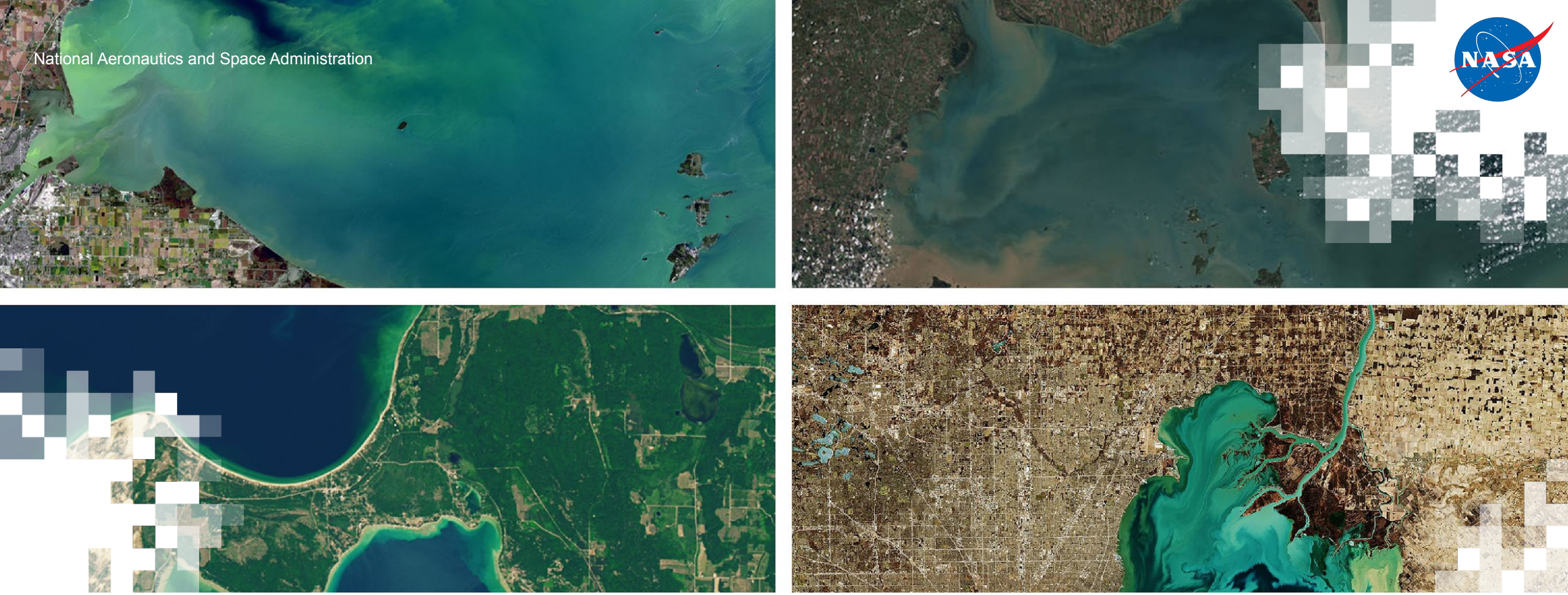
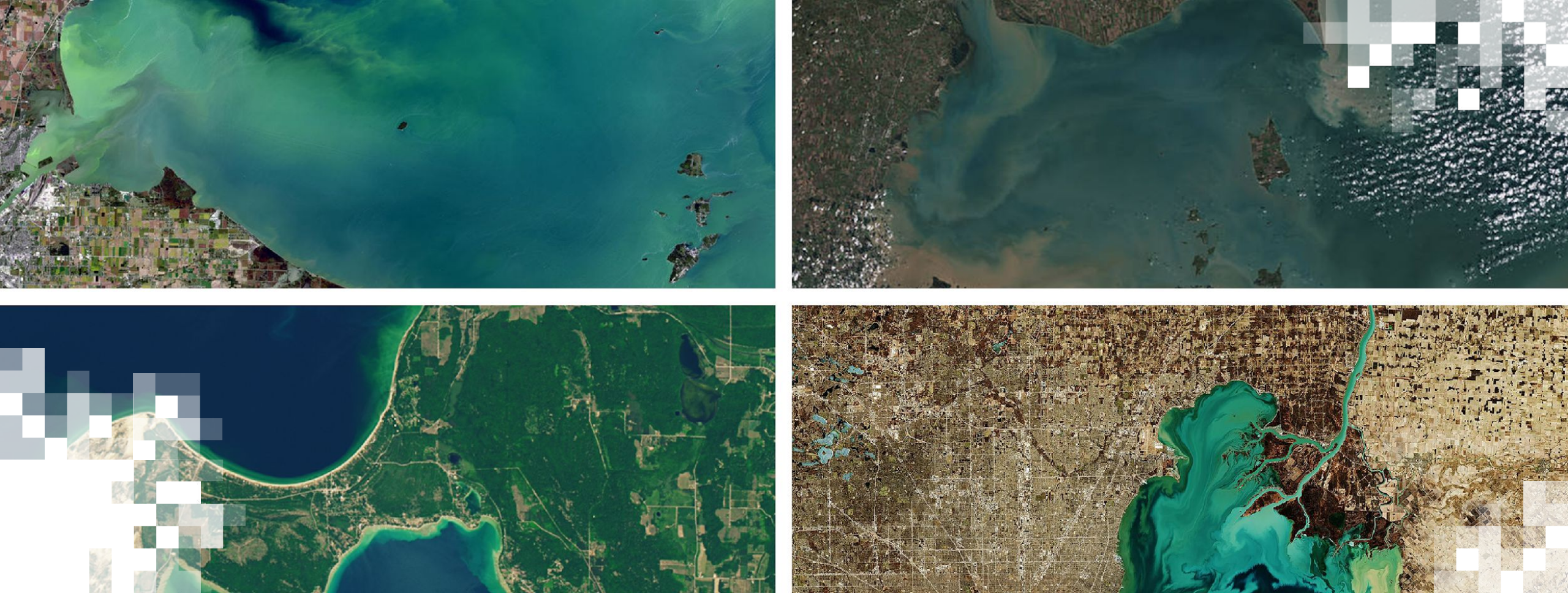


Monitoring Water Quality of Inland Lakes using Remote Sensing

Part 1: Overview of Remote Sensing Observations to Assess Water Quality

Amita Mehta and Sean McCartney

July 18, 2023



About ARSET

About ARSET

- **ARSET provides accessible, relevant, and cost-free training on remote sensing satellites, sensors, methods, and tools.**

- Trainings include a variety of applications of satellite data and are tailored to audiences with a variety of experience levels.


AGRICULTURE


CLIMATE & RESILIENCE


DISASTERS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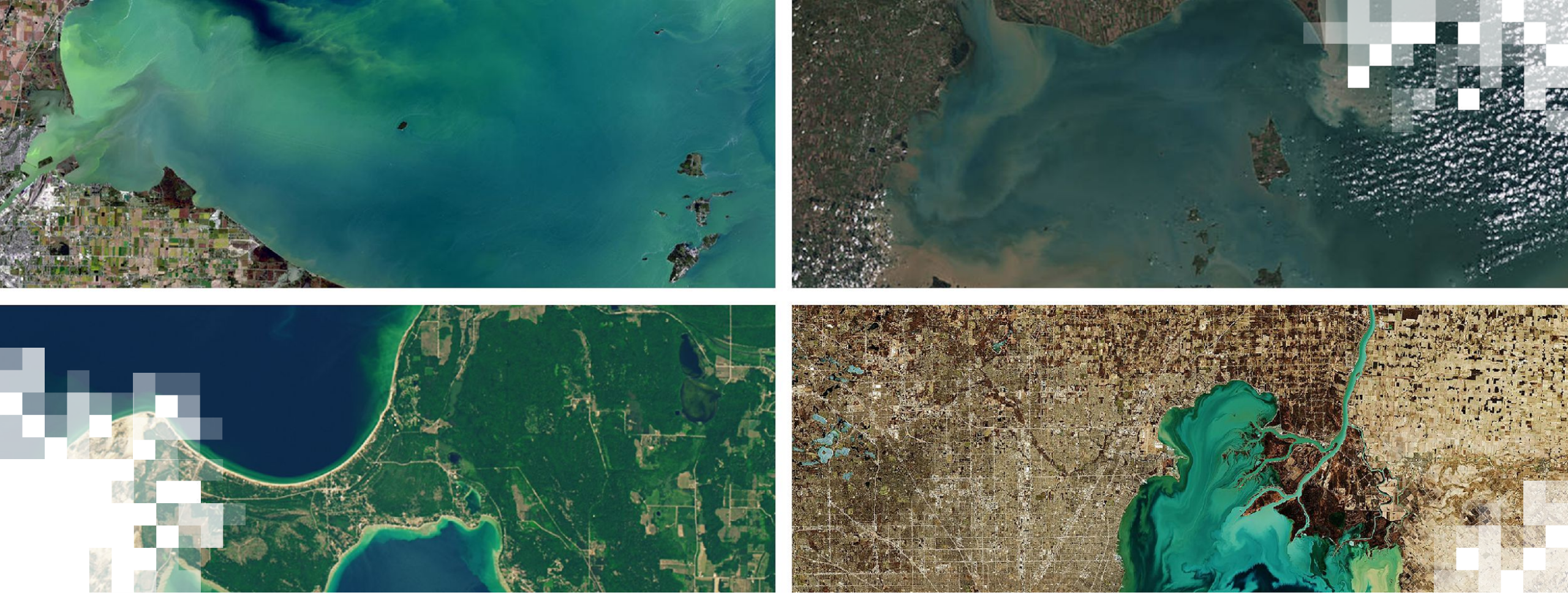
About ARSET Trainings

- Online or in-person
- Live and instructor-led or asynchronous and self-paced
- Cost-free
- Bilingual and multilingual options
- Only use open-source software and data
- Accommodate differing levels of expertise

- Visit the ARSET website to learn more.



Monitoring Water Quality of Inland Lakes using Remote Sensing

Overview

Training Learning Objectives

By the end of this training, participants will be able to:

- Identify remote sensing observations useful for assessing water quality parameters in inland lakes.
- Recognize the importance of *in situ* measurements together with satellite observations in developing methodologies for operational water quality monitoring.
- Obtain an overview of Cyanobacteria Assessment Network (CyAN), an early warning system to assess algal blooms in freshwater lakes.
- Access satellite data and develop methodologies to assess water quality parameters.

Prerequisites

- Fundamentals of Remote Sensing
- Monitoring Coastal and Estuarian Water Quality Using Remote Sensing and In Situ Data
- Integrating Remote Sensing into a Water Quality Monitoring Program
- Introduction to Remote Sensing of Harmful Algal Blooms

Training Outline

Part 2

Cyanobacteria Assessment Network (CyAN)

July 20, 2023

Part 3

Assess Water Quality using Satellite and *In Situ* Observations

July 25, 2023

Homework

Opens July 25 – Due August 10 – Posted on Training Webpage

A **certificate of completion** will be awarded to those who attend all live sessions and complete the homework assignment(s) before the given due date.

Water Quality of Freshwater Lakes

Water quality of lakes, streams, and rivers impacts:

- **Human Health**
  - Bacteria and pathogens make water unsafe for drinking and recreation.
- **Aquatic Life and Ecosystems**
  - Chemicals in surface water can harm ecosystems and aquatic plants and animals.
- US Environmental Protection Agency develops state-wise water quality criteria according to the Clean Water Act.

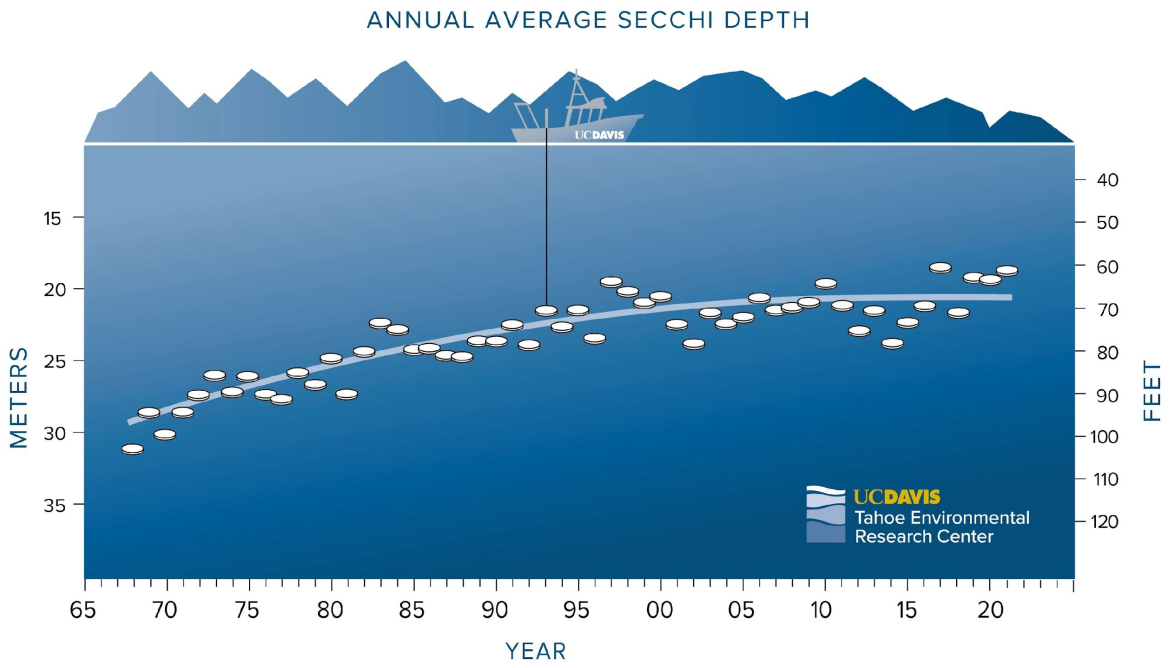
Image Credit: gimono

Image Credit: Lisac Mark, USFWS

Factors Affecting Water Quality of Freshwater Systems

Natural and anthropogenic factors influence freshwater quality in lakes.

- Pollutants from stormwater
- Excess nutrients from runoff from agricultural areas and wastewater discharges
- Water temperature changes associated with the change of landcover around water bodies
- Changes in water flow



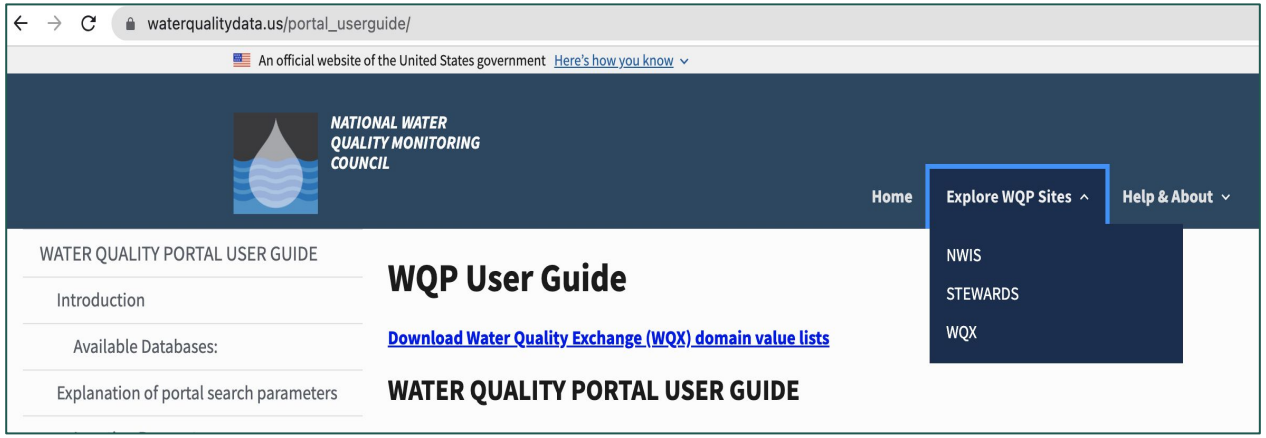
Lake Tahoe Water Clarity Report

Typical *In Situ* Observations of WQ in Freshwater Systems

- Chlorophyll Concentration
- Temperature
- Water Clarity
- Nutrients
- Metals
- pH & Alkalinity
- Dissolved Organic Matter
- Phytoplankton
- Cyanobacteria
- Condition of Indicator Species
- Suspended Sediments
- *E. coli*
- Plastics

In Situ Observations of WQ

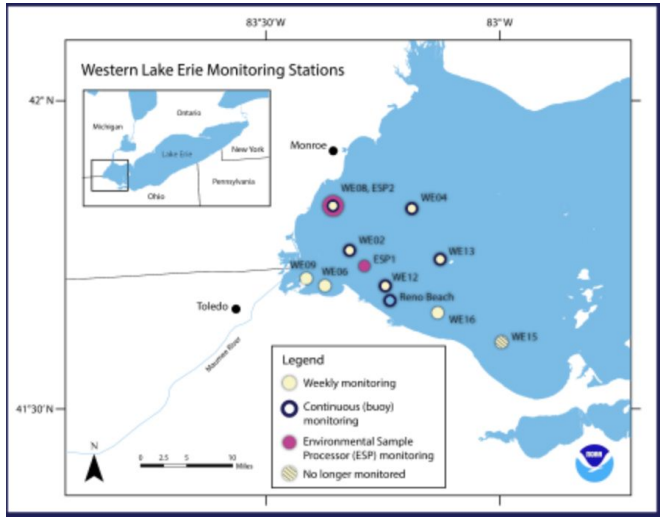
- In the US, water-quality monitoring data are available from the U.S. Geological Survey, Environmental Protection Agency, and the U.S. Department of Agriculture, distributed on the National Water Quality Portal.
- These measurements are point measurements and do not provide complete spatial coverage of lakes.
- Water sample collections and analysis for WQ monitoring can be expensive and may not have uniform temporal coverage.



Water Quality Portal User Guide

Why Use Satellite Remote Sensing for Monitoring WQ?

- Regular and consistent observations over a large area
- Consistent revisit rate for well-structured time series analyses
- Large number of data products available
- Complements *in situ* sampling
- Mostly free and open access

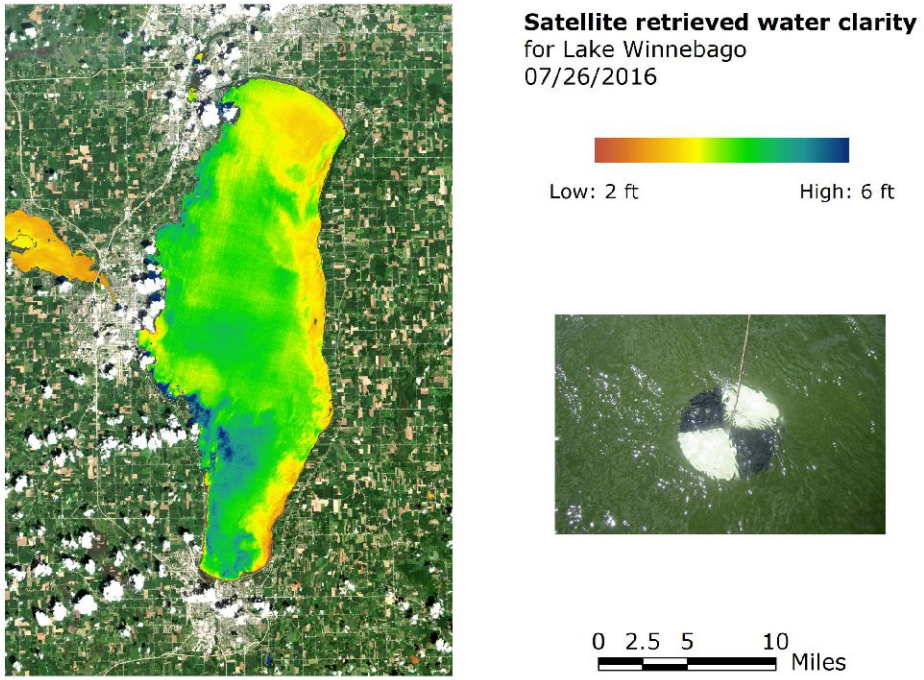


Western Lake Erie Buoy data locations from NOAA Great Lakes Environmental Laboratory

From Landsat: A bloom of freshwater cyanobacteria is the source of the vivid green color in Western Lake Erie

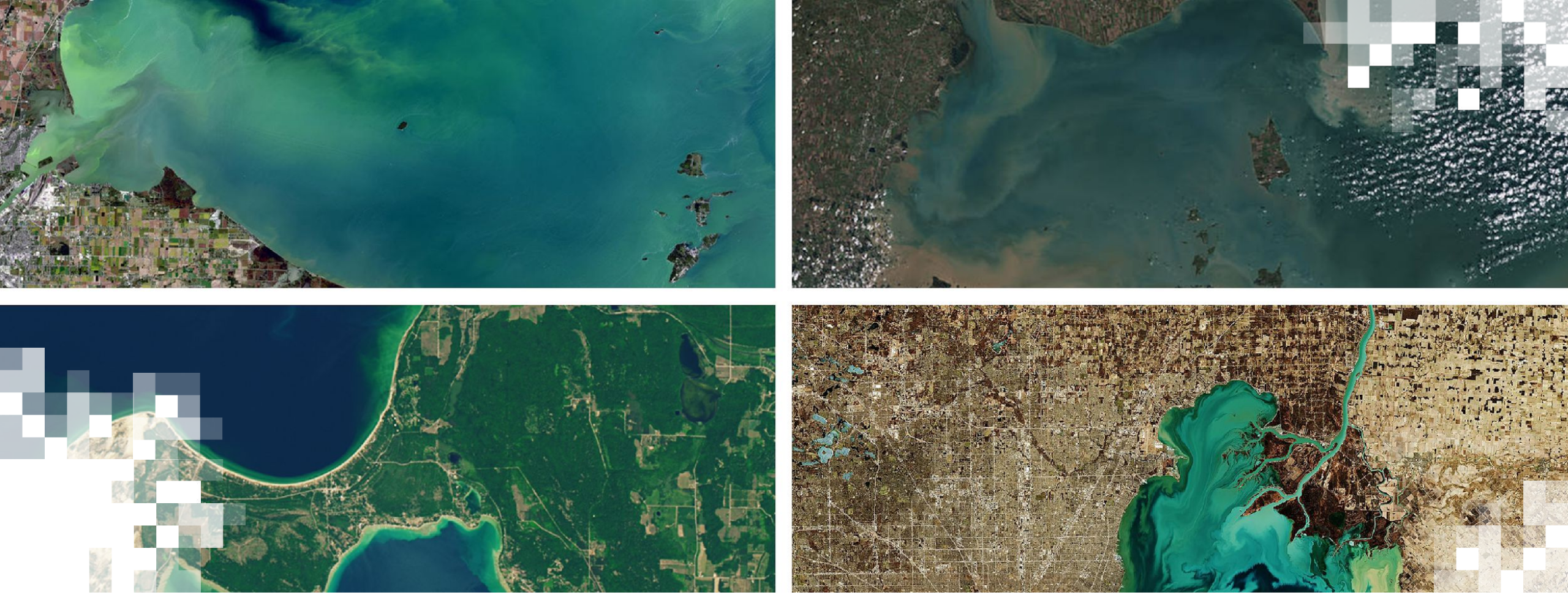
Some Water Quality Indicators Satellites Can Observe

- Colored Dissolved Organic Matter (CDOM)
- Chlorophyll-a (Phytoplankton)
- Total Suspended Solids (TSS)
- Fluorescence Line Height
- Euphotic Depth
- Diffuse Attenuation of Light
- Sea Surface Temperature (SST)
- Salinity



Satellite water clarity retrieval for Lake Winnebago on 07/26/2016 (Source of Landsat 8 OLI data: U.S. Geological Survey).

Satellite Water Clarity Retrieval for Lake Winnebago on 07/26/2016



Part 1

Overview of Remote Sensing Observations to Assess Water Quality

Part 1 Trainers

Amita Mehta

Instructor, Water & Disasters

Sean McCartney

Instructor, Water & Disasters

Part 1 Objectives

By the end of Part 1, participants will be able to:

- Describe state-of-the art, high spatial and spectral resolution observations for water quality remote sensing and their access using Google Earth Engine (GEE)
- Understand algorithm development procedure for remote sensing of WQ
- Describe selected open source, *in situ* measurements of water quality parameters
- **Demonstration and Exercise:**
  - Introduction to GEE
  - Explore and download *in situ* measurements of water quality parameters (chlorophyll-a concentration, TSS, and water clarity) for Lake Erie
  - Access optical reflectance data from various satellites for lake Erie using GEE

Part 1 Outline

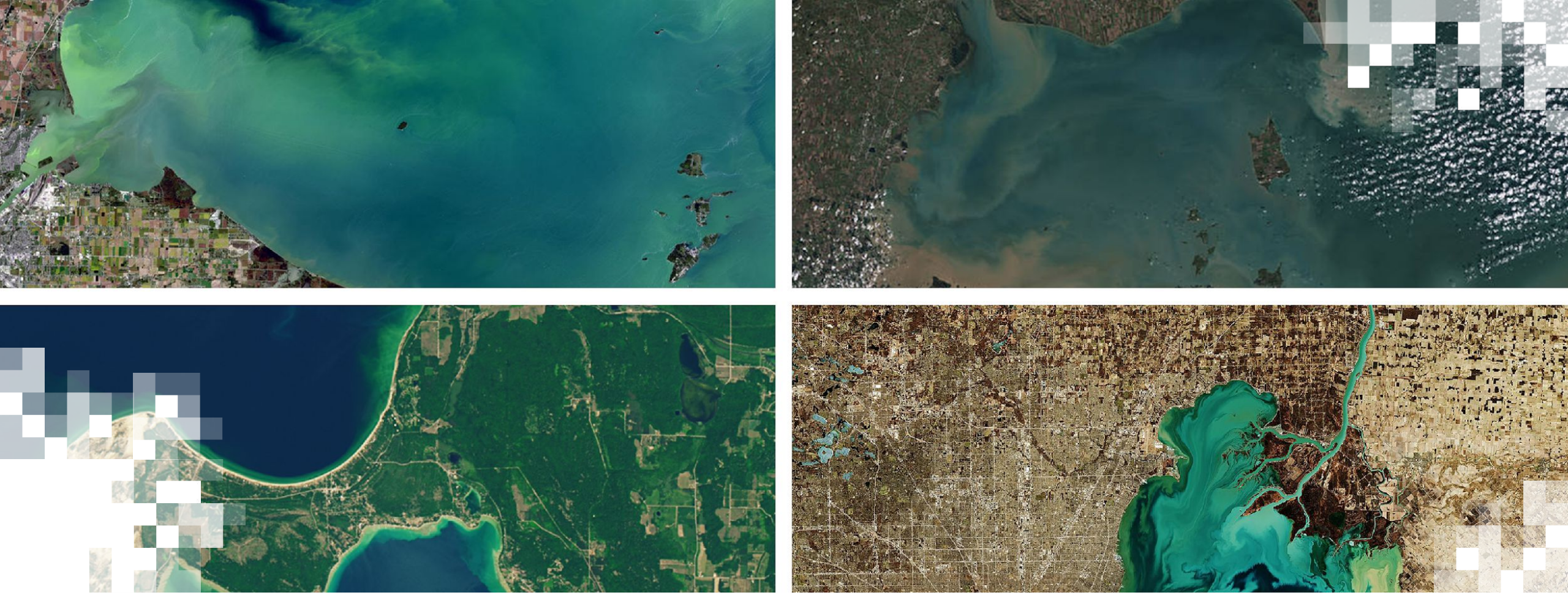
- Satellite observations for water quality (WQ) monitoring
- Remote sensing of WQ parameters
- Overview of selected *in situ* WQ data
- **Demonstration**

  Case Study: Access *In Situ* and Satellite Data for Lake Erie

  - Download *in situ* data for Lake Erie from The GLObal Reflectance community dataset for Imaging and optical sensing of Aquatic environments (GLORIA)
  - Access Landsat 8, Sentinel-2, and Sentinel-3 optical reflectance for Lake Erie using GEE

How to Ask Questions

- Please put your questions in the Questions box and we will address them at the end of the webinar.
- Feel free to enter your questions as we go. We will try to get to all of the questions during the Q&A session after the webinar.
- The remainder of the questions will be answered in the Q&A document, which will be posted to the training website about a week after the training.



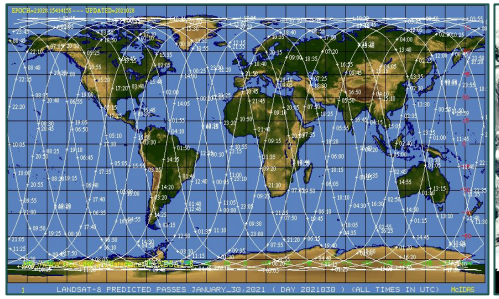
Satellite Observations for WQ Monitoring

Current Satellites and Sensors for Water Quality Monitoring

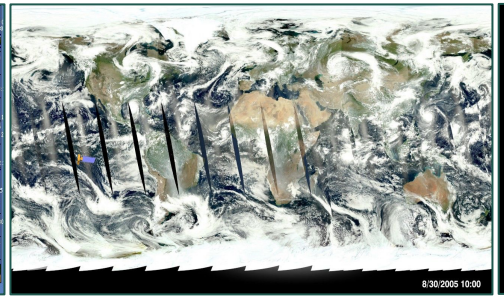
Satellites	Sensors	Resolution
Landsat 8 & 9	Operational Land Imager (OLI & OLI2)	185 km Swath; 15 m, 30 m, 60 m; 16-Day Revisit
Terra & Aqua	MODerate Resolution Imaging Spectroradiometer (MODIS)	2330 km Swath; 250 m, 500 m, 1 km; 1–2-Day Revisit
SNPP[1] and JPSS[2]	Visible Infrared Imaging Radiometer Suite (VIIRS)	3040 km Swath; 375 m – 750 m; 1–2-Day Revisit
Sentinel-2A and -2B	Multi Spectral Imager (MSI)	290 km Swath; 10 m, 20 m, 60 m; 5-Day Revisit
Sentinel-3A and -3B	Ocean and Land Color Instrument (OLCI)	1270 km Swath; 300 m; 27-Day Revisit

[1]SNPP: Suomi National Polar-orbiting Partnership
[2]JPSS: Joint Polar Satellite System

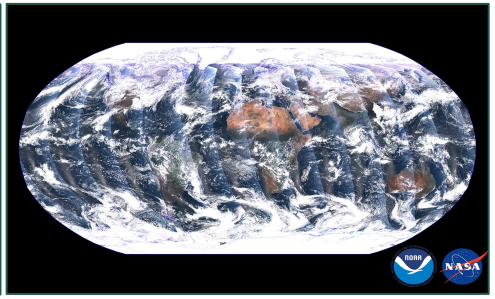
Current Satellite Missions for Water Quality Monitoring



Landsat 8

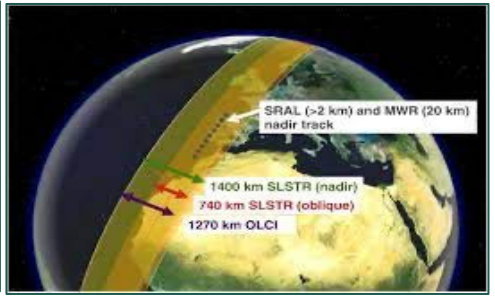


Aqua MODIS



JPSS VIIRS

Sentinel-2 MSI



Sentnel-3 OLCI

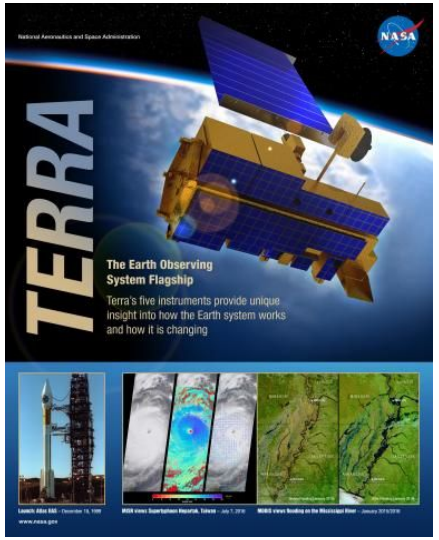
- All are polar orbiting satellites with different swath widths and revisit times.
- Multi-satellite data are also used for water quality information (e.g., Pahlevan et al., 2022; Rangzan et al., 2020).

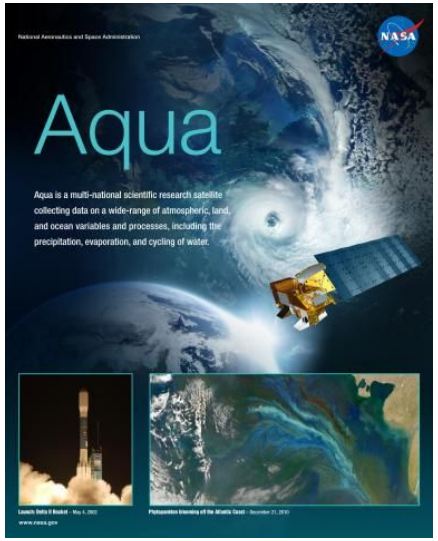
Pahlevan, et al. 2022: Simultaneous retrieval of selected optical water quality indicators from Landsat-8, Sentinel-2, and Sentinel-3, Remote Sensing of Environment, 270, 112860,ISSN 0034-4257, https://doi.org/10.1016/j.rse.2021.112860.

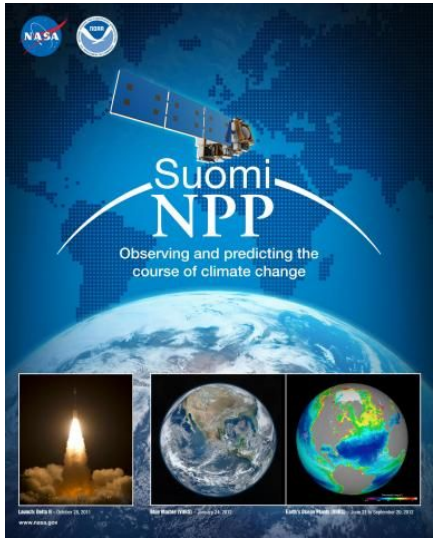
Rangzan et al., 2020: Improved water quality mapping based on cross-fusion of Sentinel-2 and Landsat-8 imageries, IET Image Processing, 14,1382-1392, **DOI:** 10.1049/iet-ipr.2019.1503.

Current Satellite Missions for Water Quality Monitoring

- Landsat 9 (9/27/2021 – Present)
- Landsat 8 (2/1/2013 – Present)
- Terra (12/18/1999 – Present)
- Aqua (5/4/2002 – Present)
- SNPP (11/21/2011 – Present)
- JPSS (11/18/2017 – Present)
- Sentinel-2A (6/23/2015 – Present)
- Sentinel-2B (3/7/2017 – Present)
- Sentinel-3A (2/16/2016 – Present)
- Sentinel-3B (4/25/2018 – Present)

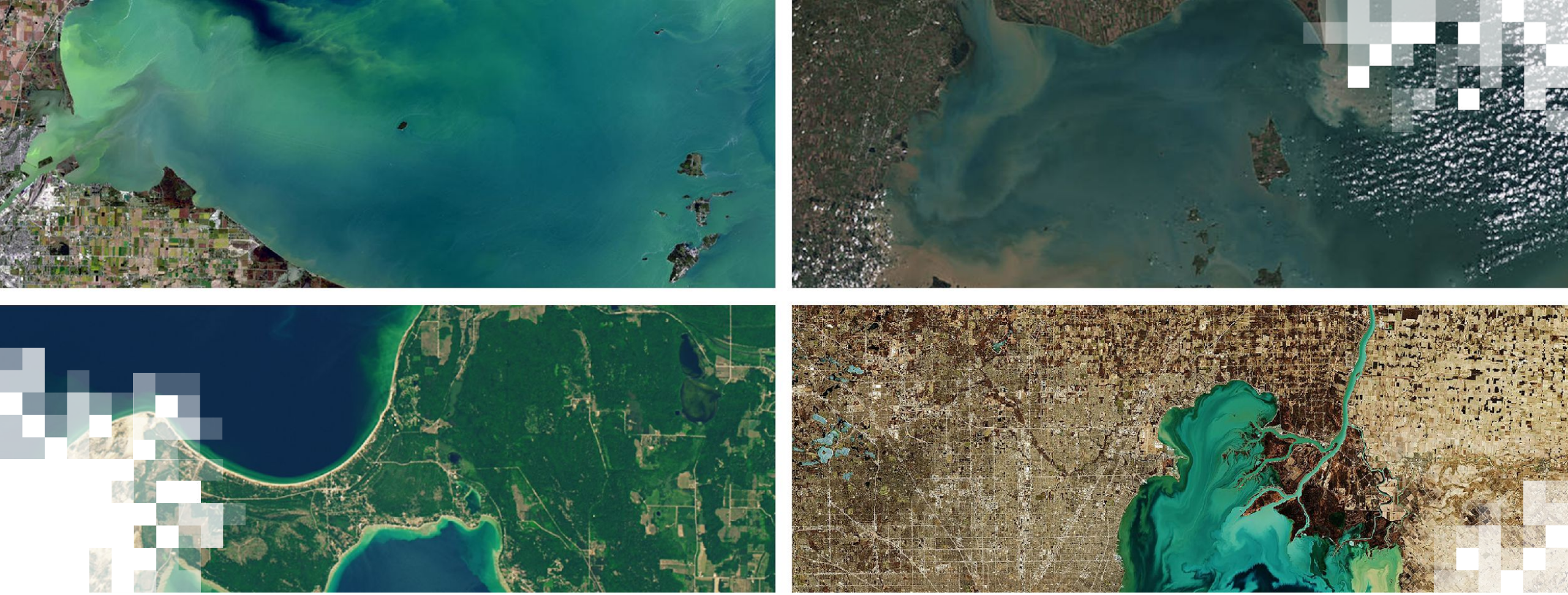






Sensor Spectral Bands Wavelength (Band Widths) in Nanometers

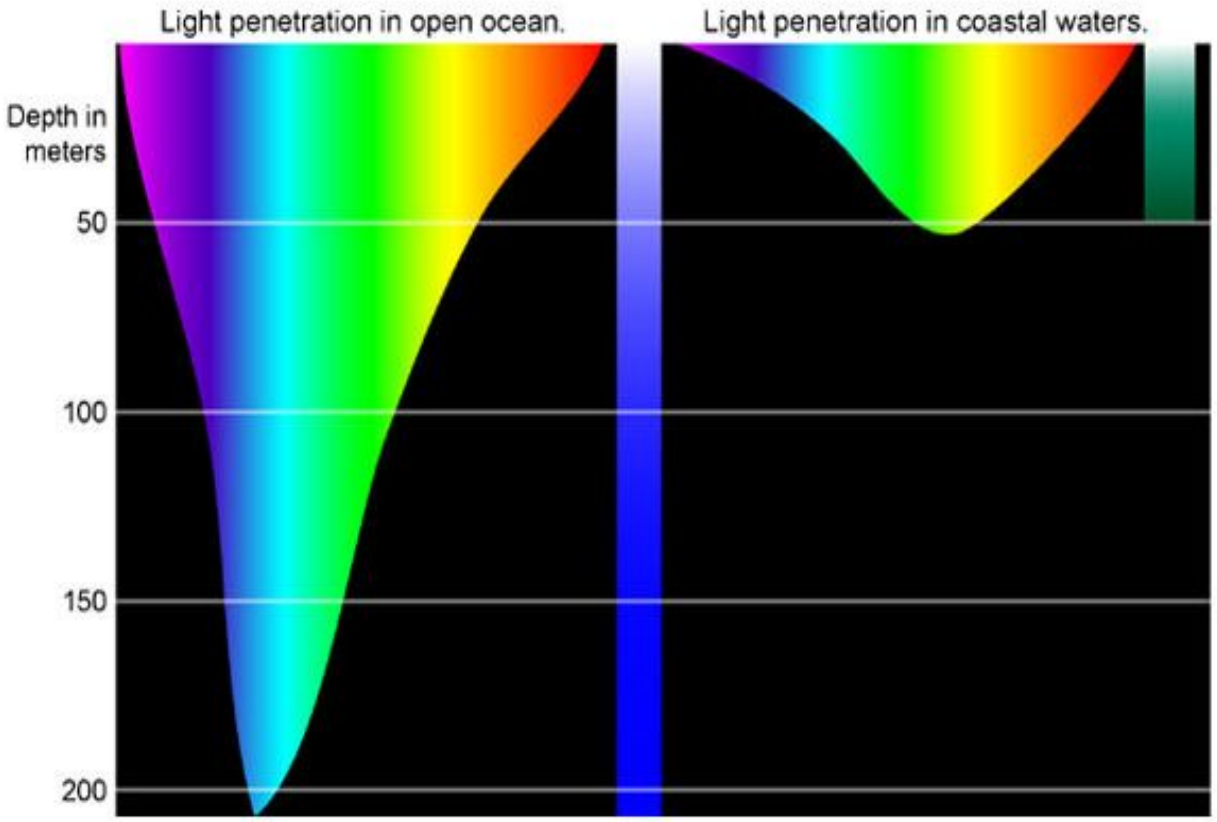
Landsat 8 OLI	Sentinel-2A MSI	Sentinel-2B MSI	Sentinel-3A/3B OLCI	Terra/Aqua MODIS	SNPP/JPSS VIIRS
443.0 (20)	442.7 (21)	442.3 (21)	400. (15)	412.5 (15)	412.0 (20)
482.0 (65)	492.4 (66)	492.1 (66)	412.5 (10)	443.0 (10)	445.0 (18)
561.0 (75)	559.8 (36)	559.0 (36)	442.5(10)	488.0 (10)	483.0 (10)
655.0 (50)	664.6 (31)	665.0 (31)	442.0 (10)	531.0 (10)	555.0 (20)
865.0 (40)	704.1 (16)	703.8 (16)	510.0(10)	551.0 (10)	672.0 (20)
1609.0 (100)	740.5 (15)	739.1 (15)	560.0 (10)	667.0 (10)	742.0 (6)
2201.0 (200)	782.8 (20)	779.7 (20)	665.0 (10)	678.0 (10)	
590 (180)	832.8 (106)	833.0 (106)	674.5 (7.5)	748.0 (10)	
1375 (30)	864.7 (22)	864.0 (22)	681.25 (7.5)		
10800 (1000)	945.1 (21)	943.2 (21)	708.75 (10)		
12000 (1000)	1373.5 (30)	1376.9(30)	753.75 (7.5)		
	1613.7 (94)	1610.4 (94)	761.25 (2.5)		
	2202.4 (185)	2185.7(185)	764.38 (3.5)		
			764.5 (2.5)		
			778.75 (15)		
			865.0 (20)		
			885.0 (10)		
			900.0 (10)		
			940.0 (20)		
			1020.0 (40)		

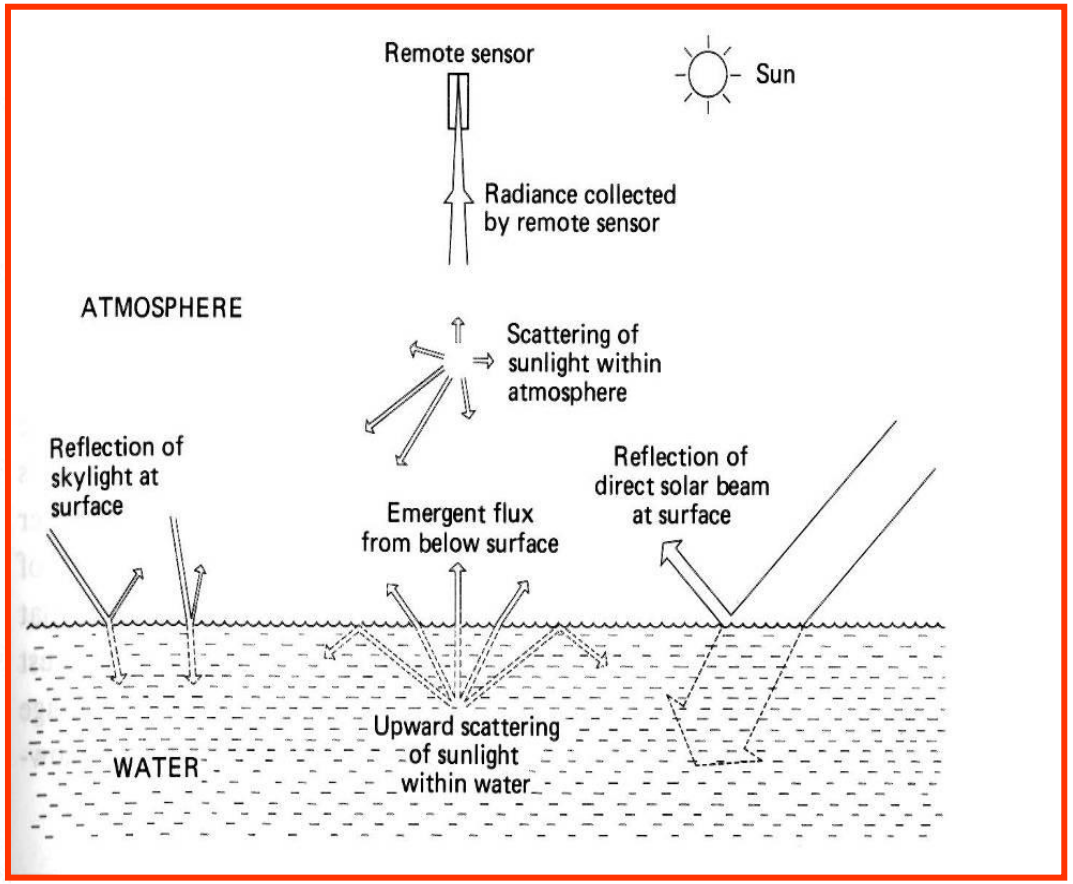


Remote Sensing of WQ Parameters

Water Quality Affects Water Optical Properties

Natural water contains material that is optically active. Monitoring light reflectance from the water surface with remote sensing can indicate the quality of the water.





Remote Sensing of Water Quality

- Satellite sensors measure top-of-atmosphere (TOA) radiances.
- The TOA radiances result from a combination of surface and atmospheric conditions, including the effects of clouds and aerosol particles.
- Water-leaving reflectance depends on backscattering and absorption of radiation due to water, sediments, phytoplankton, and colored dissolved organic matter (CDOM).

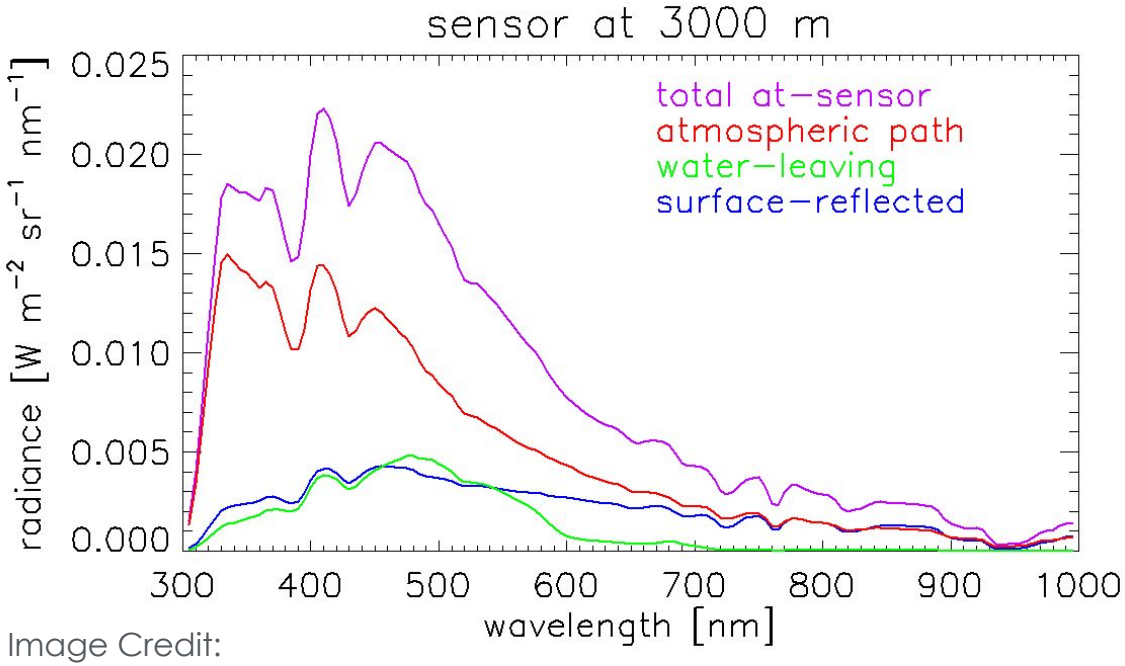
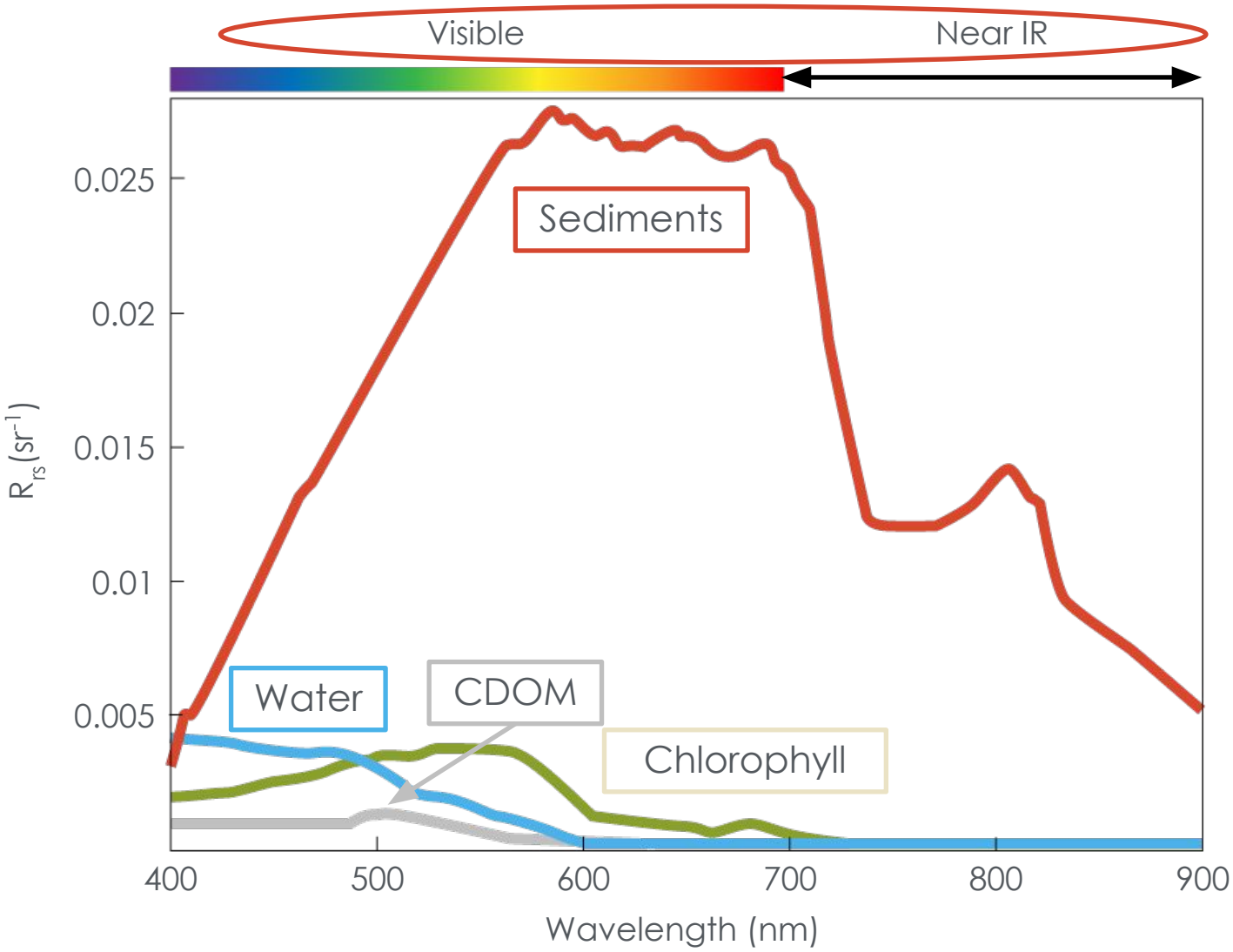


Image Credit: http://www.oceanopticsbook.info/view/remote_sensing/the_atmospheric_correction_problem

Inherent Optical Properties (IOPs) and the 'Color' of Water

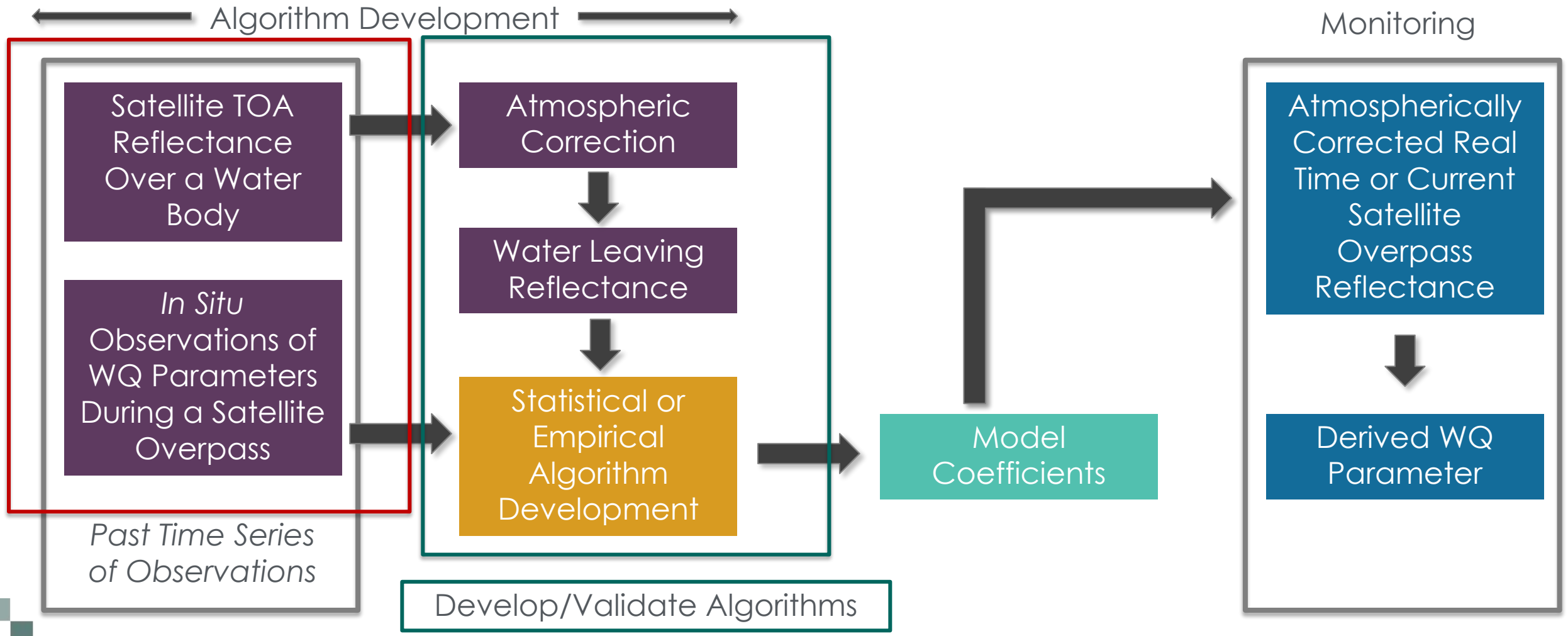
Inherent Optical Properties:

- Absorption by…
  - Phytoplankton (ph)
  - Non-Algal Particles (nap)
  - Colored Dissolved Organic Matter (CDOM)
  - Water (w)
- Scattering in forward (f) and backward (b) directions



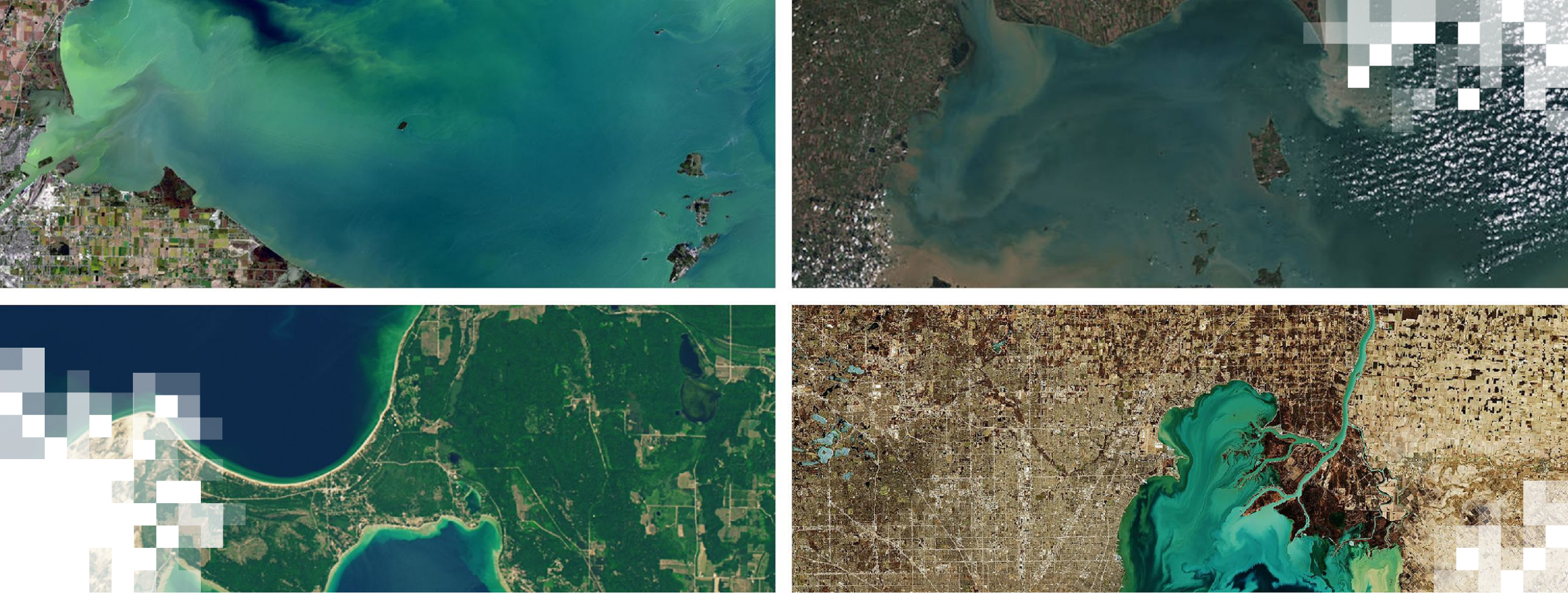
Water Quality Parameters from Remote Sensing Observations

Quantitative Technique



Requirements for Algorithm Development

- Geographic region
- *In situ* water quality parameter measurements – spatial and temporal colocation with satellite overpass
- Spectral water reflectance from satellite images
  - Cloud-free scenes are necessary
- Seasonal to annual coverage of *in situ* and satellite data preferable
- Analysis and statistical algorithm coefficient derivations from the *in situ* and remote sensing observations
- Independent *in situ* data for algorithm validation

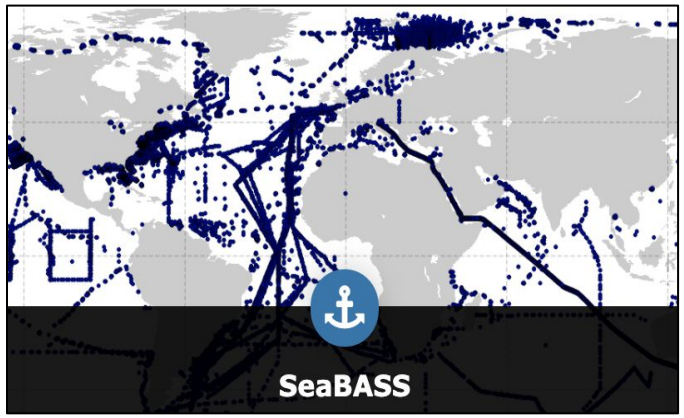


Description of Selected *In Situ* WQ Data

SeaWiFS Bio-optical Archive and Storage System (SeaBASS)

https://seabass.gsfc.nasa.gov/wiki/System_Description

- The NASA Ocean Biology Processing Group (OBPG) maintains SeaBASS, a repository of *in situ* oceanographic data to support satellite data validation.
- SeaBASS data include measurements of inherent optical properties, phytoplankton pigment concentrations, water temperature, salinity, and stimulated fluorescence.
- Data are collected by using a variety of platforms, including ships and moorings. Different instrument packages include profilers, buoys, and hand-held instruments.



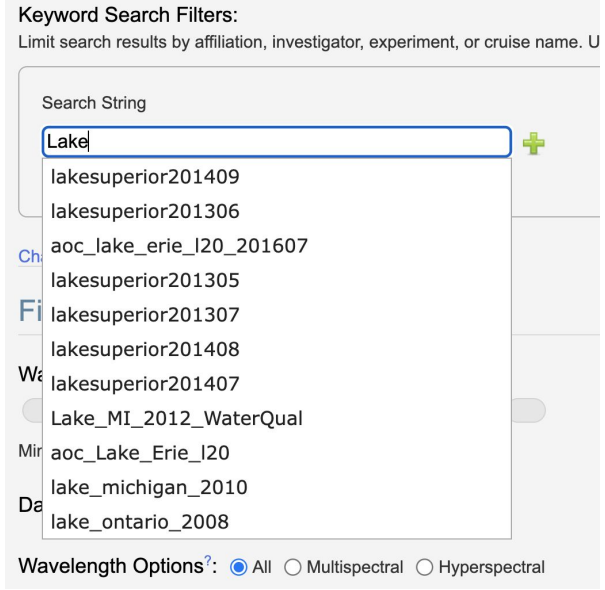
Primary data collection is in costal and open oceans.

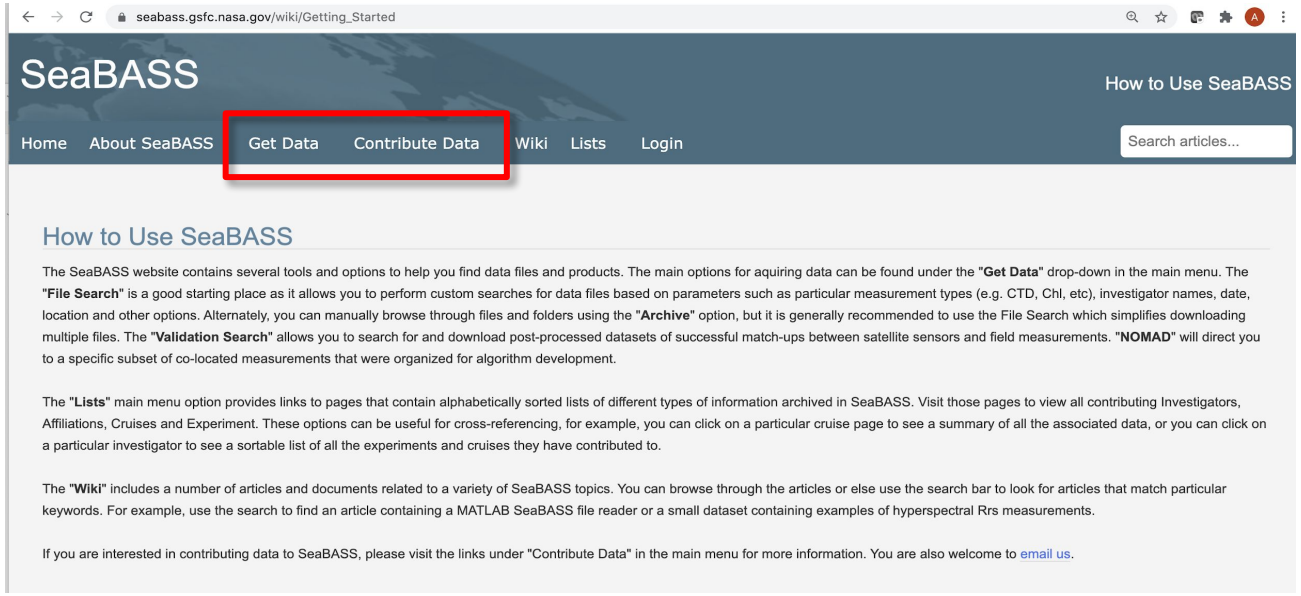
SeaWiFS: Sea-viewing Wide Field-of-view Sensor

SeaBASS Data

https://seabass.gsfc.nasa.gov/wiki/Getting_Started

- *In situ* measurements data from SeaBASS can be downloaded for selected lakes.
- Your own *in situ* measurements can also be contributed to SeaBASS.
- SeaBASS data have a specific file format.

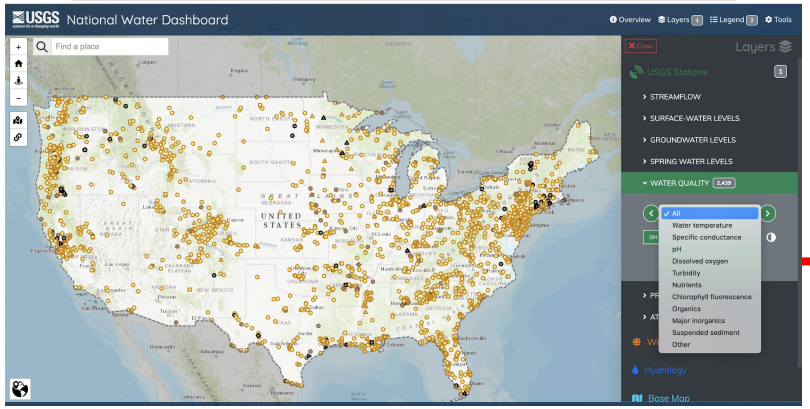




National Water Dashboard

https://dashboard.waterdata.usgs.gov/app/nwd/en/?aoi=default

- Water quality measurements are taken in streams in general, not in the lakes.
- Several streams open into lakes.
- Not all parameters are measured at all locations.

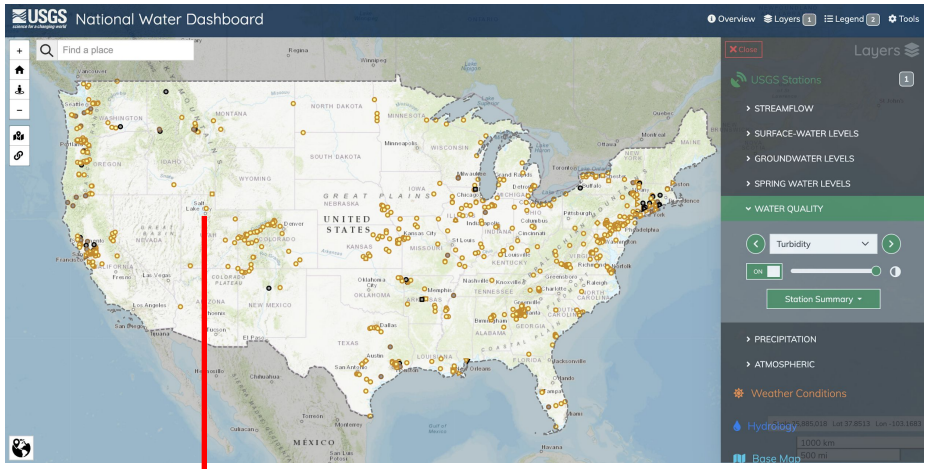


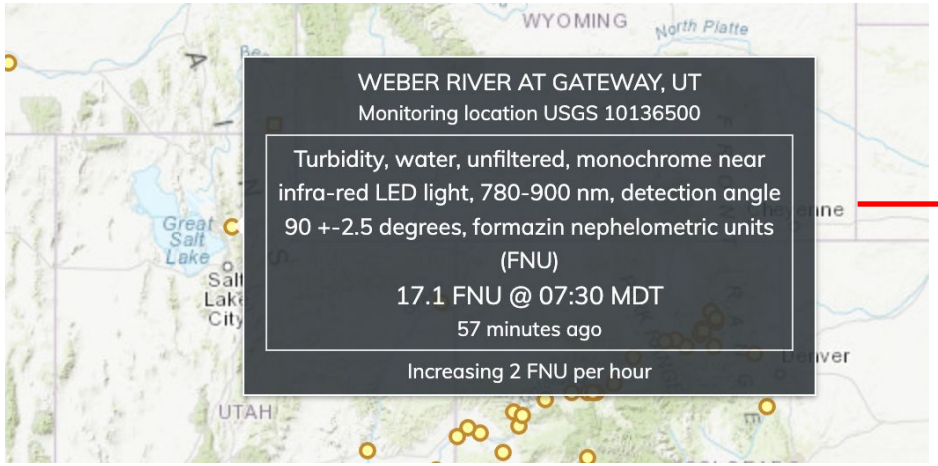
USGS Water Quality Monitoring Locations in Inland Streams

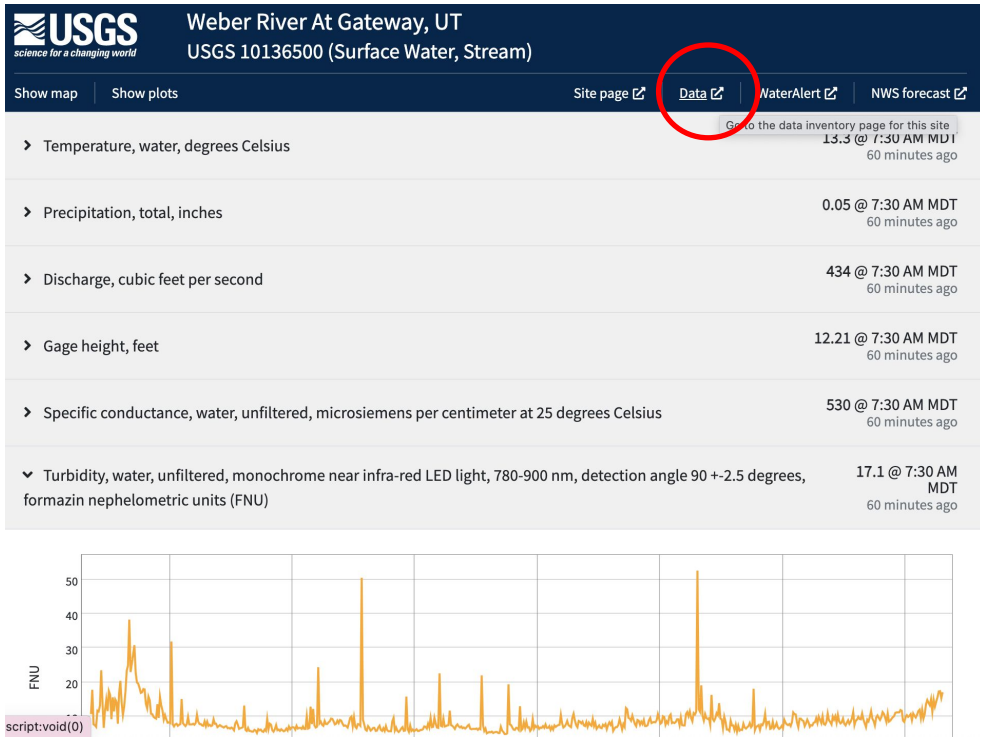
Water temperature
Specific conductance
pH
Dissolved oxygen
Turbidity
Nutrients
Chlorophyll fluorescence
Organics
Major inorganics
Suspended sediment
Other

National Water Dashboard: Turbidity Measurements

https://dashboard.waterdata.usgs.gov/app/nwd/en/?aoi=default



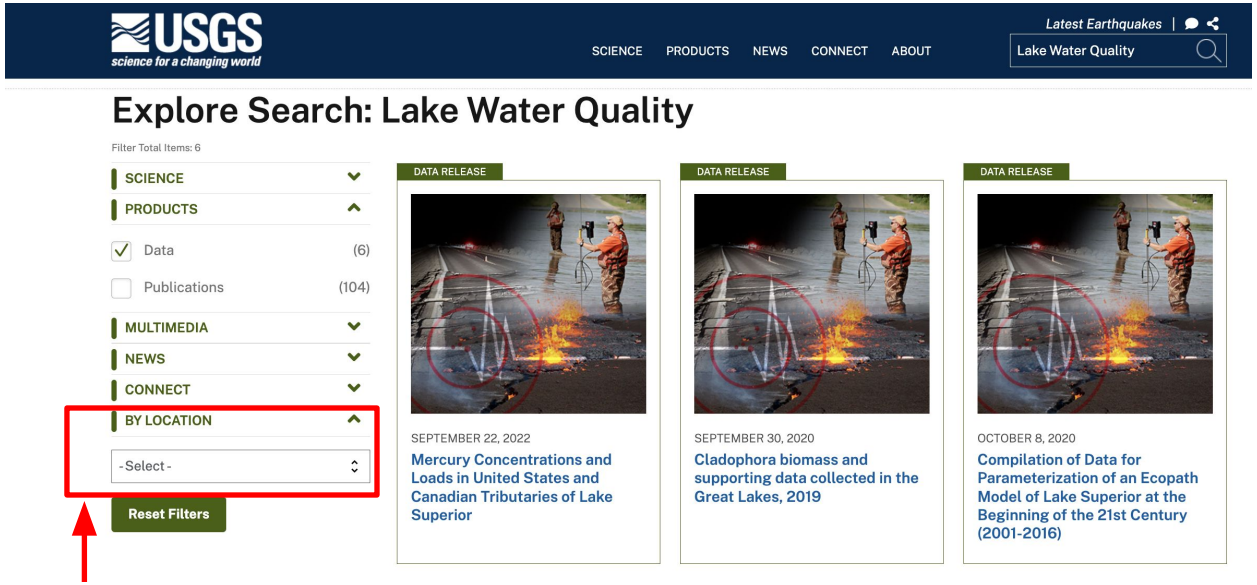




USGS Lake Water Quality Measurements

"The USGS works with partners to monitor, assess, conduct **targeted research**, and deliver information on a wide range of water resources and conditions including streamflow, groundwater, **water quality**, and water use and availability."

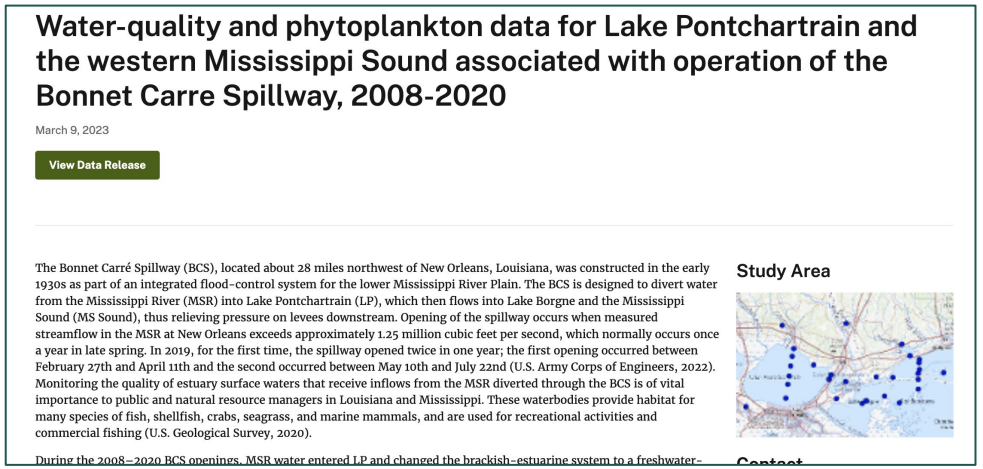
Explore Search: Lake Water Quality



Select by State

USGS Lake Water Quality Measurements Example: Lake Pontchartrain

Explore Search: Lake Water Quality



Water-quality and phytoplankton data for Lake Pontchartrain and the western Mississippi Sound associated with operation of the Bonnet Carre Spillway, 2008-2020

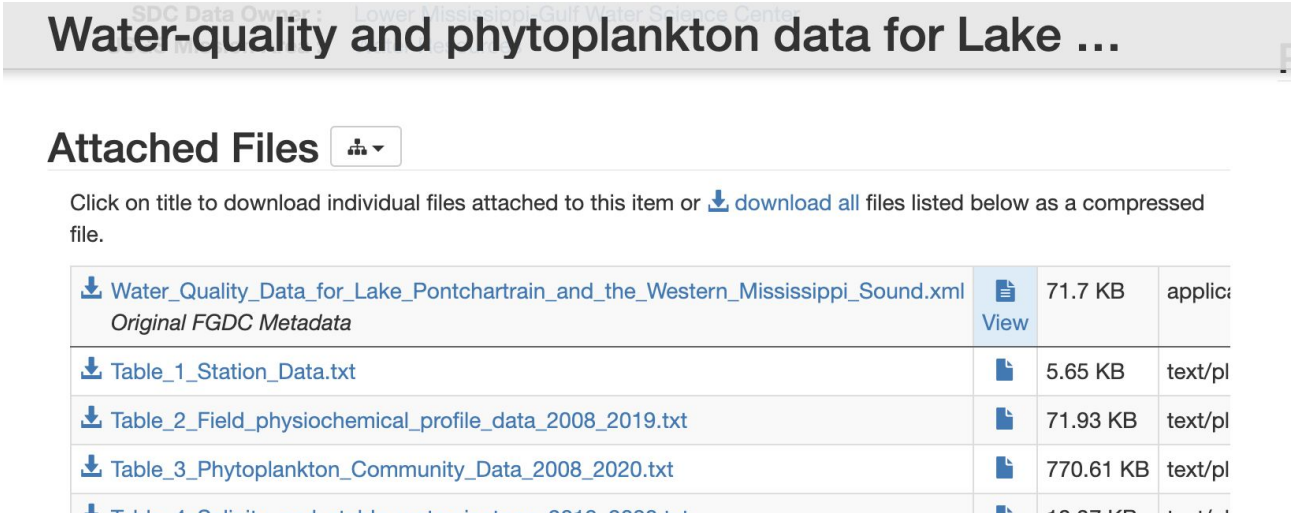
March 9, 2023

View Data Release

The Bonnet Carré Spillway (BCS), located about 28 miles northwest of New Orleans, Louisiana, was constructed in the early 1930s as part of an integrated flood-control system for the lower Mississippi River Plain. The BCS is designed to divert water from the Mississippi River (MSR) into Lake Pontchartrain (LP), which then flows into Lake Borgne and the Mississippi Sound (MS Sound), thus relieving pressure on levees downstream. Opening of the spillway occurs when measured streamflow in the MSR at New Orleans exceeds approximately 1.25 million cubic feet per second, which normally occurs once a year in late spring. In 2019, for the first time, the spillway opened twice in one year; the first opening occurred between February 27th and April 11th and the second occurred between May 10th and July 22nd (U.S. Army Corps of Engineers, 2022). Monitoring the quality of estuary surface waters that receive inflows from the MSR diverted through the BCS is of vital importance to public and natural resource managers in Louisiana and Mississippi. These waterbodies provide habitat for many species of fish, shellfish, crabs, seagrass, and marine mammals, and are used for recreational activities and commercial fishing (U.S. Geological Survey, 2020).

During the 2008–2020 BCS openings, MSR water entered LP and changed the brackish-estuarine system to a freshwater-

Study Area



Water-quality and phytoplankton data for Lake …

SDC Data Owner : Lower Mississippi Gulf Water Science Center

Attached Files

Click on title to download individual files attached to this item or download all files listed below as a compressed file.

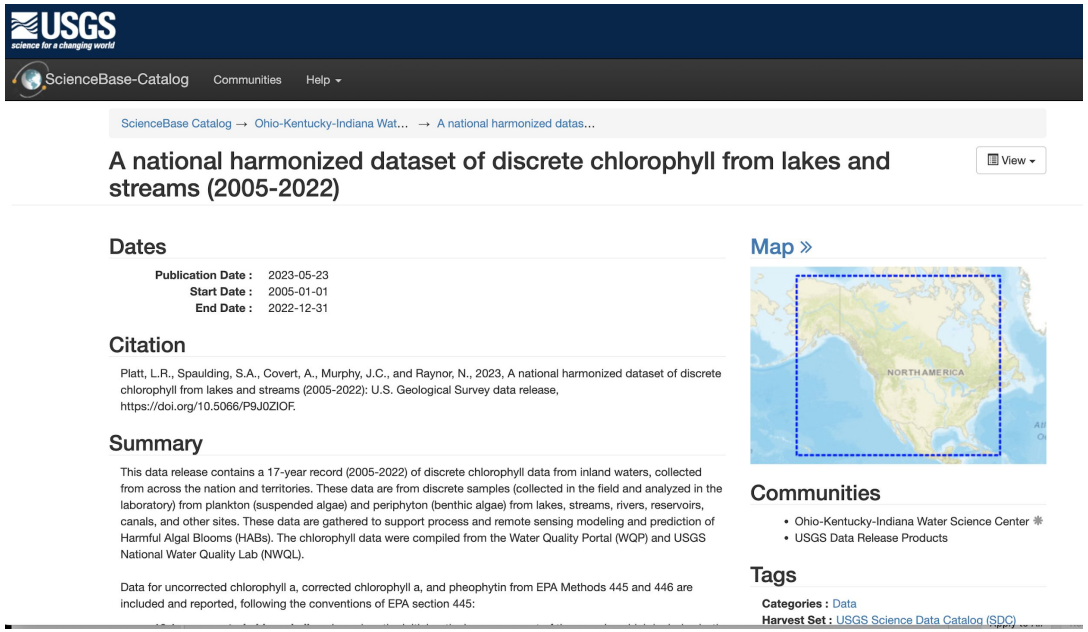
Water_Quality_Data_for_Lake_Pontchartrain_and_the_Western_Mississippi_Sound.xml *Original FGDC Metadata*	View	71.7 KB	applic
Table_1_Station_Data.txt		5.65 KB	text/pl
Table_2_Field_physiochemical_profile_data_2008_2019.txt		71.93 KB	text/pl
Table_3_Phytoplankton_Community_Data_2008_2020.txt		770.61 KB	text/pl
Table_4_Salinity_and_stable_water_isotope_2019_2020.txt		18.37 KB	text/pl

Data files can be downloaded.

National Harmonized Chlorophyll Dataset

https://www.sciencebase.gov/catalog/item/638f5472d34ed907bf7c8f23

- Chlorophyll data and site information can be downloaded.
- Data are available between 2005–2022 when measurements are available.



Attached Files

Click on title to download individual files attached to this item or download all files listed below as a compressed file.

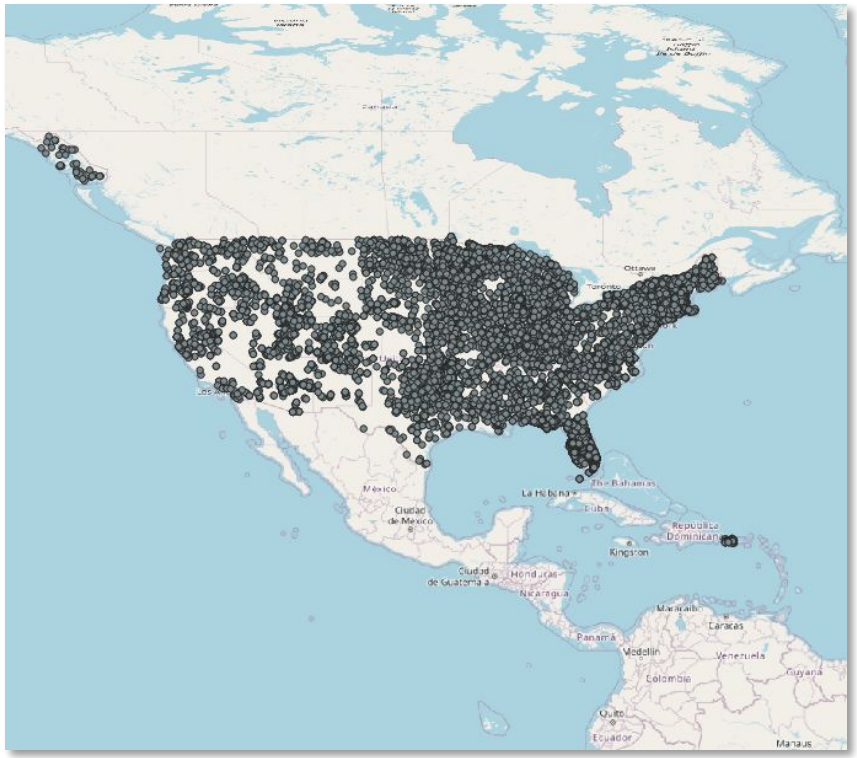
national_chlorophyll_data_metadata.xml *Original FGDC Metadata*	View	55.23 KB	application/fgdc+xml
national_chlorophyll_site_metadata.csv		10.59 MB	text/csv
national_chlorophyll_corrected_chlorophyll_a_data.csv		106.56 MB	text/csv
national_chlorophyll_pheophytin_data.csv		72.35 MB	text/csv
national_chlorophyll_uncorrected_chlorophyll_a_data.csv		68.77 MB	text/csv

Purpose

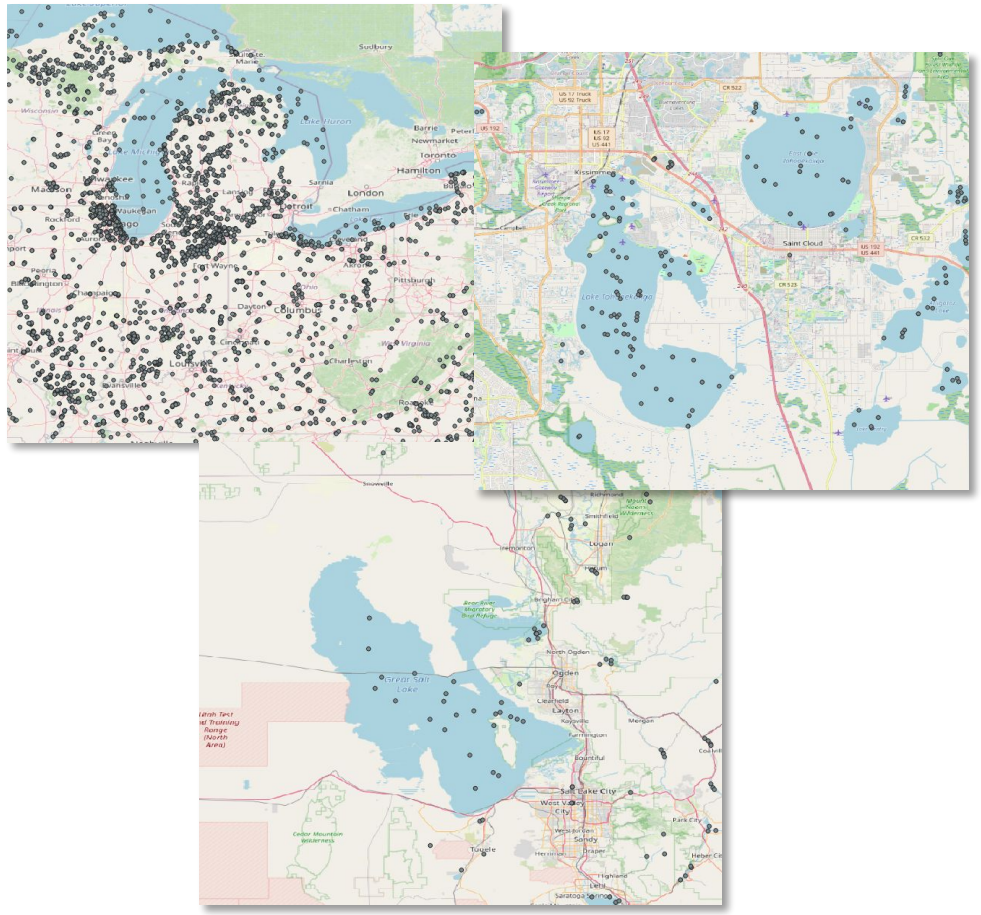
Chlorophyll data were gathered to support the development of process and remote sensing modeling and prediction of Harmful Algal Blooms (HABs) in freshwaters.

National Harmonized Chlorophyll Dataset

https://www.sciencebase.gov/catalog/item/638f5472d34ed907bf7c8f23

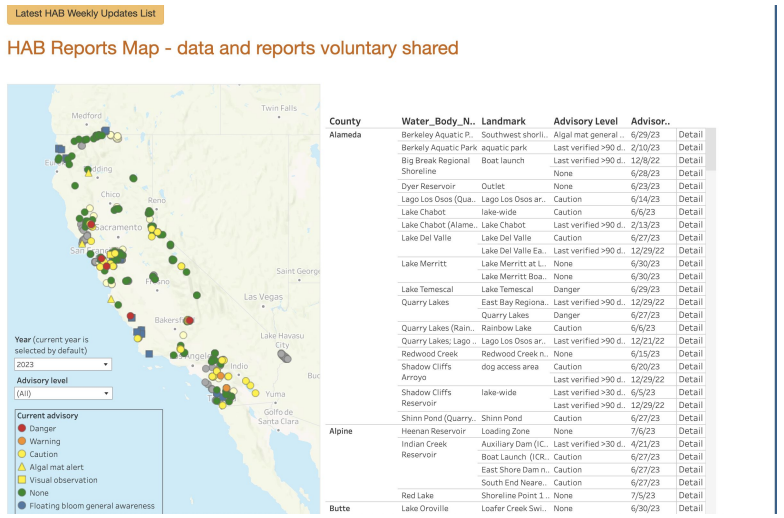


Measurement Locations

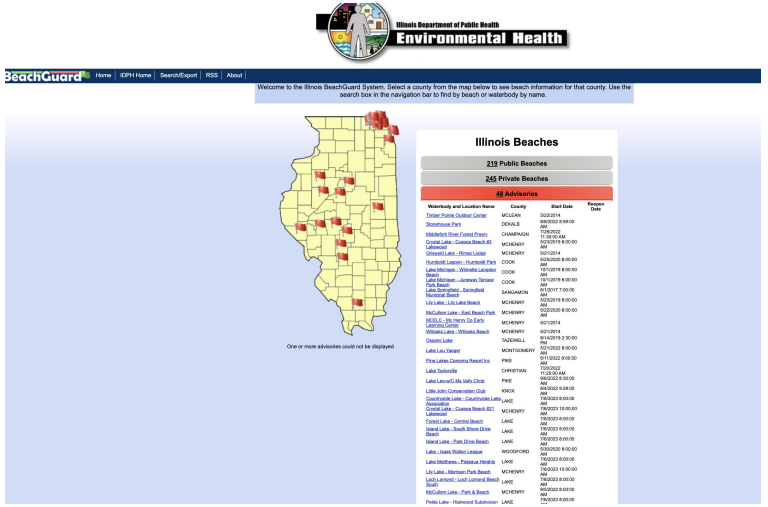


Water Quality Data for Health Safety

- Several states and local entities in the United States routinely or periodically collect lake water samples and analyze water quality for health safety focusing on Harmful Algal Blooms (Center for Disease Control: Water Quality Information for Oceans, Lakes, and Rivers by State).



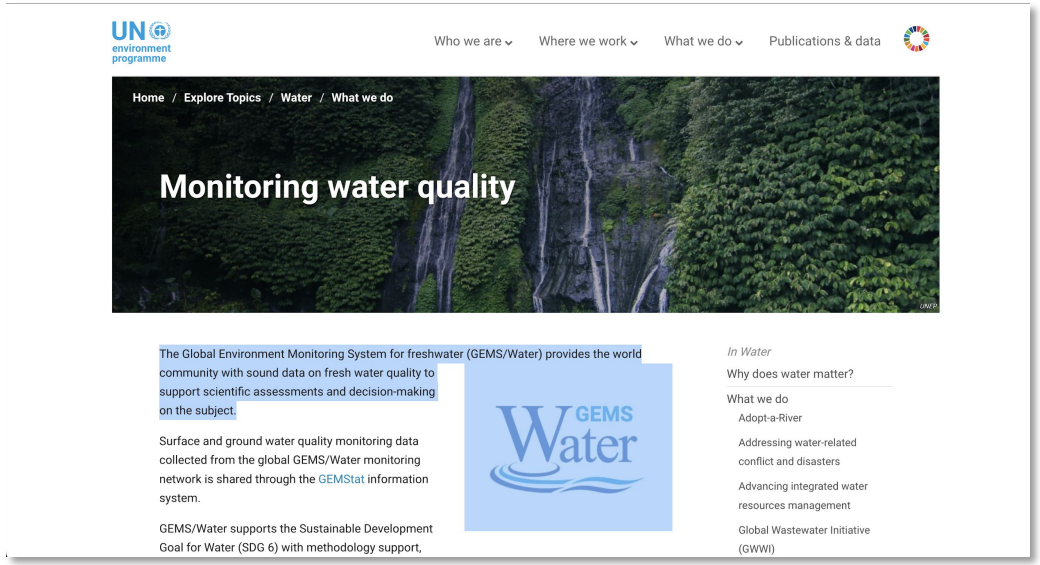
https://mywaterquality.ca.gov/habs/

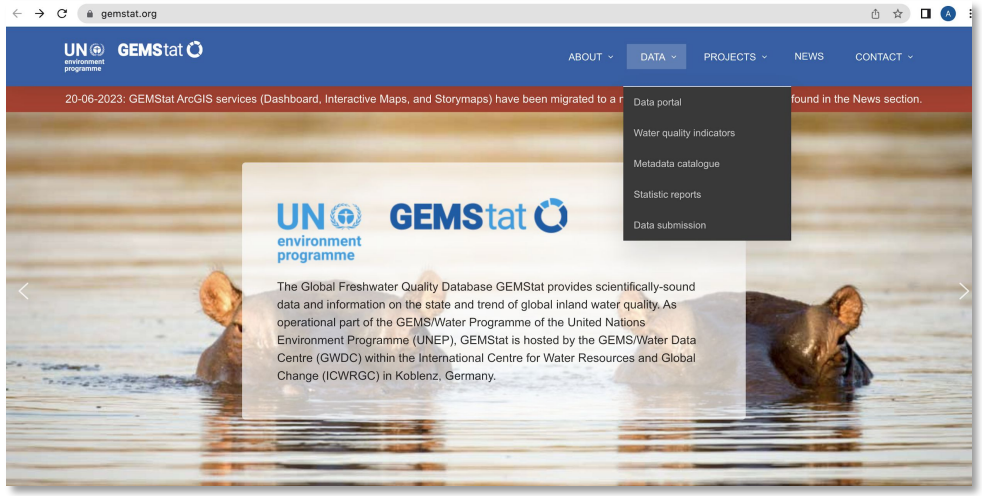


http://www.idph.state.il.us/envhealth/ilbeaches/public/

Global Freshwater Quality Data

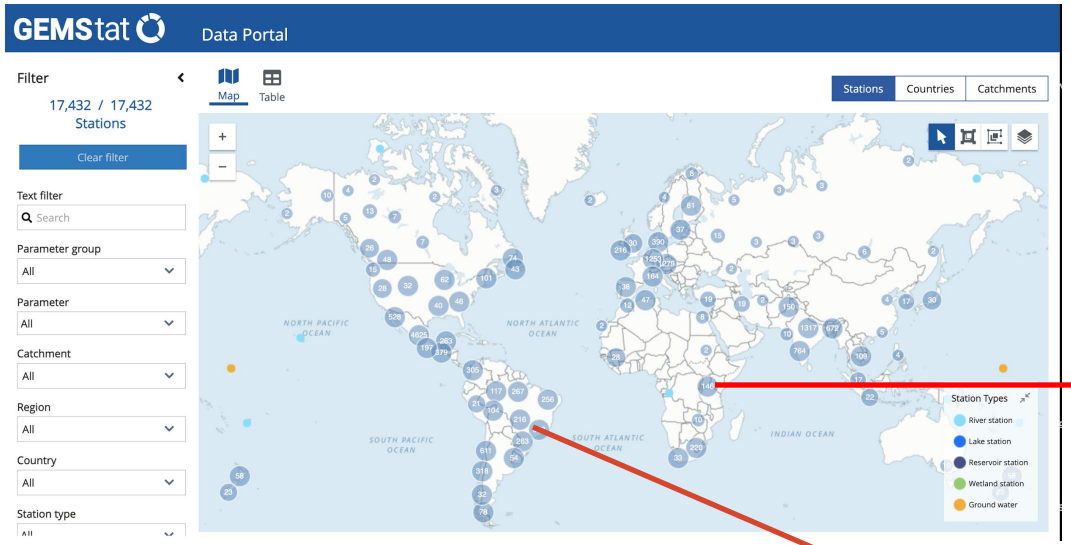
- United Nations Environmental Program established the Global Environment Monitoring System for freshwater (GEMS/Water) in 1978.
- Data are shared from many countries around the world and are made available via GEMStat data portal.

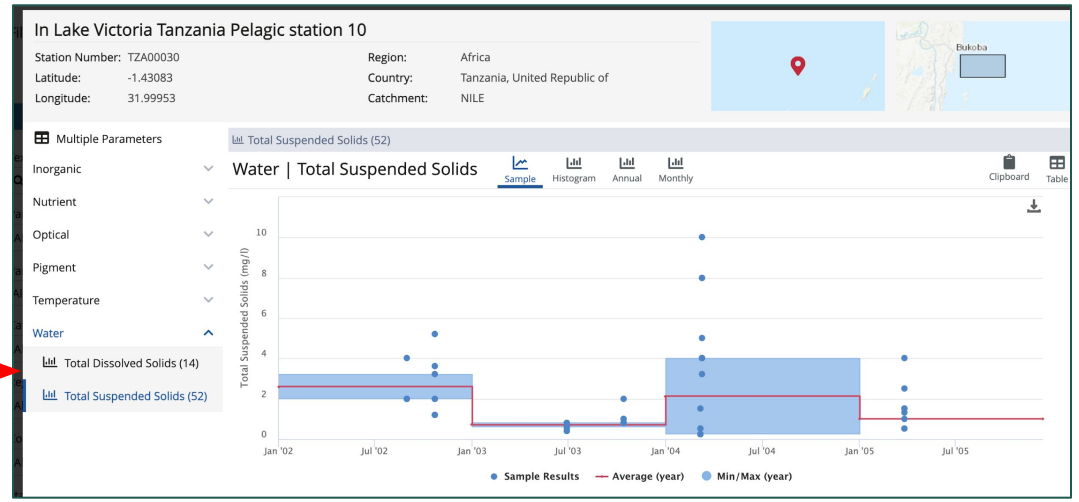


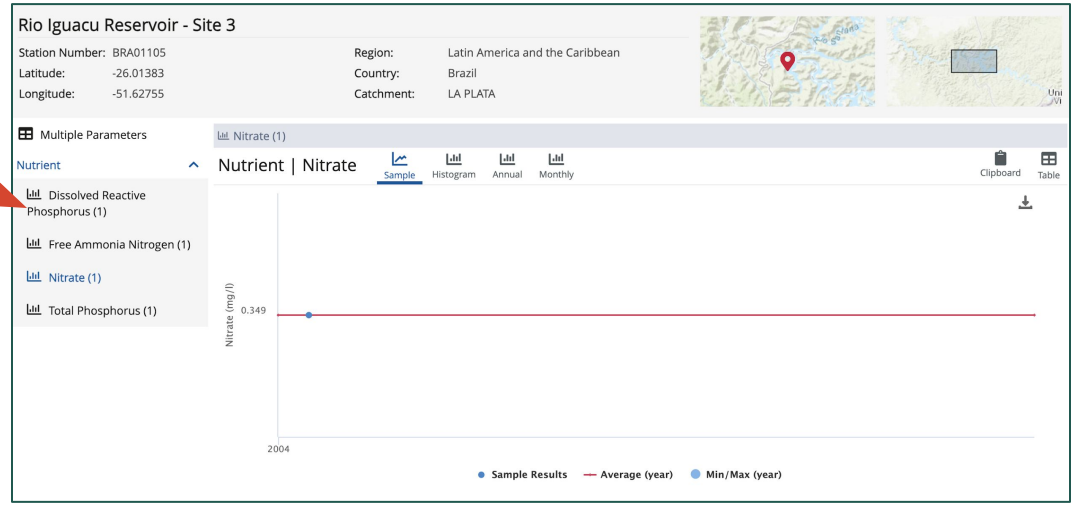


GEMStat/Water Data Portal

https://gemstat.bafg.de/applications/public.html?publicuser=PublicUser#gemstat/Stations







- Non-uniform coverage in time and limited water quality parameters available.

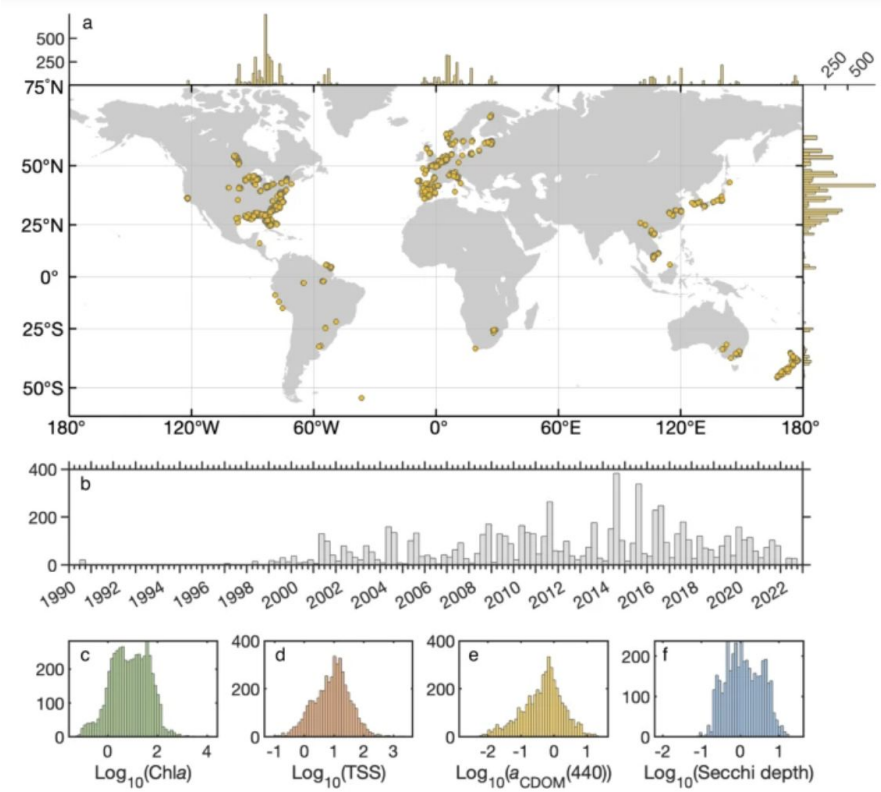
The GLObal Reflectance community dataset for Imaging and optical sensing of Aquatic environments (GLORIA)

- GLORIA is a hyperspectral reflectance data set collected from 450 water bodies around the world[1].
- Along with the reflectance data, at least one **co-located water quality measurement** of chlorophyll *a (Chla)*, total suspended solids (TSS), absorption by dissolved substances, and Secchi depth, is provided.
- These data are contributed by researchers from 59 institutions around the world.
- Data collection started in 1990 and the sampling effort has been steady since 2001.

[1]Lehmann, M.K., Gurlin, D., Pahlevan, N. *et al.* GLORIA - A globally representative hyperspectral *in situ* dataset for optical sensing of water quality. *Sci Data* **10**, 100 (2023). https://doi.org/10.1038/s41597-023-01973-y

In Situ Water Sample Measurements for GLORIA

- Water Samples were analyzed and Chl*a*, TSS and $a_{CDOM}(440)$ were determined by using well established high-accuracy laboratory methods.
- Secchi depth was determined by an observer by lowering a black and white disk of 20 or 30 cm diameter into water. The depth when the disk was no longer visible was noted as the Secchi depth.
- The data collection started in 1990 but became more established after 2002.
- Some SeaBASS inland WQ data are included in GLORIA.

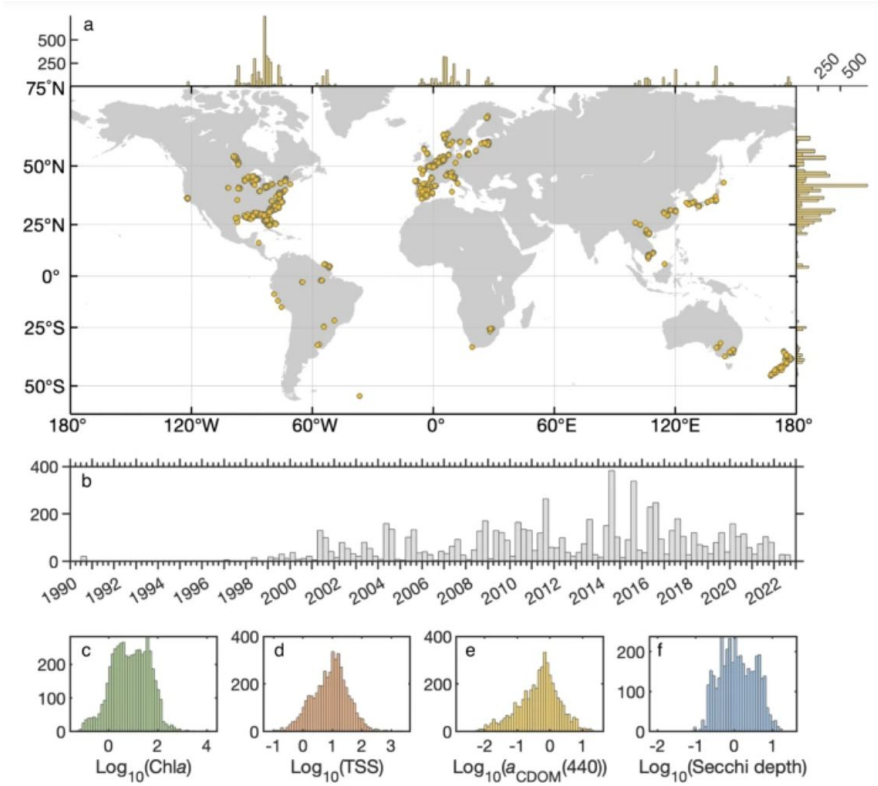


Sample Locations and WQ Statistics

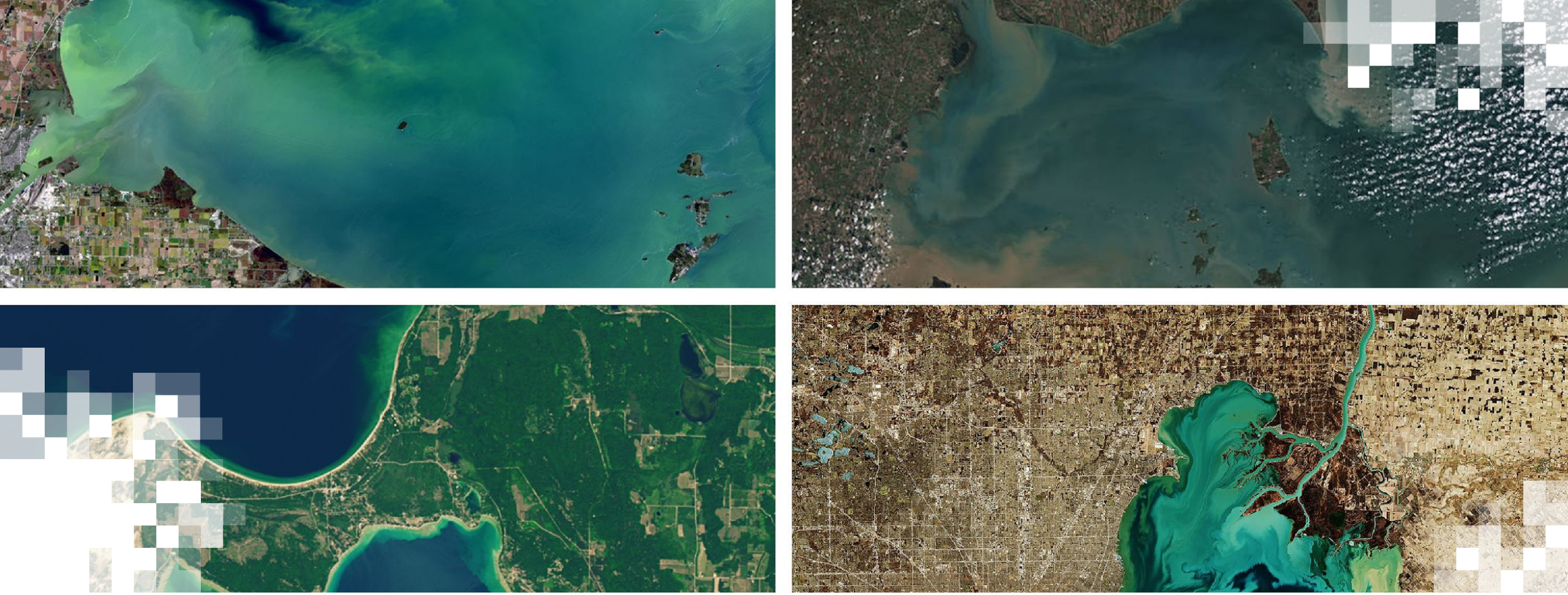
Lehmann, M.K., Gurlin, D., Pahlevan, N. *et al.* GLORIA - A globally representative hyperspectral *in situ* dataset for optical sensing of water quality. *Sci Data* **10**, 100 (2023). https://doi.org/10.1038/s41597-023-01973-y

In Situ Water Sample Measurements for GLORIA

- While limited to ~450 water bodies around the world, these data are open-source, well organized and distributed with detailed information.
- We will use these *in situ* water sample analysis data along with satellite remote sensing data to learn how to develop algorithm for WQ.
- The data are available in a .csv file and can be downloaded from: https://doi.org/10.1594/PANGAEA.948492



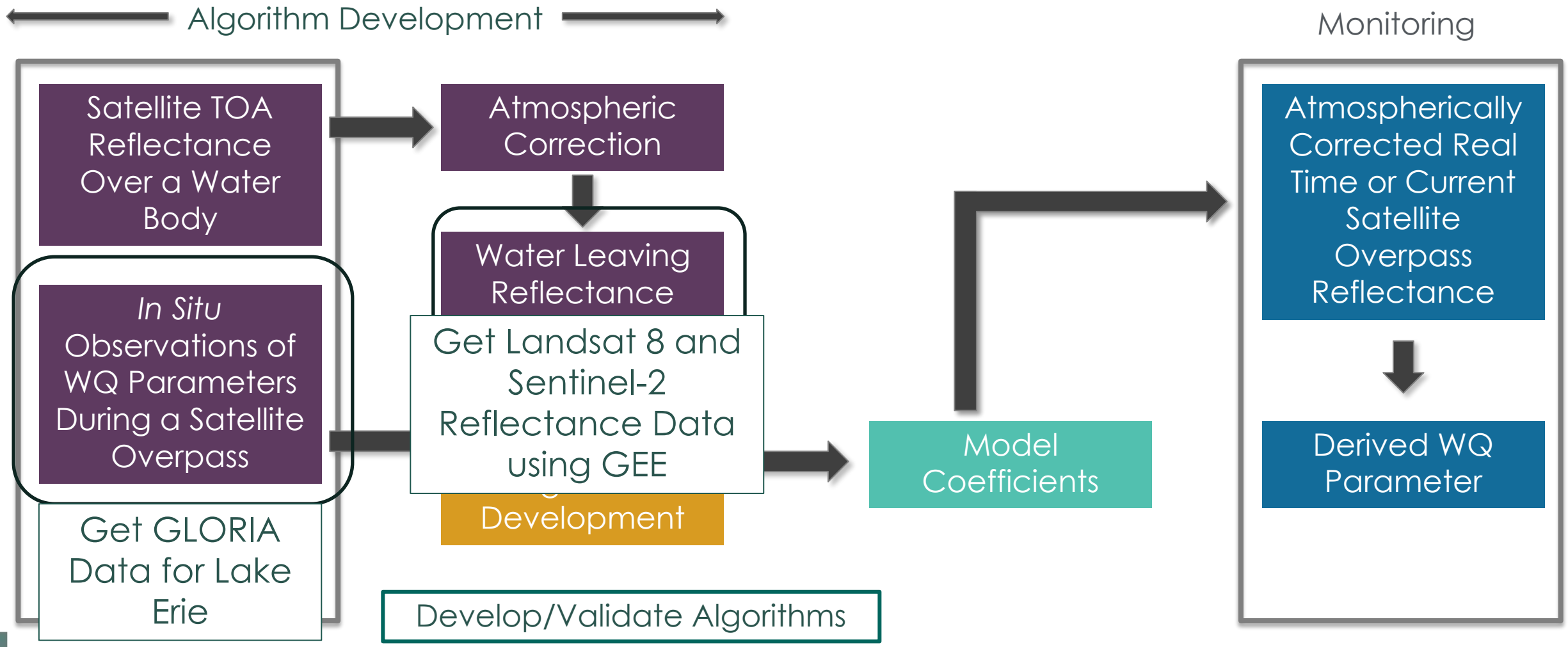
Lehmann, M.K., Gurlin, D., Pahlevan, N. *et al.* GLORIA - A globally representative hyperspectral *in situ* dataset for optical sensing of water quality. *Sci Data* **10**, 100 (2023). https://doi.org/10.1038/s41597-023-01973-y

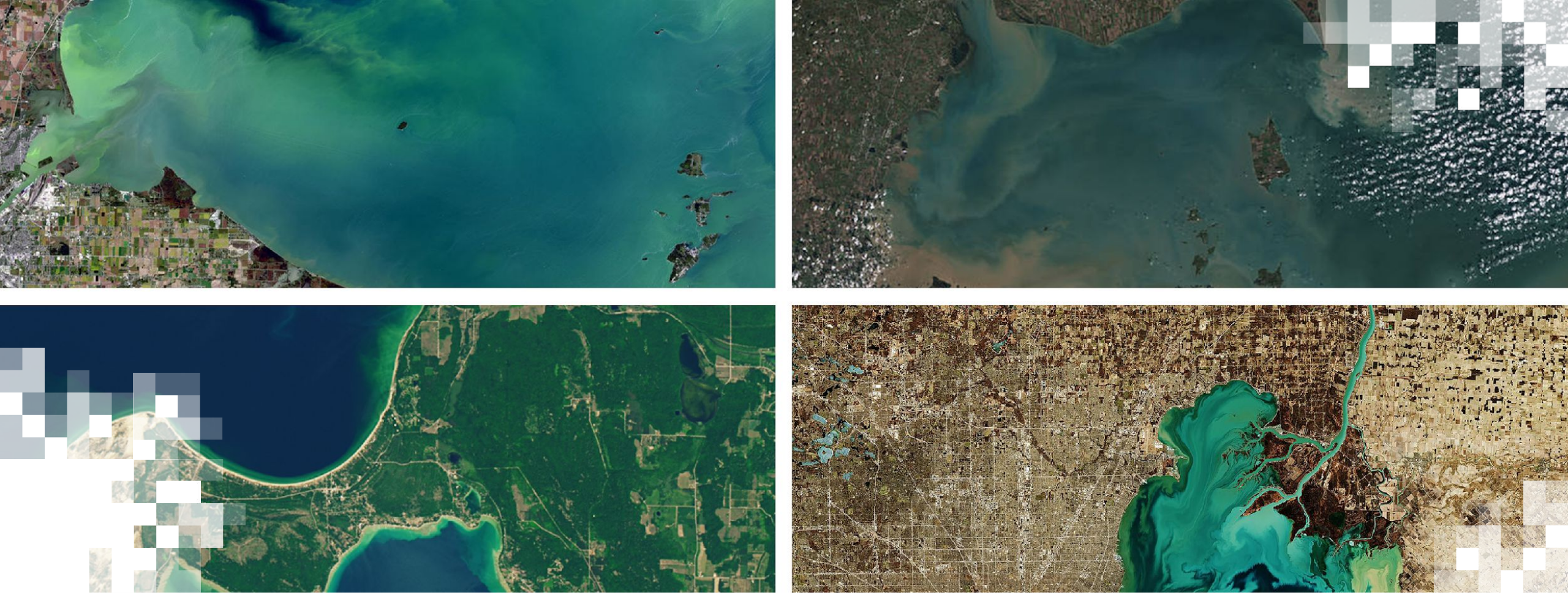


Case Study:
Acquiring *In Situ* and Satellite Data for Lake Erie

Water Quality Parameters from Remote Sensing Observations

Quantitative Technique

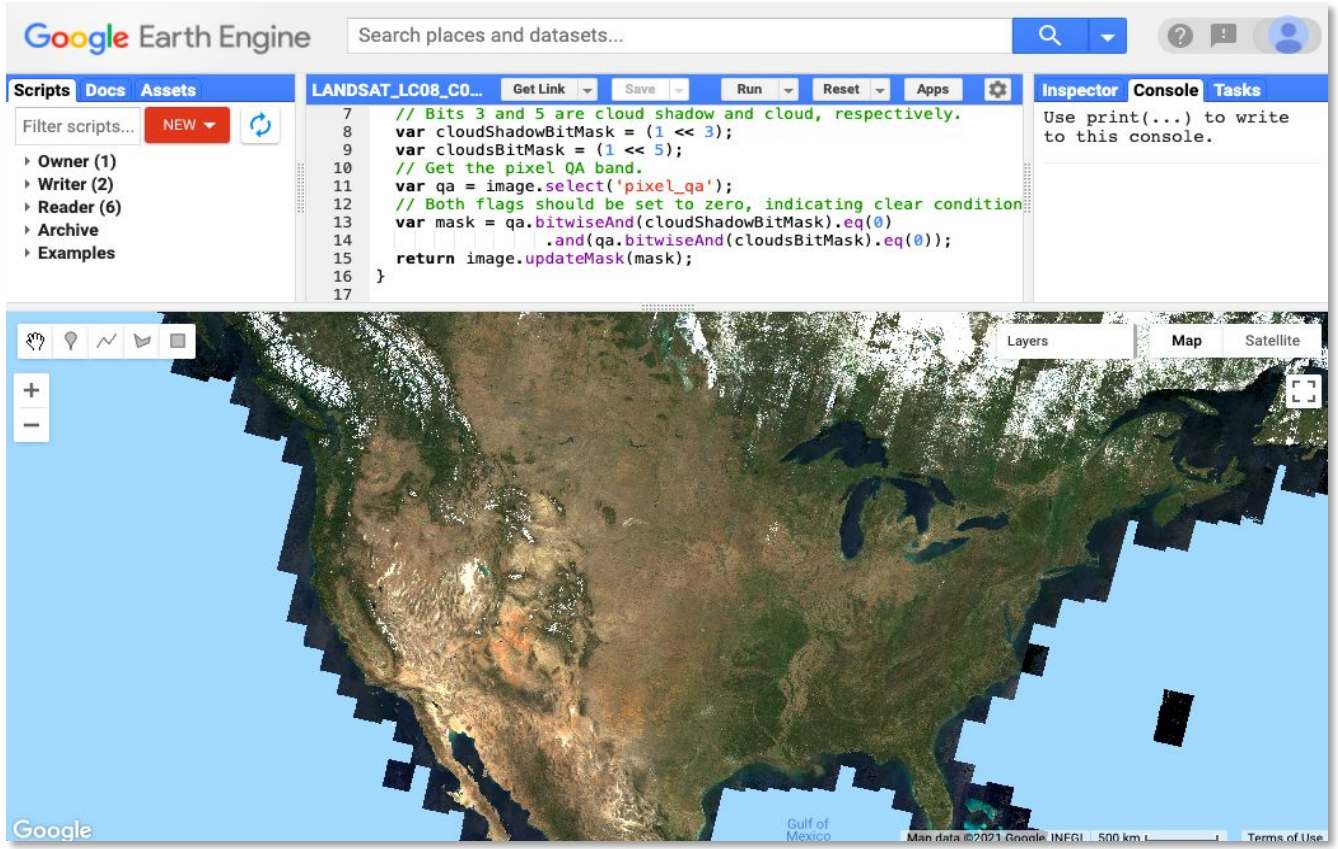




Introduction to GEE

Cloud-Based Raster Computing for Remote Sensing Analysis

- A catalog of publicly available datasets
- Removes barriers and limitations related to data hosting and storage
- GEE is free for scientists, researchers, and developers



Google Earth Engine code editor interface using the JavaScript API, displaying Landsat 8 surface reflectance true color imagery for the U.S.
Credit: Google Earth Engine Developers

The Google Earth Engine Platform

- Google Earth Engine takes advantage of cloud computing capabilities to provide users with a single place for **accessing satellite data, applying remote sensing methodologies, and displaying analysis results**.
- GEE's application programming interface (API) allows users to easily use algorithms for various applications (e.g., WQ monitoring, landcover classification, weather and climate analysis).

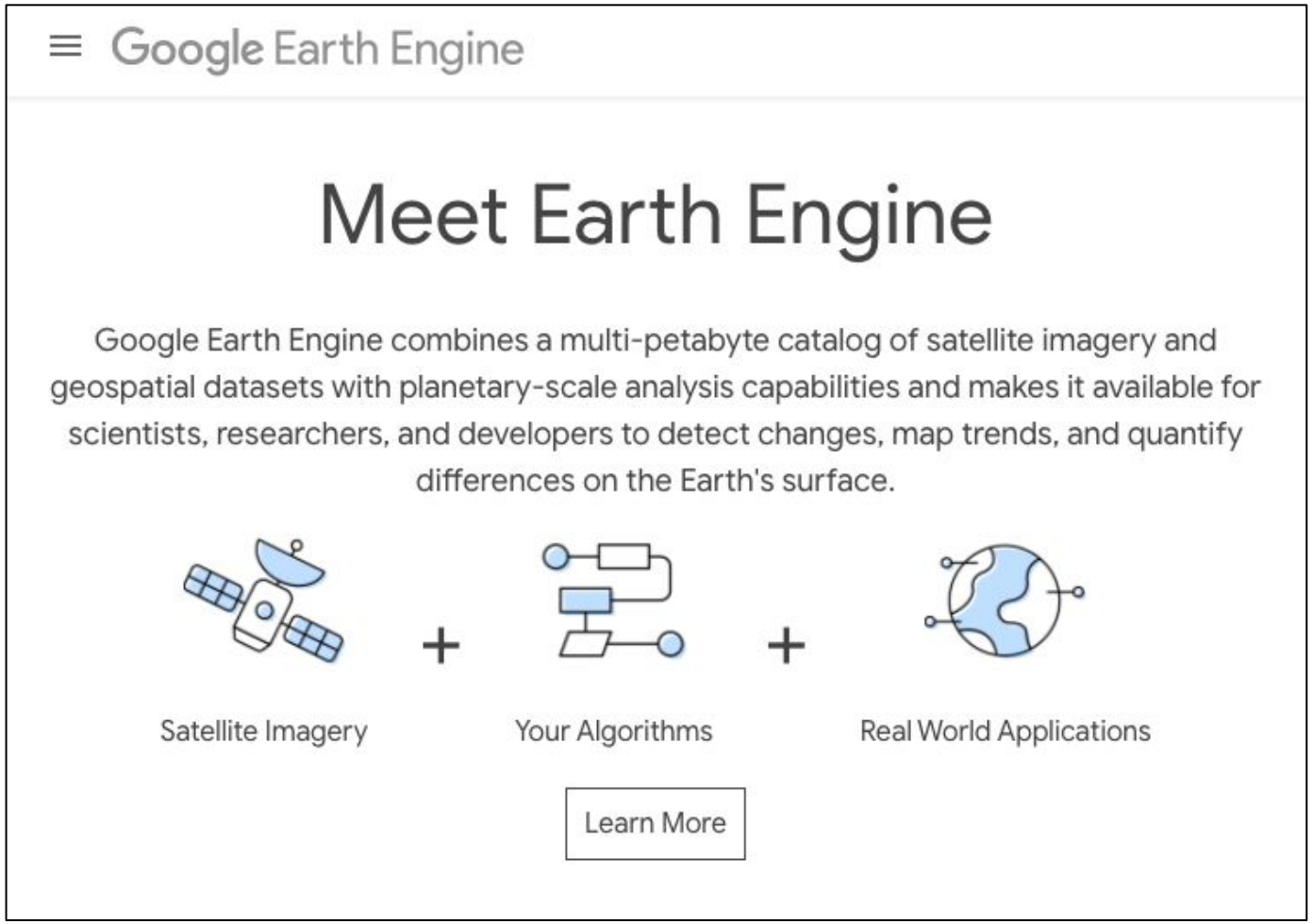
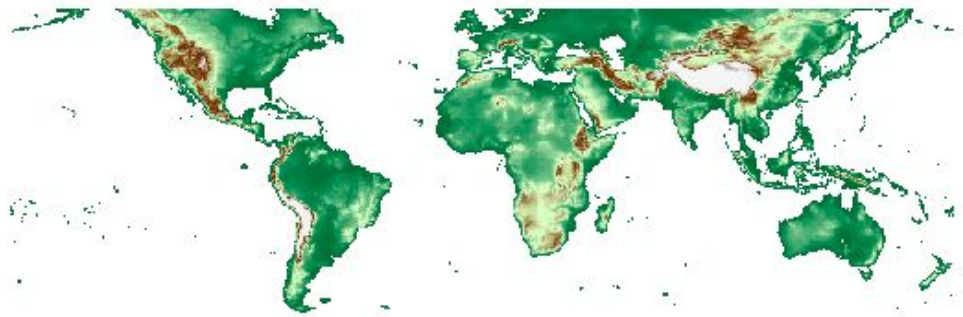


Image Credit: Google Earth Engine

Application Programming Interface (API)

- The Earth Engine JavaScript API is currently the most widely used method of working with GEE.
- A Python API through Google Colaboratory (Colab) is also available for those interested in using Python.
  - This is a bit more complicated than working directly in the GEE code editor with JavaScript.

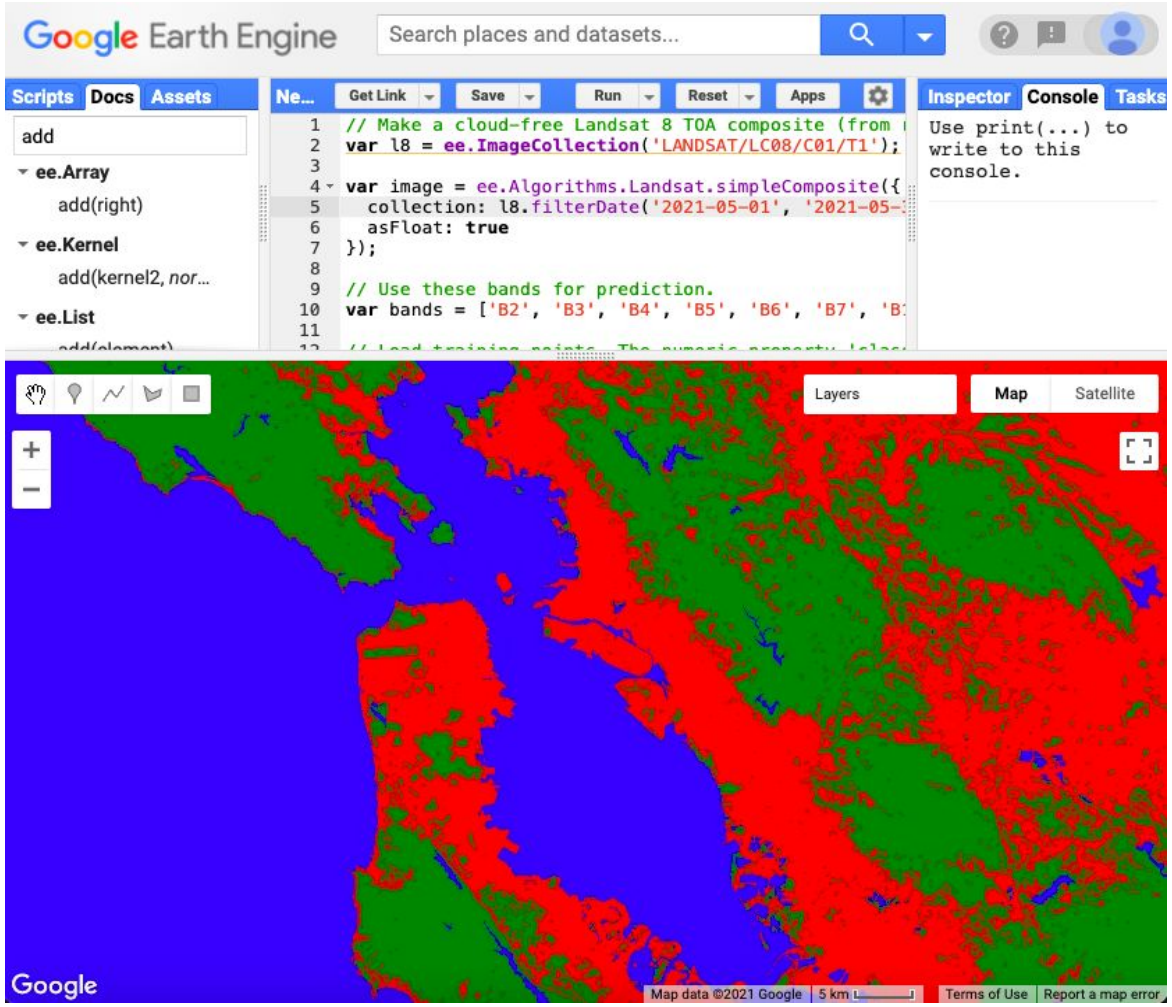
```
# Import the Image function from the IPython.display module.
from IPython.display import Image

# Display a thumbnail of global elevation.
Image(url = dem.updateMask(dem.gt(0))
  .getThumbURL({'min': 0, 'max': 4000, 'dimensions': 512,
                'palette': ['006633', 'E5FFCC', '662A00', 'D8D8D8', 'F5F5F5']}))
```



Google Colab notebook using a coded section to display elevation in an output cell. Credit: Google Colab

Google Earth Engine Functionality

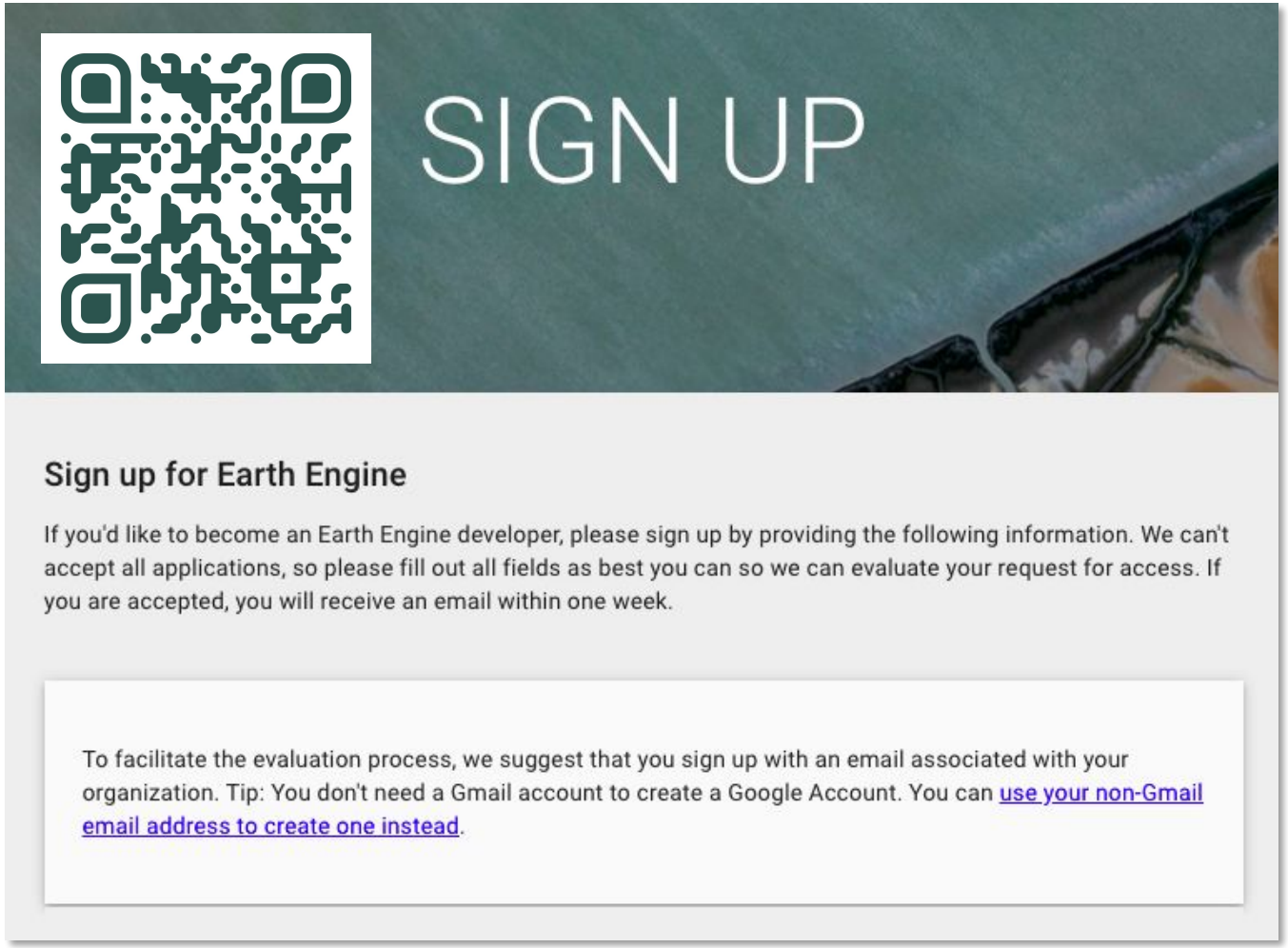
- Uses of GEE for satellite imagery analysis include:
  - Automation of data processing and display
  - Near real-time monitoring (limited by the availability of data in the catalog)
  - Machine learning algorithm application
  - Graphical User Interface implementation

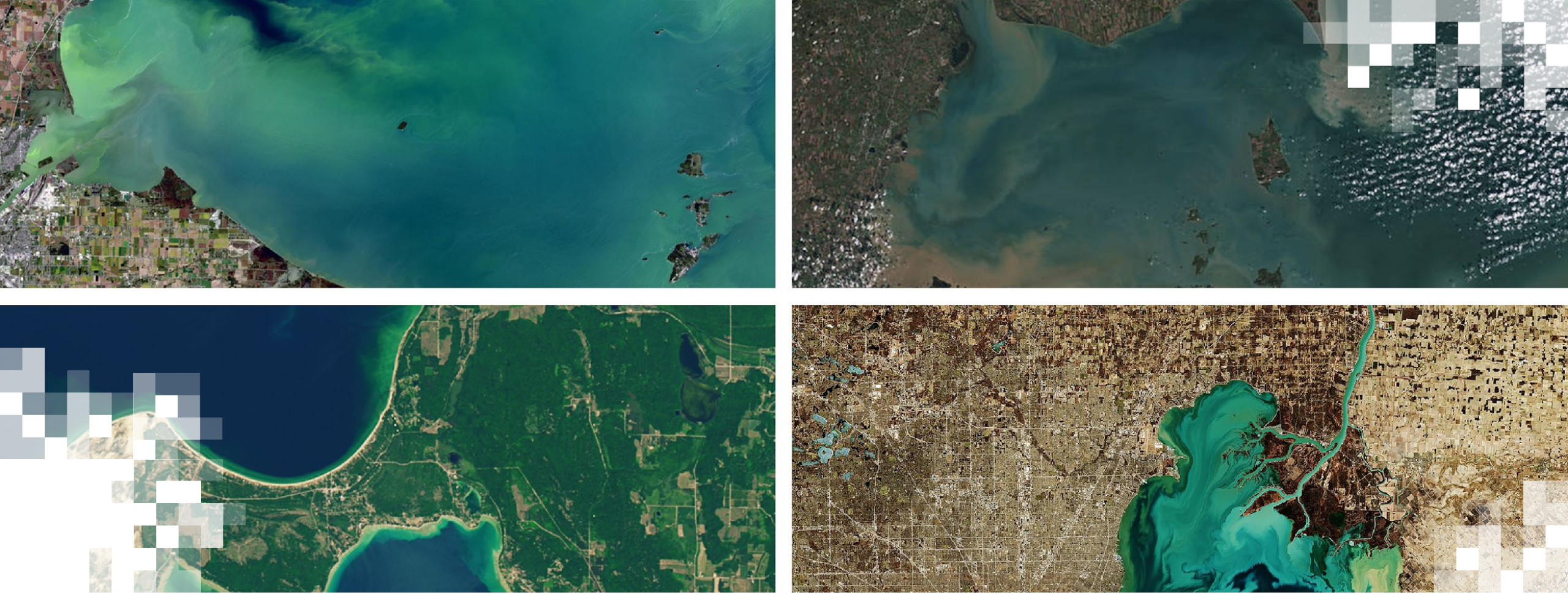


Simple Classification and Regression Trees (CART) classifier implemented in the GEE API to identify three classes urban, forest, and water in the San Francisco Bay Area for May 2021 using Landsat 8 imagery.
Credit: Google Earth Engine Developers

Google Earth Engine Account Reminder

- Make sure you sign up for a Google Earth Engine account as soon as possible (if you haven't already) using the link below:
  - https://signup.earthengine.google.com/#!/
  - A Gmail address is not required. It is recommended that you use your work/institutional email.



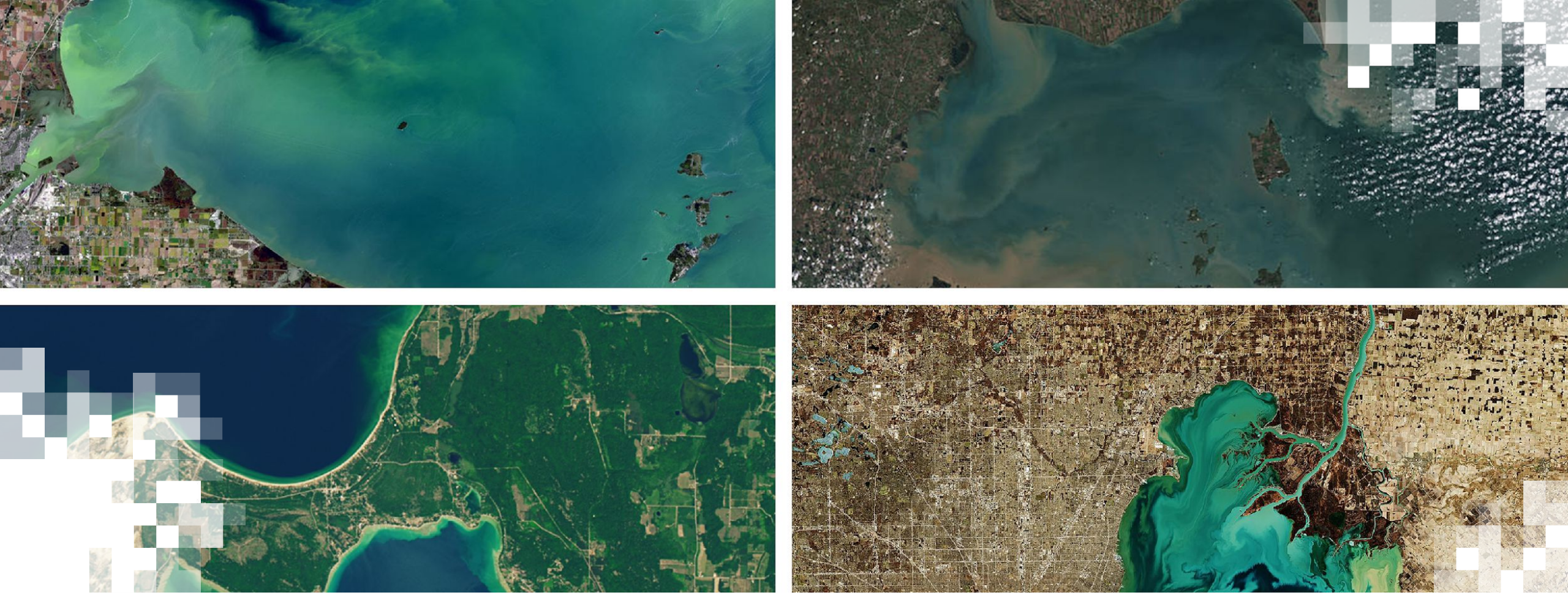


Demonstration:
Access GLORIA Data

About GLORIA Data

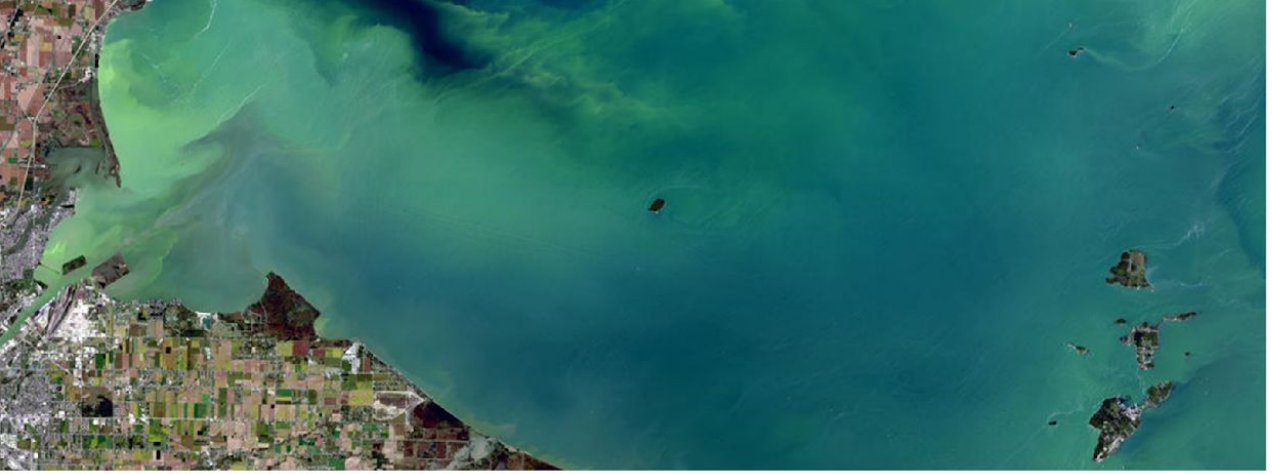
- Data Descriptor: https://www.nature.com/articles/s41597-023-01973-y
- Data Access: https://doi.org/10.1594/PANGAEA.948492

Acknowledgment: Dr. Nima Pahlevan, NASA Ocean Biology and Biogeochemistry, Remote Sensing of Water Quality Group, co-led the GLORIA dataset and shared this information.



Demonstration:

Access Sentinel-2, Landsat 8, and Sentinel-3 Reflectance Data using GEE




Summary

Summary

- Described state-of-the art, high spatial and spectral resolution observations from Landsat 8, Sentinel-2, and Sentinel-3 for water quality remote sensing.
- Described selected open source, *in situ* measurements of water quality parameters including from USGS Water Dashboard and Lake Water Quality Portal, National Harmonized Chlorophyll Data, UNEP GEMStat, and GLORIA.
- Explored and downloaded GLORIA *in situ* measurements of chlorophyll-a concentration, TSS, and Secchi Depth for Lake Erie.
- Searched and identified optical reflectance data from Landsat-8 and Sentinel-2 collocated with GLORIA *in situ* measurements for lake Erie using GEE.

Looking Ahead to Part 2

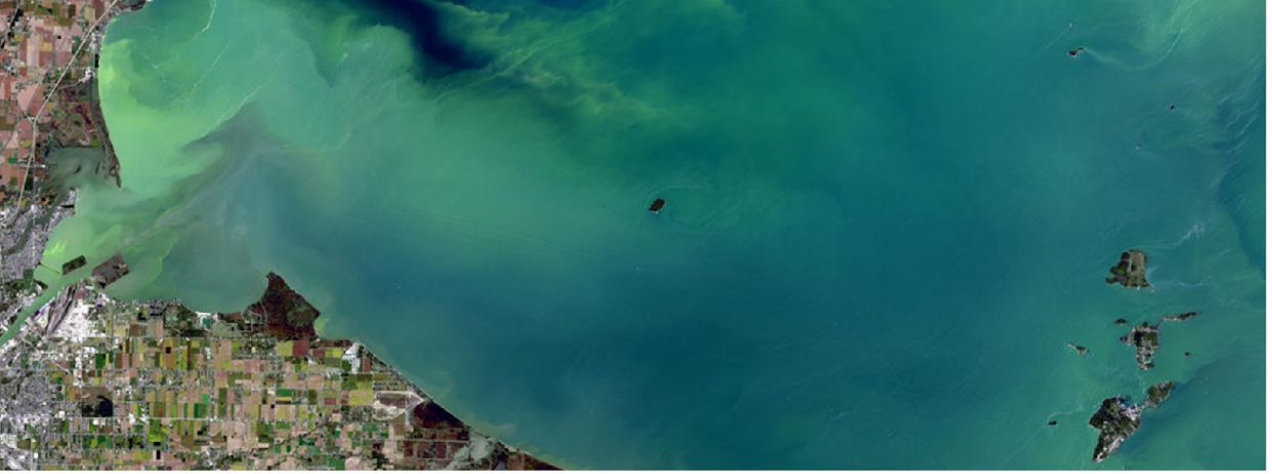
Part 2 will focus on:

- Getting familiar with Cyanobacteria Assessment Network (CyAN) and CyAN Web-app for monitoring toxic cyanobacteria in lakes.

Homework and Certificates

- **Homework:**
  - One homework assignment
  - Opens on July 25, 2023
  - Access from the training webpage
  - Answers must be submitted via Google Forms
  - **Due by August 8, 2023**
  - There will be hands-on exercises in all sessions. **You will be instructed to submit results of these exercises to a Google Drive folder.**

- **Certificate of Completion:**
  - Attend all three live webinars (attendance is recorded automatically)
  - Complete the homework assignment by the deadline
  - You will receive a certificate via email approximately two months after completion of the course.



Exercise

Contact Information

Trainers:

- Amita Mehta
  - Amita.v.mehta@nasa.gov
- Sean McCartney
  - Sean.mccartney@nasa.gov

- ARSET Website
- Follow us on Twitter!
  - @NASAARSET
- ARSET YouTube

Visit our Sister Programs:

- DEVELOP
- SERVIR

Questions and Answers

- Please put your questions in the Questions box.
- We will try to get to all of the questions during the Q&A session.
- Any remaining questions will be answered in the Q&A document, which will be posted to the training website about a week after the training.


APPLIED REMOTE SENSING TRAINING PROGRAM
TRAIN - EMPOWER - ADVANCE

Thank You!