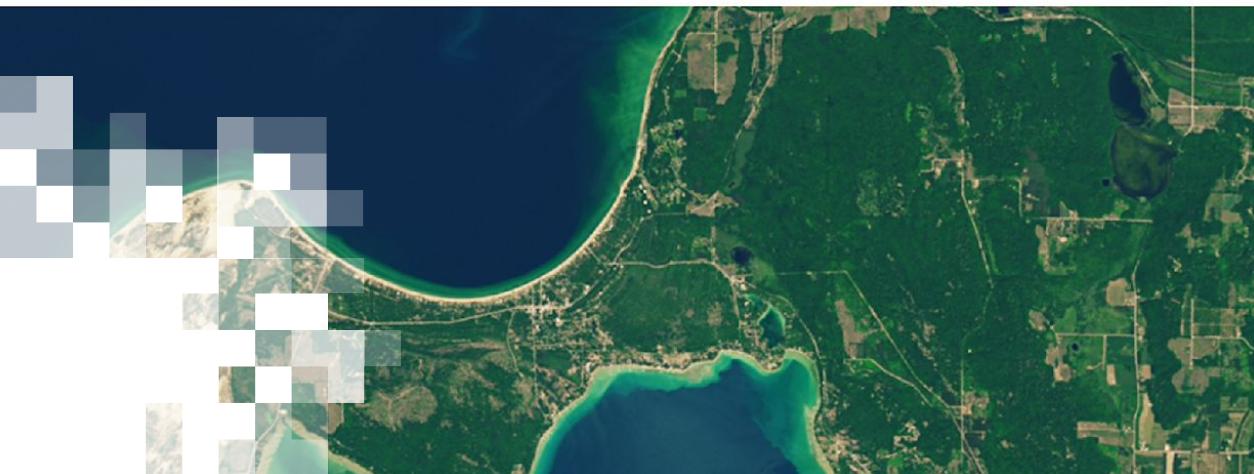


# Monitoring Water Quality of Inland Lakes using Remote Sensing

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



ECOLOGICAL CONSERVATION



HEALTH & AIR QUALITY



WATER RESOURCES

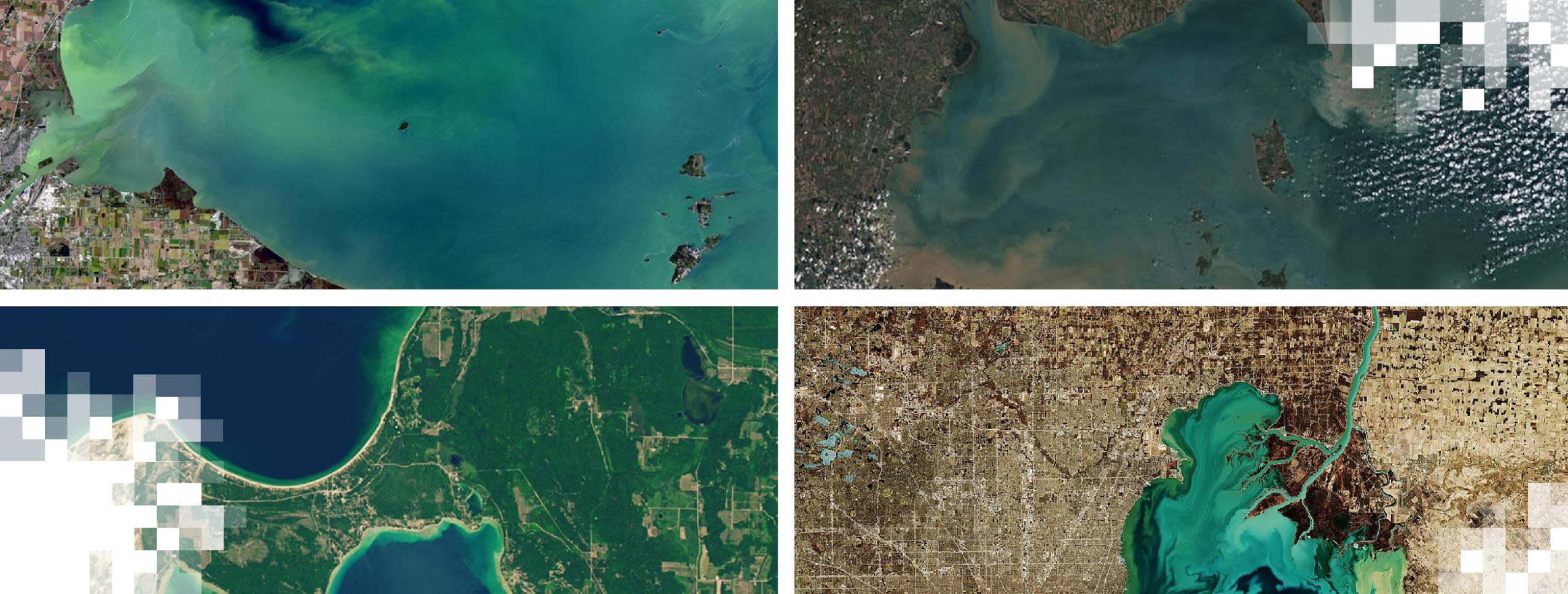


# About ARSET Trainings



- 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.

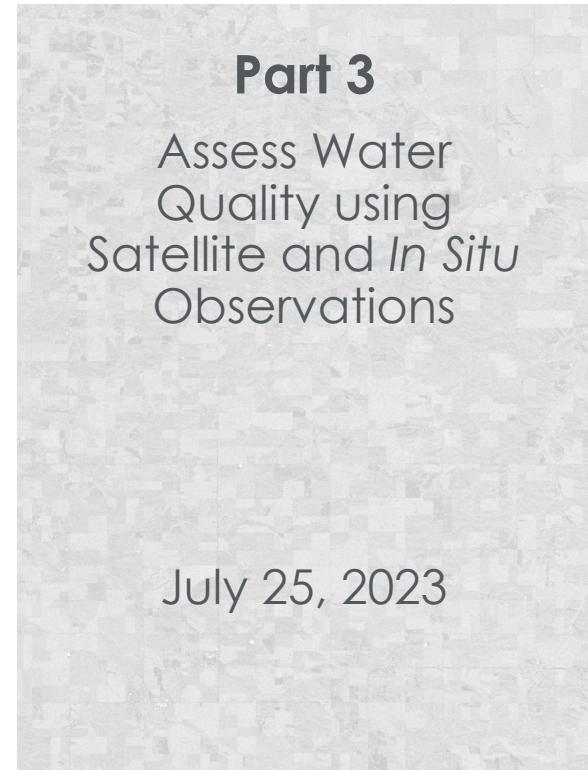
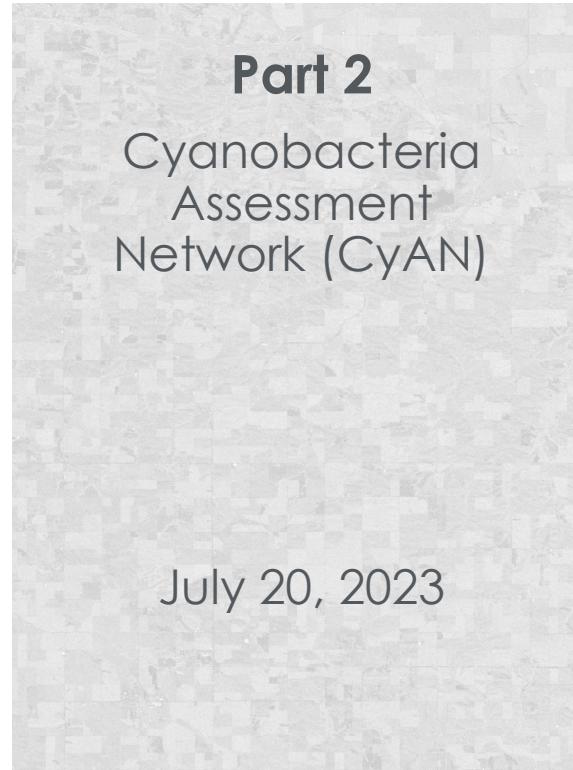


# Prerequisites

- 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



## 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](#)

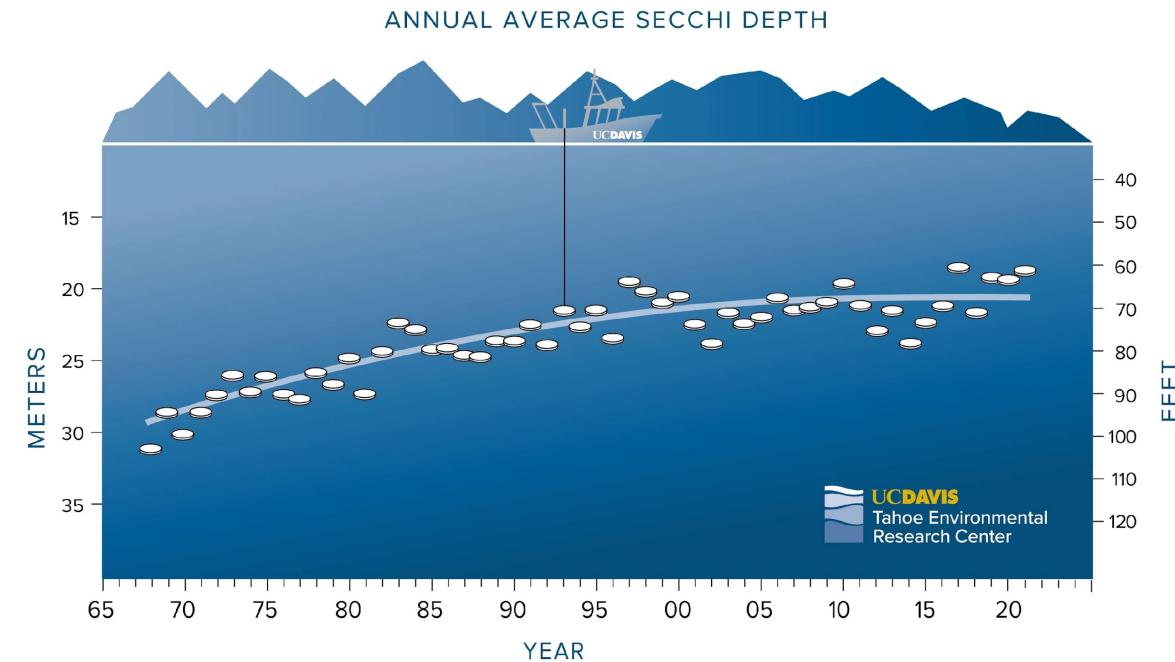


# Factors Affecting Water Quality of Freshwater Systems



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



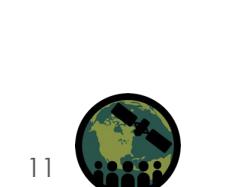
[Lake Tahoe Water Clarity Report](#)



# 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.

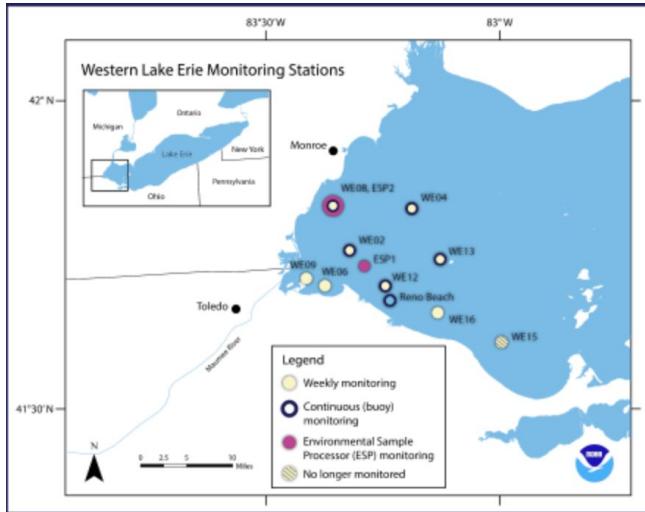
The screenshot shows a web browser displaying the URL [waterqualitydata.us/portal\\_userguide/](http://waterqualitydata.us/portal_userguide/). The page is titled "WATER QUALITY PORTAL USER GUIDE". At the top right, there are links for "Home", "Explore WQP Sites", and "Help & About". Under "Explore WQP Sites", three categories are listed: "NWIS", "STEWARDS", and "WQX". The main content area features a large heading "WQP User Guide" and a link "Download Water Quality Exchange (WQX) domain value lists". Below these, there are sections for "Introduction", "Available Databases:", and "Explanation of portal search parameters". The page has a dark blue header and footer, with a watermark of the National Water Quality Monitoring Council logo in the center.

## 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](#)

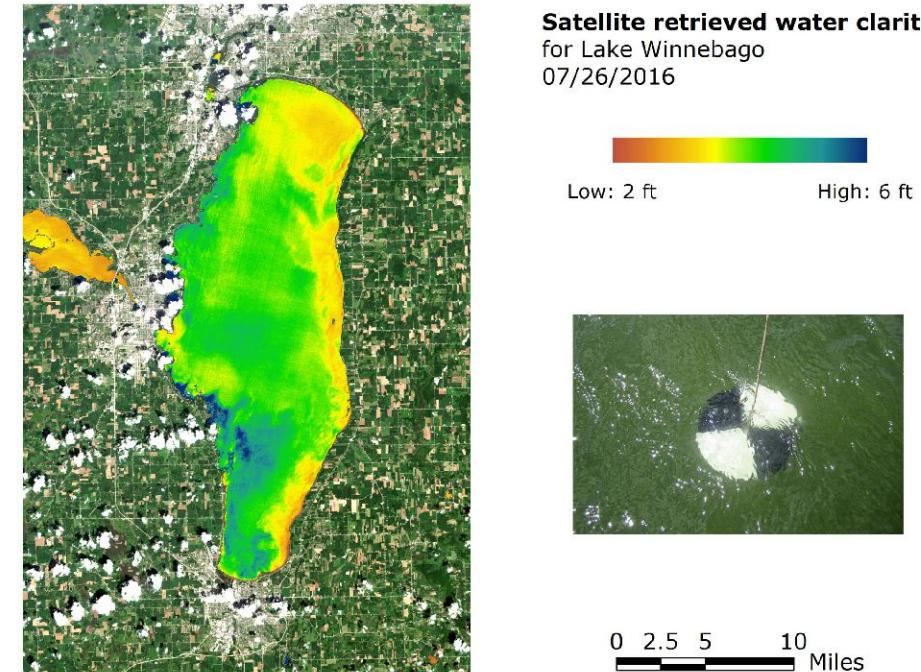


[From Landsat: A bloom of freshwater cyanobacteria is the source of the vivid green color in Western Lake Erie](#)



# Some Water Quality Indicators Satellites Can Observe

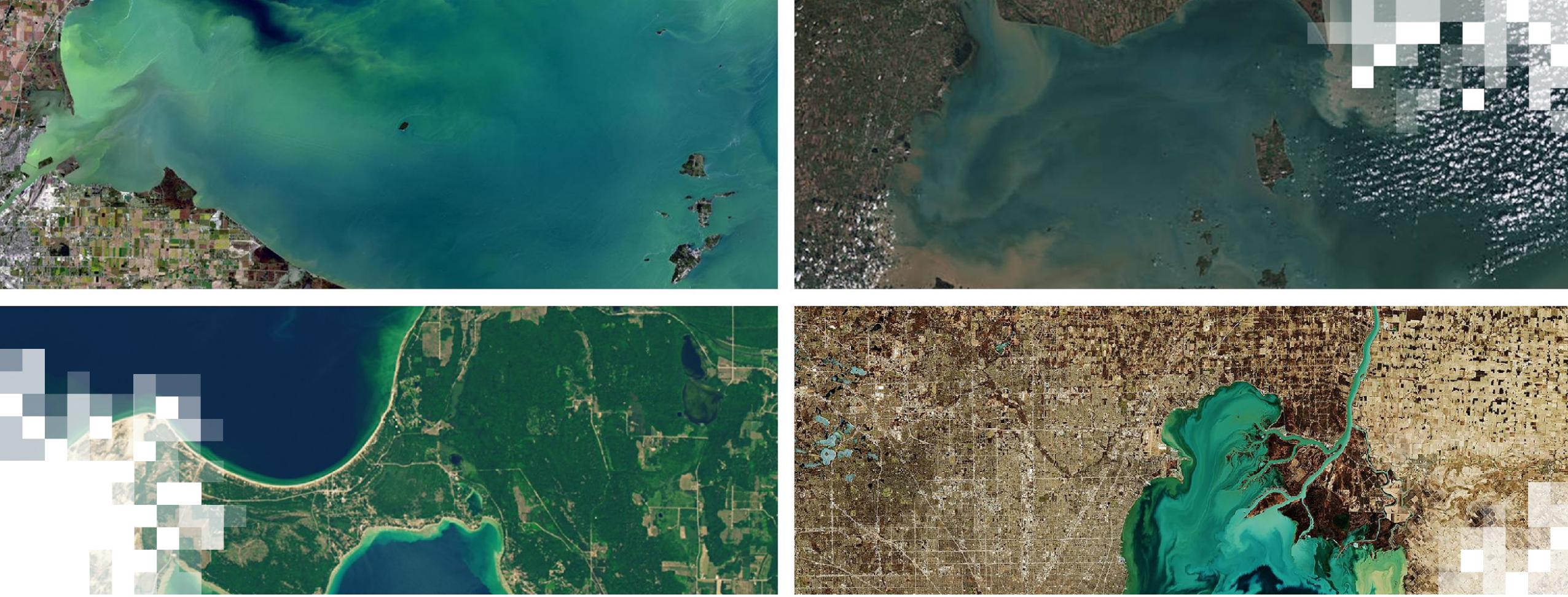
- Colored Dissolved Organic Matter (CDOM)
- Chlorophyll-a (Phytoplankton)
- Total Suspended Solids (TSS)
- Fluorescence Line Height
- Euphotic Depth
- Diffuse Attenuation of Light
- Sea Surface Temperature (SST)
- Salinity



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



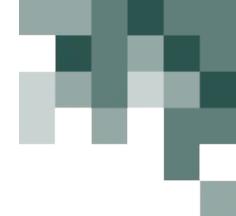
# Part 1 Objectives

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

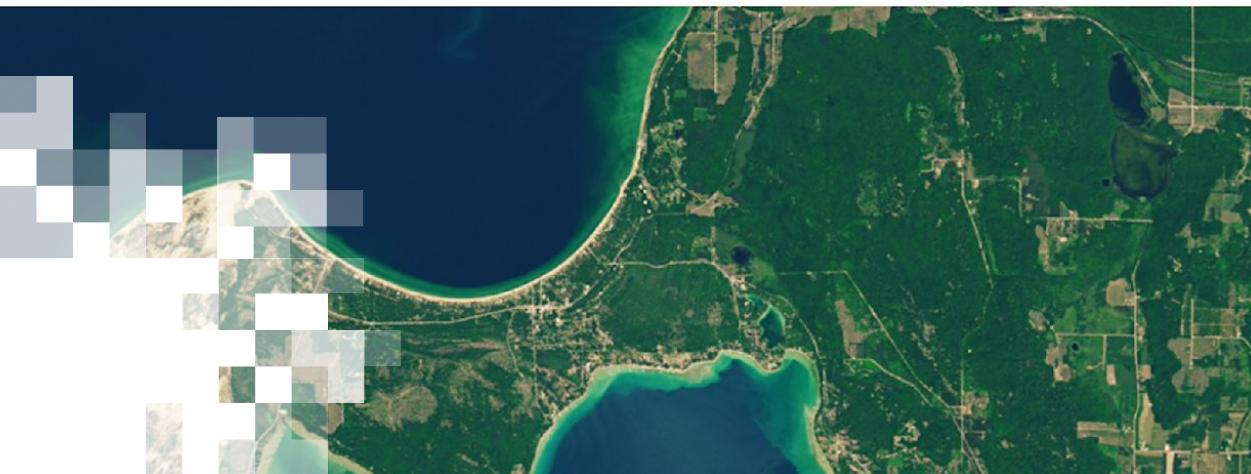


# How to Ask Questions



- 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

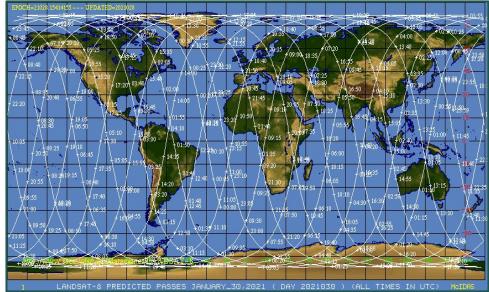
Satellites	Sensors	Resolution
Landsat 8 & 9	Operational Land Imager (OLI & OLI2)	185 km Swath; 15 m, 30 m, 60 m; 16-Day Revisit
Terra & Aqua	MODerate Resolution Imaging Spectroradiometer (MODIS)	2330 km Swath; 250 m, 500 m, 1 km; 1–2-Day Revisit
SNPP <sup>1</sup> and JPSS <sup>2</sup>	Visible Infrared 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

<sup>1</sup>SNPP: Suomi National Polar-orbiting Partnership

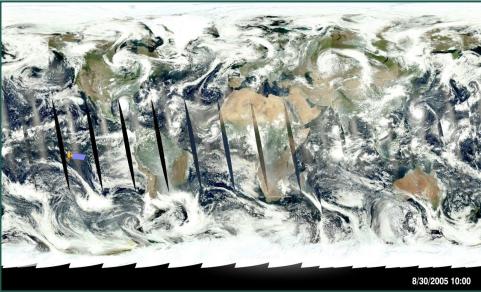
<sup>2</sup>JPSS: Joint Polar Satellite System



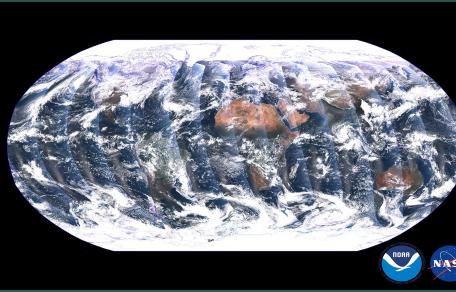
# Current Satellite Missions for Water Quality Monitoring



Landsat 8



Aqua MODIS



JPSS VIIRS



Sentinel-2 MSI



Sentinel-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

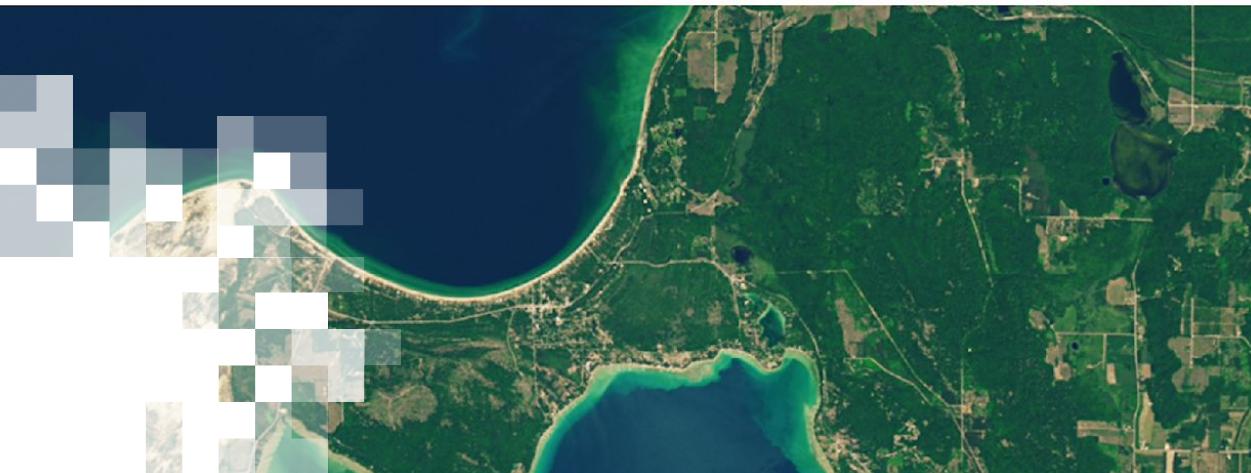
- Landsat 9 (9/27/2021 – Present)
- Landsat 8 (2/1/2013 – Present)
- Terra (12/18/1999 – Present)
- Aqua (5/4/2002 – Present)
- SNPP (11/21/2011 – Present)
- JPSS (11/18/2017 – Present)
- Sentinel-2A (6/23/2015 – Present)
- Sentinel-2B (3/7/2017 – Present)
- Sentinel-3A (2/16/2016 – Present)
- Sentinel-3B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

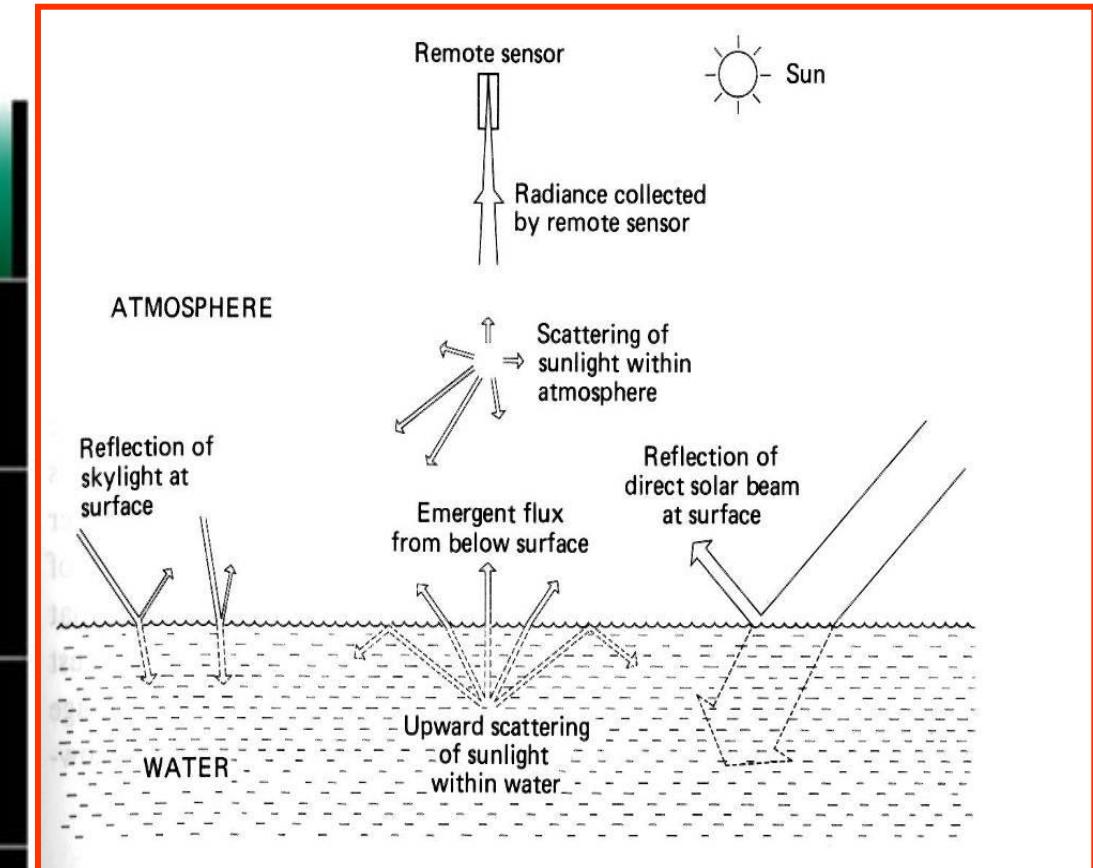
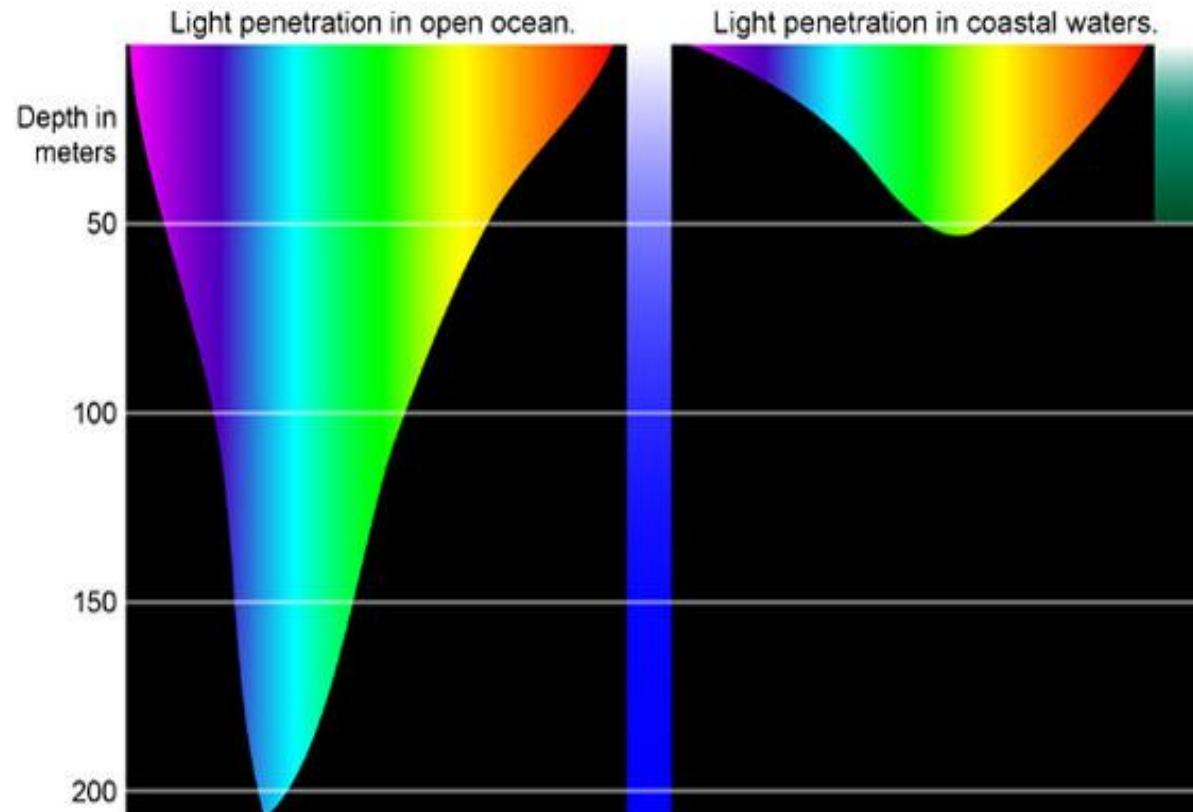




# Remote Sensing of WQ Parameters

# 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).

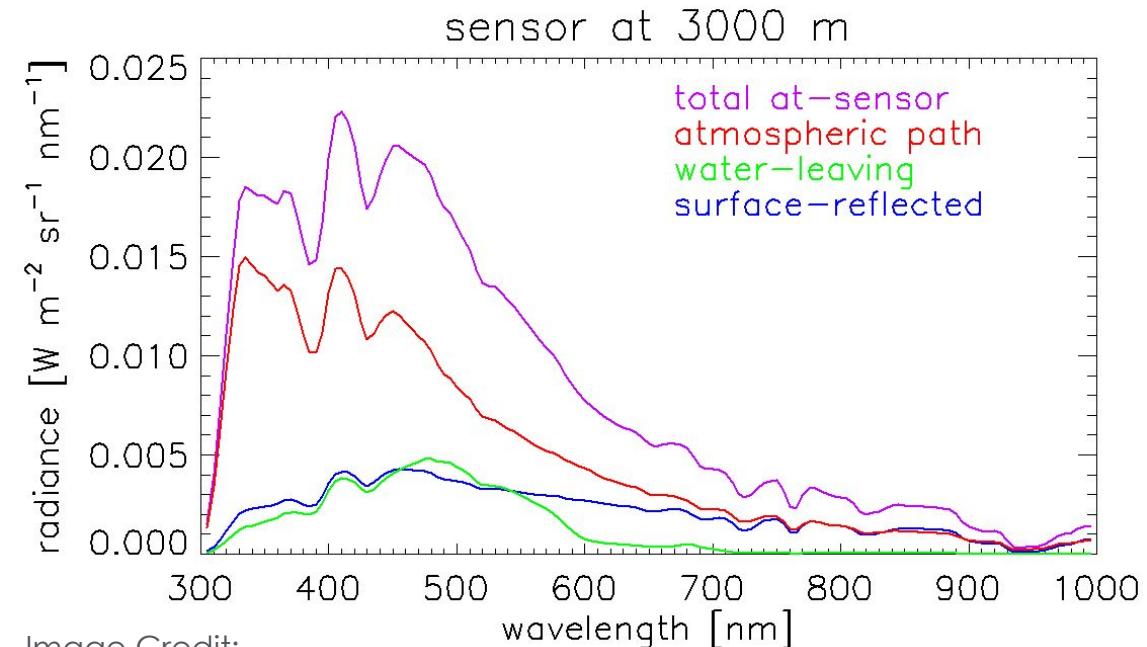


Image Credit:  
[http://www.oceanopticsbook.info/view/remote\\_sensing/the\\_atmospheric\\_correction\\_problem](http://www.oceanopticsbook.info/view/remote_sensing/the_atmospheric_correction_problem)

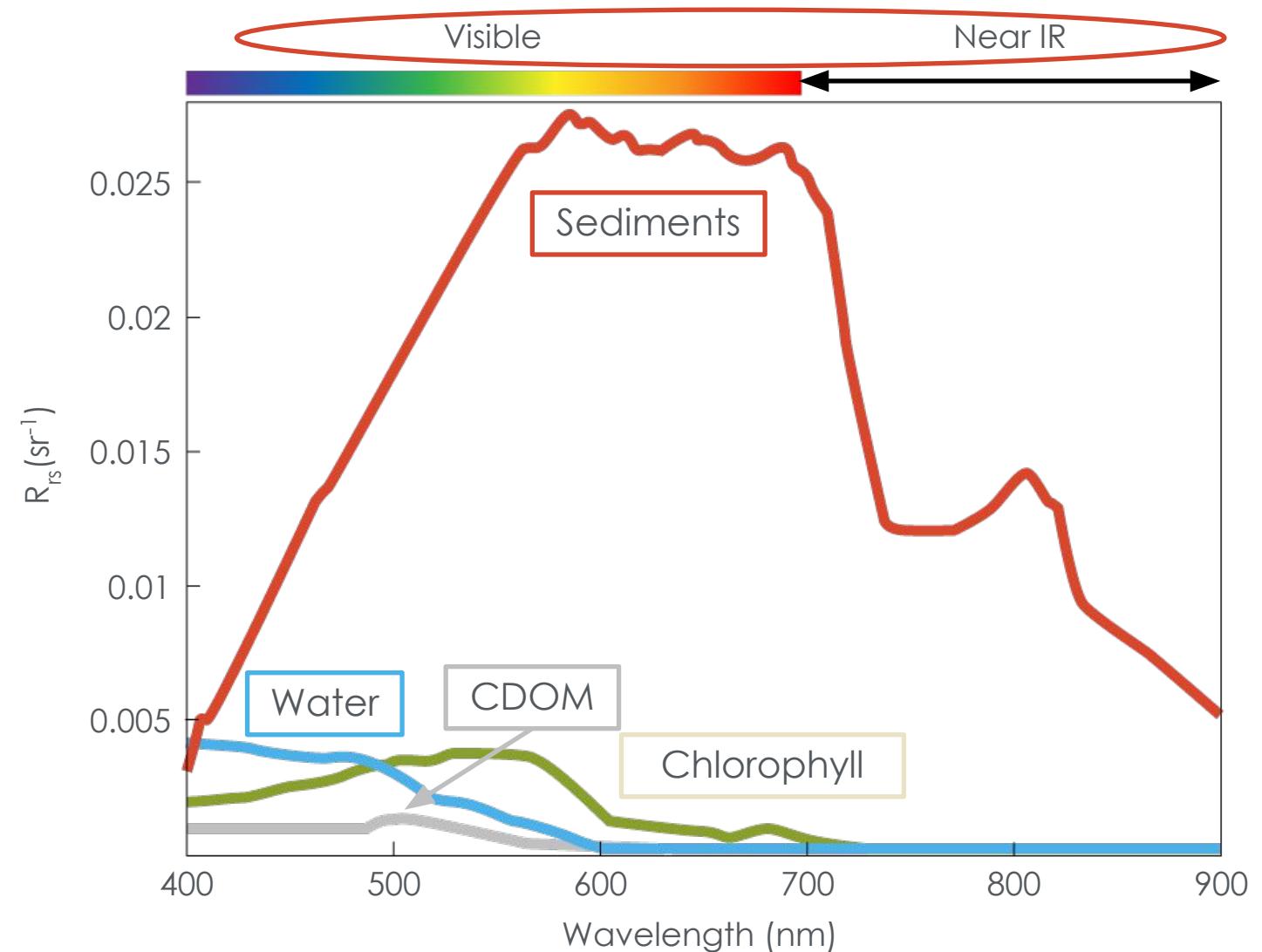


# Inherent Optical Properties (IOPs) and the ‘Color’ of Water

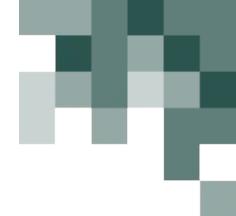


## Inherent Optical Properties:

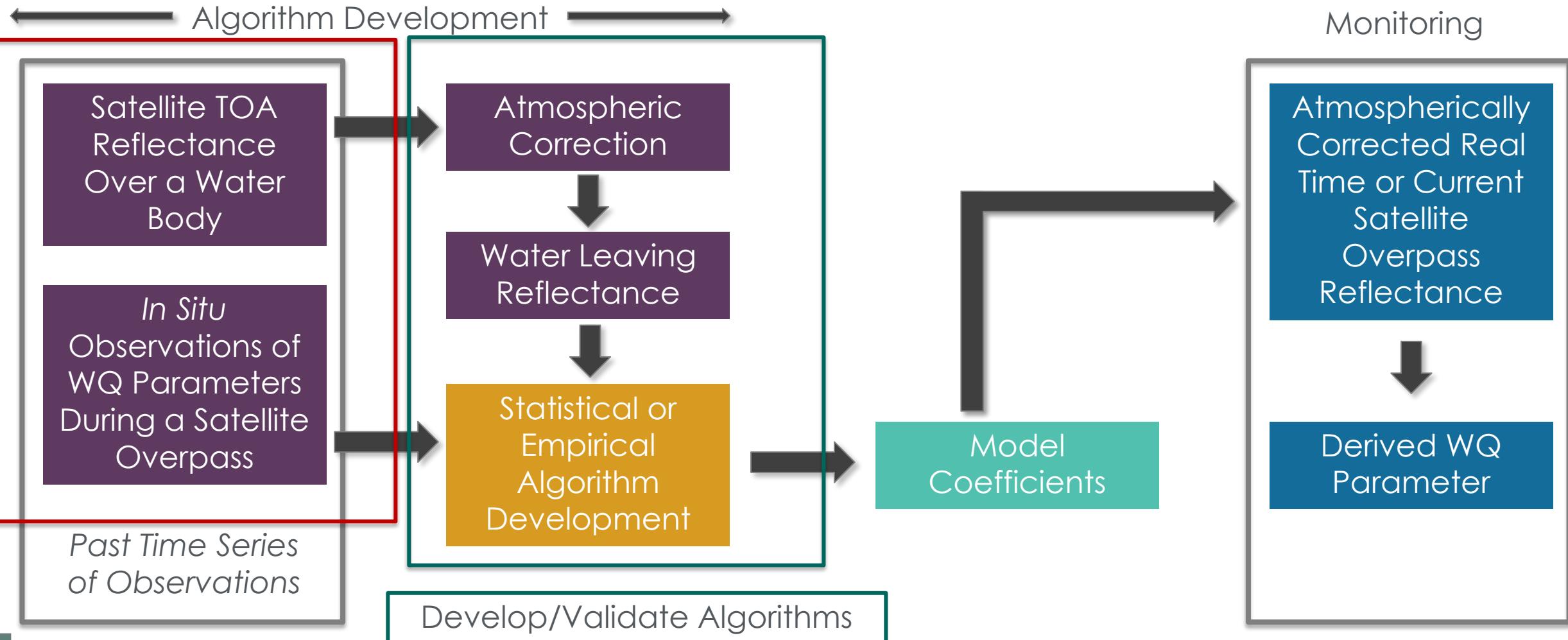
- Absorption by...
  - Phytoplankton (ph)
  - Non-Algal Particles (nap)
  - Colored Dissolved Organic Matter (CDOM)
  - Water (w)
- Scattering in forward (f) and backward (b) directions



# Water Quality Parameters from Remote Sensing Observations



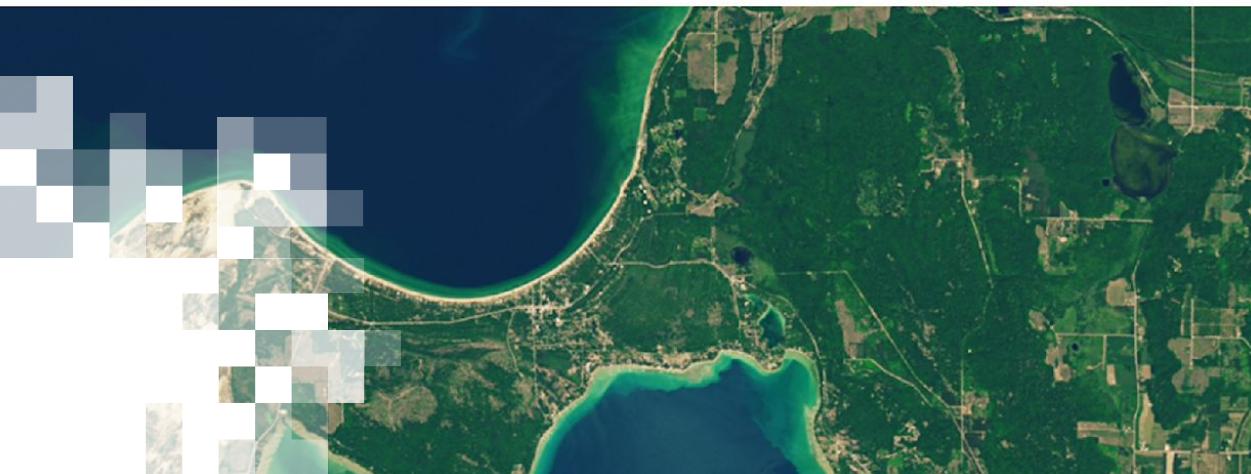
## Quantitative Technique



# 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



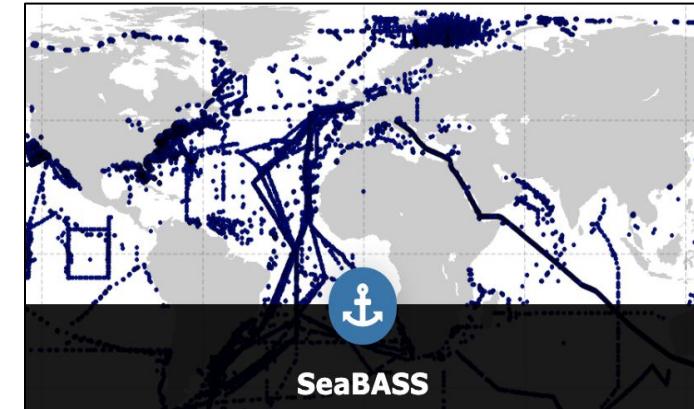


## Description of Selected *In Situ* WQ Data

# SeaWiFS Bio-optical Archive and Storage System (SeaBASS)

[https://seabass.gsfc.nasa.gov/wiki/System\\_Description](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 coastal and open oceans.

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

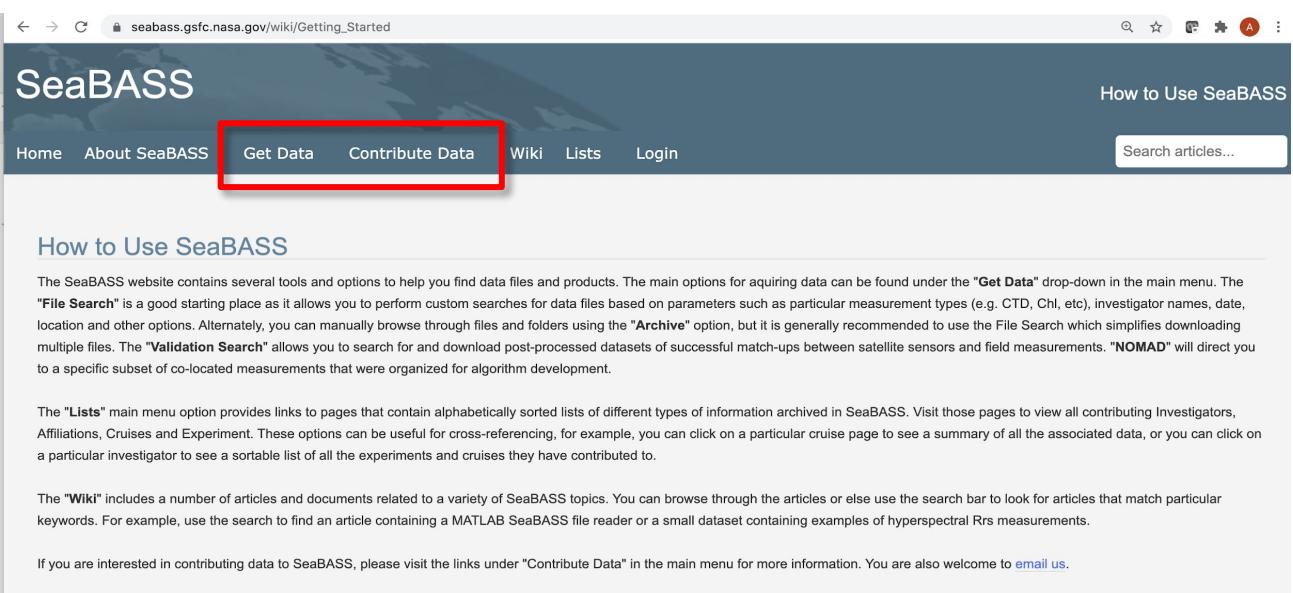
NASA ARSET – Monitoring Water Quality of Inland Lakes using Remote Sensing



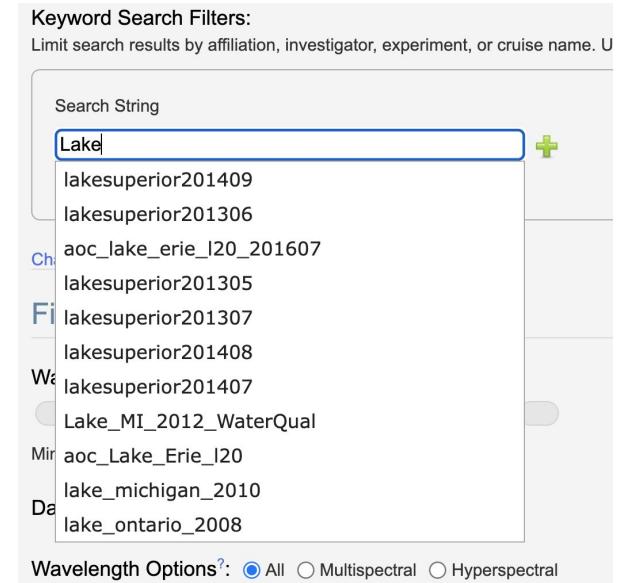
# SeaBASS Data

[https://seabass.gsfc.nasa.gov/wiki/Getting Started](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.



The screenshot shows the SeaBASS website homepage. At the top, there is a navigation bar with links for Home, About SeaBASS, Get Data (which is highlighted with a red box), Contribute Data, Wiki, Lists, and Login. Below the navigation bar, there is a search bar labeled "Search articles...". The main content area is titled "How to Use SeaBASS". It contains several paragraphs of text explaining the various tools available on the site, such as the File Search, Validation Search, Lists, and Wiki. At the bottom of the page, there is a note about contributing data.



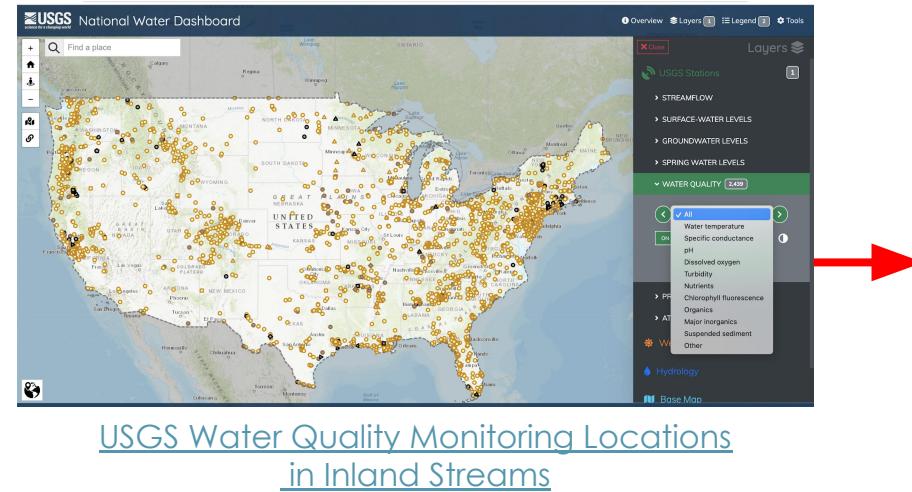
The screenshot shows the "Keyword Search Filters" interface. It includes a "Search String" input field containing the word "Lake", a "Wavelength Options" section with radio buttons for All (selected), Multispectral, and Hyperspectral, and a list of search results. The results are organized into columns for Category (e.g., Chl, Fi, Wa, Mir, Da) and include entries like "lakesuperior201409", "aoc\_lake\_erie\_l20\_201607", and "lake\_michigan\_2010".



# 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.

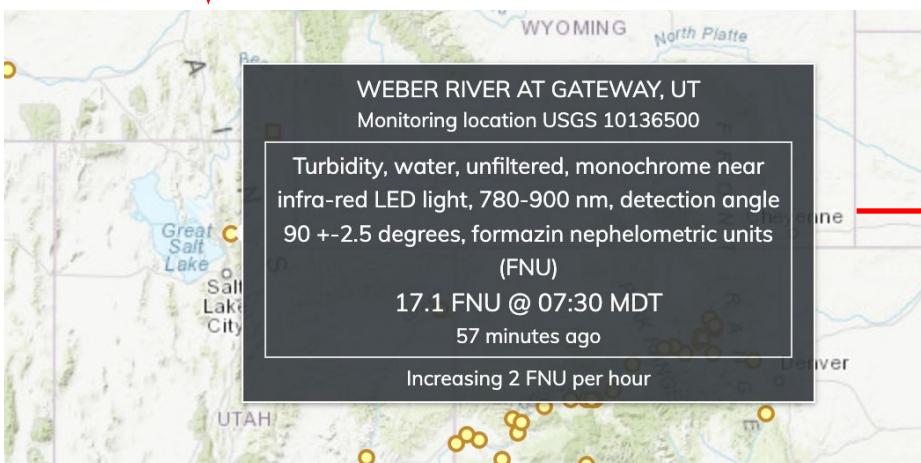
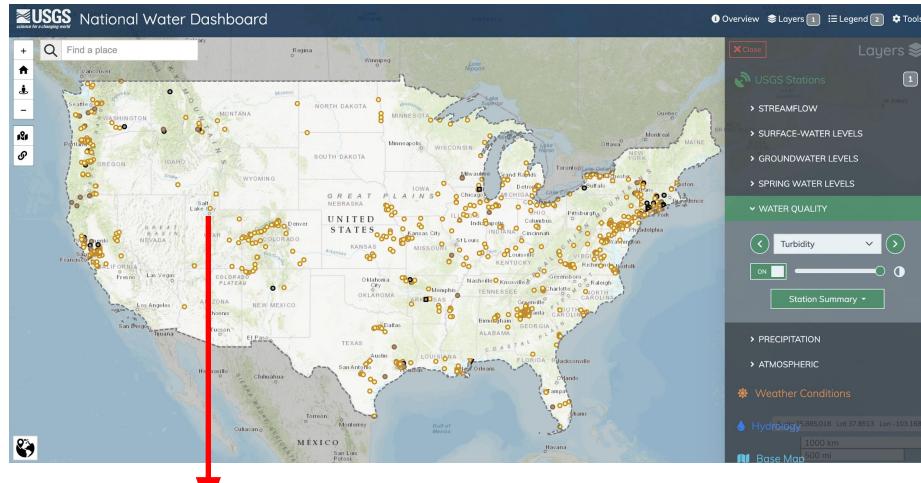


Water temperature  
Specific conductance  
pH  
Dissolved oxygen  
Turbidity  
Nutrients  
Chlorophyll fluorescence  
Organics  
Major inorganics  
Suspended sediment  
Other



# National Water Dashboard: Turbidity Measurements

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



USGS science for a changing world

Weber River At Gateway, UT  
USGS 10136500 (Surface Water, Stream)

Site page | Show plots | Data | WaterAlert | NWS forecast

Temperature, water, degrees Celsius  
0.05 @ 7:30 AM MDT 60 minutes ago

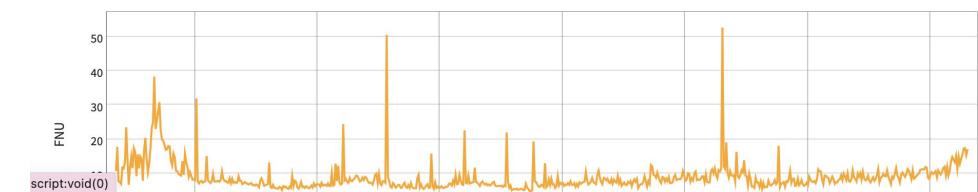
Precipitation, total, inches  
434 @ 7:30 AM MDT 60 minutes ago

Discharge, cubic feet per second  
12.21 @ 7:30 AM MDT 60 minutes ago

Gage height, feet  
530 @ 7:30 AM MDT 60 minutes ago

Specific conductance, water, unfiltered, microsiemens per centimeter at 25 degrees Celsius  
17.1 @ 7:30 AM MDT 60 minutes ago

Turbidity, water, unfiltered, monochrome near infra-red LED light, 780-900 nm, detection angle 90 +2.5 degrees, formazin nephelometric units (FNU)  
13.3 @ 7:30 AM MDT 60 minutes ago



# 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

The screenshot shows the USGS website interface for exploring lake water quality data. At the top right, there is a search bar with the placeholder "Lake Water Quality". Below the search bar, there are links for "Latest Earthquakes" and "Science". The main content area is titled "Explore Search: Lake Water Quality". On the left, there is a sidebar with filter options: "SCIENCE", "PRODUCTS", "MULTIMEDIA", "NEWS", "CONNECT", and "BY LOCATION". The "BY LOCATION" section is highlighted with a red box and has a dropdown menu with the option "-Select-". A red arrow points from the text "Select by State" down to this dropdown menu. To the right of the sidebar, there are three data release cards:

- DATA RELEASE** (September 22, 2022): Mercury Concentrations and Loads in United States and Canadian Tributaries of Lake Superior
- DATA RELEASE** (September 30, 2020): Cladophora biomass and supporting data collected in the Great Lakes, 2019
- DATA RELEASE** (October 8, 2020): Compilation of Data for Parameterization of an Ecopath Model of Lake Superior at the Beginning of the 21st Century (2001-2016)

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**



[Contact](#)

SDC Data Owner : Lower Mississippi-Gulf Water Science Center

### Water-quality and phytoplankton data for Lake ...

**Attached Files** More

Click on title to download individual files attached to this item or [download all](#) files listed below as a compressed file.

<a href="#">Download</a>	File Name	Size	Type
<a href="#">Download</a>	Water_Quality_Data_for_Lake_Pontchartrain_and_the_Western_Mississippi_Sound.xml Original FGDC Metadata	71.7 KB	application/xml
<a href="#">Download</a>	Table_1_Station_Data.txt	5.65 KB	text/plain
<a href="#">Download</a>	Table_2_Field_physiochemical_profile_data_2008_2019.txt	71.93 KB	text/plain
<a href="#">Download</a>	Table_3_Phtoplankton_Community_Data_2008_2020.txt	770.61 KB	text/plain
<a href="#">Download</a>	Table_4_Salinity_and_stable_water_isotope_2019_2020.txt	18.37 KB	text/plain

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.

<a href="#"> national_chlorophyll_data_metadata.xml</a>	<a href="#"> View</a>	55.23 KB	application/fgdc+xml
<i>Original FGDC Metadata</i>			
<a href="#"> national_chlorophyll_site_metadata.csv</a>	<a href="#"></a>	10.59 MB	text/csv
<a href="#"> national_chlorophyll_corrected_chlorophyll_a_data.csv</a>	<a href="#"></a>	106.56 MB	text/csv
<a href="#"> national_chlorophyll_pheophytin_data.csv</a>	<a href="#"></a>	72.35 MB	text/csv
<a href="#"> national_chlorophyll_uncorrected_chlorophyll_a_data.csv</a>	<a href="#"></a>	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.

The screenshot shows the USGS ScienceBase Catalog interface. At the top, the USGS logo and the text "science for a changing world" are visible. Below the logo, there are links for "ScienceBase-Catalog", "Communities", and "Help". The main content area has a header: "A national harmonized dataset of discrete chlorophyll from lakes and streams (2005-2022)". Below this, there are sections for "Dates", "Citation", "Summary", "Map", "Communities", and "Tags". The "Attached Files" section is shown at the bottom left of the main content area, with a red arrow pointing to it from the slide's content.

**Dates**  
Publication Date : 2023-05-23  
Start Date : 2005-01-01  
End Date : 2022-12-31

**Citation**  
Platt, L.R., Spaulding, S.A., Covert, A., Murphy, J.C., and Raynor, N., 2023, A national harmonized dataset of discrete chlorophyll from lakes and streams (2005-2022): U.S. Geological Survey data release, <https://doi.org/10.5066/P9J0ZIOF>.

**Summary**  
This data release contains a 17-year record (2005-2022) of discrete chlorophyll data from inland waters, collected from across the nation and territories. These data are from discrete samples (collected in the field and analyzed in the laboratory) from plankton (suspended algae) and periphyton (benthic algae) from lakes, streams, rivers, reservoirs, canals, and other sites. These data were gathered to support process and remote sensing modeling and prediction of Harmful Algal Blooms (HABs). The chlorophyll data were compiled from the Water Quality Portal (WQP) and USGS National Water Quality Lab (NWQL).

**Map**   
The map shows the outline of North America with a dashed blue rectangle highlighting the region covered by the dataset.

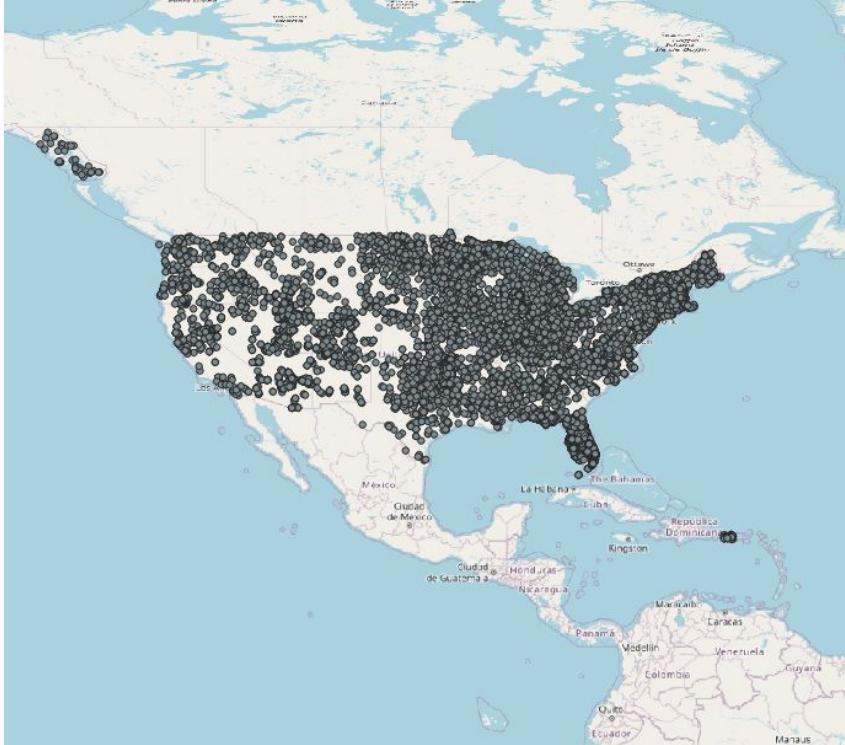
**Communities**  
• Ohio-Kentucky-Indiana Water Science Center \*  
• USGS Data Release Products

**Tags**  
Categories : Data  
Harvest Set : USGS Science Data Catalog (SDC)

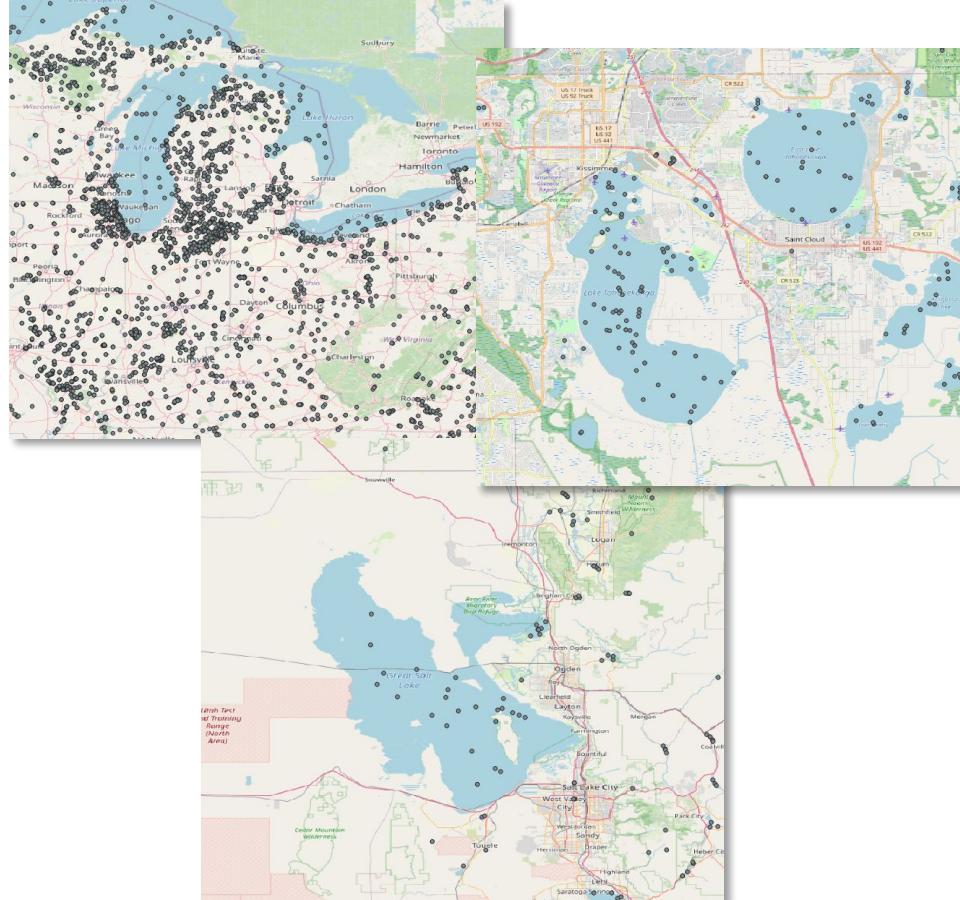


# National Harmonized Chlorophyll Dataset

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



Measurement Locations

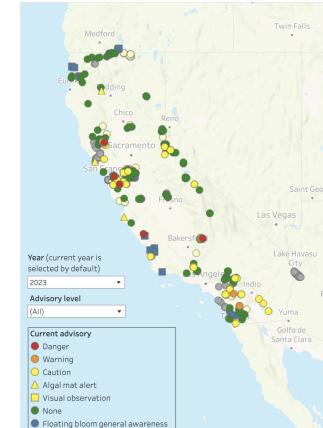


# Water Quality Data for Health Safety

- 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](#)).

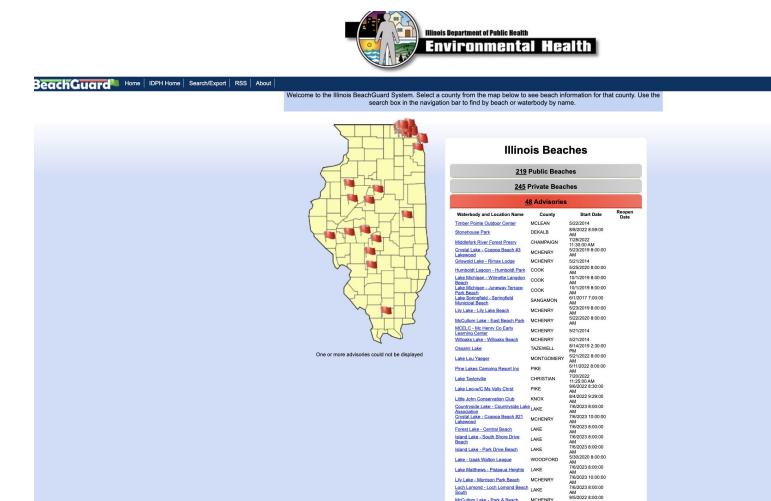
Latest HAB Weekly Updates List

HAB Reports Map - data and reports voluntary shared



County	Water_Body_N.	Landmark	Advisory Level	Advisor..
Alameda	Berkeley Aquatic P.	Southwest shorel.	Algal mat general	6/29/23 Detail
	Beverly Aquatic Park	aquatic park	Last verified >90 d.	2/10/23 Detail
	Big Break Regional	Boat launch	Last verified >90 d.	12/8/22 Detail
	Shoreline		None	6/28/23 Detail
	Dyer Reservoir	Outlet	None	6/23/23 Detail
	Lago Los Osos (Qu)	Lago Los Osos ar.	Caution	6/14/23 Detail
	Lake Chabot	lake-wide	Caution	6/6/23 Detail
	Lake Chabot (Alame.	Lake Chabot	Last verified >90 d.	2/13/23 Detail
	Lake Del Valle	Lake Del Valle	Caution	6/27/23 Detail
	Lake Del Valle Ea..	Lake Del Valle Ea..	Last verified >90 d.	12/29/22 Detail
	Lake Merritt	Lake Merritt at L..	None	6/29/23 Detail
	Lake Merritt Boa..	Boat launch	None	6/29/23 Detail
	Lake Tomales		Danger	6/29/23 Detail
	Quarry Lakes	East Bay Regiona...	Last verified >90 d.	12/20/22 Detail
	Quarry Lakes	Quarry Lakes	Danger	6/27/23 Detail
	Quarry Lakes (Rain	Rainbow Lake	Caution	6/6/23 Detail
	Quarry Lakes (Lago	Lago Los Osos ar.	Last verified >90 d.	1/22/22 Detail
	Redwood Creek	Redwood Creek n.	None	6/15/23 Detail
	Shadow Cliffs Arro	dog access area	Caution	6/20/23 Detail
	Shadow Cliffs Rese		Last verified >90 d.	12/29/22 Detail
	Shinn Pond (Quarry	Shinn Pond	Caution	6/29/23 Detail
	Heenan Reservoir	Looding Zone	None	7/6/23 Detail
	Indian Creek Reserv	Auxiliary Dam (IC	Last verified >30 d.	4/21/23 Detail
		Boat Launch (ICR..	Caution	6/27/23 Detail
		East Shore Damm..	Caution	6/27/23 Detail
		South End Neare..	Caution	6/27/23 Detail
	Red Lake	Shoreline Point 1..	None	7/5/23 Detail
	Lake Oroville	Loafier Creek Swi..	None	6/30/23 Detail

<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.

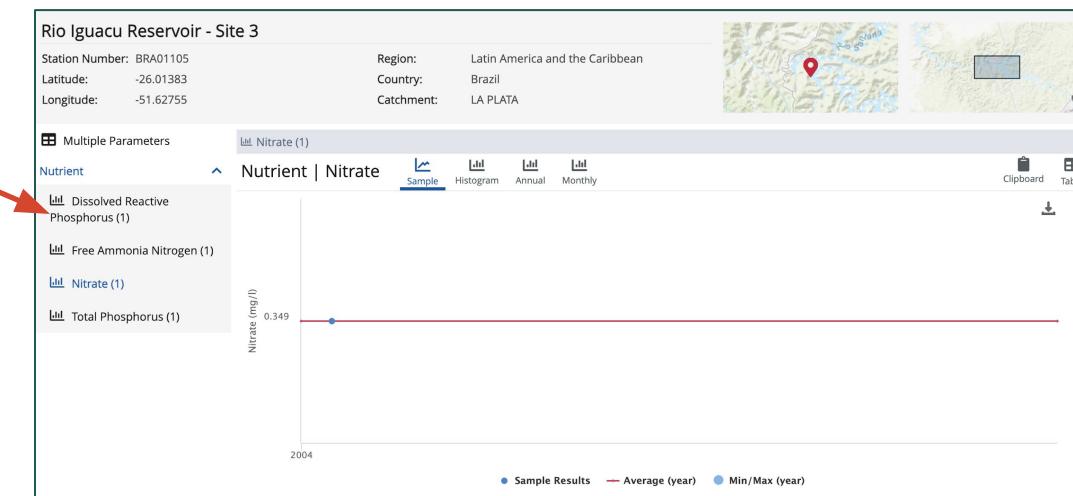
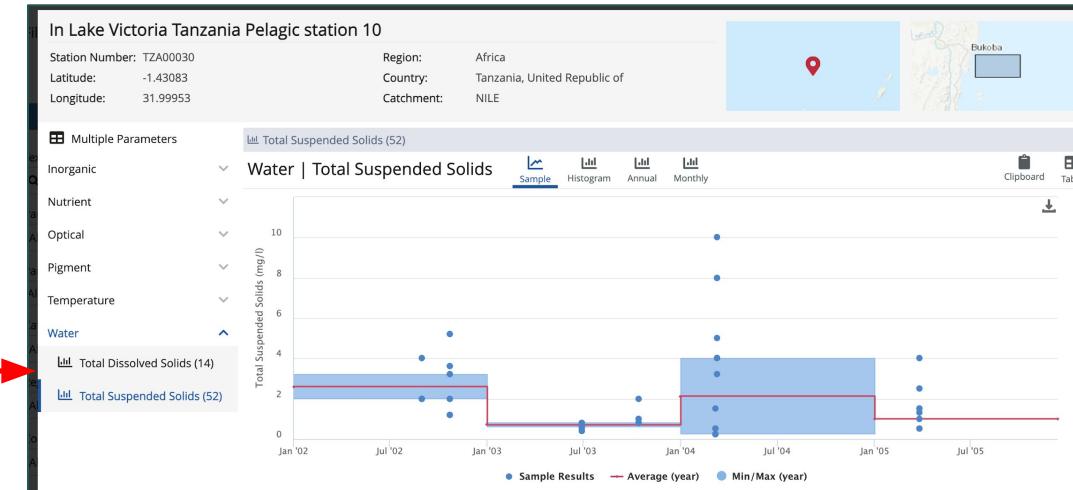
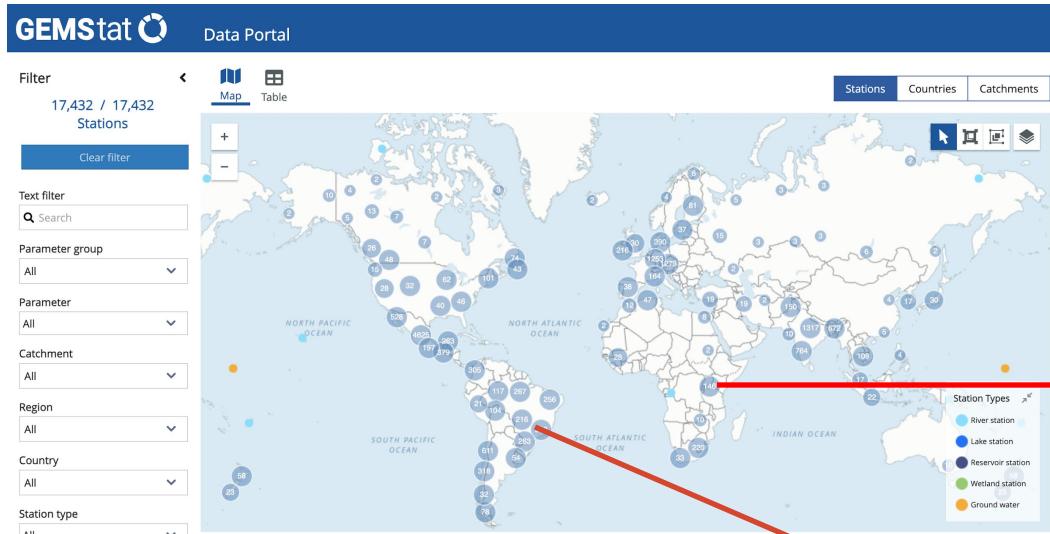
The screenshot shows the homepage of the UN Environment Programme GEMS/Water website. At the top, there's a navigation bar with links for "Who we are", "Where we work", "What we do", and "Publications & data". Below the navigation is a large banner image of a waterfall. Overlaid on the banner is the text "Monitoring water quality". To the left of the banner, there's a box containing text about the GEMS/Water program and its methodology. To the right, there's a sidebar with links related to water quality and management. The GEMS/Water logo is prominently displayed in the center of the page.

The screenshot shows the GEMStat data portal website. The header includes the UN Environment Programme logo and the GEMStat logo. A banner at the top has a message about the migration of ArcGIS services. The main content area features a background image of a hippopotamus in water. On the right side, there's a sidebar with links for "Data portal", "Water quality indicators", "Metadata catalogue", "Statistic reports", and "Data submission". A central text box provides information about the GEMStat database and its purpose.



# 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)



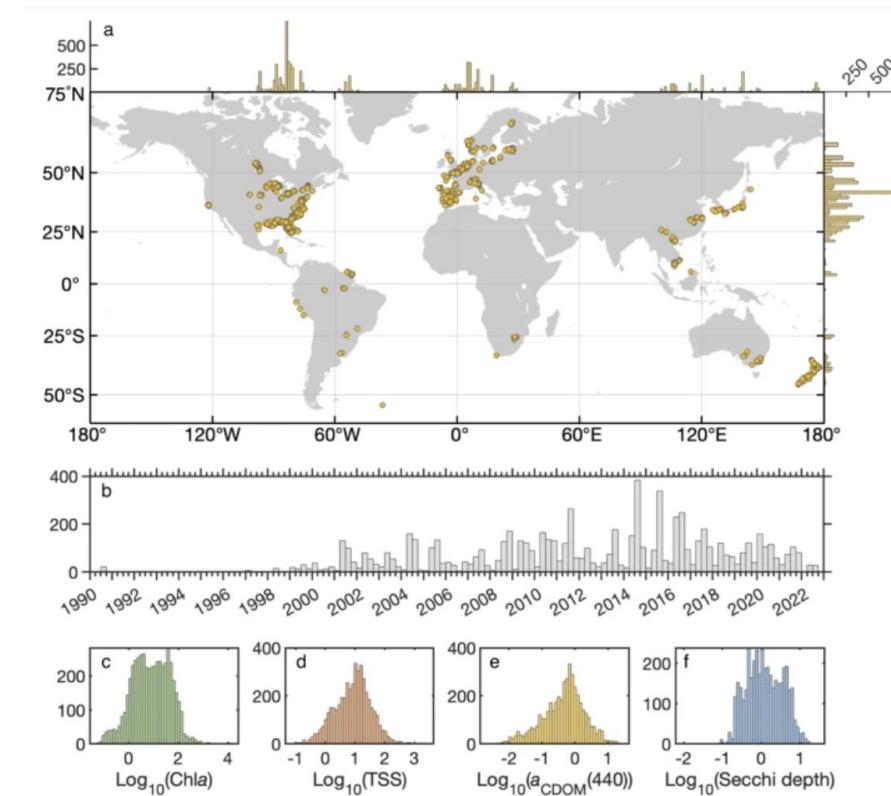
- GLORIA is a hyperspectral reflectance data set collected from 450 water bodies around the world<sup>1</sup>.
- Along with the reflectance data, at least one **co-located water quality measurement** of chlorophyll a (Chla), total suspended solids (TSS), absorption by dissolved substances, and Secchi 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.

<sup>1</sup>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 Chla, 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.



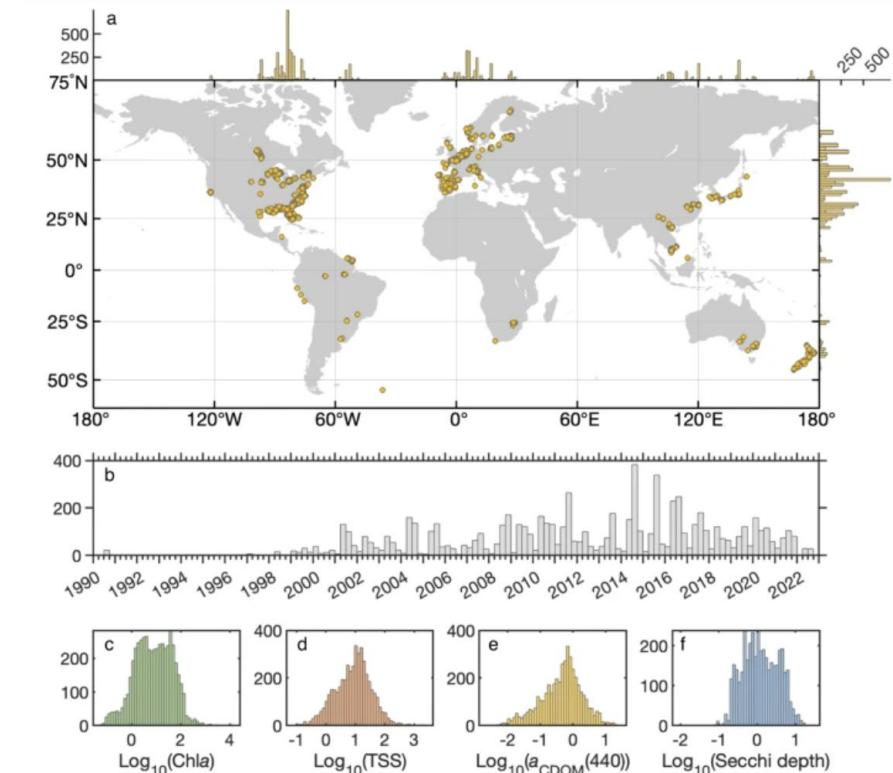
Sample Locations and WQ Statistics

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>



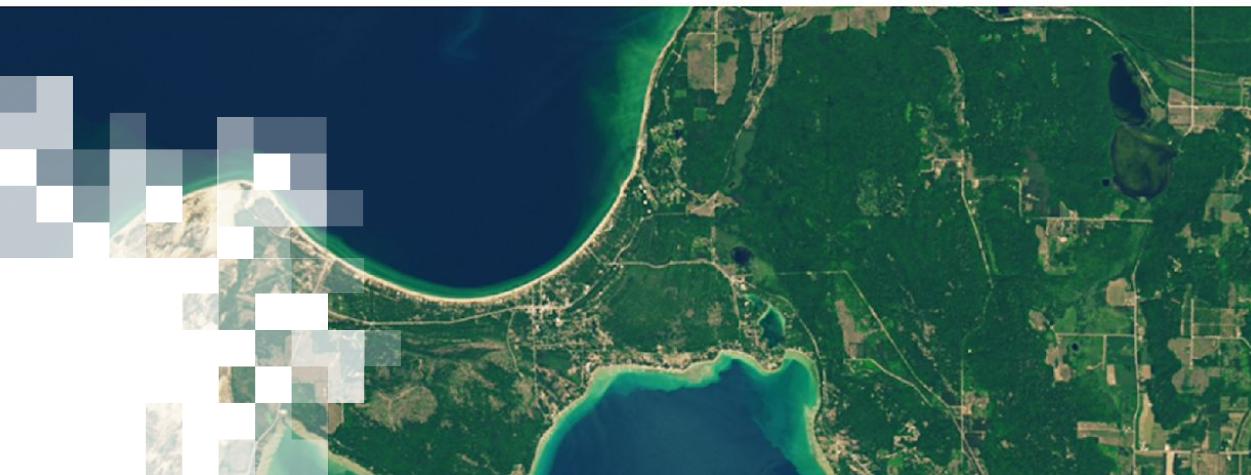
# In Situ Water Sample Measurements for GLORIA

- 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>



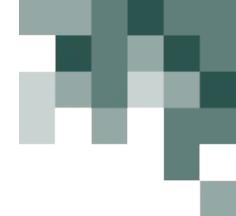
Lehmann, M.K., Gurlin, D., Pahlevan, N. et al. GLORIA - A globally representative hyperspectral *in situ* dataset for optical sensing of water quality. *Sci Data* **10**, 100 (2023). <https://doi.org/10.1038/s41597-023-01973-y>



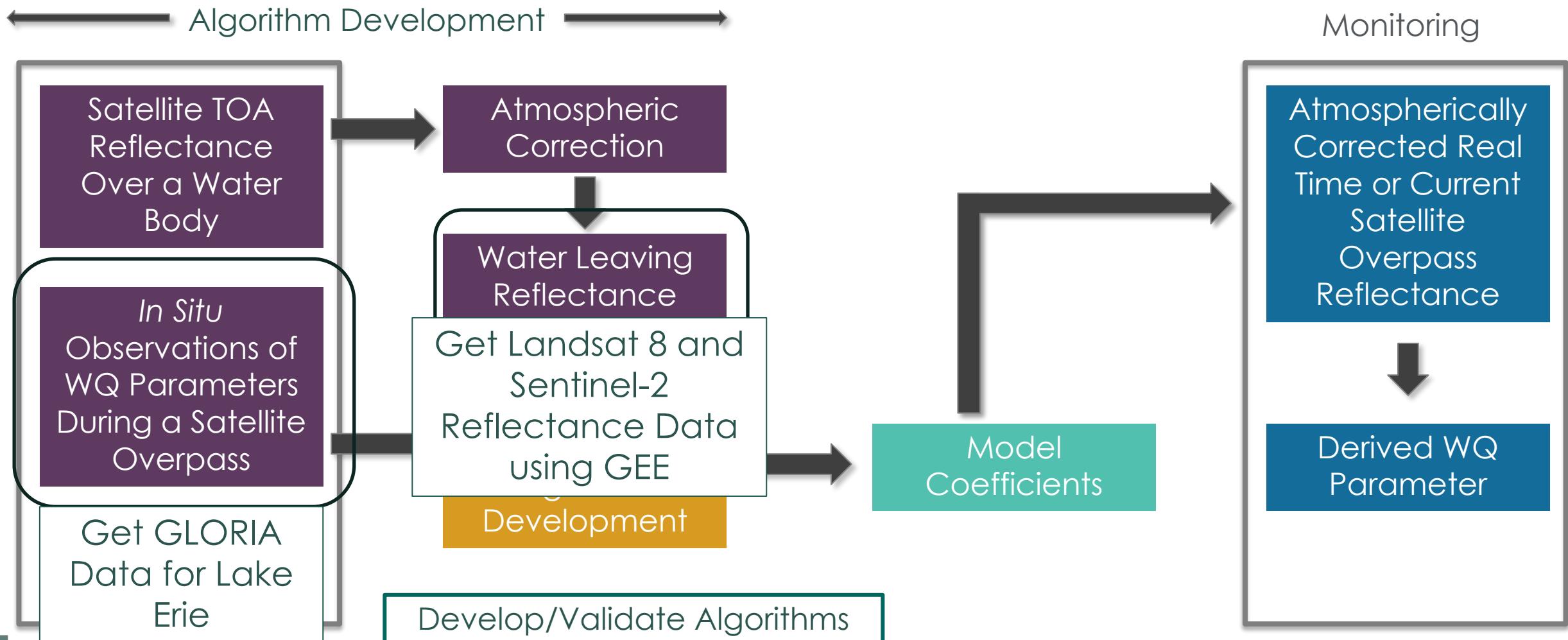


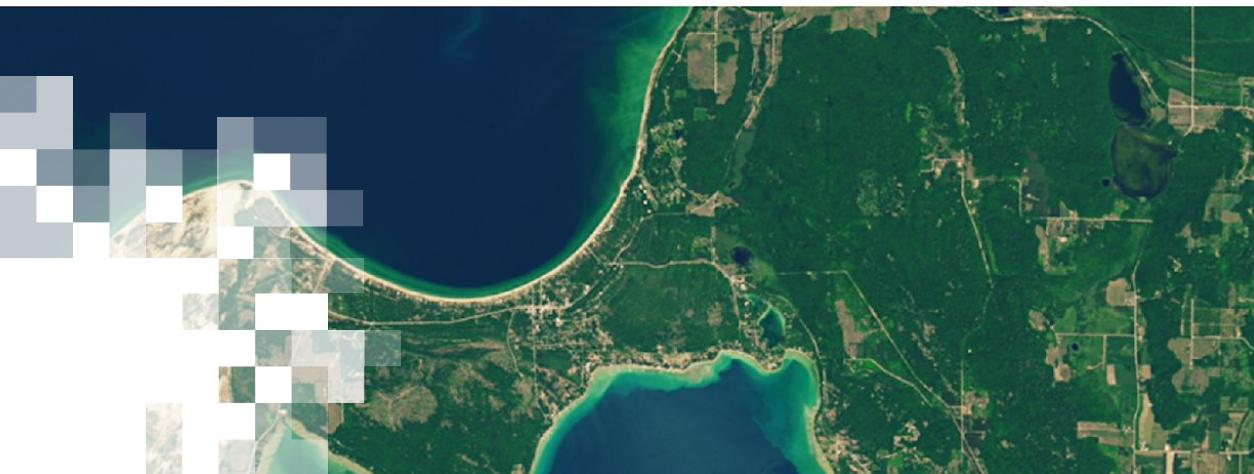
# Case Study: *Acquiring In Situ and Satellite Data for Lake Erie*

# Water Quality Parameters from Remote Sensing Observations



## Quantitative Technique

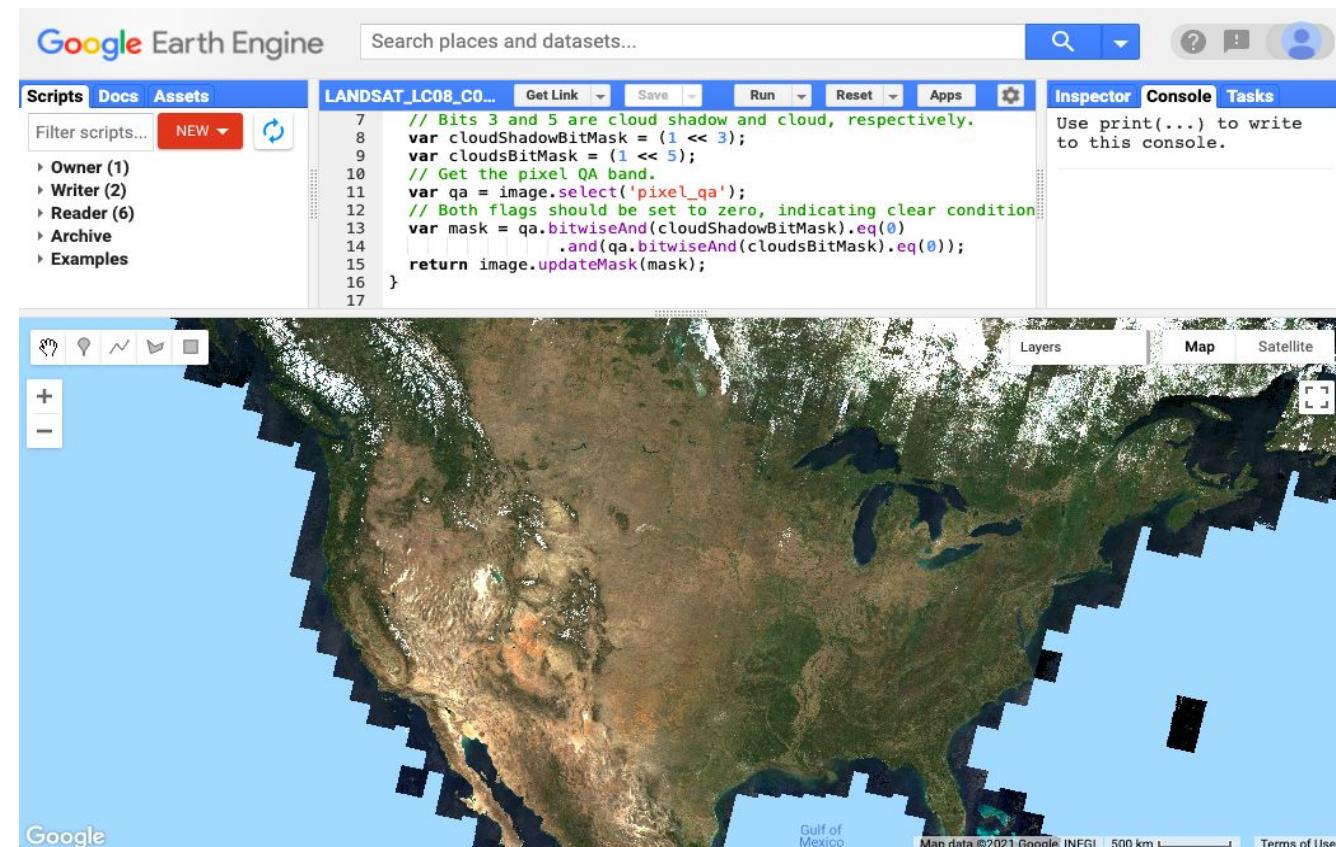




# Introduction to GEE

# 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).

≡ Google Earth Engine

## Meet Earth Engine

Google Earth Engine combines a multi-petabyte catalog of satellite imagery and geospatial datasets with planetary-scale analysis capabilities and makes it available for scientists, researchers, and developers to detect changes, map trends, and quantify differences on the Earth's surface.

The diagram shows three components: a satellite icon labeled "Satellite Imagery", a flowchart icon labeled "Your Algorithms", and a globe icon labeled "Real World Applications". These three are connected by plus signs (+) to represent their integration into the Google Earth Engine platform. A "Learn More" button is located at the bottom right of the diagram area.

Satellite Imagery + Your Algorithms + Real World Applications

Learn More

Image Credit: [Google Earth Engine](#)

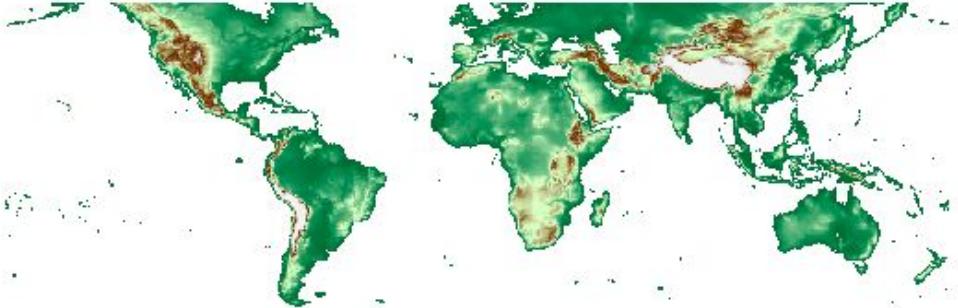


# Application Programming Interface (API)

- 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']}))
```

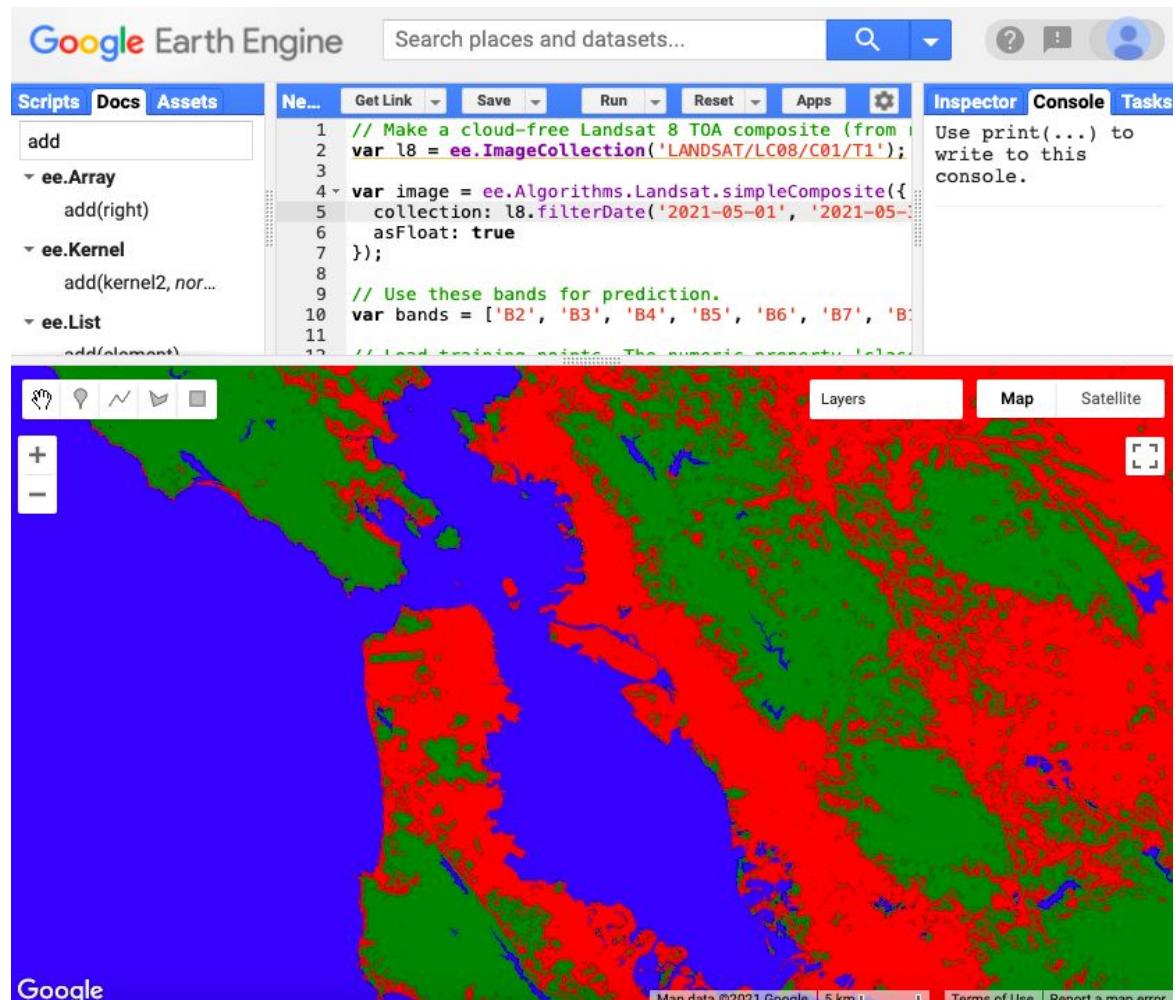


Google Colab notebook using a coded section to display elevation in an output cell.  
Credit: [Google Colab](#)



# 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

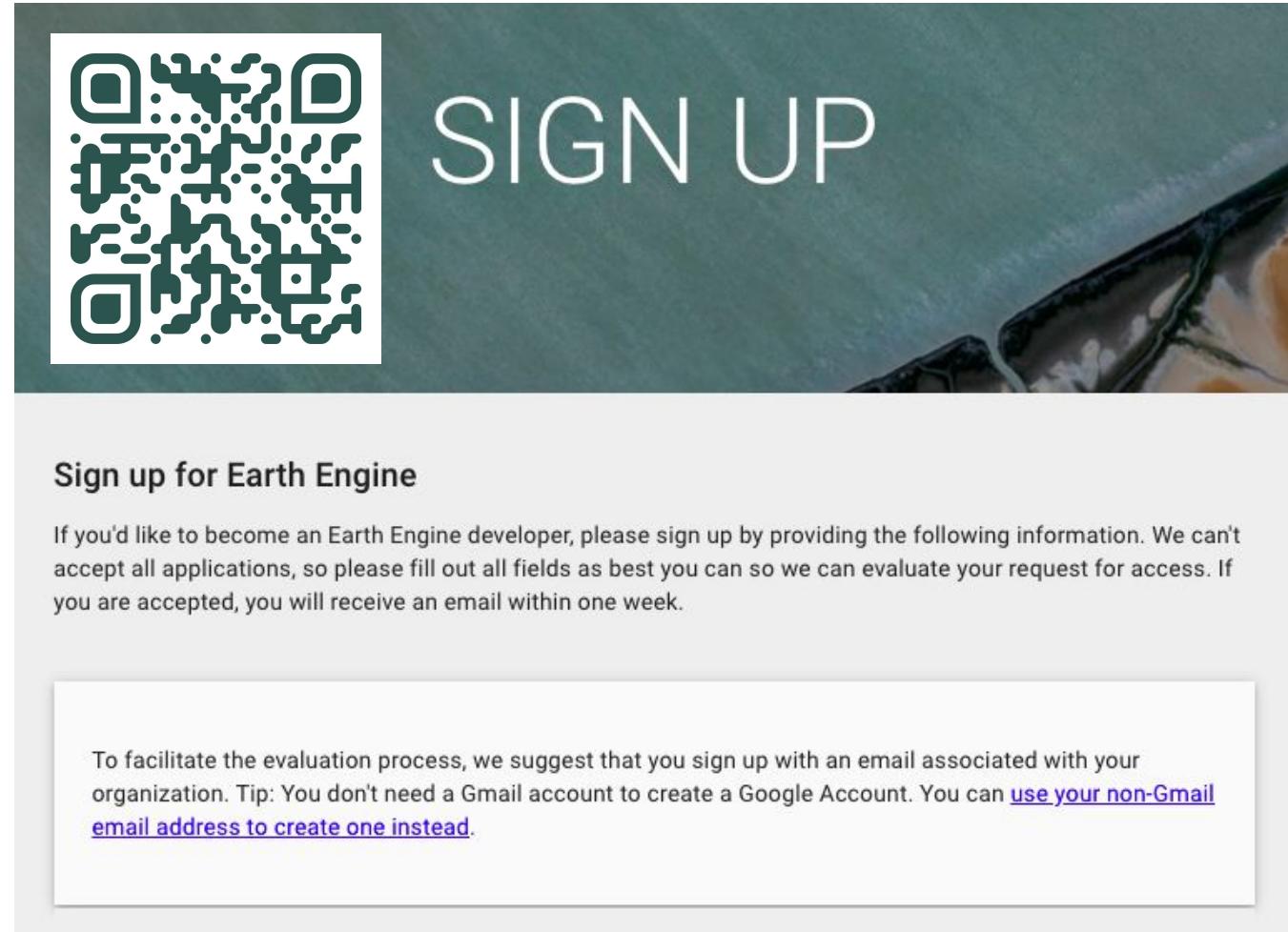


Simple Classification and Regression Trees (CART) classifier implemented in the GEE API to identify three classes urban, forest, and water in the San Francisco Bay Area for May 2021 using Landsat 8 imagery.  
Credit: [Google Earth Engine Developers](#)



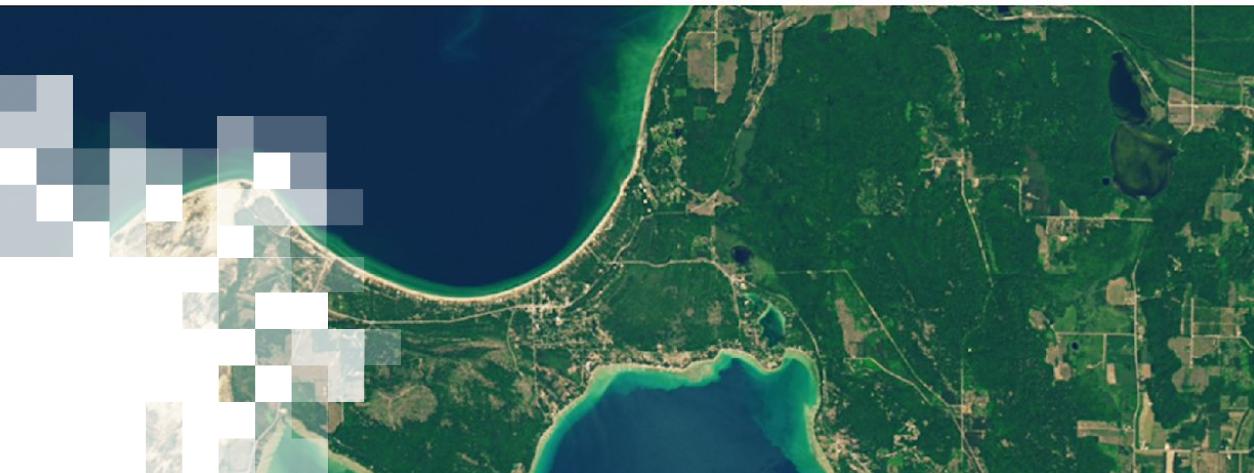
# Google Earth Engine Account Reminder

- 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.



The screenshot shows a sign-up page for Google Earth Engine. At the top right, there is a large "SIGN UP" button. To its left is a QR code. Below the QR code, the text "Sign up for Earth Engine" is displayed. Underneath this, there is a paragraph of text: "If you'd like to become an Earth Engine developer, please sign up by providing the following information. We can't accept all applications, so please fill out all fields as best you can so we can evaluate your request for access. If you are accepted, you will receive an email within one week." At the bottom of the page, within a callout box, there is a tip: "To facilitate the evaluation process, we suggest that you sign up with an email associated with your organization. Tip: You don't need a Gmail account to create a Google Account. You can [use your non-Gmail email address to create one instead](#)."





Demonstration:  
**Access GLORIA Data**

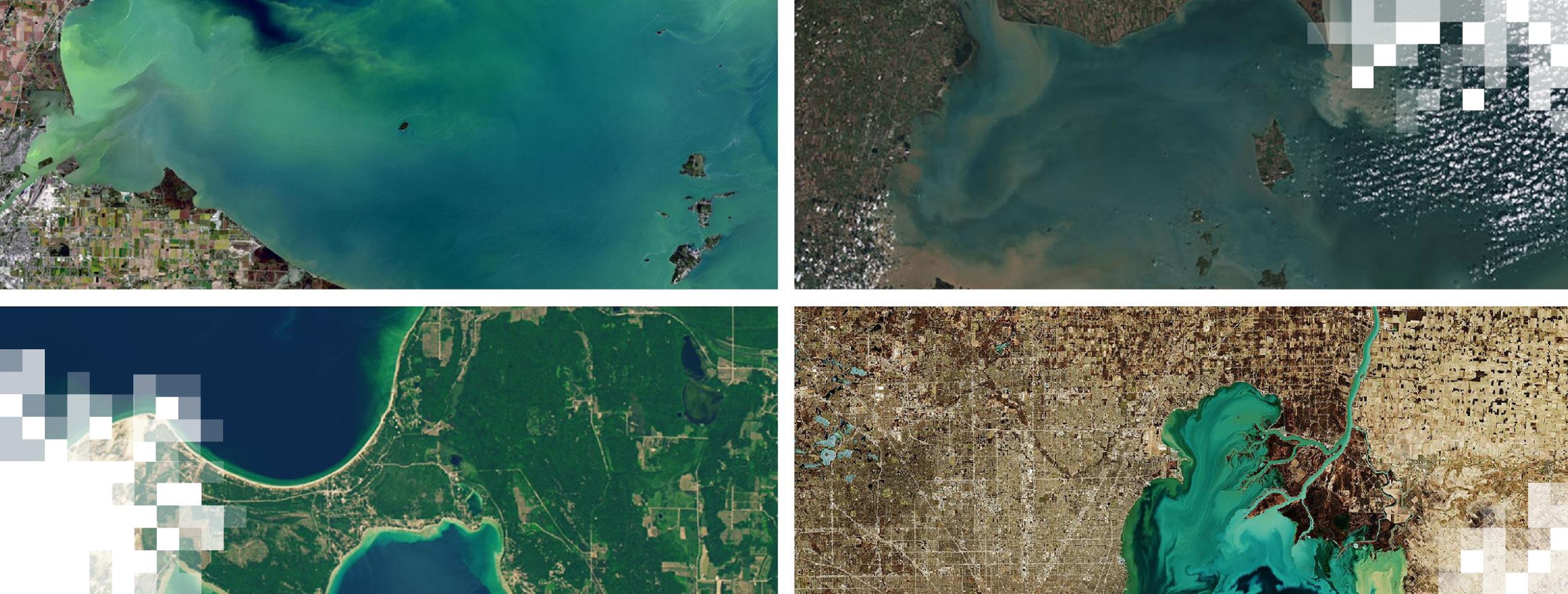
# About GLORIA Data



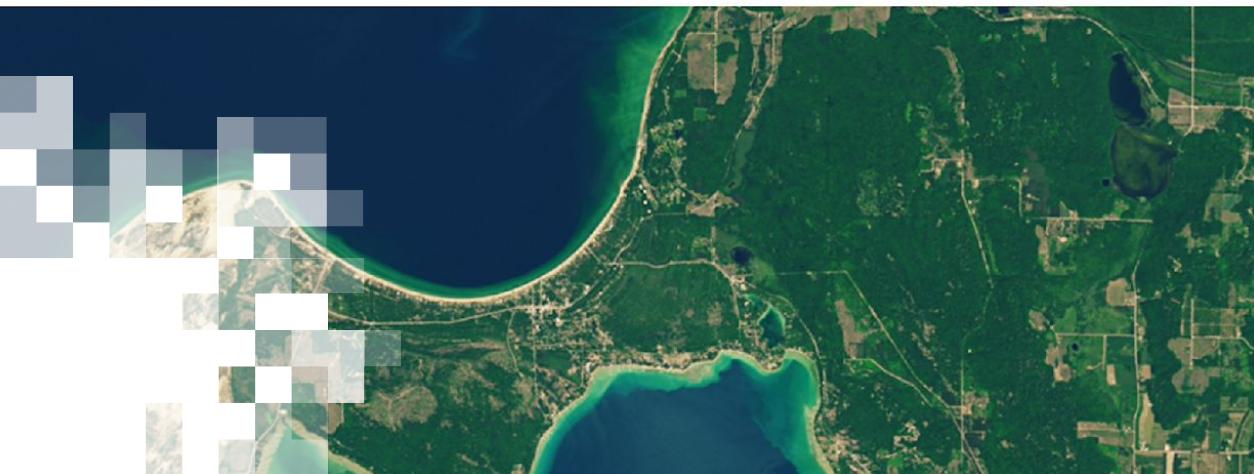
- Data Descriptor: <https://www.nature.com/articles/s41597-023-01973-y>
- Data Access: <https://doi.org/10.1594/PANGAEA.948492>

**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

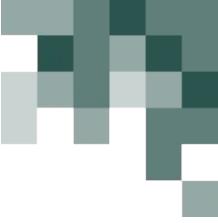


# Summary

- 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

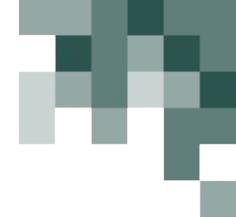


Part 2 will focus on:

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

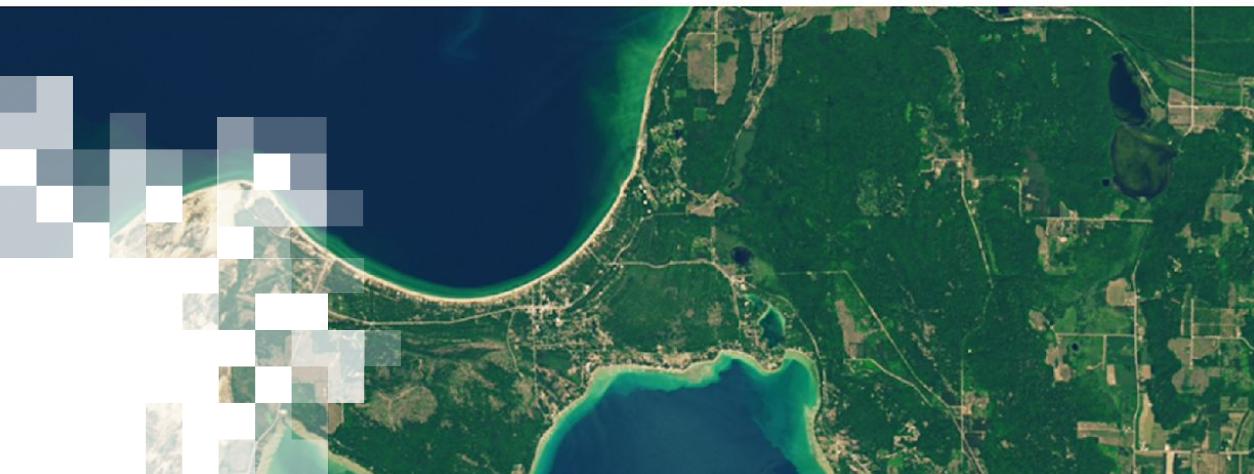


# Homework and Certificates



- **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](mailto:Amita.v.mehta@nasa.gov)
- Sean McCartney
  - [Sean.mccartney@nasa.gov](mailto:Sean.mccartney@nasa.gov)

- [ARSET Website](#)
- Follow us on Twitter!
  - [@NASAARSET](https://twitter.com/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.





# Thank You!

