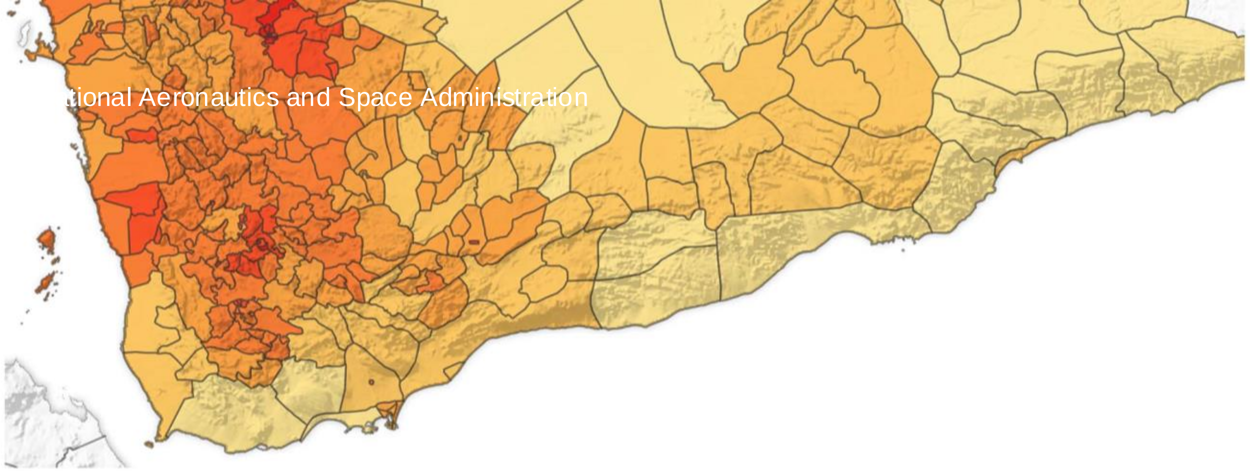
tional Aeronautics and Space Administration

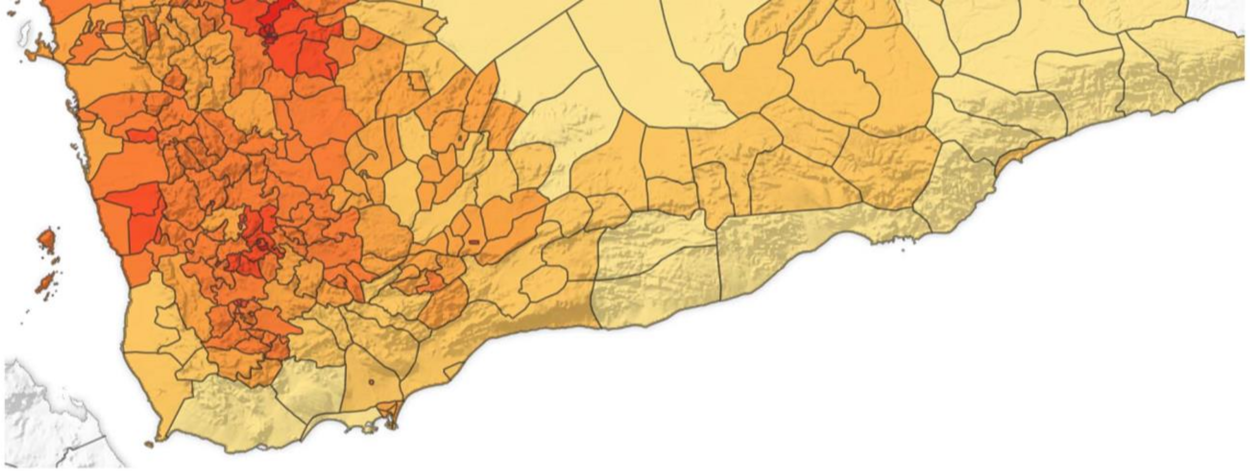


# The Application of Earth Observations for Assessing Waterborne Disease Risk

## Part 1: Overview of Monitoring Waterborne Diseases using Remote Sensing Observations

Amita Mehta (612 NASA, UMBC GESTAR II)

March 25, 2025




# 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

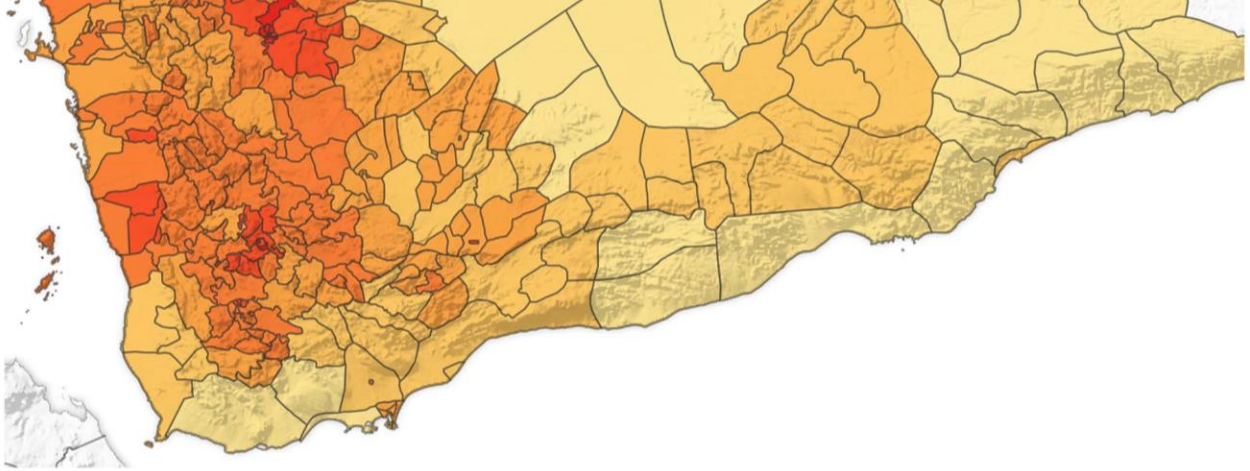
HEALTH & AIR QUALITY

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.




# The Application of Earth Observations for Assessing Waterborne Disease Risk
# Overview

# Waterborne Diseases

- The US Centers for Disease Control (CDC) defines waterborne diseases as diseases spread through exposure to infectious pathogens from water*.

- Waterborne disease outbreaks can include outbreaks of respiratory, skin, intestinal, or other types of illness spread through:
  - Drinking water
  - Recreational water activities
  - Consuming contaminated seafood+

*Collier, S. A., L. Deng, E. A. Adam, K. M. Benedict, E. M. Beshearse, A. J. Blackstock, .et al., 2021: Estimate of Burden and Direct Healthcare Cost of Infectious Waterborne Disease in the United States. *Emerging Infectious Diseases*, *27*(1), 140-149. https://doi.org/10.3201/eid2701.190676

+https://www.cdc.gov/nors/about/index.html

# Training Learning Objectives

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

- Identify the factors that affect the presence of microbial contaminants in water, leading to waterborne diseases in which satellite remote sensing can improve risk assessment.
- Identify Earth observations used for monitoring key environmental factors relevant for assessing the presence of contaminants in drinking and recreational waters and risk of waterborne disease outbreaks.
- Recognize how satellite observations are integrated with in situ water quality data to develop risk assessment models for waterborne diseases such as Cholera.

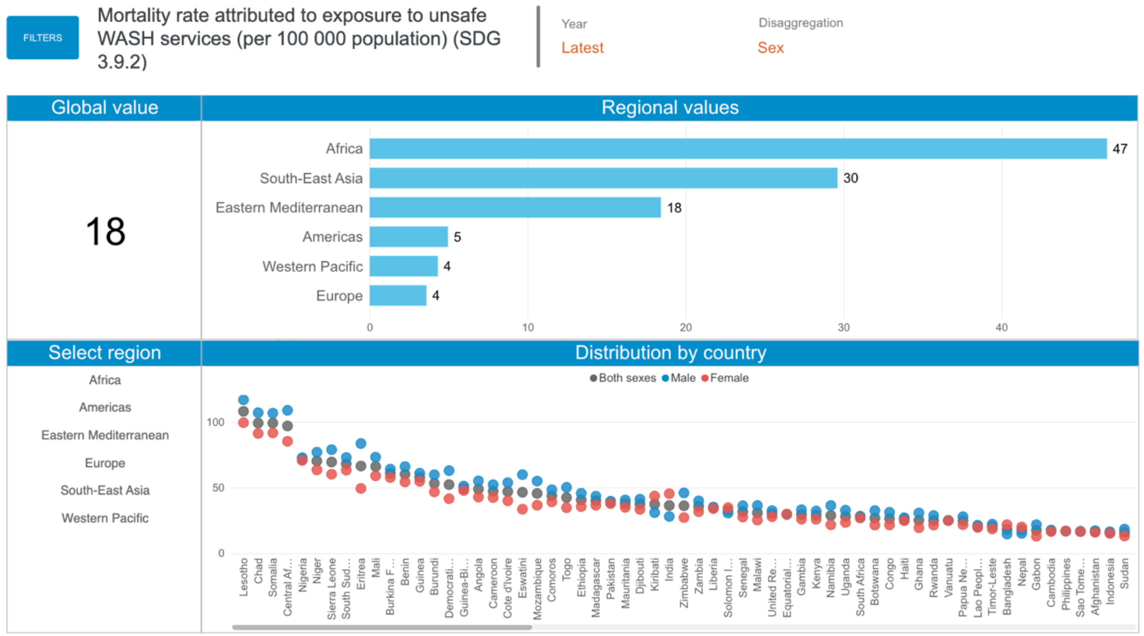
# Prerequisites

- Fundamentals of Remote Sensing
  - Satellites and Sensors
  - Orbits, Swaths, Pixels, and Spatial Resolution
  - Electromagnetic Spectrum and Spectral Bands
  - Data Processing Levels

# Global Impact of Waterborne Diseases

- According to the CDC-WASH, over 2 billion people worldwide lack access to safe drinking water and about 1.5 billion lack basic sanitation facilities.
- Globally, at least 1.7 billion people drink water with microbial contamination, causing diarrhea, cholera, dysentery, typhoid, and polio each year (WASH).
- Annually, more than 3 million deaths result from poor WASH conditions worldwide*.
- Diarrhea alone is responsible for approximately one million deaths, the majority of which are children under the age of five (WASH).

Mortality Due to Unsafe WASH Services 2019




Water, sanitation, and hygiene related burden of disease indicators

*https://www.voanews.com/a/a-13-2005-03-17-voa34-67381152/274768.html

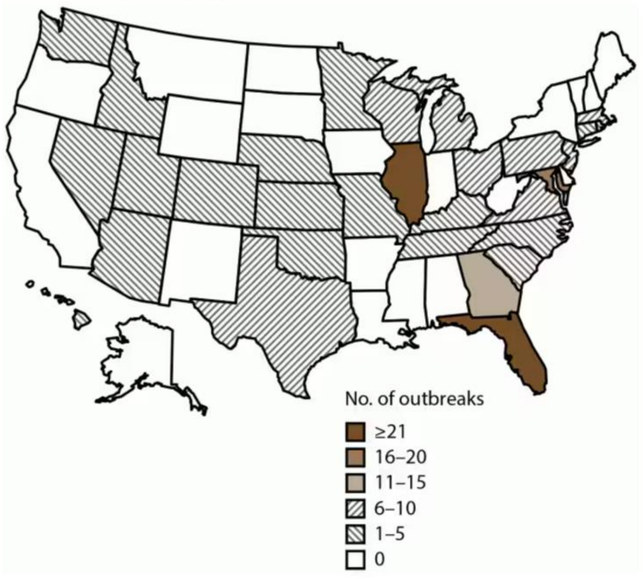
# Impact of Waterborne Diseases in the U.S.

- Each year, in the U.S., pathogens transmitted through water cause an estimated 7.2 million cases of waterborne illness,120,000 hospitalizations, and 6,600 deaths (CDC, Kunz et al., 2024).
- Estimated cost of $3.3 billion incurred to the U.S. healthcare system due to waterborne illnesses (Collier et al., 2021).

**Monitoring risk of waterborne disease outbreaks is crucial for protecting public health and preventing the spread of waterborne diseases.**

## Waterborne Disease Outbreaks 2015-2020

**FIGURE 1. Number of reported drinking water-associated outbreaks,* by state of exposure — National Outbreak Reporting System, United States, 2015–2020**




* N = 214 outbreaks.

Collier, S. A., L. Deng, E. A. Adam, K. M. Benedict, E. M. Beshearse, A. J. Blackstock, .et al., 2021: Estimate of Burden and Direct Healthcare Cost of Infectious Waterborne Disease in the United States. *Emerging Infectious Diseases*, *27*(1), 140-149. https://doi.org/10.3201/eid2701.190676
Kunz J.M., H. Lawinger, S. Miko et al. 2024: Surveillance of Waterborne Disease Outbreaks Associated with Drinking Water — United States, 2015–2020. MMWR Surveill Summ 2024;73(No. SS-1):1–23. DOI: http://dx.doi.org/10.15585/mmwr.ss7301a1

# Training Outline

**Part 1**

**Overview of Monitoring Waterborne Diseases using Remote Sensing Observations**

**March 25, 2025**

**Part 2**

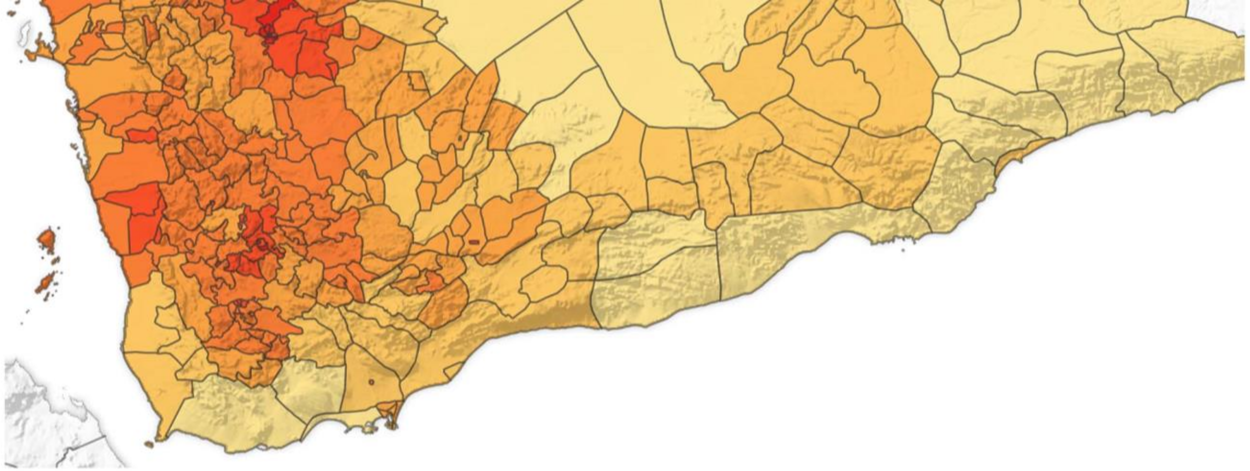
**Using Remote Sensing-Based Cholera Predictive Intelligence for Intervention and Mitigation**

**March 27, 2025**

**Homework**

Opens 3/27/2025 – Due 4/10/2025 – 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.



The Application of Earth Observations for Assessing Waterborne Disease Risk

**Part 1: Overview of Monitoring Waterborne Diseases using Remote Sensing Observations**

# Part 1 – Trainer

**Amita Mehta**

ARSET

NASA-UMBC GESTAR-II

# Part 1 Objectives

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

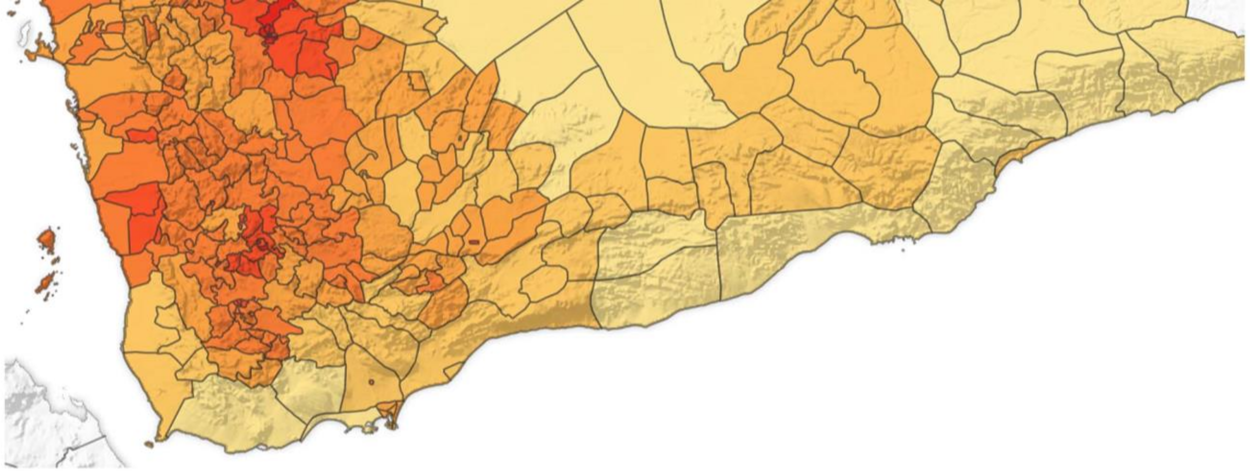
- Identify diseases resulting from the presence of microbial contaminants (pathogens) in waters.
- Identify earth observations used for monitoring key environmental parameters relevant for assessing the presence of contaminants in drinking water leading to risk of waterborne disease outbreaks.

# Part 1 Outline

- A Brief Overview of Waterborne Diseases
- Monitoring Waterborne Pathogens
- Overview of Earth Observations Relevant for Inferring to Waterborne Pathogens
- Demonstration of Data Access:
  - NASA Earthdata Search
  - NASA Worldview
  - Cyanobacteria Assessment Network (CYaN)

# 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.




# A Brief Overview of Waterborne Diseases

# Waterborne Diseases

- Caused by **pathogens** in drinking or recreational waters, beverages, food.

- *__Pathogens are__ disease producing microorganisms that include:

  **Bacterium:** A single cell living microorganism (many makeup our microbiome, many other can cause diseases).

  **Virus:** A microorganism that needs a host, such as a human, animal, or plant to reproduce (e.g., Covid-19), cause infections.

  **Parasite:** A microorganism that needs host to survive and spread (e.g., intestinal worms).

- Contaminated water can affect fish and seafood consumed by humans, causing illnesses (water-related illnesses).

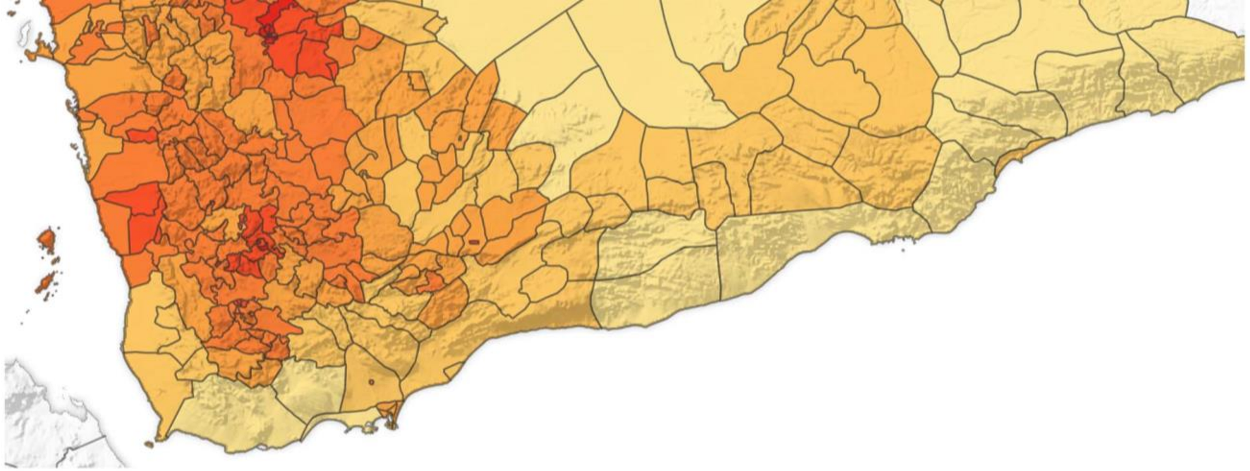
Waterborne Pathogens (EPA)

*https://my.clevelandclinic.org/health/articles/

# Common Waterborne Diseases

- **Diarrhea:** Caused by viral or bacterial infections from water & food. Can also result from food allergies.
  - Dehydration resulting from diarrhea can be life threatening, particularly to young children.
- **Typhoid:** Caused by *Salmonella* bacteria in water and food. Highly contagious.
  - Regular outbreaks in Southeast Asia and Africa.
- **Cholera:** Caused by *Vibrio cholerae* bacteria from contaminated water and poor sanitation.
  - Deadly if not treated immediately. Most prevalent in Southeast Asia, Africa, Haiti.
- ***Escherichia coli (E. coli)*:** Caused by bacterial infection.
- **Giardia:** Caused by parasites infecting intestine. Found in waters worldwide.
- **Hepatitis A:** Caused by Hepatitis A virus. It is a highly contagious liver infection.
- **Polio:** Caused by a virus that mainly affects the nerves in the spinal cord or brain stem.
  - High risk areas are Africa, the Middle East, and Southern and Central Asia.

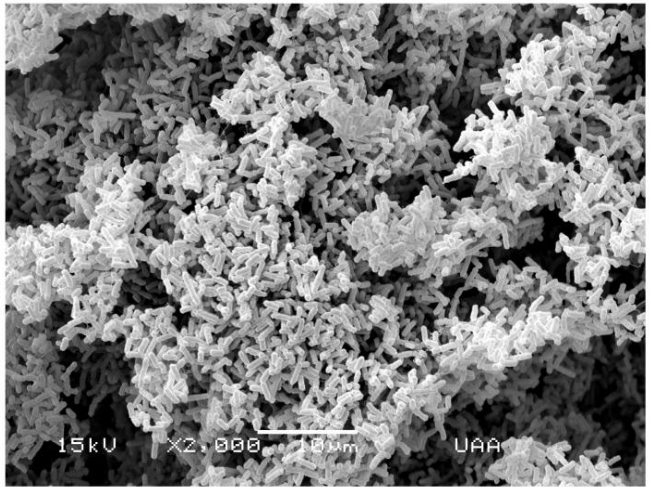
https://www.mayoclinic.org/diseases-conditions/



# Monitoring Waterborne Diseases

# Detection of Pathogens Leading to Waterborne Diseases

- Conventionally, water samples are collected then analysis is conducted in laboratories to assess types and concentration of pathogens.
- There are challenges in this process:
  - Low concentration of pathogens in a large volume of water requires enrichment and concentration of samples prior to detection processing
  - No unified methods for collection and analysis, affecting reproducibility of results
  - Differences in pathogen groups require different treatments
  - Inadequate spatial and temporal samplings
  - Cost of water collection and analysis



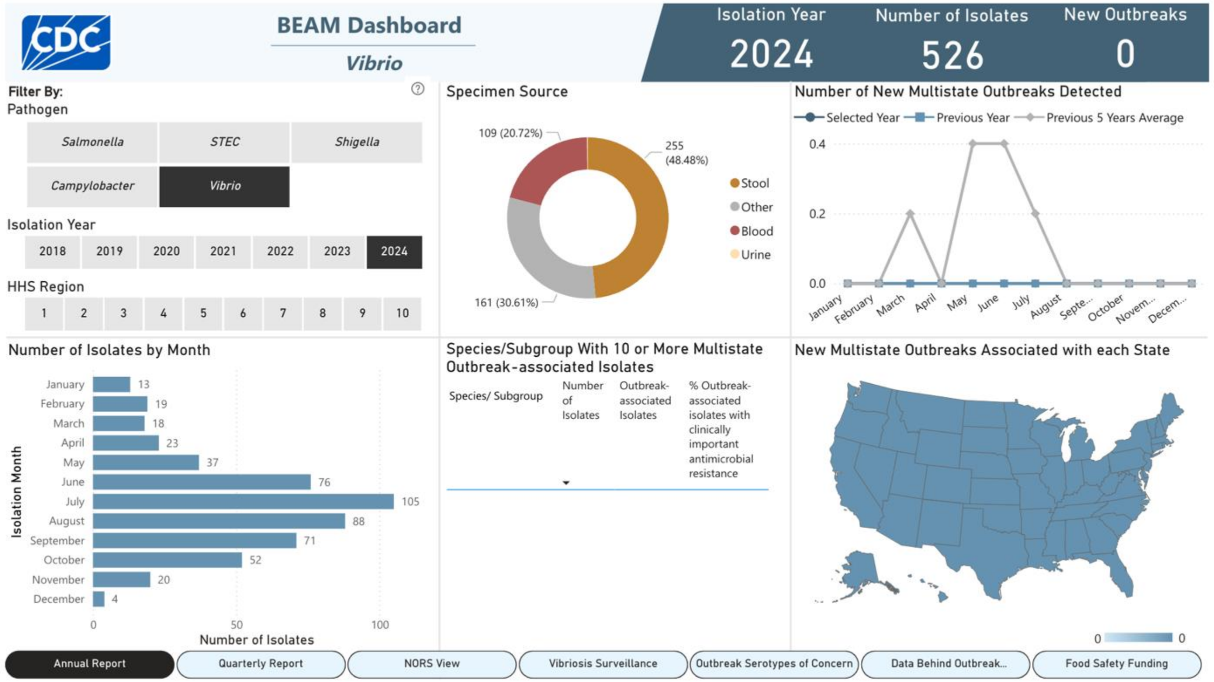

Scanning Electron Micrograph of *E. coli* Isolated from River Water

Ramírez-Castillo, F. Y., A. Loera-Muro, M. Jacques, P. Garneau, F. J. Avelar-González, J. Harel, and A. L. Guerrero-Barrera, 2015: Waterborne pathogens: Detection methods and challenges. *Pathogens*, 4, 307–334, doi:10.3390/pathogens4020307. National Library of Medicine, PMID: 26011827; PMCID: PMC4493476.

# Waterborne Diseases: Data and Information

**In the US, CDC provides statistics about waterborne diseases via The BEAM and NORS.**

The BEAM (Bacteria, Enterics, Ameba, and Mycotics) Dashboard



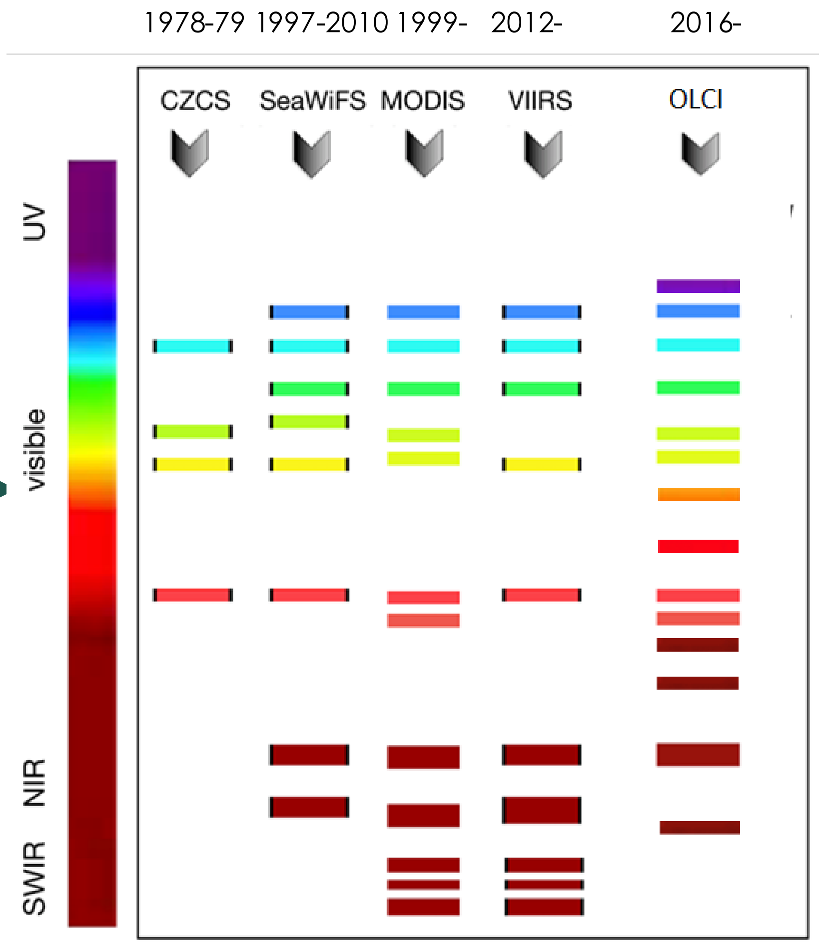

National Outbreak Reporting System (NORS)

NORS collects data on several types of outbreaks in the United States:

**Waterborne Disease Outbreaks** – All outbreaks of respiratory, skin, enteric, or other types of illness spread through water, including water that people drink, swim in, or use for other purposes.

# Can Pathogens be Detected by Satellite Remote Sensing?

- Used to monitor water quality in coastal and inland water bodies based on the spectral signature of the waters.
- Pathogens which affect spectral signature of water can be detected.
  - E.g., cyanobacteria and harmful algal bloom in water.
- Most water pathogens **cannot be detected by the medium spectral band** observations from satellites.
- Some harmful algal constituents can be detected from **hyperspectral** remote sensing observations.
- Several **environmental parameters** that affect waterborne pathogens can be monitored.



# Environmental Parameters Affecting Waterborne Pathogens

- These factors affect survival, growth, and spread pf pathogens (water-related illnesses):
  - Water Temperature
  - Precipitation/Flooding
  - Nutrients and Chemicals from Agricultural and Industrial Runoff
  - Chlorophyll/Harmful Algal Bloom
  - Dissolved Organic Matter
  - Salinity
  - Water Currents/Stagnation
  - Solar Radiation
  - Biofilms: Communities of Pathogens Attached to Surface

Racault, M.-F., A. Abdulaziz, G. George, N. Menon, J. C., M. Punathil, K. McConville, B. Loveday, T. Platt, S. Sathyendranath, and V. Vijayan, 2019: Environmental reservoirs of *Vibrio cholerae*: Challenges and opportunities for ocean-color remote sensing. *Remote Sens.*, **11**, 2763, https://doi.org/10.3390/rs11232763.

# Environmental Parameters Affecting Waterborne Pathogens

- These factors affect survival, growth, and spread of pathogens (water-related illnesses):
  - **Water Temperature**
  - **Precipitation/Flooding**
  - Nutrients and Chemicals from **Agricultural and Industrial Runoff (Landcover, Soil Moisture)**
  - **Chlorophyll/Harmful Algal Blooms**
  - **Dissolved Organic Matter**
  - **Salinity**
  - Water Currents/Stagnation
  - **Solar Radiation**
  - Biofilms: Communities of Pathogens Attached to Surface

**Chlorophyll/Harmful Algal Blooms and Colored Dissolved Organic Matter can be detected in water bodies from satellites, other parameters can be obtained from satellite observations or Earth System models in which satellite data are used.**

Racault, M.-F., A. Abdulaziz, G. George, N. Menon, J. C., M. Punathil, K. McConville, B. Loveday, T. Platt, S. Sathyendranath, and V. Vijayan, 2019: Environmental reservoirs of *Vibrio cholerae*: Challenges and opportunities for ocean-color remote sensing. *Remote Sens.*, **11**, 2763, https://doi.org/10.3390/rs11232763.

# Using Earth Observations to Predict Waterborne Diseases

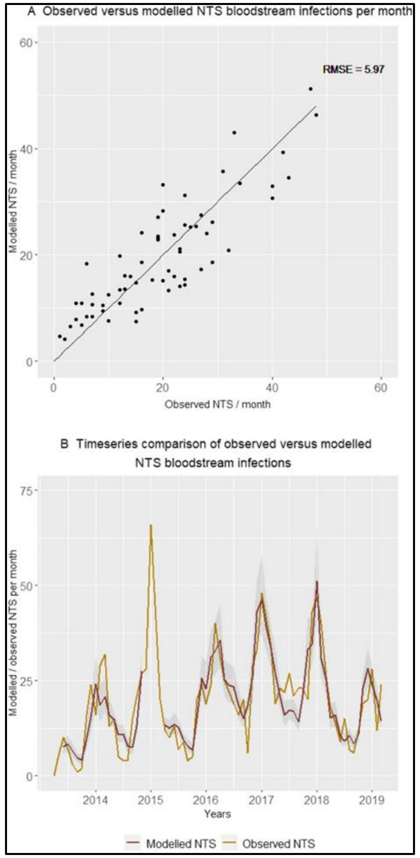
- The environmental factors affecting waterborne pathogens, including weather, climate, and hydrology parameters, are available from satellite observations and earth system model data.
- Combination of in situ and remote sensing data are used for monitoring, prediction, and risk mapping of pathogen occurrence and disease outbreaks.
- Empirical relationships between disease incidence and relevant geophysical parameters are used to predict disease outbreaks.
- Commonly used parameters include water surface temperature, Chlorophyll-a concentration, land cover type, precipitation, and runoff.

Racault, M.-F., A. Abdulaziz, G. George, N. Menon, J. C., M. Punathil, K. McConville, B. Loveday, T. Platt, S. Sathyendranath, and V. Vijayan, 2019: Environmental reservoirs of *Vibrio cholerae*: Challenges and opportunities for ocean-color remote sensing. *Remote Sens.*, **11**, 2763, https://doi.org/10.3390/rs11232763.

# Example: Non-Typhoid Salmonella (NTS) Prediction

- An empirical model derived using:
  - Rainfall data from Climate Hazards Group InfraRed Precipitation with Station Data (CHIRPS)
  - 2-meter temperature data from the European Centre for Medium-range Weather Forecast (ERA5)
  - In Situ Data: Hospital admission data and blood culture surveillance

- The model showed a direct epidemiological association between rainfall and NTS infections.




Tack B, Vita D, Phoba MF, Mbuyi-Kalonji L, Hardy L, Barbé B, Jacobs J, Lunguya O, Jacobs L. Direct association between rainfall and non-typhoidal Salmonella bloodstream infections in hospital-admitted children in the Democratic Republic of Congo. Sci Rep. 2021 Nov 3;11(1):21617. DOI: 10.1038/s41598-021-01030-x. PMID: 34732799; PMCID: PMC8566593, National Library of Medicine.

# Earth Observations for Society

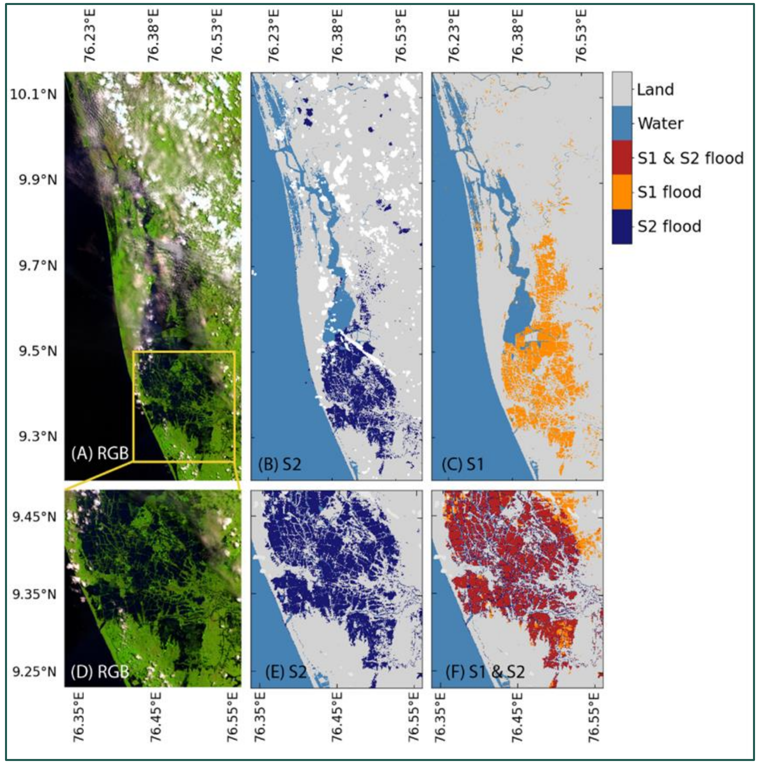
- European Space Agency ‘eo science for society’ has launched WIDGEON: Waterborne Infectious Diseases and Global Earth Observation in the Nearshore:
  - Builds capacity and resilience against waterborne diseases under extreme weather conditions using flooding information from Sentinel-1 and Sentinel-2 observations.

# Impact of Monsoon Floods on Waterborne Pathogens in South India

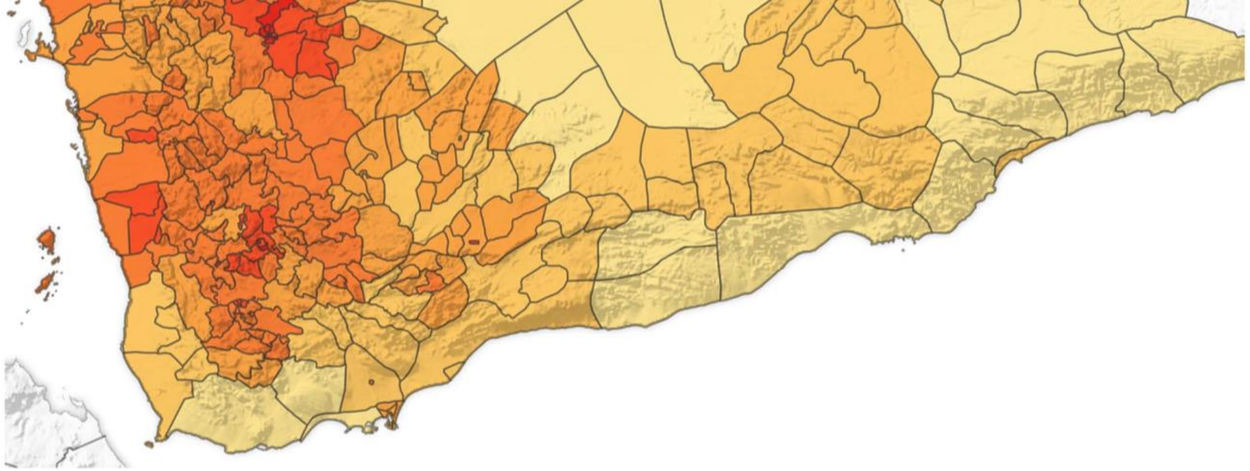
- ‘eo science for society’ examined impact of extreme rain and floods in South India.
- Sentinel-1 and Sentinel-2 flood maps, *E. Coli* data from in situ water samples, and incidence of acute diarrheal disease were analyzed.
- Flood maps from remote sensing, along with maps of water quality information, showed potential for assessing risk of pathogens in water.

**August 2018 Flood Case**

Lake Vembanad, South India

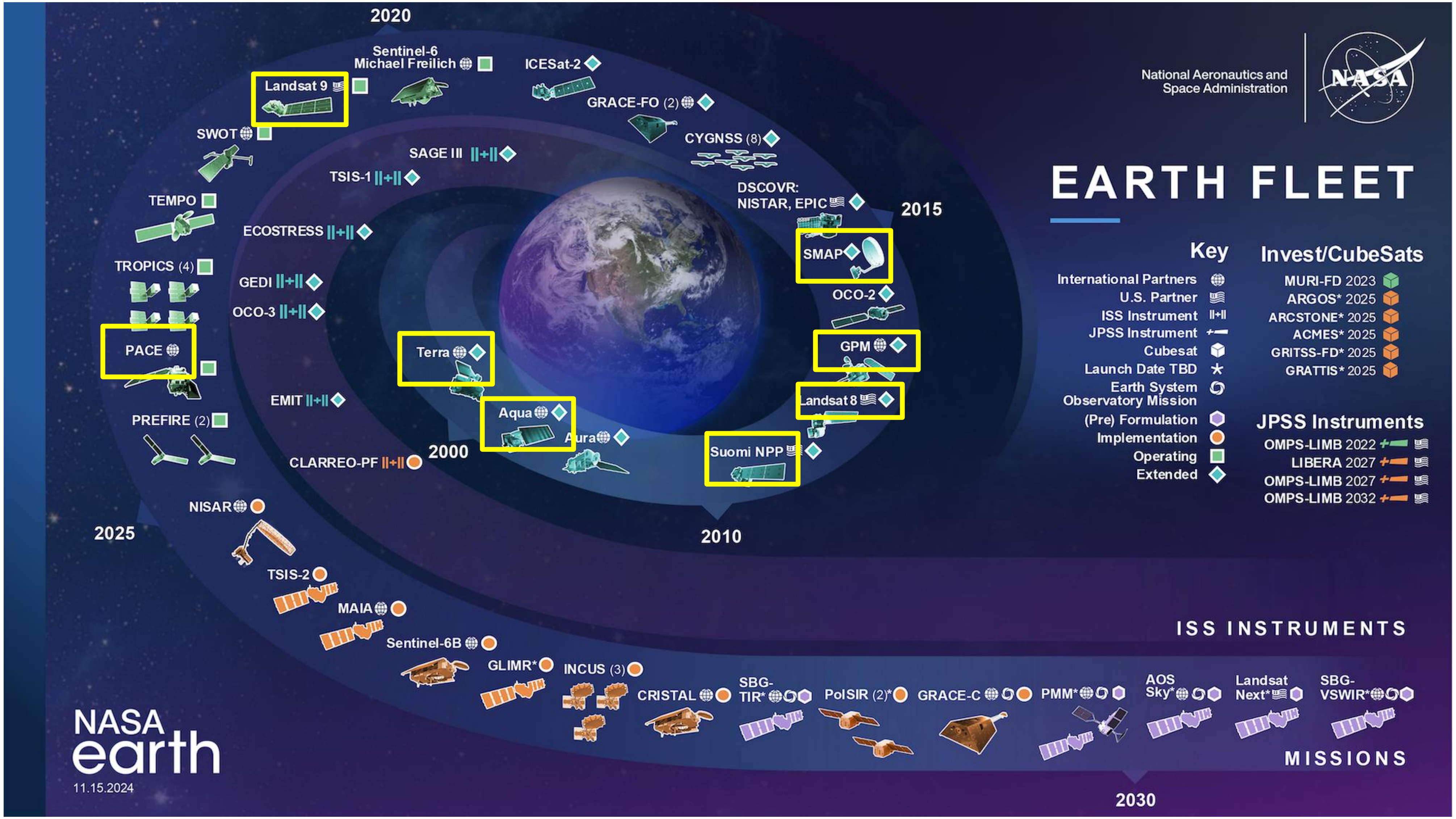



A false-color RGB map of the Sentinel-2 (S2) image on 22 August 2018 (A), the S2 flood map based on the Modified Normalized Difference Water Index (MNDWI)(B), the Sentinel-1 (S1) flood map (C). Detailed images of the South of Lake Vembanad: the false-color RGB map (D), the MNDWI-based flood map (E), and the difference between the S1- and S2-based flood maps (F).




# Overview of Earth Observations Relevant for Inferring to Waterborne Diseases

# NASA's Earth Observing Satellites

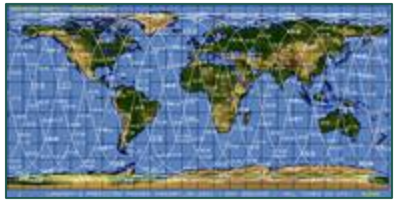



[NASA SVS]

# Current Satellite Missions Relevant for Inferring to Waterborne Pathogens

- GPM is in a low inclination orbit.
- All other satellites are in polar orbit.
- All satellites have multiple sensors and different swarth widths and spatial/temporal resolutions.

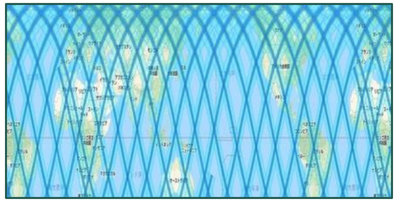
Landsat 8 & 9



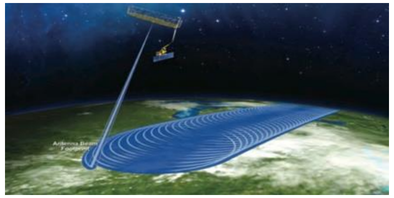
Aqua & Terra

SNPP, JPSS 1 & 2

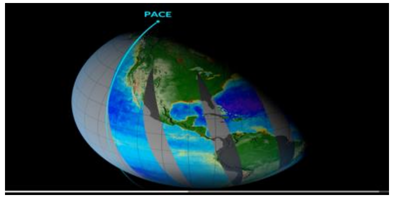
GPM



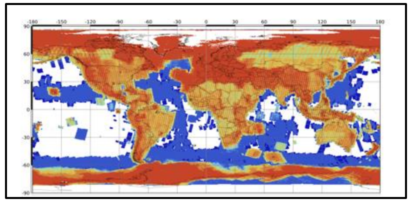
SMAP



PACE

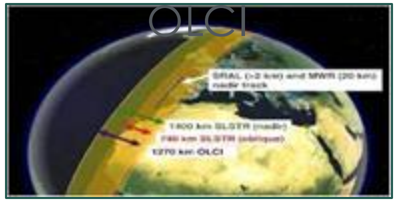



Sentinel-1



Sentinel-2

Senitnel-3 OLCI



The acronyms are defined on the next two slides

| **Satellites** | **Launch Dates** |
|---|---|
| Landsat 8: | 02/2013 |
| Landsat 9: | 09/2021 |
| Terra: | 12/1999 |
| Aqua: | 05/2002 |
| SNPP: | 10/2011 |
| GPM: | 02/2014 |
| SMAP: | 01/2015 |
| JPSS 1 (NOAA 20): | 11/2017 |
| JPSS 2 (NOAA 21): | 11/2022 |
| Sentinel-1A*: | 04/2014 |
| Sentinel 2A*: | 06/2015 |
| Sentinel 2B*: | 03/2017 |
| Sentinel 3A*: | 02/2016 |
| Sentinel 3B*: | 04/2018 |
| PACE: | 02/2024 |

* European Space Agency Missions

# Satellites and Sensors for Monitoring Land and Waterbody Parameters

| Parameters | Satellites & Sensors | Resolutions |
|---|---|---|
| **Water:** Temperature, Chlorophyll-a, Sediments, CDOM<br>**Land:** Land Cover | **Landsat 8 & 9**<br>Operational Land Imager (OLI & OLI2) – Optical<br>Thermal Infrared Sensor (TIRS1 & TIRS2) – Thermal IR | 185 km Swath; 15 m, 30 m, 60 m; 16-Day |
| **Water:** Temperature, Chlorophyll-a, Total Suspended Matter, CDOM.<br>**Land:** Land Cover and Vegetation Indices | **Terra & Aqua**<br>MODerate Resolution Imaging Spectroradiometer (MODIS) – Optical and Thermal IR | 2,330 km Swath; 250 m, 500 m, 1 km; 1–2-Day |
| **Water:** Temperature, Chlorophyll-a, Total Suspended Matter, CDOM.<br>**Land:** Land Cover | **SNPP and JPSS**<br>Visible Infrared Imaging Radiometer Suite (VIIRS) – Optical and Thermal IR | 3,040 km Swath; 375 m – 750 m; 1–2-Day |
| **Water:** Temperature, Chlorophyll-a, Total Suspended Matter | **Sentinel-3A and -3B**<br>Ocean and Land Color Instrument (OLCI) – Optical<br>Sea and Land Surface Temperature Radiometer (SLSTR) – Optical and Thermal | 1,270 km Swath; 300 m; 1-2 -Day |
| **Water:** Chlorophyll-a, Turbidity, CDOM, Cyanobacteria<br>**Land:** Landcover | **Sentinel-2A and -2B**<br>Multi Spectral Imager (MSI) - Optical | 290 km Swath; 10 m, 20 m, 60 m; 5-Day |
| **Water:** Chlorophyll-a, Suspended Particulate Matter, CDOM, Phytoplankton Constituents | **PACE**<br>Ocean Color Instrument (OCI) - Optical<br>Hyperspectral Measurements | 2,500 km Swath, 1 km, 1-2 Day |

SNPP: Suomi National Polar-orbiting Partnership JPSS: Joint Polar Satellite System PACE: Plankton Aerosol, Cloud, ocean, Ecosystem

# Satellites and Sensors for Monitoring Hydrology Parameters

| Parameters | Satellites & Sensors | Resolution |
|---|---|---|
| Precipitation (IMERG) | **GPM & Constellation of National/International Satellites** GPM Microwave Imager (GMI) Dual-frequency Precipitation Radar (DPR) Microwave Radiometers & Sounders | 0.1°x0.1° 30-minutes |
| Soil Moisture | **SMAP** L-band Microwave Radiometer | 1000 km Swath 36 km and 9 km, 2-3 Day |
| Flooding | **Sentinel-1** C-band Synthetic Aperture Radar (SAR) | 80 km Swath 5 m; 12-Day |

GPM: Global Precipitation Measurements

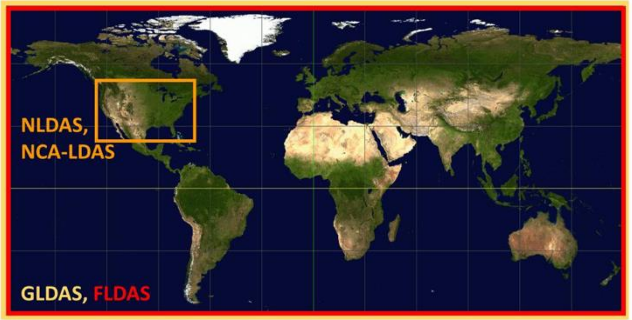
IMERG: Integrated Multi-satellitE Retrievals for GPM

SMAP: Soil Moisture Active Passive

# Earth System Models for Weather and Hydrology Parameters

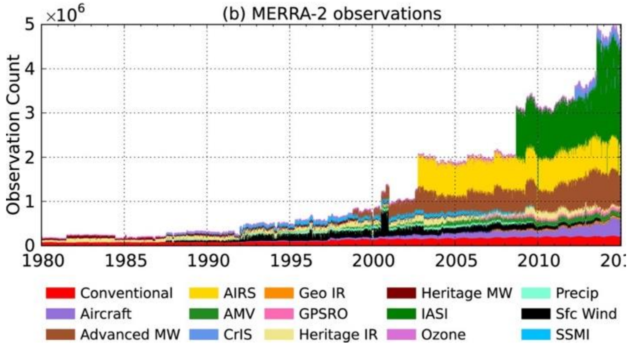
- **LDAS** integrates surface-based and remote sensing observations in land surface models.
- LDAS provides quantities that are not directly observed by satellites **(e.g., runoff)**.

Global and Regional
Land Data Assimilation System (LDAS)




https://ldas.gsfc.nasa.gov/

- **MERRA-2** Blends the vast quantities of observational data with output data of the Goddard Earth Observing System (GEOS) model (1980 – Present).
- Provides state-of-the-art global analyses of weather **(temperature, humidity)**
- Focuses on improvement in the hydrological cycle



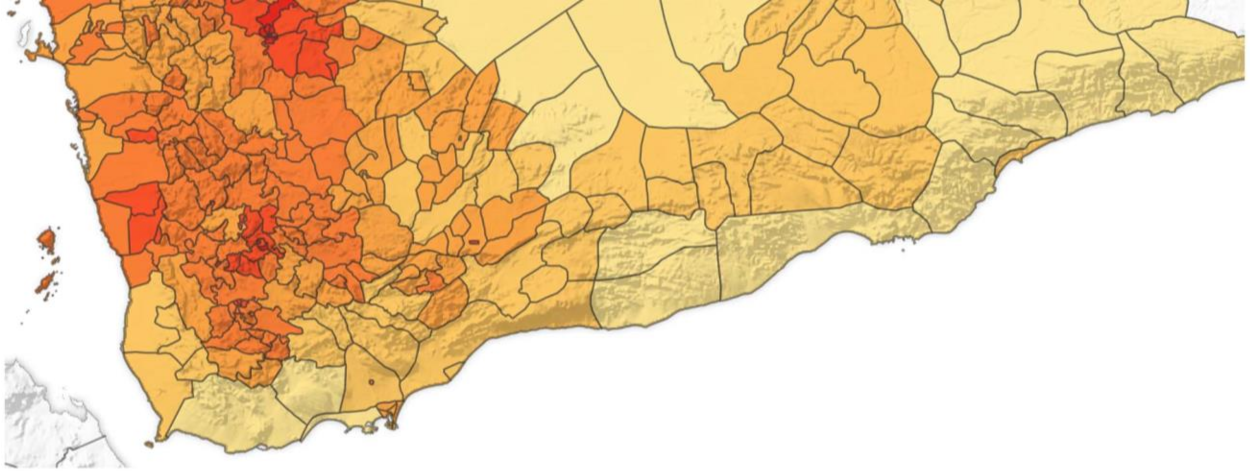

MERRA-2: The Modern-Era Retrospective Analysis for Research and Applications, Version 2 (MERRA-2)

GLDAS: Global Land Data Assimilation System
NLDAS: North American Land Data Assimilation System

# Earth System Models Data Useful for Inferring Waterborne Pathogens

| Parameters | Model | Spatial/Temporal Resolutions and Coverage |
|---|---|---|
| Temperature, Winds, Humidity | MERRA-2 | 0.5° x 0.667°, Hourly, Monthly<br>1980 to Present |
| Runoff, Soil Moisture | GLDAS 2.1<br><br>NLDAS 2.0 | 0.25° x 0.25°, Hourly<br>2000 to Present<br><br>0.125° x 0.125°, Hourly<br>1979 to Present |

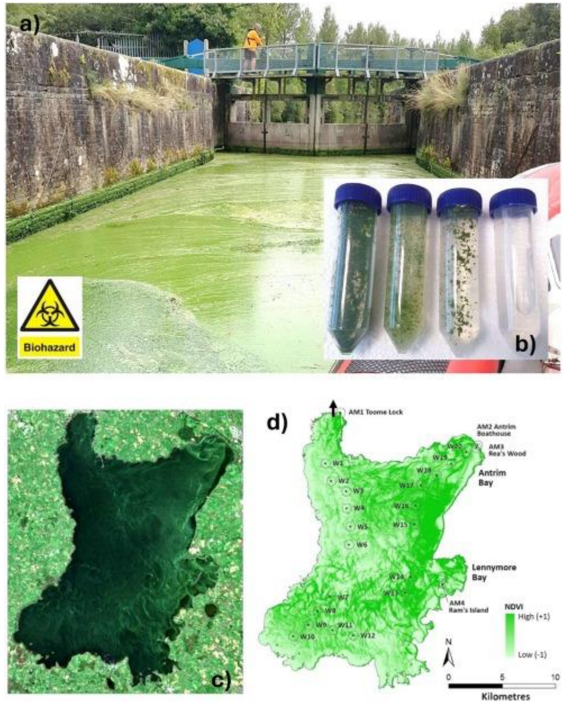
MERRA-2: Modern-Era Retrospective analysis for Research and Applications, Version 2
GLDAS: Global Land Data Assimilation System
NLDAS: North American Land Data Assimilation System



# Demonstration of Data Access

# Example: Algal Bloom in Ireland & U.K. Lough Neagh and Public Health Risk

- An unprecedented algal bloom occurred in Ireland & U.K. Lough Neagh (54.5933° N, 6.4162° W) in August – September 2023.
- Sentinel-2 images and Normalized Difference Vegetation index (NDVI)calculated from the imagery showed the extent of the algal bloom.
- Analysis of the algal sample showed the presence of:
  - Pathogens such as E. coli, Salmonella, Enterobacter and Clostridium
  - several types of microcystins and cyanotoxins
- Nutrient runoff and water temperature were responsible for the algal bloom.




a) A photograph of an algal mat at Toome Lock sampled on the 23rd August 2023.**b)** Four 50 ml Falcon tubes showing (left-to-right) an algal mat sample and three surface water samples with varying algal concentrations. Photographs © Neil Reid. **c)** Copernicus Sentinel-2 RGB natural colour satellite image of Lough Neagh captured on the 4th September 2023 converted to **d)** a Normalized Difference Vegetation Index (NDVI) showing the extent and spatial structure of the Harmful Algal Bloom.

Reid, N., M. I. Reyne, W. O'Neill, B. Greer, Q. He, O. Burdekin, J. W. McGrath, and C. T. Elliott, 2024: Unprecedented harmful algal bloom in the UK and Ireland's largest lake associated with gastrointestinal bacteria, microcystins and anabaenopeptins presenting an environmental and public health risk. *Environ. Int.*, 190, 108934, https://doi.org/10.1016/j.envint.2024.108934.

# Example: Algal Bloom in New York Finger Lakes

- Blooms of toxic cyanobacteria spread across the Finger Lakes (42.7238° N, 76.9297° W) - Seneca, Canandaigua, Skaneateles and Cayuga - between June to October 2024.
- The algal outbreak affected swimmers, animals, and some local drinking water supplies.
- The EPA warned of the risks of skin rashes and blisters from skin exposure, gastroenteritis, liver toxicity, and neurotoxicity from ingestion.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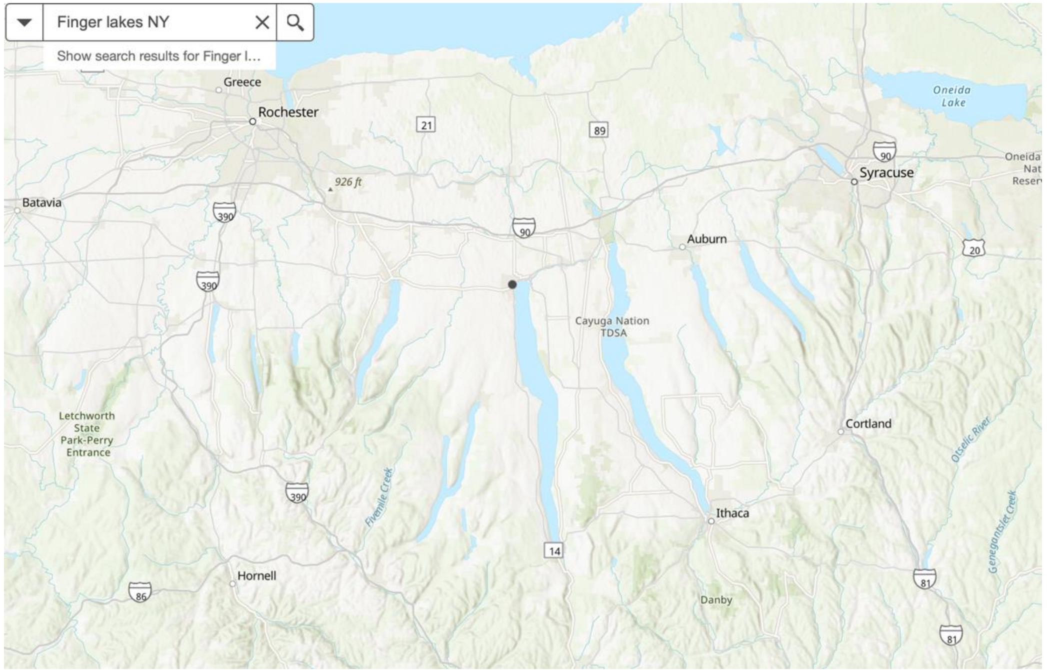
**Harmful algal blooms spread across nearly every Finger Lake**

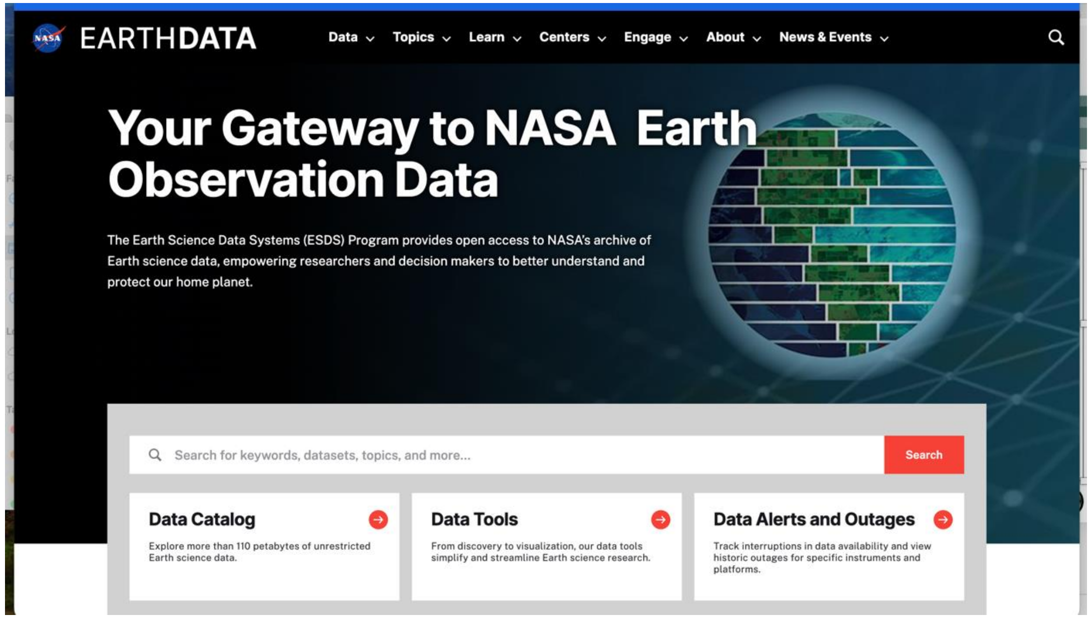



[Toxic Blooms in New York's Finger Lakes Set Record in 2024](#)

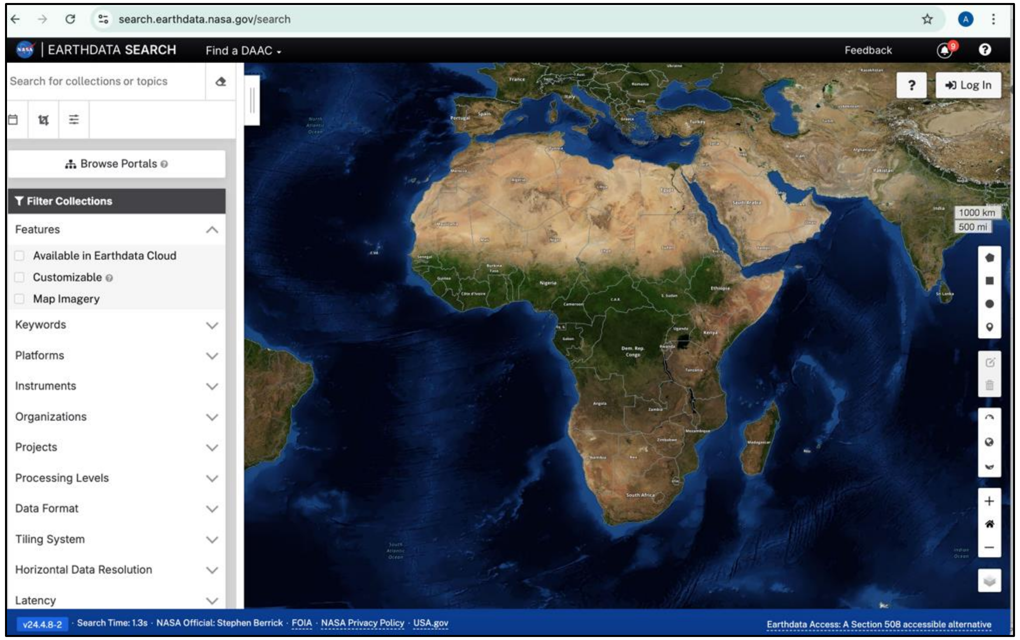
[Democrat & Chronicle](#)

# NASA Earthdata Search

- [Earthdata]

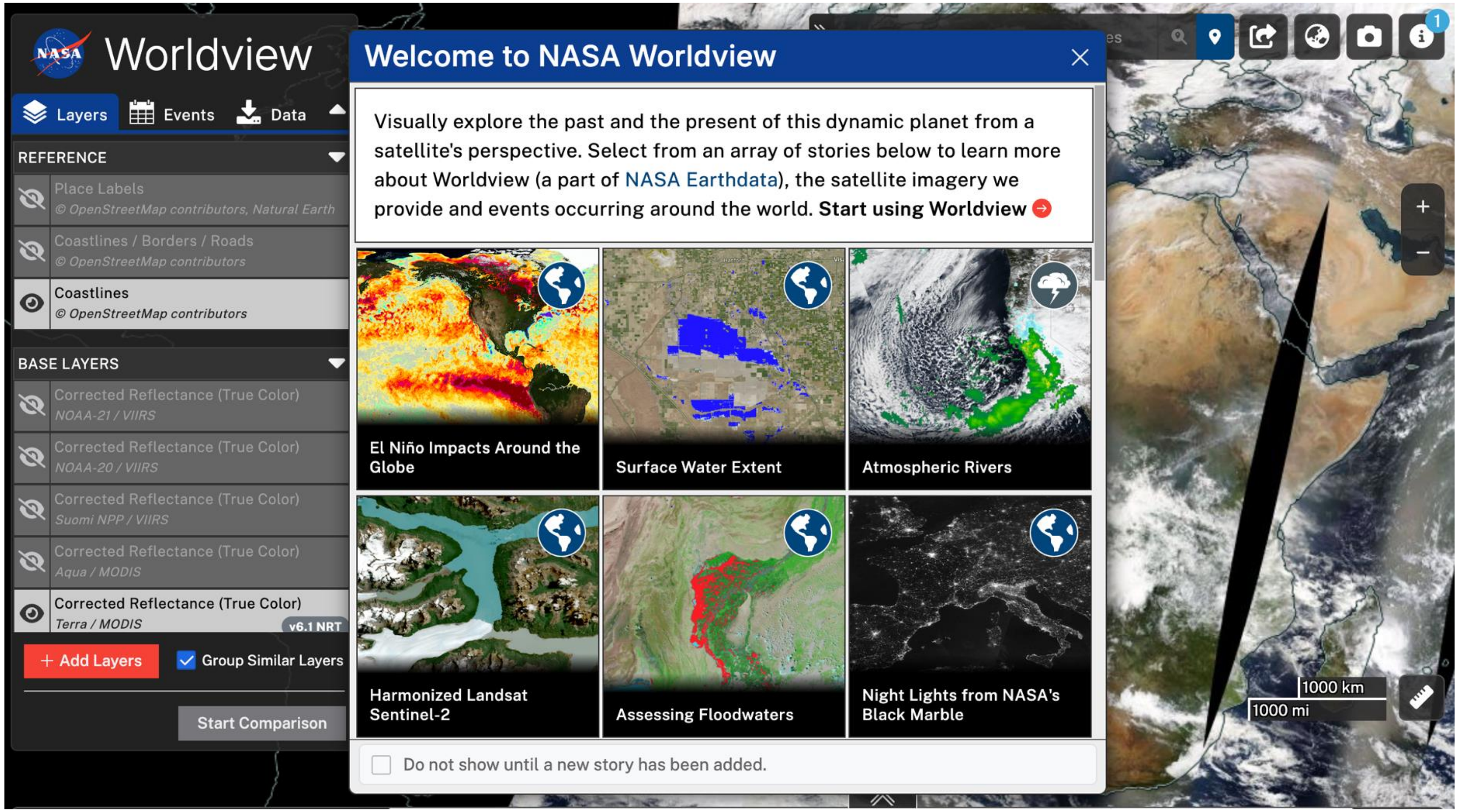



- [Earthdata Search]



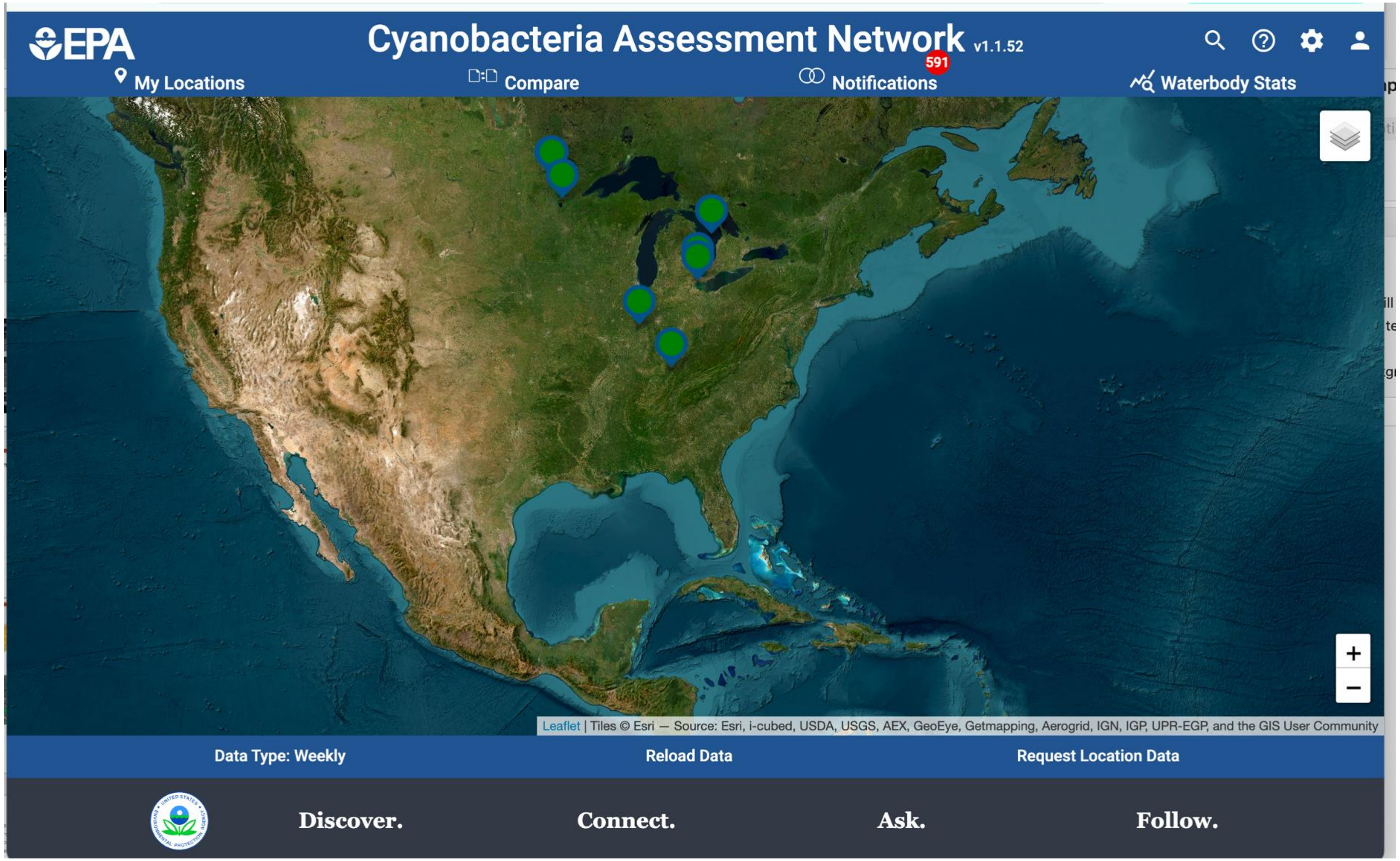
# NASA Worldview

- [Worldview]

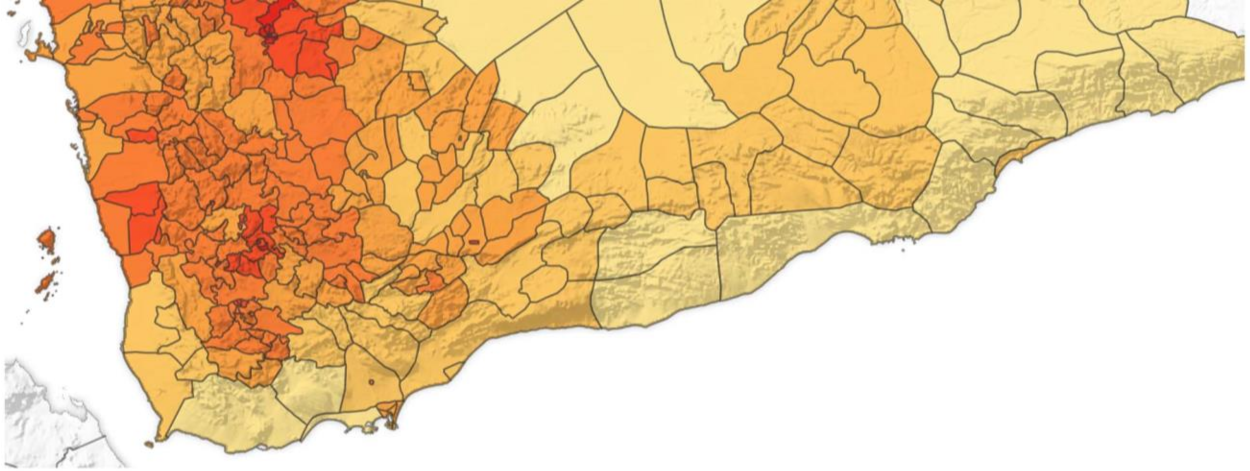


# Cyanobacteria Assessment Network

- [CYaN]




[ARSET CyAN Training]




# Part 1:
# **Summary**

# Advantages and Limitations of using Earth Observations for Monitoring Waterborne Diseases

- Though waterborne pathogens are not directly observed, observations of many environmental parameters complement *in situ water sample data, which are sparse and infrequent*.
- Regular and consistent observations over a large area.
- Consistent spatial and temporal resolutions, allow for time series analyses.
- Large number of data products available.
- Mostly free and open access.

- Varying spatial and temporal resolutions and coverage.
- Optical observations can not monitor water surfaces in the presence of clouds.
- Data extraction and processing are required for developing waterborne disease prediction models.

# Summary

- Reviewed common waterborne diseases and pathogens.
- Identified environmental parameters relevant for inferring the presence of pathogens.
- Introduced satellites, sensors, and Earth system models to obtain the environmental parameters.
- Demonstrated webtools to access satellite and model data and to monitor cyanobacteria.

# Looking Ahead to Part 2

- Part 2 will be on March 27 and present case studies showing model development for predicting cholera outbreak using Earth observations.

# Homework and Certificates

- **Homework:**
  - One homework assignment
  - Opens on 03/27/2025
  - Access from the training webpage
  - Answers must be submitted via Google Forms
  - **Due by 04/10/2025**

- **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.

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# Resources

- [GPM Health Appplications]
- [PACE Applications]
- [Waterborne Diseases: CDC]

## Thank You!