

# Satellite Observations of Water Quality for Sustainable Development Goal 6

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30 July 2018



# Course Objectives

At the end of this session you will obtain:

- information about monitoring coastal and inland water quality using satellite observations that can contribute to the United Nations Sustainable Goal 6, related to availability of clean water
- a basic understanding about developing water quality monitoring applications using satellite observations and in situ measurements for your region of interest
- a hands-on exercise for accessing and analyzing selected water quality indicators for Harmful Algal Blooms (HABs), e.g. chlorophyll-a concentration (Ch-a) and sea surface temperature (SST)





# Agenda

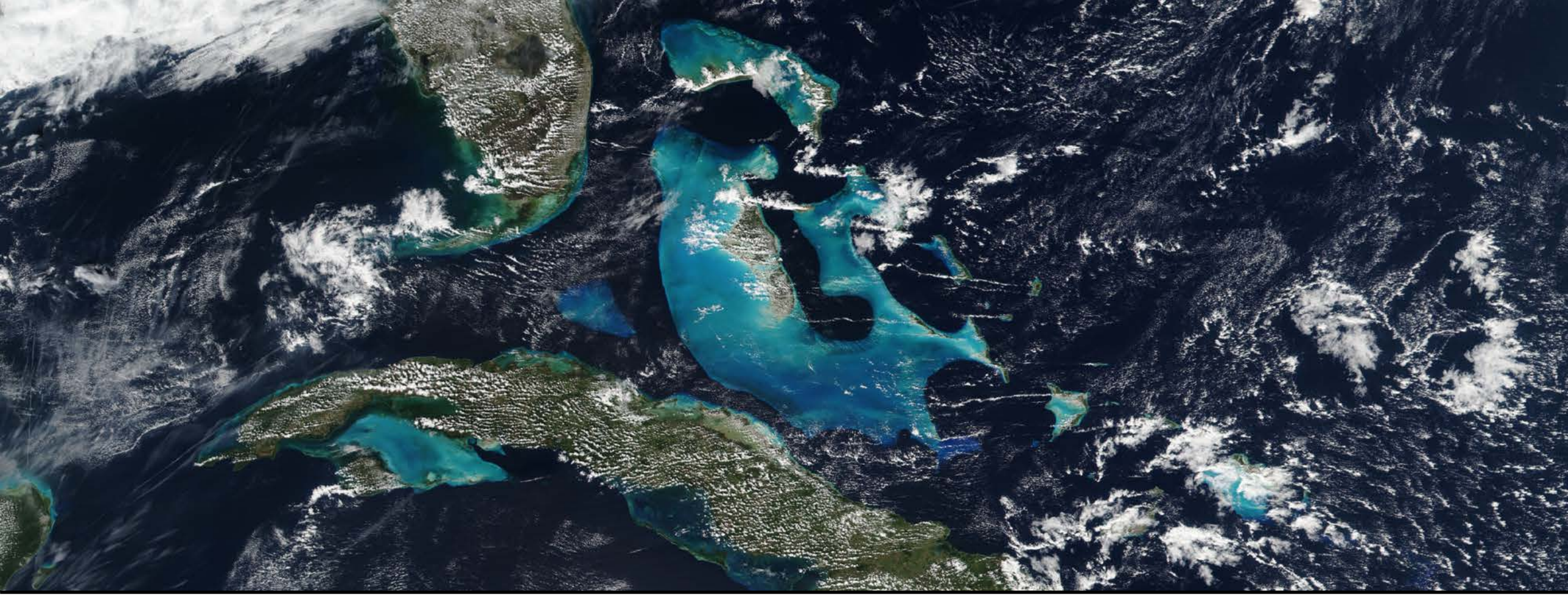
- Overview of:
  - Applied Remote Sensing Training (ARSET) Program
  - The UN Sustainable Development Goal (SDG) 6
  - Satellite Data Products for Water Quality (WQ) Monitoring For SDG 6.6.1: Sub-Indicator 2 – water quality of lakes and artificial water bodies
- Examples of Monitoring Harmful Algal Boom Indicators
- Demonstration and Hands-on Exercise for **Lake Titicaca**: Chl-a and SST Data Access Using Web-based Tools
- Break-out Groups: Discussion on Data Needs for WQ Monitoring and Decision Support



# Materials

- Today's presentation and exercises are available at:
  - <http://arset.gsfc.nasa.gov/water/workshops/geoweek-sdg6>
- Hard copies of exercises will also be available
- Questions?
  - Amita Mehta: [amita.v.mehta@nasa.gov](mailto:amita.v.mehta@nasa.gov)
  - Brock Blevins: [brockbl1@umbc.edu](mailto:brockbl1@umbc.edu)
  - Ana Prados: [aprados@umbc.edu](mailto:aprados@umbc.edu)





# NASA's Applied Remote Sensing Training Program (ARSET)



# NASA's Applied Remote Sensing Training Program (ARSET)

<http://arset.gsfc.nasa.gov/>

- Empowering the global community through remote sensing training
- Part of NASA's Applied Sciences Capacity Building Program
- Seeks to increase the use of Earth science in decision-making through training for:
  - policy makers
  - environmental managers
  - other professionals in the public and private sector

Topics for Trainings Include:



# ARSET Team Members

## Program Support

- Ana Prados, Program Manager (GSFC)
- Brock Blevins, Training Coordinator (GSFC)
- David Barbado, Spanish Translator (GSFC)
- Annelise Carleton-Hug, Program Evaluator (Consultant)
- Elizabeth Hook, Technical Writer/Editor (GSFC)
- Selwyn Hudson-Odoi, Training Coordinator (GSFC)
- Marines Martins, Project Support (GSFC)
- Stephanie Uz, Program Support (GSFC)

## Disasters & Water Resources

- Amita Mehta, Instructor (GSFC)
- Erika Podest, Instructor (JPL)

## Land & Wildfires

- Cynthia Schmidt, Lead (ARC)
- Amber Jean McCullum, Instructor (ARC)

## Health & Air Quality

- Pawan Gupta, Lead (GSFC)
- Melanie Cook, Instructor (GSFC)

## Acknowledgement:

- We wish to thank Nancy Searby for her continued support



# ARSET Training Levels

## Advanced (Level 2)

Requires level 1 training or equivalent knowledge

In-depth and highly focused topics

*Advanced Webinar: SAR Image and Data Processing*

## Basic (Level 1)

Requires level 0 training or equivalent knowledge

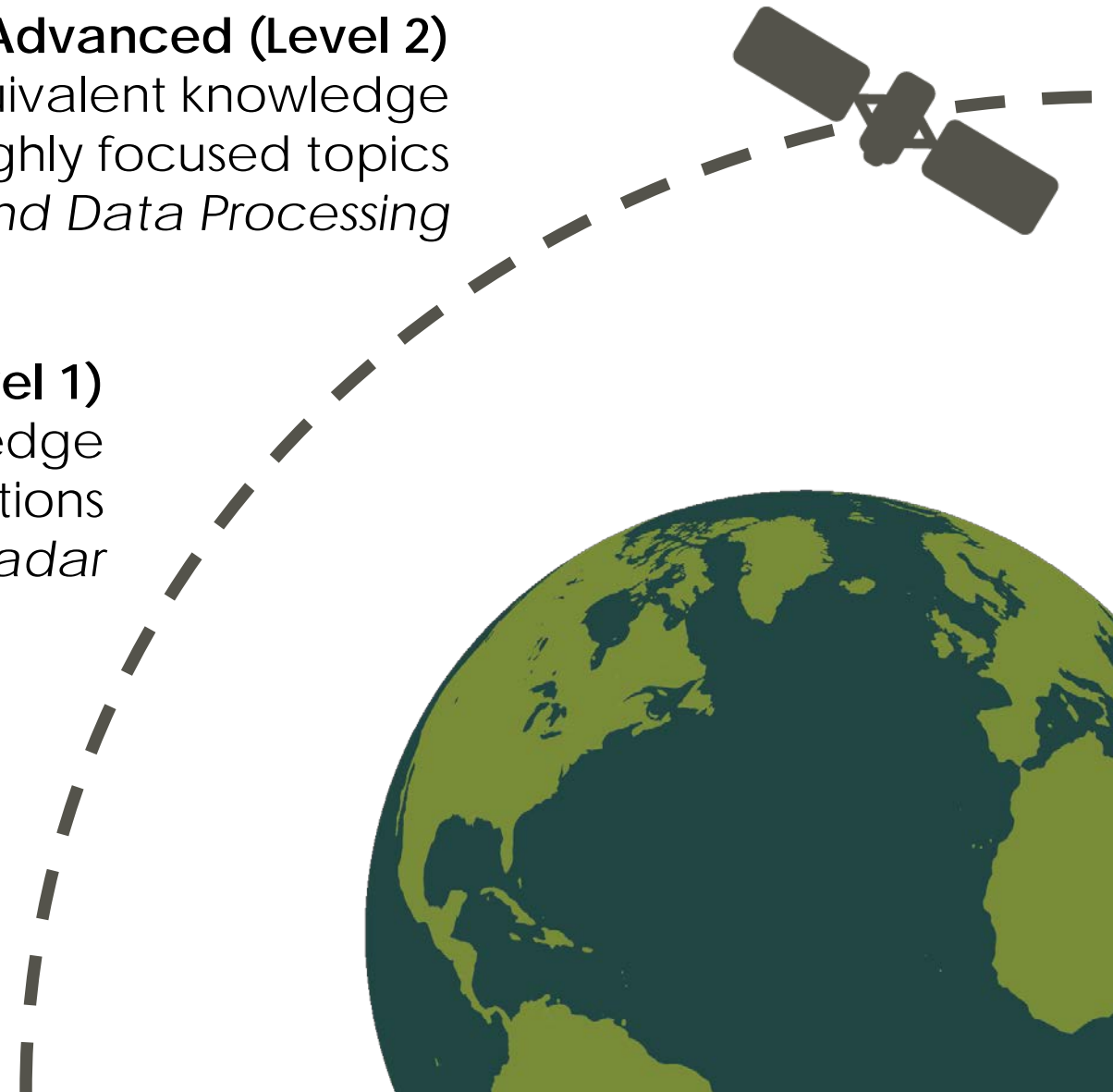
Covers specific applications

*Introduction to Synthetic Aperture Radar*

## Fundamentals (Level 0)

Assumes no prior knowledge of remote sensing

*Fundamentals of Remote Sensing*





# ARSET Trainings



100 trainings



13,000+ participants



160+ countries



3,700+ organizations



\* size of bubble corresponds to number of attendees



# Learn More About ARSET


<http://arset.gsfc.nasa.gov/>

The screenshot displays the ARSET website interface. At the top, the NASA logo and 'ARSET Applied Remote Sensing Training' are visible, along with navigation links for 'Earth Sciences Division', 'Applied Sciences', and 'ASP Water Resources'. A search bar and a Twitter icon are also present. A main navigation menu includes 'Home', 'About', and 'Trainings'. The 'Trainings' menu is open, showing categories: 'Fundamentals', 'Disasters', 'Health & Air Quality', 'Land', and 'Water Resources'. A featured training announcement for 'Introduction to Remote Sensing of Harmful Algal Blooms' is highlighted, with details: 'Tuesdays, Sep 5-26, 2017, 11:00-12:00 or 21:00-22:00 EDT (UTC-4)' and a 'Register Now' button. The background image is a satellite view of a coastal area with greenish water. A sidebar on the right lists 'ARSET' links: 'Online Trainings', 'In-Person Trainings', 'Sign up for the Listserv' (highlighted with a mouse cursor), 'Tools Covered', 'Suggest a Training', 'Personnel', and 'Resources'. Below this is an 'Upcoming Training' section for 'Water' with the title 'Satellite Observations of Water Quality for...'. Navigation arrows are at the bottom of the main content area.



# Sign up for the ARSET Listserv

<https://lists.nasa.gov/mailman/listinfo/arset>



APPLIED REMOTE SENSING TRAINING  
**NEWSLETTER**

As the weather warms in the Northern Hemisphere, many will notice an increase in algal blooms like [this one](#) which occurred in Washington last year. [Learn the basics of aquatic remote sensing, including how to access satellite-derived chlorophyll data.](#)


### UN Sustainable Development Goals

In the 2030 Agenda for Sustainable Development, the United Nations established a series of goals for protecting the planet and ending global poverty. In a recent ARSET webinar, nearly 400 participants learned to use satellite observations of air quality in support of the goals. The training was featured on the [SDG Knowledge Hub](#), and materials from the training are now available on the [ARSET website](#). This June, the program is offering a three day webinar on remote sensing of land indicators for Sustainable Development Goal 15.

[Register Here](#)

NASA EOSDIS recently announced that Reverb data search would be replaced with Earthdata Search by the end of the year. The new system will be faster and easier to use. [Read the full announcement here.](#)

Remote Sensing of Aquatic Environments



UPCOMING  
APPLIED REMOTE SENSING TRAINING PROGRAM  
**TRAINING**

### Introduction to Synthetic Aperture Radar Introducción al Radar de Apertura Sintética

June 28, 29 and July 5, 6  
English: 21:00-22:00 EDT (UTC-4)


SAR can observe the Earth's surface day and night, through most weather conditions, and the signal can penetrate the vegetation canopy. There are a number of existing SAR datasets from current and past airborne and satellite missions, as well as exciting upcoming missions. This online webinar will focus on building the skills needed to acquire and understand SAR data, including polarimetric and interferometric SAR (PolSAR and InSAR), as well as potential applications.

[Register](#)

28, 29 de junio y 5, 6 de julio  
Español: 12:00-13:00 EDT (UTC-4)

SAR puede observar la superficie terrestre de día y de noche y a través de la mayoría de las condiciones meteorológicas. Además, la señal puede penetrar la cubierta vegetal y proporcionar información relacionada al estado de inundación de la vegetación. Existen datos de SAR del presente y del pasado obtenidos desde satélites y aviones y habrá más con futuras misiones. Esta capacitación en línea se enfocará en desarrollar los conocimientos necesarios para adquirir y entender datos de SAR incluyendo polarimetría e interferometría y sus potenciales aplicaciones.

[Register](#)



APPLIED REMOTE SENSING TRAINING  
**NEWSLETTER**

The MODIS image above (Credit: [NASA Earth Observatory](#)) shows a wildfire burning in Greenland. Many areas around the world are experiencing above average wildfire activity this year. [Learn to forecast, monitor, and manage wildfires using satellite observations.](#)

### SAR Success

We just wrapped up our first training focused on Synthetic Aperture Radar. Unlike optical sensors, SAR can penetrate through cloud cover and vegetation and is useful for nighttime observations. This four-session webinar, offered in both English and Spanish, was ARSET's largest training to date. Missed the live webinar? You can watch it on demand.

[Watch Now](#)

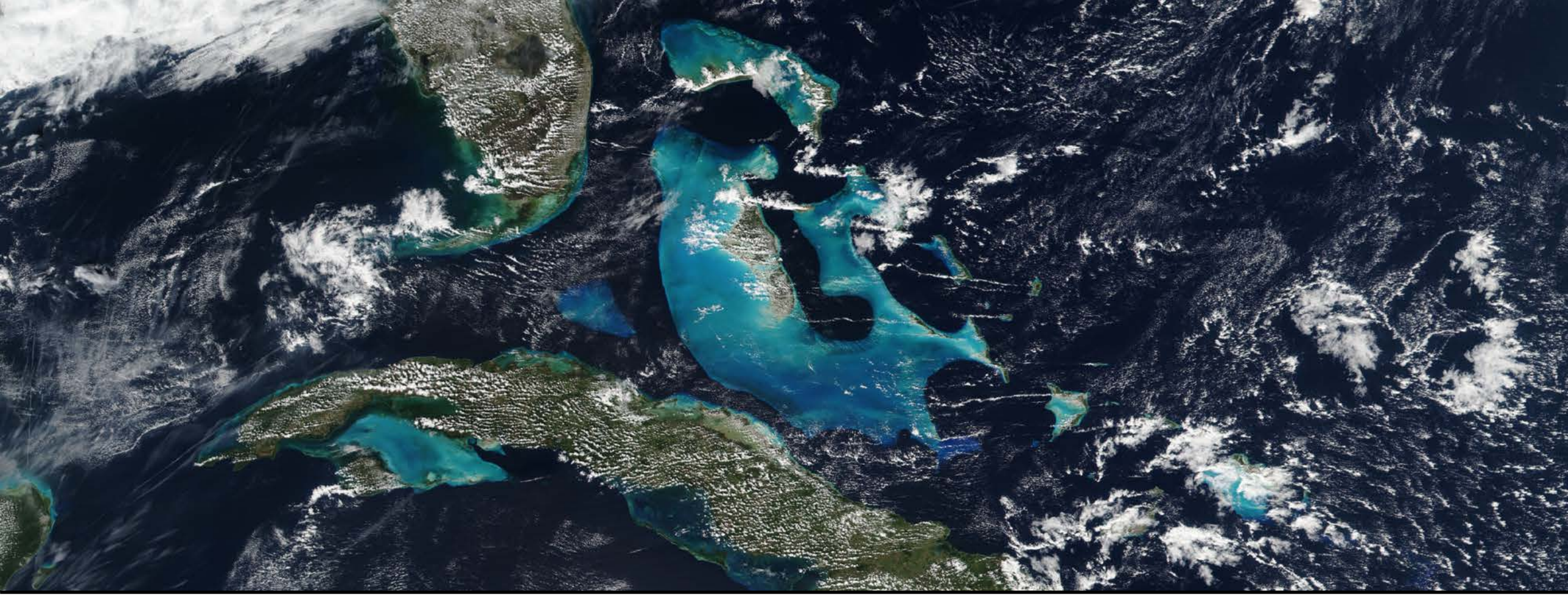
### Have You Heard of AppEARS?

Application for Extracting and Exploring Analysis Ready Samples, or AppEARS, is a useful tool for downloading remote sensing data. Download just the data you need by subsetting spatially (by point or area), temporally, and spectrally. The application also allows you to visualize the results before downloading them.

[Learn More](#)







Information about the SDGs and SDG 6



# UN Sustainable Development Goals

## Transforming Our World: The 2030 Agenda for Sustainable Development

- A plan of action for people, planet and prosperity
- All countries and all stakeholders, acting in collaborative partnership, will implement this plan
- 17 SDGs and 169 targets
- Balance the three dimensions of sustainable development:
  - economic
  - social
  - environmental



Reference: [Transforming our world: the 2030 Agenda for Sustainable Development](#)



# SDG 6: Clean Water & Sanitation Targets

## Ensure Availability and Sustainable Management of Water and Sanitation for All

6.1: By 2030, achieve universal and equitable access to safe and affordable drinking water for all

6.2: By 2030, achieve access to adequate and equitable sanitation and hygiene for all and end open defecation, paying special attention to the needs of women and girls and those in vulnerable situations

6.3: By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally

6.4: By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity

6.5: By 2030, implement integrated water resources management at all levels, including through transboundary cooperation as appropriate

6.6: By 2020, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes

6.a: By 2030, expand international cooperation and capacity-building support to developing countries in water- and sanitation-related activities and programmes, including water harvesting, desalination, water efficiency, wastewater treatment, recycling and reuse technologies

6.b: Support and strengthen the participation of local communities in improving water and sanitation management





# SDG 6: Clean Water & Sanitation Indicators

## Ensure Availability and Sustainable Management of Water and Sanitation for All

6.1.1 Proportion of population using safely managed drinking water services

6.2.1 Proportion of population using safely managed sanitation services, including a hand-washing facility with soap and water

6.3.1 Proportion of wastewater safely treated

6.3.2 Proportion of bodies of water with good ambient water quality

6.4.1 Change in water-use efficiency over time

6.4.2 Level of water stress: freshwater withdrawal as a proportion of available freshwater resources

6.5.1 Degree of integrated water resources management implementation (0-100)

6.5.2 Proportion of transboundary basin area with an operational arrangement for water cooperation

6.6.1 Change in the extent of water-related ecosystems over time

6.a.1 Amount of water- and sanitation-related official development assistance that is part of a government-coordinated spending plan

6.b.1 Proportion of local administrative units with established and operational policies and procedures for participation of local communities in water and sanitation management



# SDG 6

- Target 6.6 By 2020 protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes
- **Indicator 6.6.1 Change in the extent of water-related ecosystems over time**
- “Due to the multi-faceted nature of Indicator 6.6.1, a progressive methodology is proposed which promotes country-derived data collection to be complimented by other globally available datasets such as earth observations. Used in conjunction with national knowledge and data, global earth observations which are validated by countries can enhance an understanding of how and why water related-ecosystems are changing”

*MONITORING METHODOLOGY FOR SDG INDICATOR 6.6.1*



# SDG 6.6.1: Change in the extent of water-related ecosystems over time

Sub-Indicators based on globally available data from earth observations which will be validated by countries against their own methodologies and datasets:

- Sub-Indicator 1 – spatial extent of water-related ecosystems
- ***Sub-Indicator 2 – water quality of lakes and artificial water bodies***
- Monitoring parameters of water quality (**chlorophyll a and total suspended solids**) from earth observations
- Data for Sub-Indicator 2 generated annually and used to calculate percentage change every 5 years (reported in % and direction of change)





# Other ARSET Trainings Related to SDG 6



Remote sensing can be used to monitor and address a variety of issues related to water resource management, including drought, flooding, and reservoir management

Relevant Targets:

6.3, 6.4, 6.5, 6.6,



Level 0

Fundamentals of Remote Sensing for Water Resource Management

<http://arset.gsfc.nasa.gov/webinars/fundamentals-remote-sensing#water>

**1 Hour**



Level 1

Water Resource Management Using NASA Earth Science Data

<http://arset.gsfc.nasa.gov/water/webinars/water-resources15>

**5 Hours**



Level 1

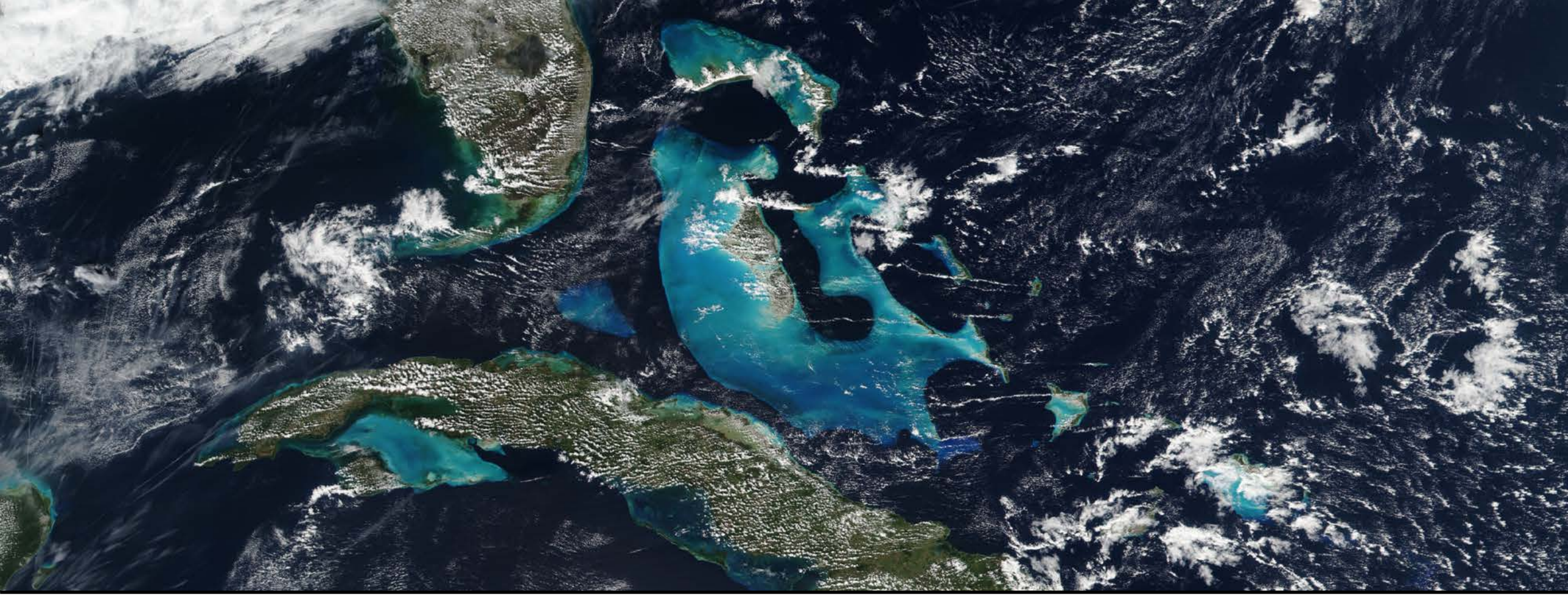
Applications of Remote Sensing to Soil Moisture & Evapotranspiration

<http://arset.gsfc.nasa.gov/water/webinars/apps-et-smap>

**5 Hours**







# Satellite Data Products for Water Quality Monitoring

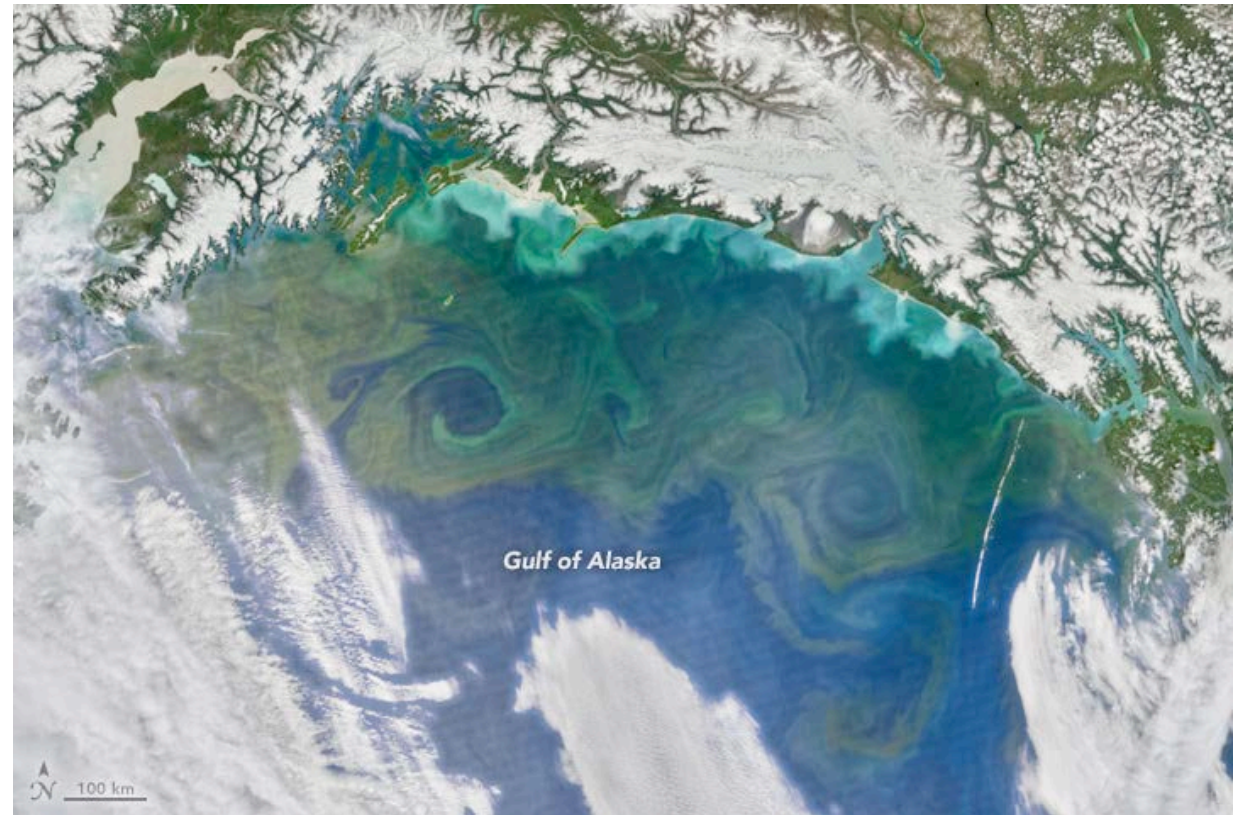


# Water Quality Indicators Observable from Satellites

- Turbidity / Sediments
- Colored Dissolved Organic Matter (CDOM)
- Sea Surface Temperature (SST)
- Chlorophyll-a (phytoplankton)
- Salinity
- TSS (Total Suspended Solids)

## Phytoplankton Bloom in the Gulf of Alaska

SNPP-VIIRS June 9, 2016





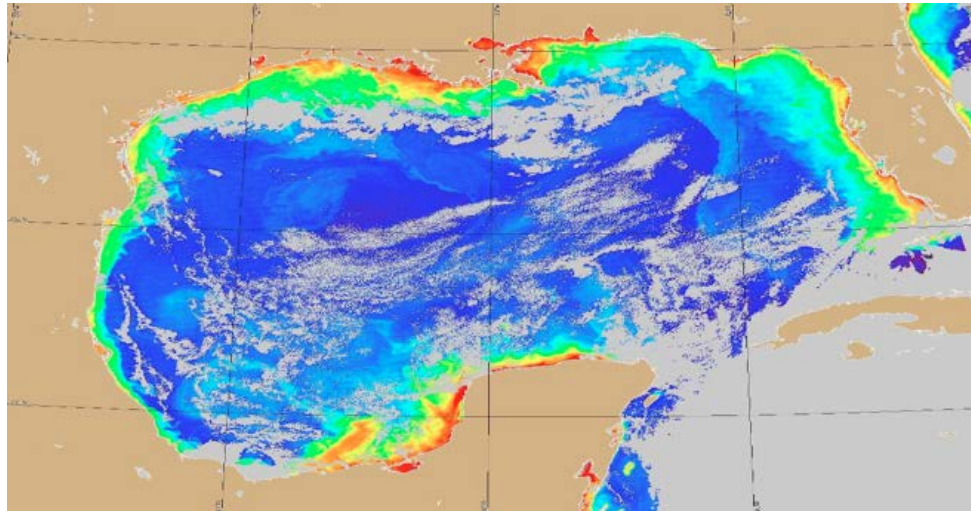
# Which Factors Cause Changes in Water Quality?

- Nutrient loading “eutrophication”
- Pollution
- Water Temperature (warmer water affects Algal Bloom)
- Food web changes
- Introduced species
- Changes in water flow
  - e.g., after major events like hurricanes, drought, or floods
- Other, yet unknown, factors



# Advantage of Satellite Observations for Water Quality Monitoring

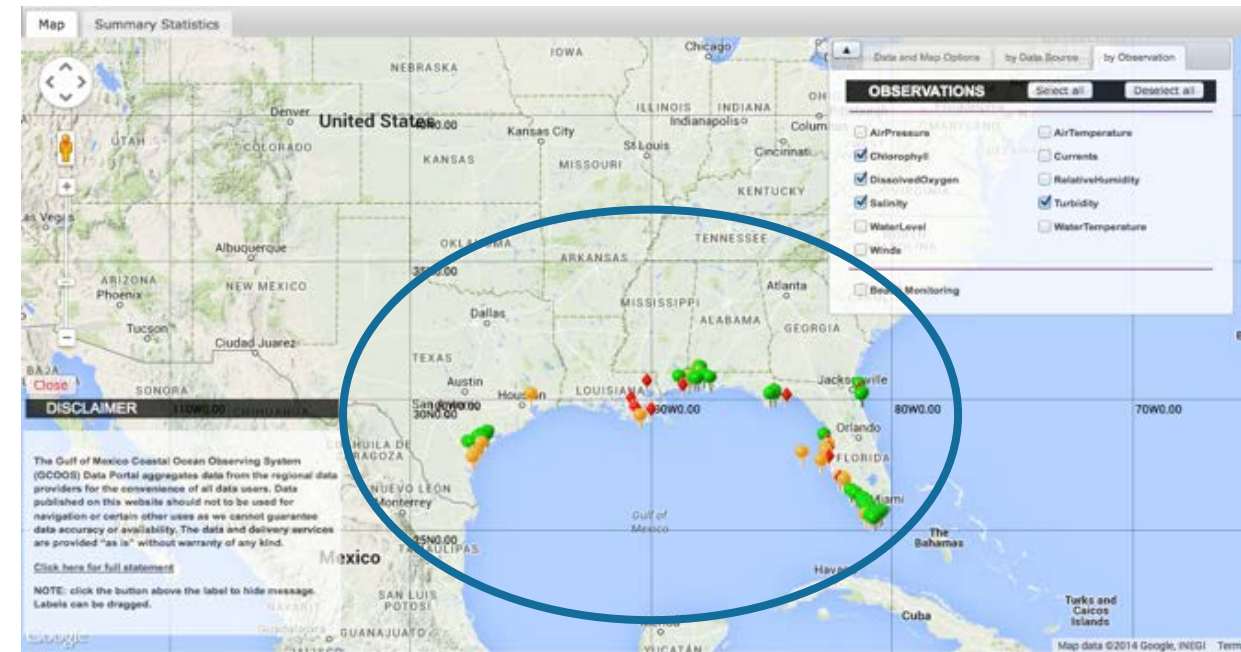
- Provides information where there are no surface-based measurements available
- Global and near-global coverage with consistent observations
- Continuous coverage in comparison to point measurements



Left: MODIS Aqua satellite image from October 23, 2011, showing areas of elevated chlorophyll a (in red and orange)

## Limited Water Sampling Locations

<http://data.gcoos.org/>



# Water Quality Affects Water Optical Properties

Remote Sensing can be used to Monitor Water Color, Indicative of Water Quality

- Dissolved and suspended matter in water change optical property and therefore its color
  - Dissolved matter include: tannin, caused by organic matter coming from leaves, roots, and plant remains
  - Suspended matter include: particles of clay, undissolved minerals, planktons and algal bloom
- Some Harmful Algal Bloom (HAB) species have unique properties that affect water color - (e.g., red tides)

Color caused by dissolved matter: tannins



Color caused by suspended material: sediment



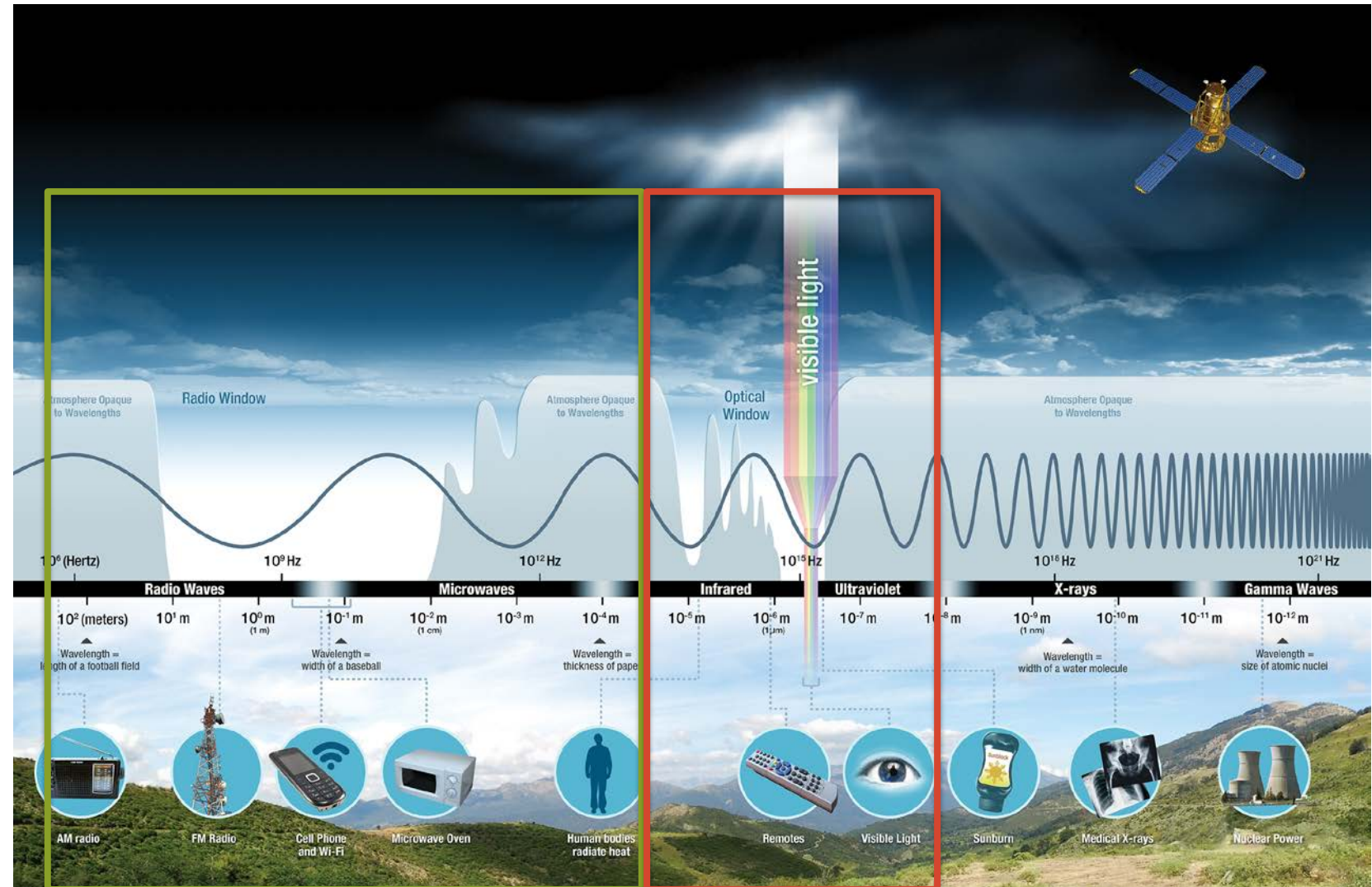
<https://water.usgs.gov/edu/color.html>



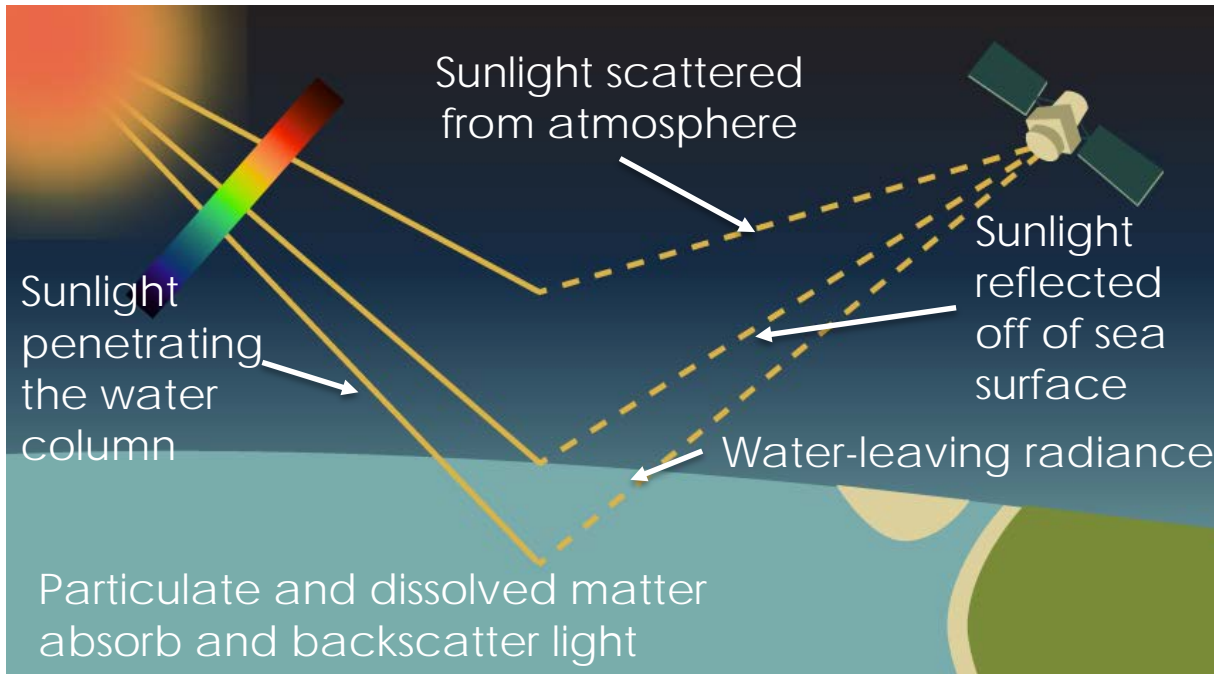


# Remote Sensing of Water Quality

- Satellites carry instruments and sensors to measure:
  - reflected solar radiation
  - emitted infrared and microwave radiation

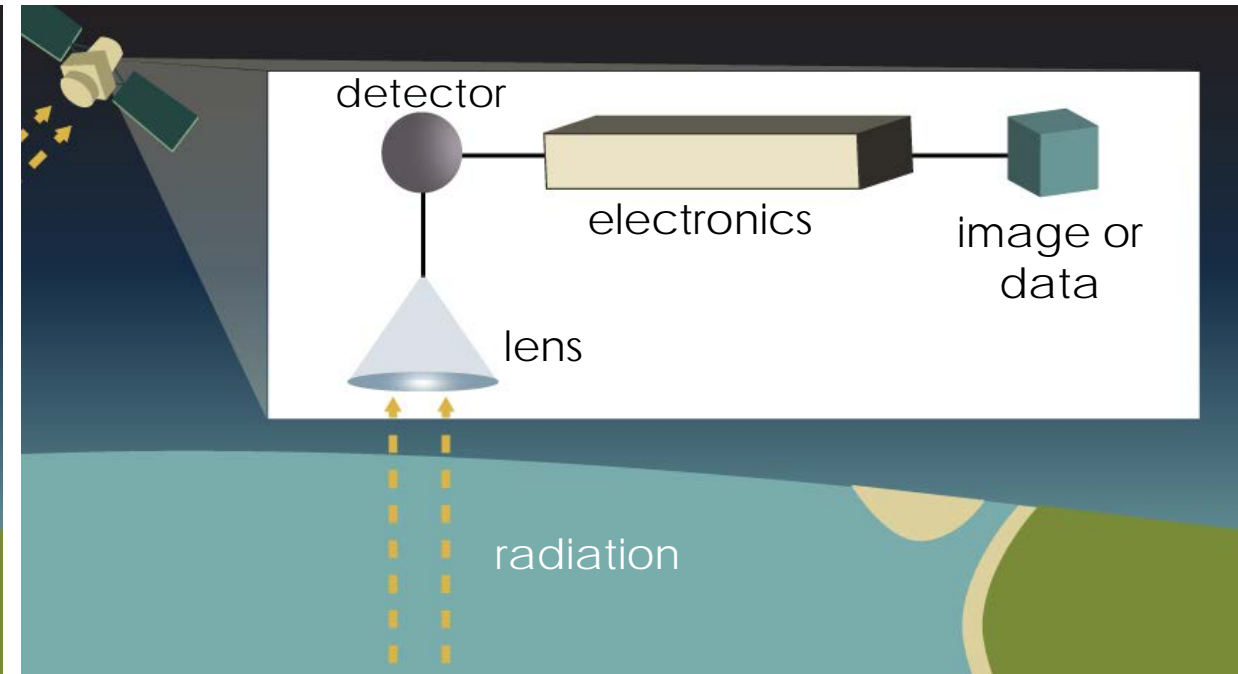


# Remote Sensing of Water Quality



Reflected solar radiation measured by satellite sensors is used to derive optically-active water constituents:

- Turbidity and Suspended Sediments
- Colored Dissolved Organic Matter (CDOM)
- Chlorophyll-a (phytoplankton)



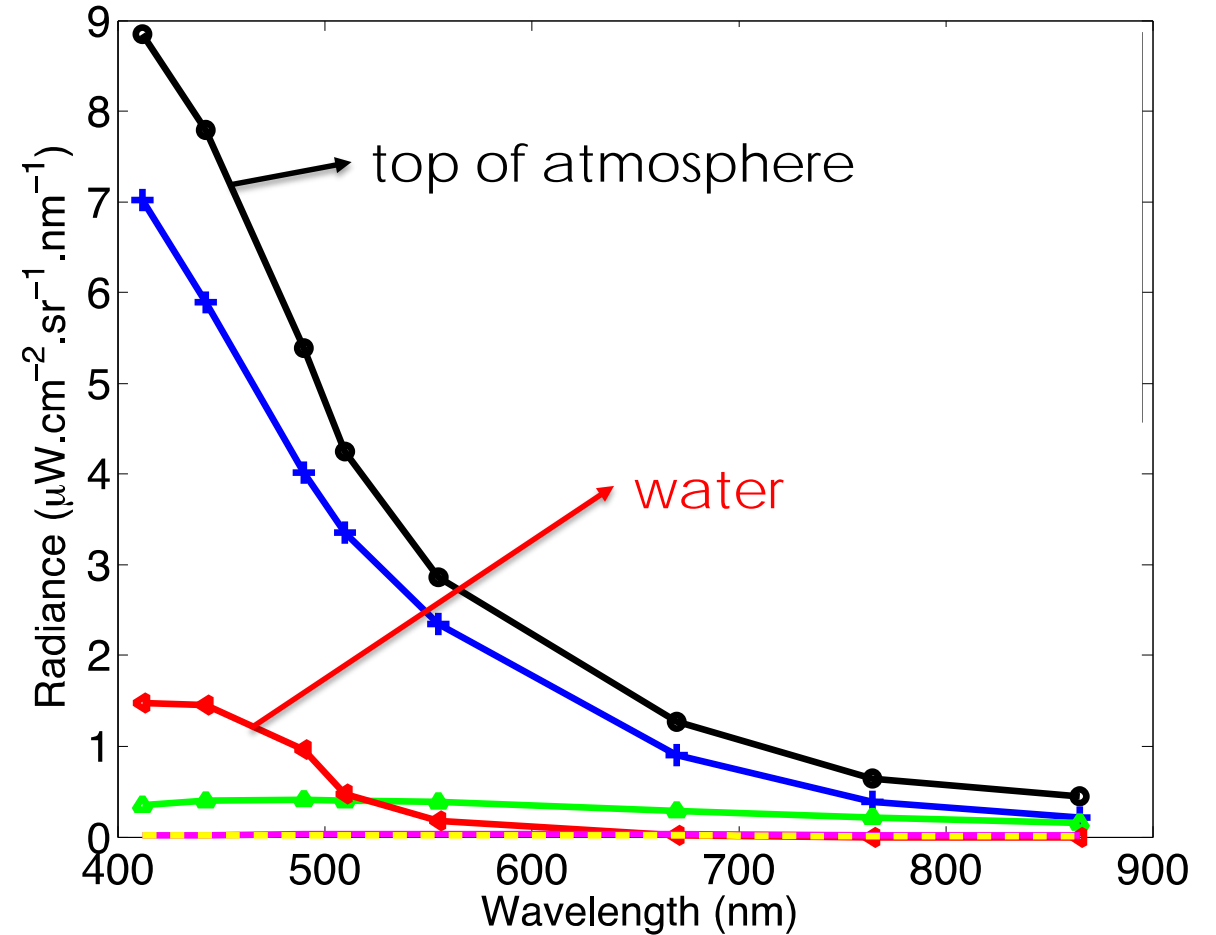
Emitted thermal infrared and microwave radiation measured by satellite sensors is used to derive:

- Surface Temperature
- Salinity



# Remote Sensing of Water Quality

- Satellite observations of reflectance has to be corrected for atmospheric effects to derive water quality





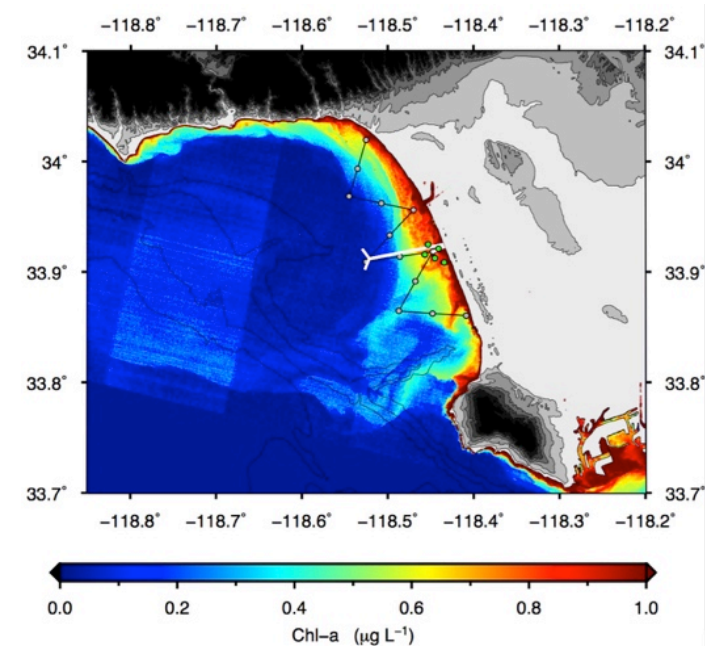
# Remote Sensing of Water Bodies

## Techniques

Simple image interpretation to derive **qualitative information** about water quality



Use of various types of algorithms combining atmospherically corrected satellite images and in situ measurements to derive **quantitative information** about water quality



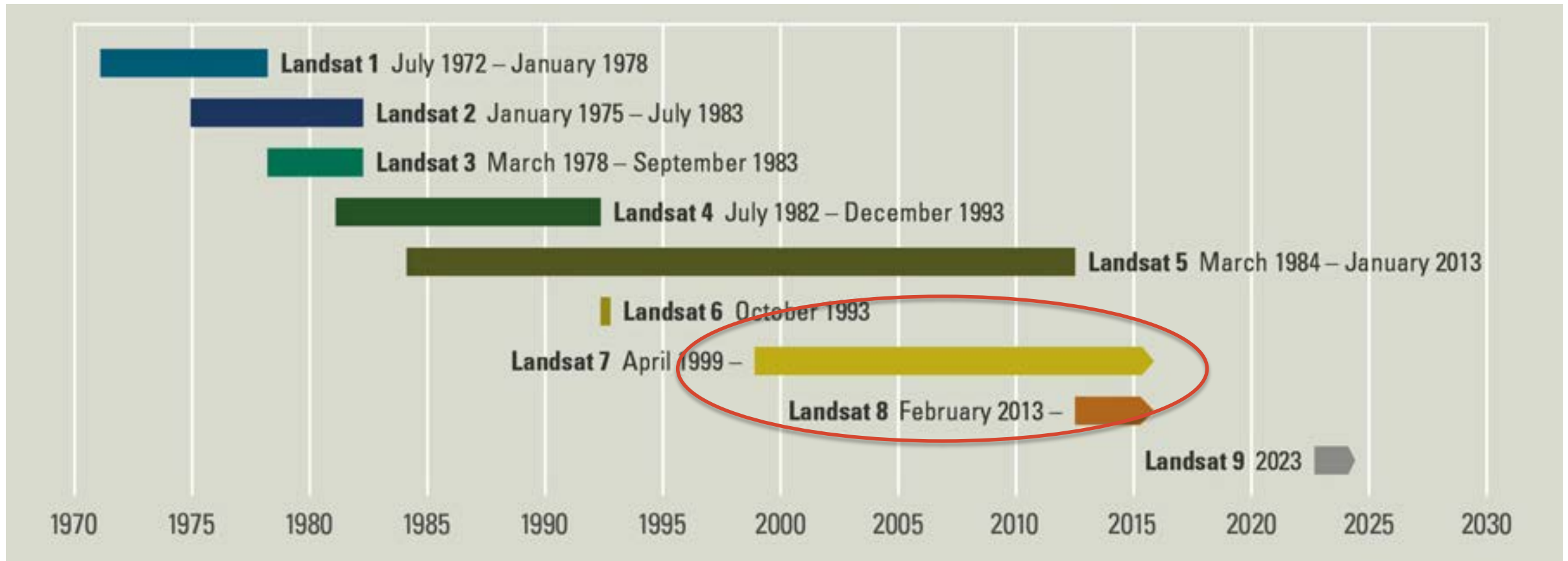
# Satellites for Water Quality Monitoring

- Current Satellite Missions:
  - Landsat 7 & Landsat 8
  - Terra
  - Aqua
  - Suomi National Polar Partnership (SNPP)
  - Sentinel-2 and Sentinel-3



# Landsat Satellites and Sensors

<http://landsat.gsfc.nasa.gov/>

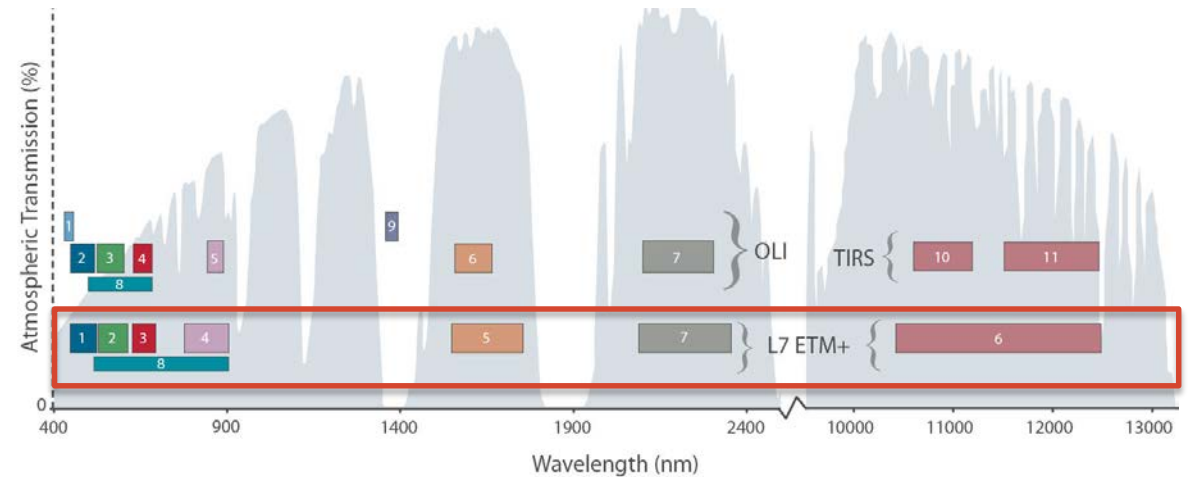




# Enhanced Thematic Mapper (ETM+)

<http://landsat.gsfc.nasa.gov/landsat-7/>

- Onboard **Landsat 7**
- Polar orbiting satellite
- Spatial Coverage and Resolution:
  - Global, Swath: 185 km
  - Spatial Resolution:
    - 15 m, 30 m, 60 m
- Temporal Coverage and Resolution:
  - April 15, 1999 – present
  - 16-day revisit time



## Spectral Bands: 8

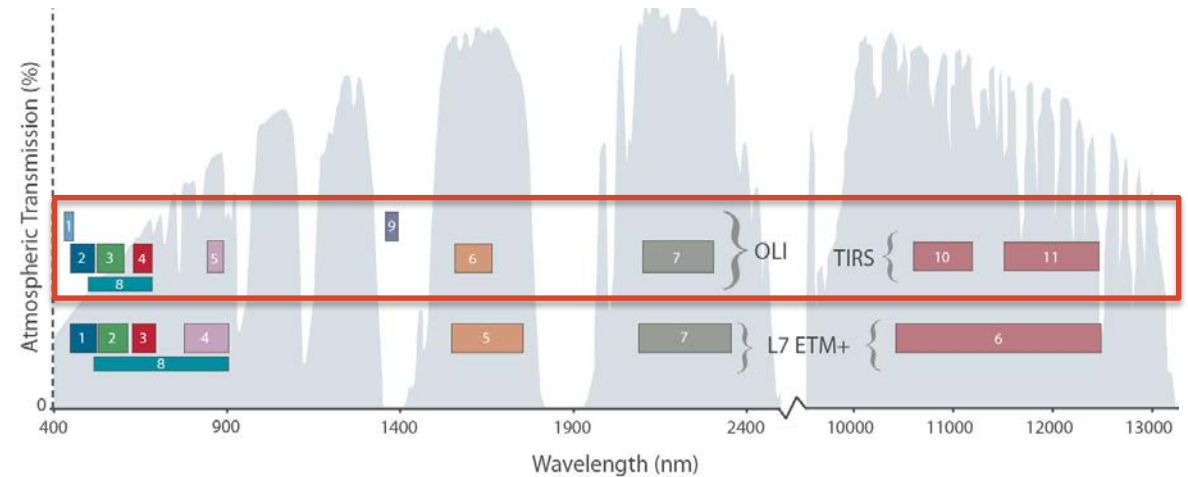
- Major Bands: blue-green, green, red, thermal IR, panchromatic
  - Bands 1-5, 7: 30 m
  - Band 6: 60 m
  - Band 8: 15 m



# Operational Land Imager (OLI)

<http://landsat.gsfc.nasa.gov/landsat-8/>

- Onboard **Landsat 8**
- Polar orbiting satellite
- Spatial Coverage and Resolution
  - Global, Swath: 185 km
  - Spatial Resolution: 15 m, 30 m
- Temporal Coverage and Resolution:
  - Feb 11, 2013 – present
  - 16-day revisit time

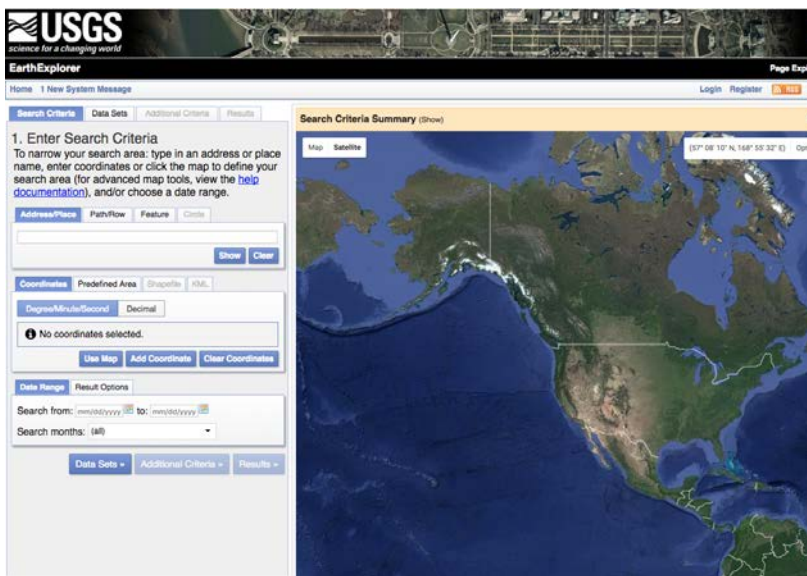


## Spectral Bands: 9

- Major Bands: blue, blue-green, red, near IR, shortwave, panchromatic
  - Bands 1-7, 9: 30 m
  - Band 8: 15 m

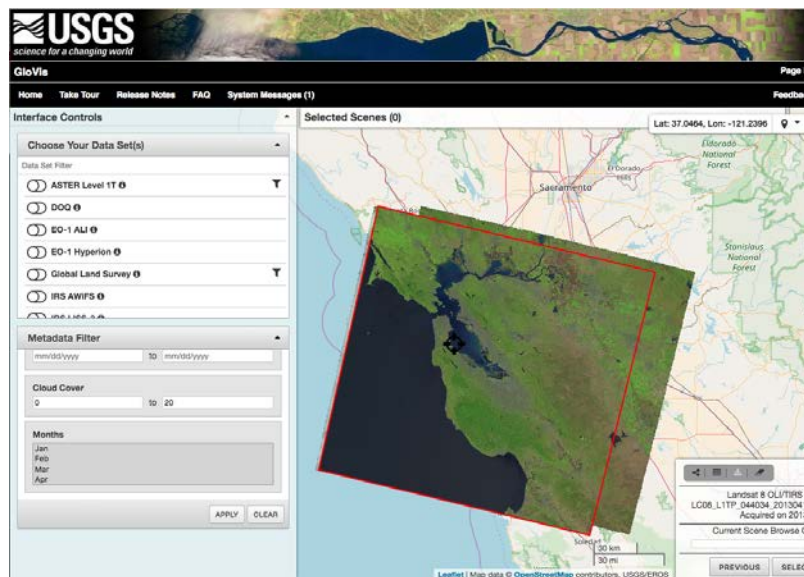


# Get Landsat Images and Band Reflectance Data



Earth Explorer:

<http://earthexplorer.usgs.gov/>



GloVis

<http://glovis.usgs.gov/>



LandLook Viewer:

<https://landlook.usgs.gov>





# Terra and Aqua Satellites and Sensors

## Terra

<http://terra.nasa.gov>

- Polar orbit, 10:30 a.m. equator crossing time
- Global Coverage
- December 18, 1999 – Present
- 1-2 observations per day
- Sensors:
  - ASTER, CERES, MISR, MODIS, MOPITT

## Aqua

<http://aqua.nasa.gov/>

- Polar orbit, 1:30 p.m. equator crossing time
- Global Coverage
- May 4, 2002 – Present
- 1-2 observations per day
- Sensors:
  - AIRS, AMSU, CERES, MODIS, AMSR-E



# MODerate Resolution Imaging Spectroradiometer (MODIS)

<http://modis.gsfc.nasa.gov/>

- Onboard **Terra** and **Aqua**
- Designed for land, atmosphere, ocean, and cryosphere observations
- Spatial Coverage and Resolution:
  - Global, swath: 2,330 km
  - Spatial resolution varies: 250 m, 500 m, 1 km
- Temporal Coverage and Resolution:
  - 2000 – present, 1–2 times per day

## Spectral Bands: 36

- Reflection and Emission Bands (Major Bands: red, blue, IR, NIR, MIR)
- Bands 1-2: 250 m; Bands 3-7: 500 m; Bands 8-36: 1,000 m

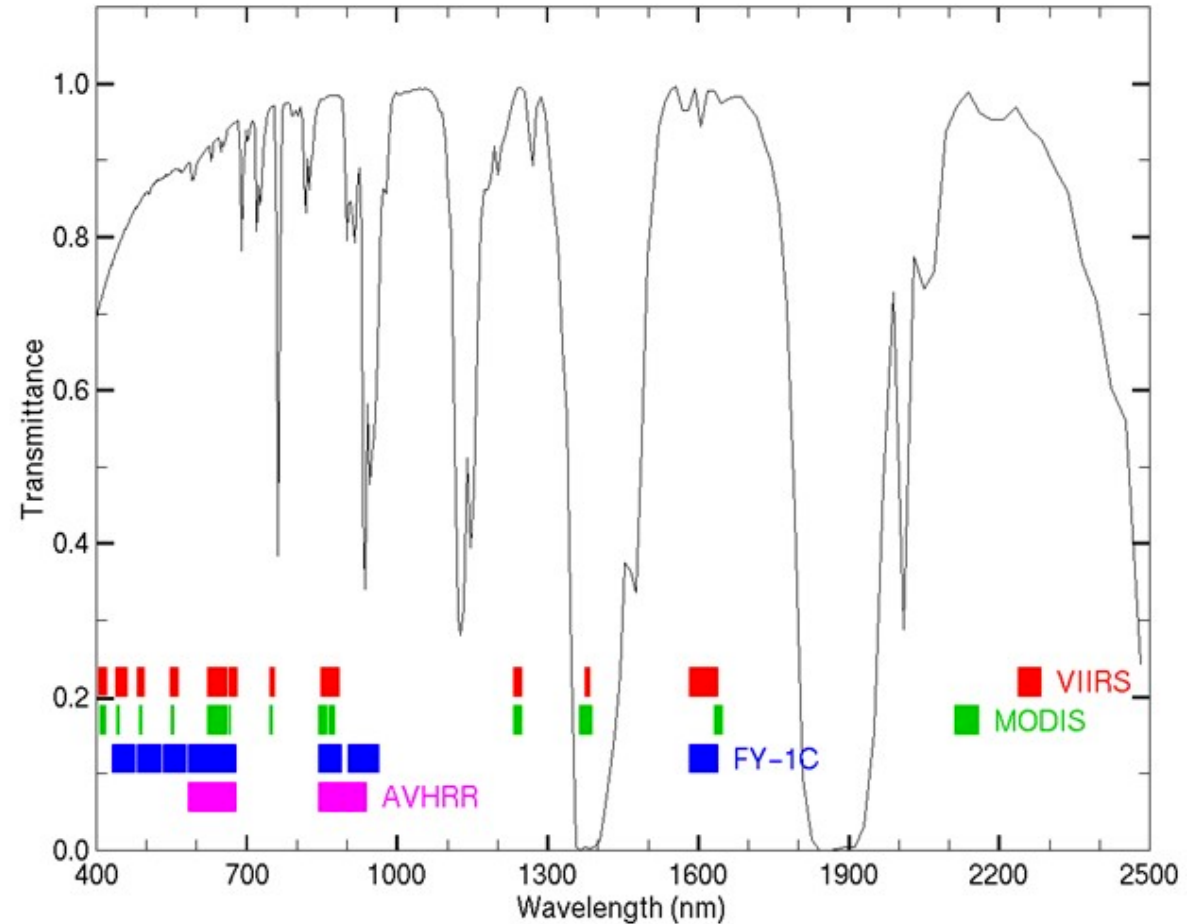


Image Credit: Li, J. (2001 Dec 18) *Atmospheric Temperature, Moisture, Ozone, and Motion-Infrared (MOD-07)*. CIMSS



# Get MODIS Band Reflectance Data

Land Processing Distributed Active  
Archive Center

[http://lpdaac.usgs.gov/dataset-discovery/modis/modis\\_products\\_table/](http://lpdaac.usgs.gov/dataset-discovery/modis/modis_products_table/)

Name	Dataset	Product	Pixel Size	Temporal Granularity
<a href="#">MOD09A1</a>	Terra MODIS	Reflectance	500	Composites
<a href="#">MOD09CMG</a>	Terra MODIS	Reflectance	5600	Daily
<a href="#">MOD09GA</a>	Terra MODIS	Reflectance	500, 1000	Daily
<a href="#">MOD09GQ</a>	Terra MODIS	Reflectance	250	Daily
<a href="#">MOD09Q1</a>	Terra MODIS	Reflectance	250	Composites
<b><a href="#">MODOCGA</a></b>	Terra MODIS	Reflectance	1000	Daily
<a href="#">MOD1BGA</a>	Terra MODIS	Reflectance	1000	Daily
<a href="#">MYD09A1</a>	Aqua MODIS	Reflectance	500	Composites
<a href="#">MYD09CMG</a>	Aqua MODIS	Reflectance	5600	Daily
<a href="#">MYD09GA</a>	Aqua MODIS	Reflectance	500, 1000	Daily
<a href="#">MYD09GQ</a>	Aqua MODIS	Reflectance	250	Daily
<a href="#">MYD09Q1</a>	Aqua MODIS	Reflectance	250	Composites
<b><a href="#">MYDOCGA</a></b>	Aqua MODIS	Reflectance	1000	Daily
<a href="#">MYD1BGA</a>	Aqua MODIS	Reflectance	1000	Daily

MODIS Band Reflectance for Oceans, Bands 8-16  
Product Name: MODOCGA (Terra), MYDOCGA (Aqua)

NASA Earthdata

<http://earthdata.nasa.gov/>

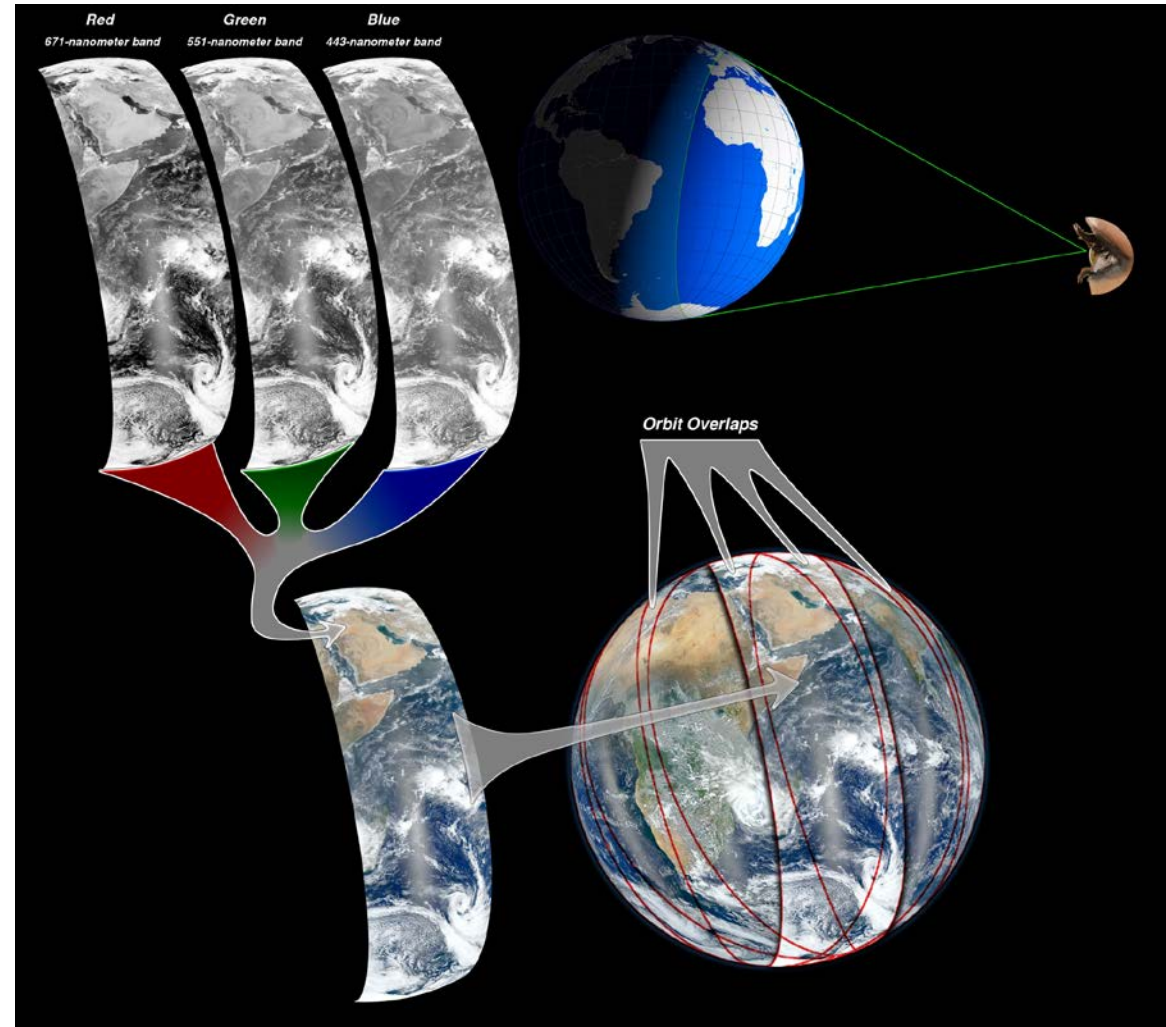




# Suomi National Polar Partnership (SNPP)

[http://nasa.gov/mission\\_pages/NPP/](http://nasa.gov/mission_pages/NPP/)

- Polar orbit, 1:30 p.m. equator crossing time
- Global coverage
- November 21, 2011 – present
- Sensors:
  - VIIRS, ATMS, CrIS, OMPS, CERES



# Visible Infrared Imaging Radiometer Suite (VIIRS)

<http://jointmission.gsfc.nasa.gov/viirs.html>

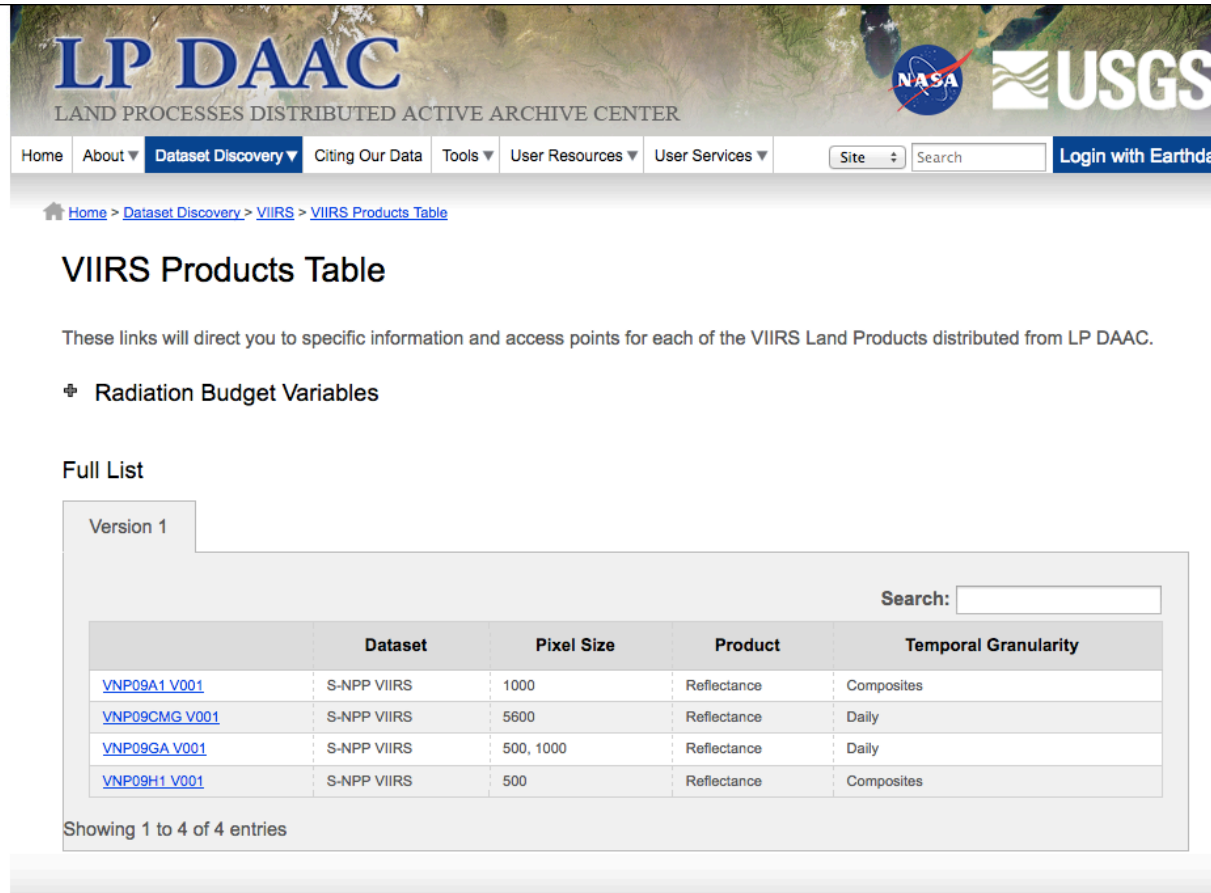
- Onboard **Suomi NPP**
- Polar orbiting satellite
- Functionality similar to MODIS
- Spatial Coverage and Resolution:
  - Global, Swath Width: 3,040 km
  - Spatial Resolution: 375 – 750 m
- Temporal Coverage and Resolution:
  - Oct 2011 – present
  - 1-2 times per day



Image: Hurricane Maria as it makes landfall over Yabucoa. [EarthObservatory](#)



# Get VIIRS Band Reflectance Data



The screenshot shows the LP DAAC website interface. At the top, there is a navigation menu with options like Home, About, Dataset Discovery, Citing Our Data, Tools, User Resources, and User Services. Below the menu, there is a breadcrumb trail: Home > Dataset Discovery > VIIRS > VIIRS Products Table. The main heading is "VIIRS Products Table". Below this, there is a paragraph stating: "These links will direct you to specific information and access points for each of the VIIRS Land Products distributed from LP DAAC." There is a sub-heading "Radiation Budget Variables" and a "Full List" section. The "Full List" section contains a table with the following data:

Version 1	Dataset	Pixel Size	Product	Temporal Granularity
<a href="#">VNP09A1 V001</a>	S-NPP VIIRS	1000	Reflectance	Composites
<a href="#">VNP09CMG V001</a>	S-NPP VIIRS	5600	Reflectance	Daily
<a href="#">VNP09GA V001</a>	S-NPP VIIRS	500, 1000	Reflectance	Daily
<a href="#">VNP09H1 V001</a>	S-NPP VIIRS	500	Reflectance	Composites

Showing 1 to 4 of 4 entries

- Land Process Distributed Active Archive Center
- [https://lpdaac.usgs.gov/dataset\\_discovery/viirs/viirs\\_products\\_table](https://lpdaac.usgs.gov/dataset_discovery/viirs/viirs_products_table)
- Product Name: VNP09GA\_V001

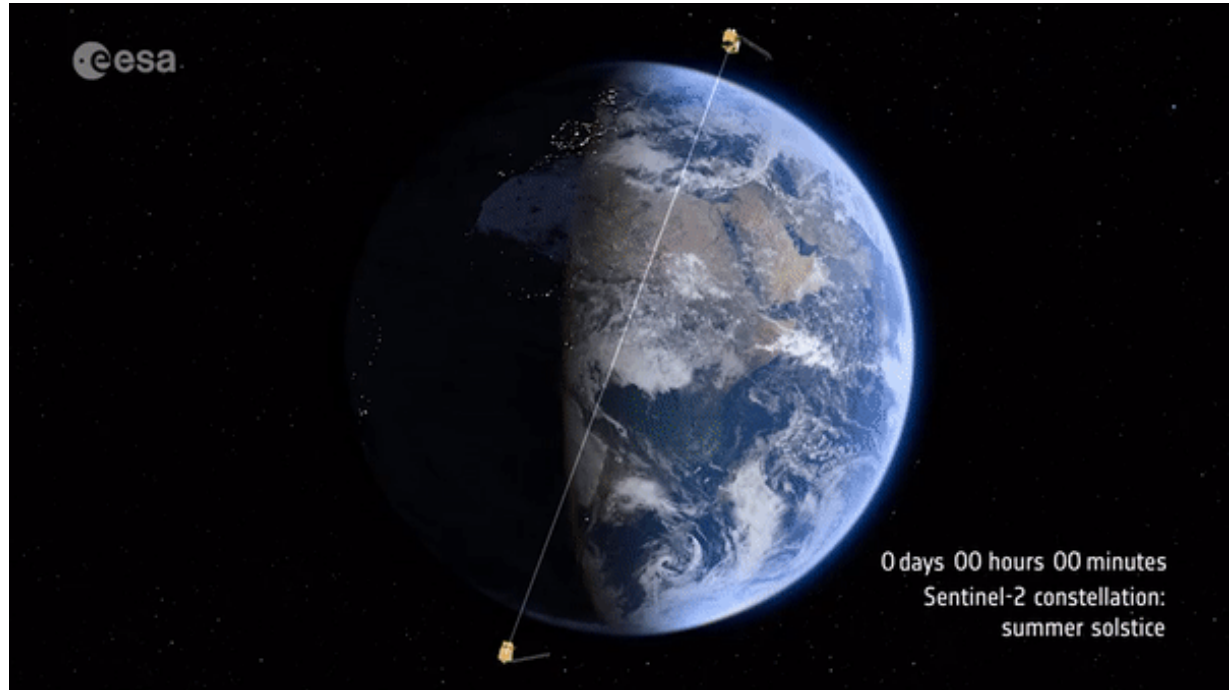




# Sentinel-2A and Sentinel-2B

[http://www.esa.int/Our\\_Activities/Observing\\_the\\_Earth/Copernicus/Sentinel-2/](http://www.esa.int/Our_Activities/Observing_the_Earth/Copernicus/Sentinel-2/)

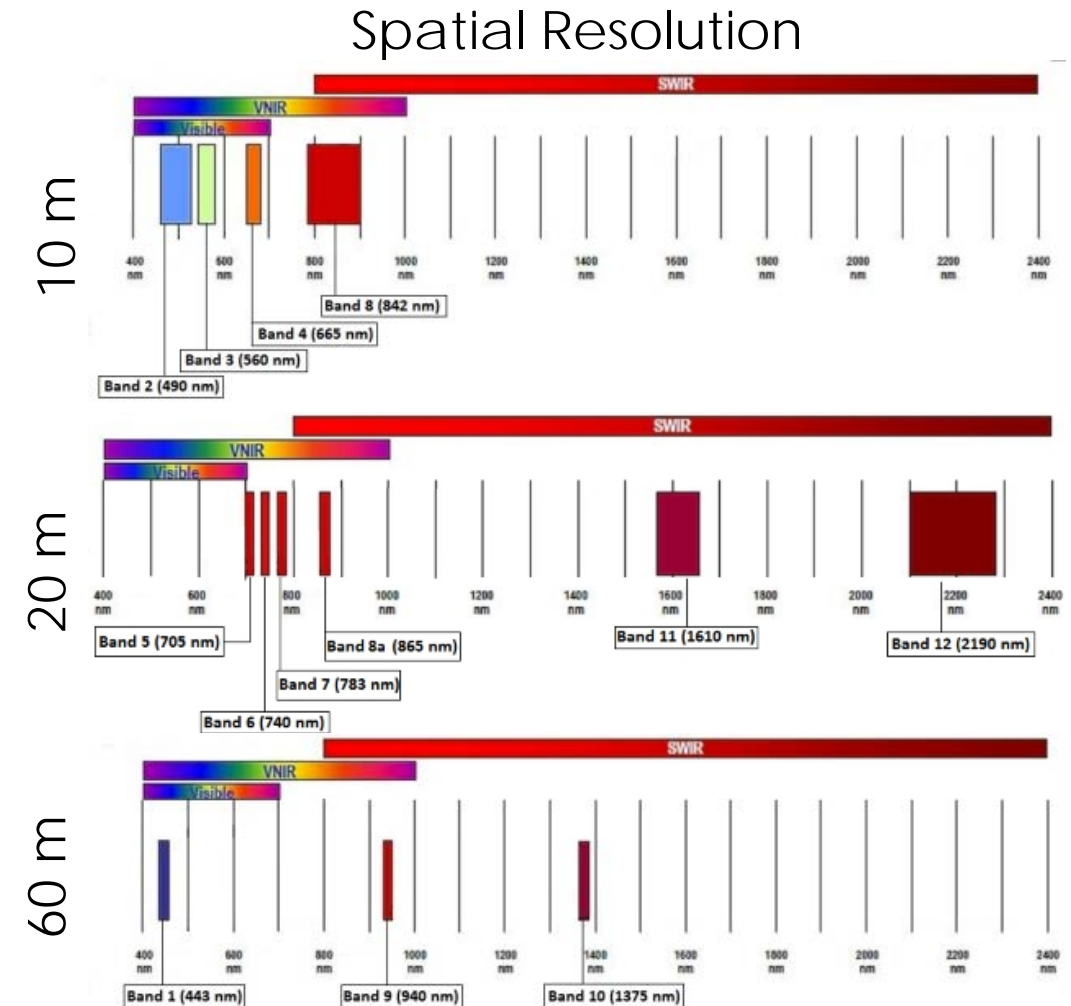
- Launched by **ESA**
- Two satellites, 180° apart, both in polar orbit
- Global coverage
- Temporal Coverage:
  - Sentinel-2A: June 23, 2015 – present
  - Sentinel-2B: March 7, 2017 – present
- 5 day revisit time
- Sensors
  - Multispectral Imager (MSI)



# Multispectral Imager (MSI)

<https://earth.esa.int/web/sentinel/user-guides/sentinel-2-msi>

- Onboard **Sentinel-2**
- Land and ocean surface observations
- Spatial Coverage and Resolution:
  - Global, swath: 290 km
  - Spatial resolution varies: 10 m, 20 m, 60 m
- Temporal Coverage and Resolution:
  - June 2015 & March 2017 – present
  - 5 day revisit time
- **Spectral Bands: 13**
  - 4 visible and NIR: 10 m
  - 6 red-edge/shortwave infrared: 20 m
  - 3 atmospheric correction: 60 m

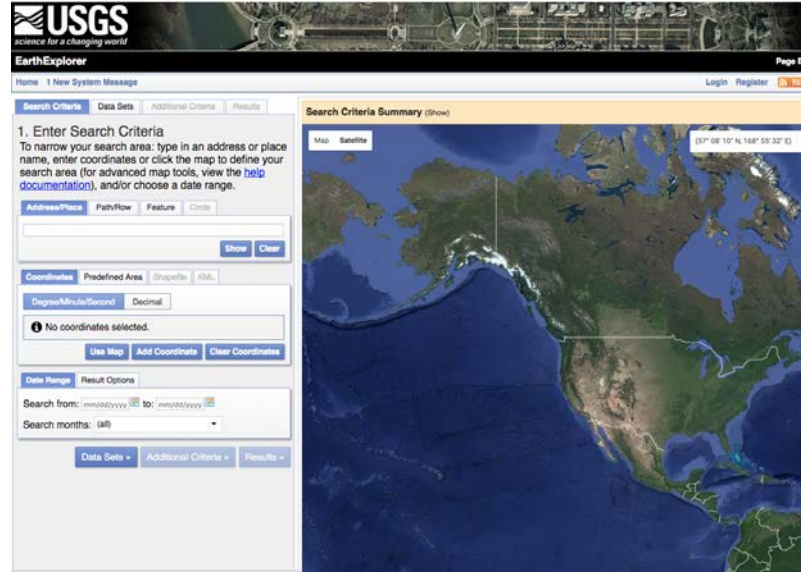


# Get MSI Data



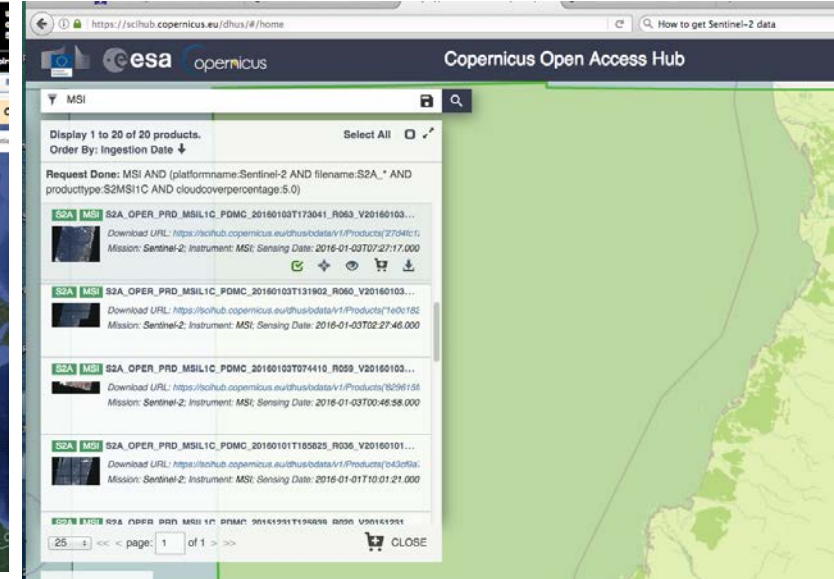
LandLook Viewer:

<https://landlook.usgs.gov/viewer.html>



Earth Explorer:

<http://earthexplorer.usgs.gov/>



ESA Copernicus Open Hub:

<http://sentinel.esa.int/web/sentinel/sentinel-data-access>

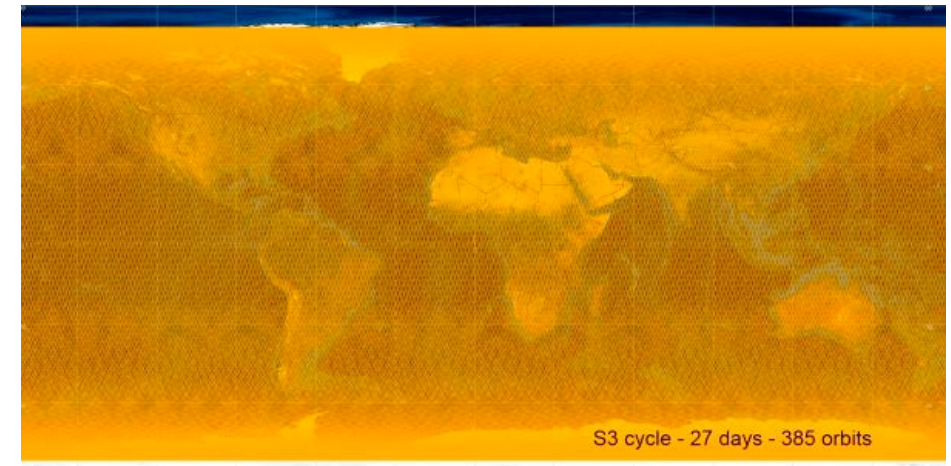




# Sentinel-3

[www.esa.int/Our\\_Activities/Observing\\_the\\_Earth/Copernicus/Sentinel-3/](http://www.esa.int/Our_Activities/Observing_the_Earth/Copernicus/Sentinel-3/)

- Launched by **ESA**
- Will consist of a two satellite system
  - Sentinel-3A: Feb 16, 2016 - present
  - Sentinel-3B: To be launched
- Global coverage
- 27 day revisit time
- Sensors:
  - **OCLI**, SLSTR, SRAL, MWR



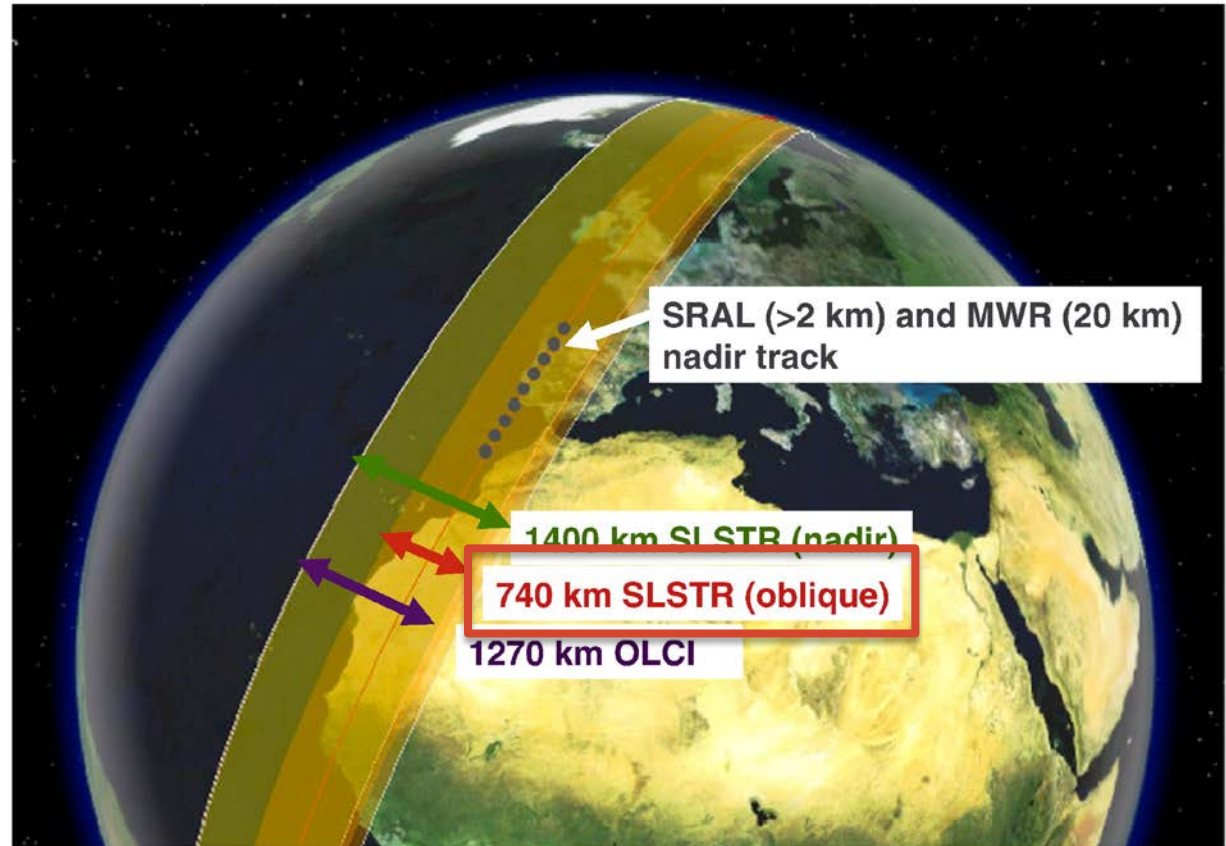
# Ocean and Land Color Instrument (OLCI)

<https://sentinel.esa.int/web/sentinel/user-guides/sentinel-3-olci>

- Onboard **Sentinel-3**
- Based on heritage from ENVISAT satellite Medium Resolution Imaging Spectrometer (MERIS)
- Spatial Coverage and Resolution:
  - Global, swath: 1,270 m
  - Spatial resolution: 300 m, also available at 1.2 km
- Temporal Coverage
  - Feb 2016 – present
  - 27 day revisit time

## Spectral Bands: 21

- 4 visible to near-infrared: 300 m



# Get OLCI Data

NOAA CoastWatch • OceanWatch  
Level-1 / Level-2 Ocean Data

The NOAA CoastWatch granule selector enables a user to select a Level-1 or Level-2 dataset by selecting a date and clicking on the granule that covers the user's area of interest. For VIIRS near real-time data is available for the last 15 days and science quality data is available from 2012 up to near real-time coverage. Clicking a granule will open an information window containing a link to the preview image and/or data file. If multiple files are desired (each file can be 18 to 550 MB), clicking on the download icon (↓) will add the selected granule to a list that can be downloaded and used to retrieve files using local software.

Sensor:  Layers:  MGRS Grid for S-2 regions  CoastWatch Regions

Date: 2017-08-08 Time: 1348  
Download Data:  
True Color Image (PNG)  
OLCI L1 Ocean Radiance Data (EUMETSAT tar)  
OLCI Ocean Color Channel Data (CW HDF)  
OLCI L2 Ocean Color Data (HDF)

Lat: 29.60, Long: -34.06

## NOAA CoastWatch

[https://coastwatch.noaa.gov/cw\\_html/cw\\_granule\\_selector.html?sensor=OLCI](https://coastwatch.noaa.gov/cw_html/cw_granule_selector.html?sensor=OLCI)

SELECT PRODUCT

Search Term:

Products **Sentinel 3 DataSets**

- Meteosat Surface Albedo - MFG - 0 degree
- Meteosat Surface Albedo - MFG - Atlantic Ocean 50 W
- Meteosat Surface Albedo - MFG - Atlantic Ocean 75 W
- Meteosat Surface Albedo - MFG - Indian Ocean 57 E
- Meteosat Surface Albedo - MFG - Indian Ocean 63 E
- Multi-Sensor Precipitation Estimate (GRIB) - MFG - Indian Ocean
- Multi-Sensor Precipitation Estimate (GRIB) - MSG - 0 degree
- Multi-Sensor Precipitation Estimate (GRIB) - MSG - Indian Ocean
- Multi-Sensor Precipitation Estimate (JPEG) - MSG - 0 degree
- Multi-Sensor Precipitation Estimate (JPEG) - MSG - Indian Ocean
- Multi-Sensor Precipitation Estimate in GRIB - Reprocessed
- NAR Sea Surface Temperature in NetCDF
- Near Surface Wind Speed
- Normalised Difference Vegetation Index - MSG - 0 degree
- Normalised Difference Vegetation Index - MSG - Indian Ocean
- Normalised Difference Vegetation Index Decadal - MSG - 0 degree
- Normalised Difference Vegetation Index Decadal - MSG - Indian Ocean
- North Atlantic and Regional Sea Surface Temperature (NAR SST) - NOAA
- OLCI Level 1B Full Resolution in NRT - Sentinel-3
- OLCI Level 1B Full Resolution in NTC - Sentinel-3
- OLCI Level 1B Reduced Resolution in NRT - Sentinel-3
- OLCI Level 1B Reduced Resolution in NTC - Sentinel-3
- OLCI Ocean Colour Full Resolution in NTC - Sentinel-3
- OLCI Ocean Colour Full Resolution in NTC - Sentinel-3
- OLCI Ocean Colour Full Resolution in NTC - Sentinel-3
- OLCI Ocean Colour Reduced Resolution in NTC - Sentinel-3
- OLCI Ocean Colour Reduced Resolution in NTC - Sentinel-3
- OSCAT Winds at 50 km Swath Grid - Oceansat

Thematic Filter

- Marine
- Land
- Atmosphere
- Aerosol
- Analysis
- Cloud
- Fire
- Forecast
- Humidity
- Model
- Observation
- Ocean
- Precipitation
- Pressure
- Radar Backscatter NRCS
- Radiation
- Soil Moisture Index
- Sea Ice
- Sea Surface Temperature
- Snow and Ice
- Temperature
- Vegetation
- Wave
- Wind

Selected Product

**OLCI Level 1B Reduced Resolution in NTC - Sentinel-3**

OLCI (Ocean and Land Colour Instrument) Reduced resolution: 1200m at nadir. All Sentinel-3 Non Time Critical (NTC) products are available at pick-up point in less than 30 days. Level 1 products are calibrated Top Of Atmosphere radiance values at OLCI 21 spectral bands. Radiances are computed from the instrument digital counts by applying geo-referencing, radiometric processing (non-linearity correction, smear correction, dark offset correction, absolute gain calibration adjusted for gain evolution with time), and stray-light correction for straylight effects in OLCI camera's spectrometer and ground imager. Additionally, spatial resampling of OLCI pixels to the 'ideal' instrument grid, initial pixel classification, and annotation at tie points with auxiliary

## EUMETSAT

<http://archive.eumetsat.int/usc/#sp;;delm=O;noti=1;udsp=OPE;qqov=ALL;seev=0>





# Challenges in Monitoring WQ for SDG 6

- For accurate and quantitative WQ monitoring analysis of spatially and temporally co-located, *in situ* measurements and satellite observations are required
- Feasibility of WQ monitoring in coastal and inland water bodies depends on spatial, temporal, and spectral resolutions of remote sensing observations
- Difficult to separate WQ parameters when sediments, dissolved matter, and Chl-a all are present
- It is not possible to characterize algal types or toxins only from remote sensing observations
- Remote sensing reflectance has to be corrected to account for contributions from atmospheric constituents such as aerosols
- Optical remote sensing observations cannot view the surface in the presence of clouds



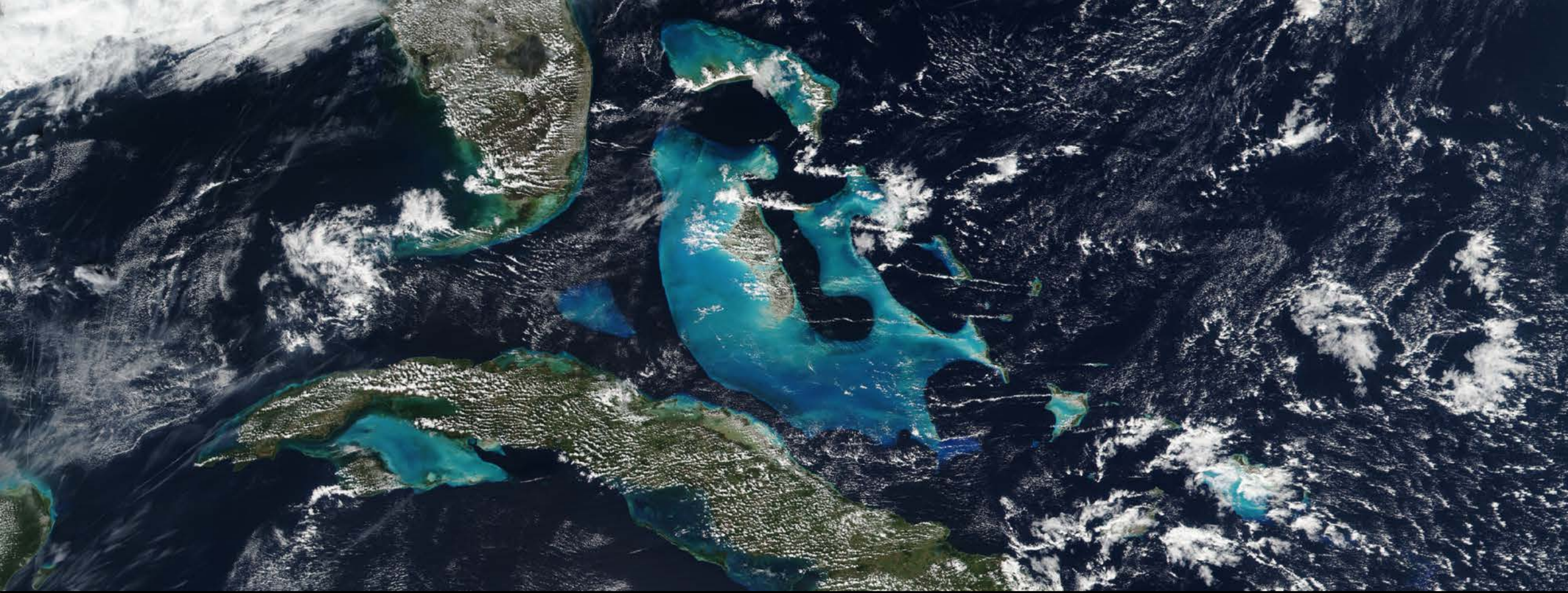
# Summary of Resources for Monitoring WQ for SDG 6

- Studies use optical and NIR remote sensing observations for qualitative and quantitative WQ monitoring in lakes, rivers, and coastal regions (see a review in Golizadeh et al., 2016 for techniques and case studies)
  - Landsat
  - Terra/Aqua MODIS
  - SNPP VIIRS
  - Sentinel-2 MSI
  - Sentinel-3 OLCI
- Several web tools use satellite-derived Chl-a and SST to monitor Harmful Algal Blooms
  - Landsat can monitor close to 170, 240 lakes
  - MODIS/OLCI would resolve ~1,862 lakes (Wilson Salls, EPA)

Reference: Gholizadeh, M. H., A. M/ Melesse, L. Reddy, 2016: Spaceborne and airborne sensors in water quality assessment, International J. of Remote Sensing, 37, 3143-3180.







Examples of Monitoring Harmful Algal Boom  
Indicators: Chlorophyll-a Concentration and  
Water Surface Temperature



# Ch-a and SST Data from Aqua and Terra MODIS

[http://optics.marine.usf.edu/cgi-bin/optics\\_data?roi=ECARIB&current=1/](http://optics.marine.usf.edu/cgi-bin/optics_data?roi=ECARIB&current=1/)

USF UNIVERSITY OF SOUTH FLORIDA

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## College of Marine Science

## Optical Oceanography Laboratory

Eastern Caribbean Region & Data Description   ? Tips   Animate

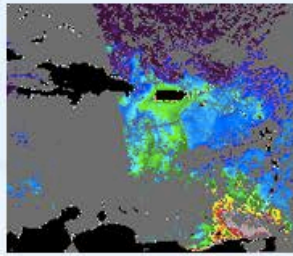
Aug 2017

Su	Mo	Tu	We	Th	Fr	Sa
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30	31		

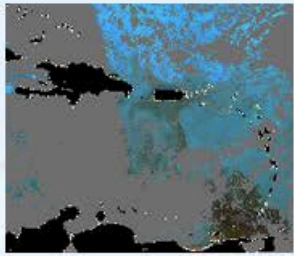
Menu

- Home
- + People
- + Projects
- + Satellite Data Products
- + Virtual Buoy Products
- + Publications
- + Events
- + Links
- + Contact

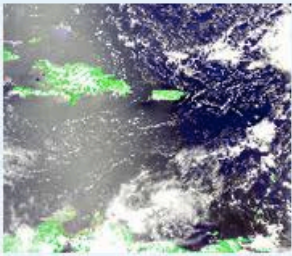
MODIST 14:50 GMT   MODISA 17:55 GMT



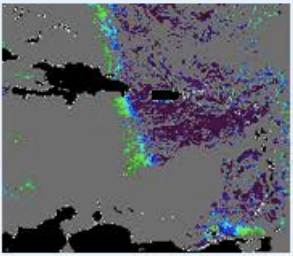
CHL L3D Information  
Get Link Here   GE



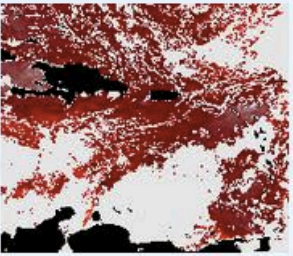
ERGB L3D Information  
Get Link Here   GE



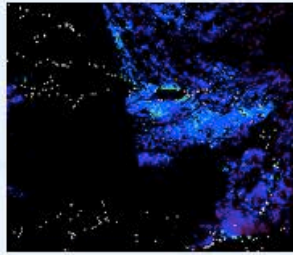
FRGB L3D Information  
Get Link Here   GE



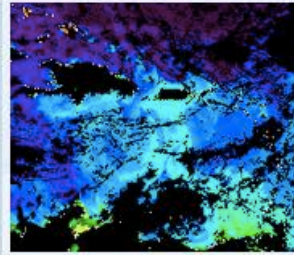
NFLH L3D Information  
Get Link Here   GE



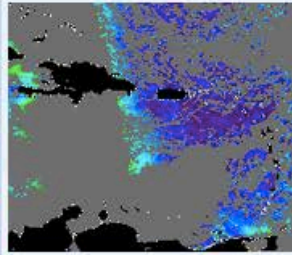
SST L3D Information  
Get Link Here   GE




AFAI L3D\_RRC Information  
Get Link Here   GE



CI L3D\_RRC Information  
Get Link Here   GE



FLH L3D\_RRC Information  
Get Link Here   GE



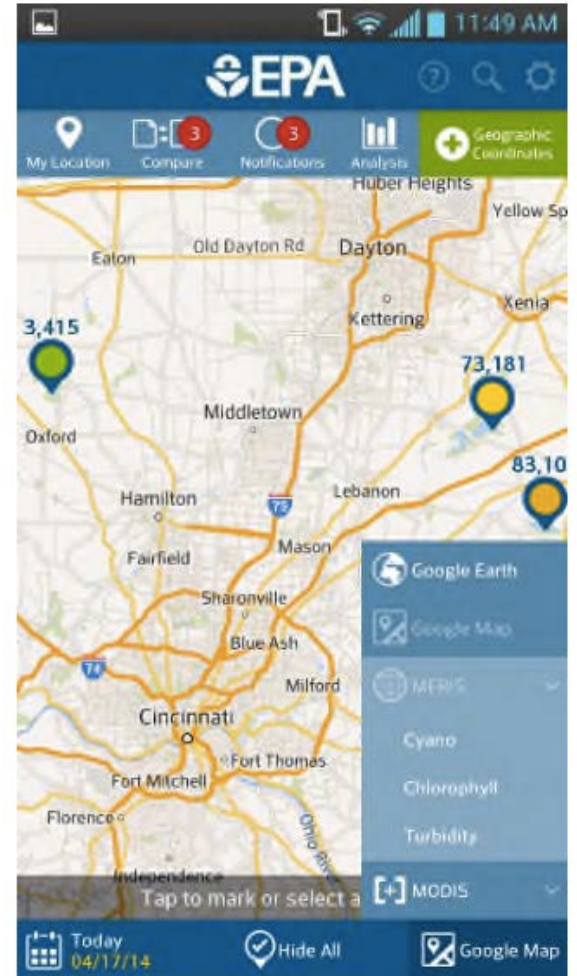
RGB L3D\_RRC Information  
Get Link Here   GE



# Cyanobacteria Assessment Network (CyAN)

<https://www.epa.gov/water-research/cyanobacteria-assessment-network-cyan#decision%20support>

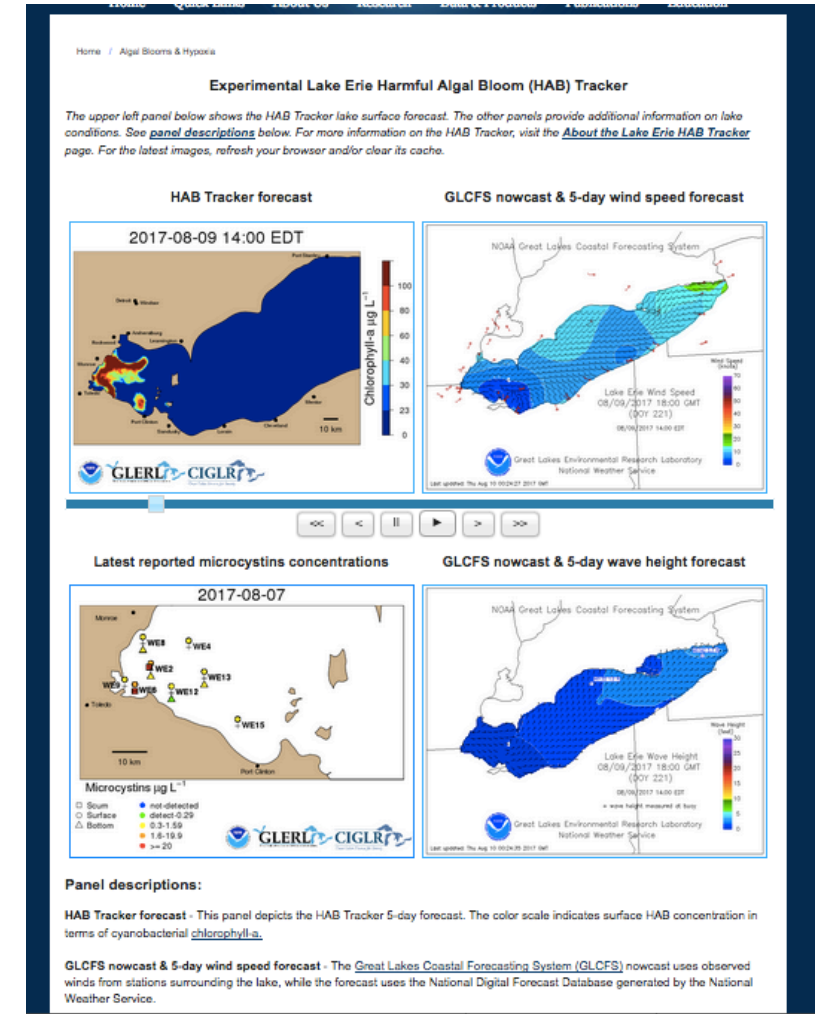
- A collaborative program among EPA, NOAA, NASA, and USGS
- Focused on an early and uniform approach to algal bloom identification using satellite remote sensing from Landsat, Sentinel-2, and Sentinel-3
- Develop a decision support system for stakeholders



# Lake Erie HAB Tracker

[https://www.glerl.noaa.gov/res/HABs\\_and\\_Hypoxia/habTracker.html](https://www.glerl.noaa.gov/res/HABs_and_Hypoxia/habTracker.html)

- A forecast model based on:
  - MODIS satellite images
  - Weather forecast information
  - Modeled currents in Lake Erie
- Provides:
  - HAB measurements based on in situ water sample collection
  - Near real-time and 5 day HAB forecasts in terms of cyanobacterial chl-a





# Lake Erie HAB Tracker

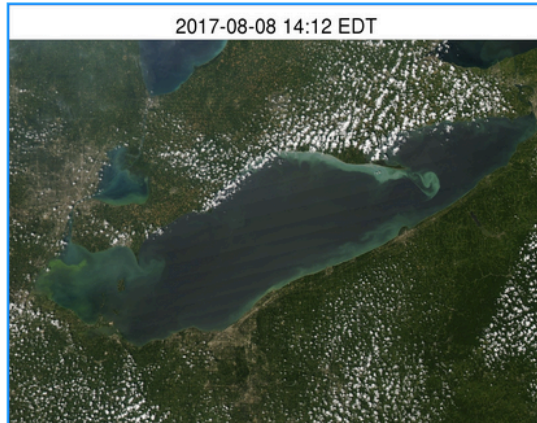
[https://www.glerl.noaa.gov/res/HABs\\_and\\_Hypoxia/habTracker.html](https://www.glerl.noaa.gov/res/HABs_and_Hypoxia/habTracker.html)

## MODIS-Derived Cyanobacterial Density

**Latest satellite-derived data used by the HAB Tracker**

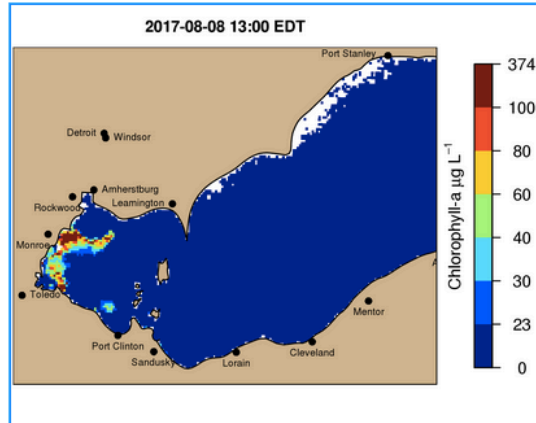
Sensors attached to satellites gather data, which is processed into the cyanobacterial index, an indicator of the abundance, or biomass, of the cyanobacteria associated with HABs. Processed satellite imagery is provided by the [NOAA HAB Operational Forecasting System](#). The cyanobacterial index scale is converted to a cyanobacterial chlorophyll scale for use in the HAB Tracker, a similar indicator of cyanobacterial abundance.

**True-color satellite image of Lake Erie**



Latest usable (relatively cloud-free) satellite image of Lake Erie. For additional satellite imagery of Lake Erie, visit the [NOAA Great Lakes CoastWatch](#) webpage.

**HABs extent analysis**



Latest HAB extent analysis from valid satellite imagery above used to update the bloom location in the model.



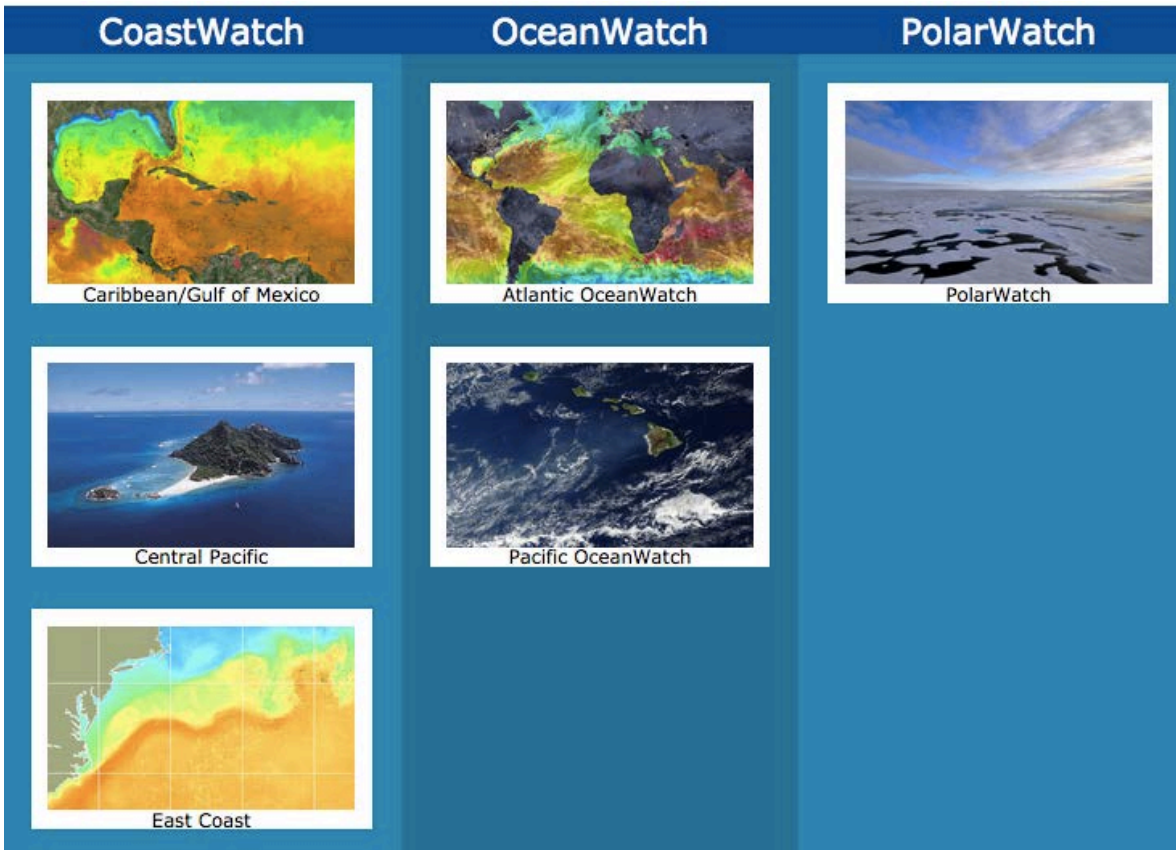
Photo Credit: NOAA GLERL



# NOAA Coast Watch

[https://coastwatch.noaa.gov/cw\\_html/index.html](https://coastwatch.noaa.gov/cw_html/index.html)

- Information provided for multiple coastal areas



- Satellite products used
  - True-color Imagery
  - Ocean Color – Radiances and Chlorophyll-a Concentration
  - Sea Surface Temperatures
  - Sea Surface Height
  - Sea Surface Salinity
  - Sea Surface Winds





# NOAA Coast Watch

[https://coastwatch.noaa.gov/cw\\_html/OceanColor.html](https://coastwatch.noaa.gov/cw_html/OceanColor.html)

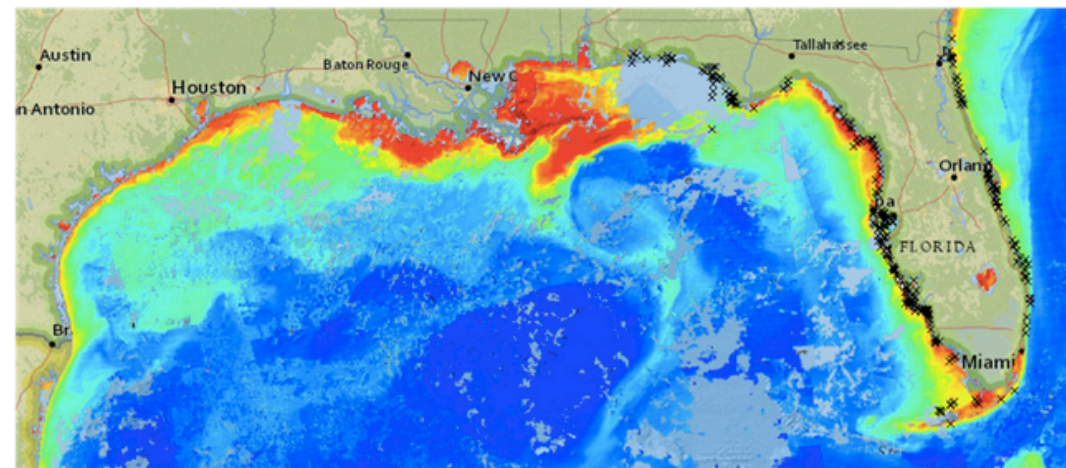
- Satellite-based HAB monitoring
- Near real-time remote sensing data used from:
  - MODIS Aqua
  - VIIRS S-NPP
  - OLCI Sentinel-3

## ▼ Harmful Algal Bloom Monitoring and Forecasting in the Gulf of Mexico - 02/17

### Harmful Algal Bloom Monitoring and Forecasting in the Gulf of Mexico - 02/17

Harmful algal blooms are a common occurrence in the Gulf of Mexico. Red tide blooms of the neurotoxin producing alga *Karenia brevis* are of particular concern. NOAA's National Ocean Service uses Coast Watch ocean color data along with cell counts and other environmental information to produce a Harmful Algal Blooms Observing System (HABSOS) and a Harmful Algal Bloom Operational Forecast System (HAB-OFS).

HABSOS is a combined data product distributed on an ArcGIS powered map. The system serves as a harmful algal bloom data resource for managers, scientists and the public. CoastWatch data available for visualization in HABSOS include chlorophyll-3 day composite data and chlorophyll anomaly data.



CoastWatch chlorophyll 3-day composite viewed on NOAA's HABSOS.





# Copernicus Marine Environment Monitoring Service

<http://marine.copernicus.eu/>

- Combined MODIS & VIIRS observations are used for monitoring HABs in:
  - North Atlantic
  - Arctic Ocean
  - Baltic Sea
  - Black Sea
  - Mediterranean Sea

The screenshot displays the Copernicus Marine Environment Monitoring Service (MEMS) website. The header includes the European Commission logo and the service name. A search bar is located in the top right. The main navigation menu includes 'ABOUT US', 'MARKETS & BENEFITS', 'NEWS', 'SCIENCE & MONITORING', 'TRAINING & EDUCATION', and 'SERVICES PORTFOLIO'. The 'SERVICES PORTFOLIO' menu is expanded, showing 'SHORT-CUT TO SERVICES'. The main content area is titled 'ONLINE CATALOGUE' and features a search bar and filters. The search results show two product listings:

**GLOBAL\_ANALYSIS\_FORECAST\_PHY\_001\_024**  
GLOBAL OCEAN 1/12° PHYSICS ANALYSIS AND FORECAST UPDATED DAILY

MODEL	● ● ● ● ● X X	GLO
MLD SSH 3DUV SIT S SIUV SIC T bottomT ⓘ		
0.083 degree x 0.083 degree (50 depth levels)		
From 2006-12-27 to Present		
daily-mean, hourly-mean		

**GLOBAL\_ANALYSIS\_FORECAST\_BIO\_001\_014**  
GLOBAL OCEAN BIOGEOCHEMISTRY ANALYSIS AND WEEKLY FORECAST

MODEL	● ● ● ● ● X X X	GLO
CHL O2 NO3 PO4 SI PHYC FE ⓘ		
0.5 degree x 0.5 degree (50 depth levels)		
From 2012-01-01 to Present		

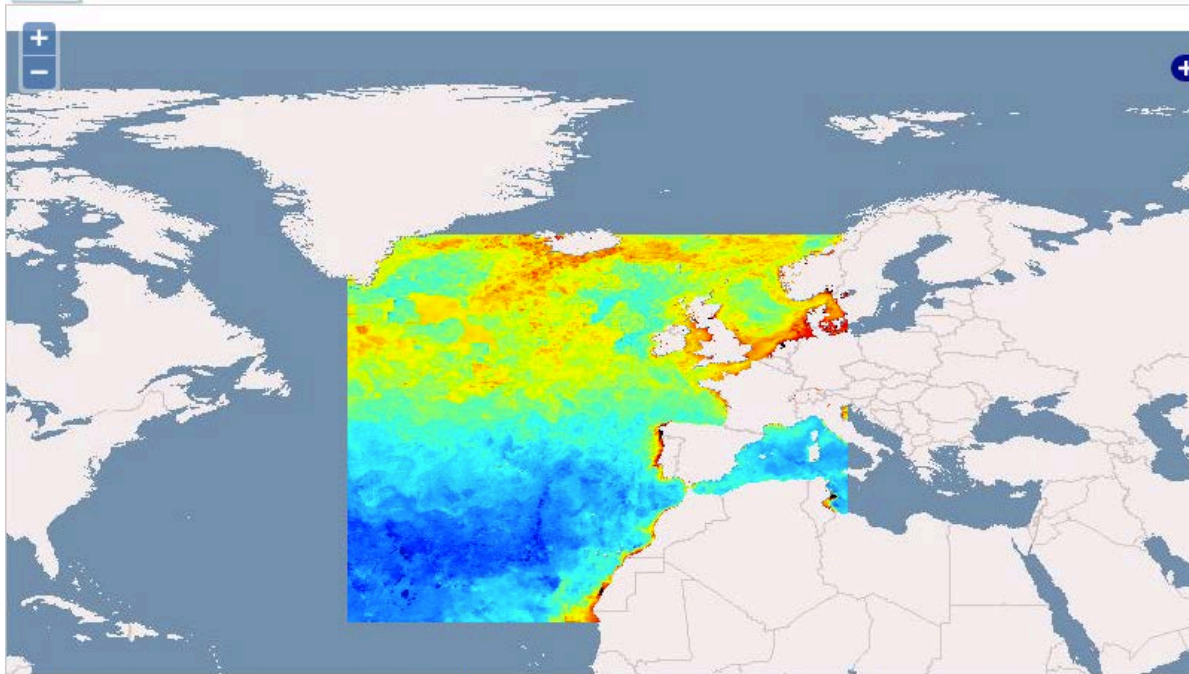
The bottom of the page features logos for the European Union and Copernicus, along with navigation links for 'ABOUT US', 'PARTNERS & STAKEHOLDERS', and 'BENEFITS'. A 'ANY QUESTIONS?' button is also present.



# Near Real-Time Algal Bloom Monitoring Services in the North Atlantic

<http://hab.nerisc.no/>

NERISC Near Real-Time Algal Bloom Monitoring Service for North Atlantic



The latest weekly average of chlorophyll-a surface concentration and sea surface temperature from Copernicus Marine Environmental Service (CMEMS). Select layers in the upper-left corner of the map.

Select date: 2017-08-14

- Based on ocean color data from Copernicus Marine Environment Monitoring Service







Demonstration of Web-Based Tools for Water  
Quality Data Access  
Example: Lake Titicaca



# Chl-a and SST Data Access for HAB Monitoring

- These tools enable data search, spatial and temporal subsetting, analysis, and visualization:
  - OceanColor Web: <https://oceancolor.gsfc.nasa.gov/>
  - Giovanni: <http://giovanni.gsfc.nasa.gov/giovanni/>
- Image Processing and Visualization Software:
  - SeaDAS: <http://seadas.gsfc.nasa.gov/>





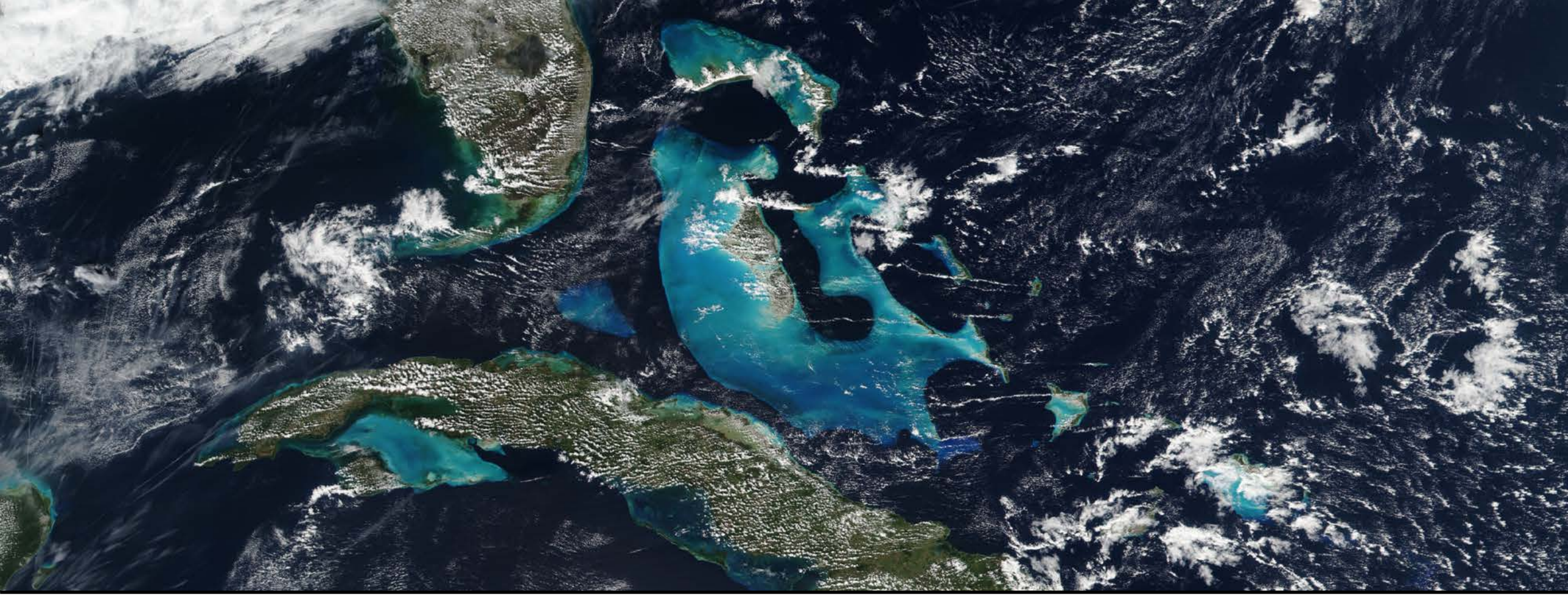
Thank You

# Questions

1. Are you using any remote sensing information?
2. Are you focusing more on coastal or inland estuaries?
3. In addition to HABs, what other parameters are you looking for? What water parameter are you most concerned about?
  - a) e.g. turbidity, sediments, salinity, SST
4. What kind of decisions do you have to make?
  - a) e.g. water intake, changing agricultural practices.
5. What time frame (weekly, daily) are you making decisions on?
6. Do you have access to in situ data that you can combine with remote sensing? (Is that something you would like to learn?)







Extra Slides

# Landsat Bands

Landsat 7 ETM+

Band	Band Range ( $\mu\text{m}$ )	Spatial Resolution (m)
1	0.45 – 0.515	30
2	0.525 – 0.605	
3	0.63 – 0.69	
4	0.775 – 0.90	
5	1.55 – 1.75	
6	10.4 – 12.5	60
7	2.08 – 2.35	30
8	0.52 – 0.9	15

Landsat 8 OLI

Band	Band Range ( $\mu\text{m}$ )	Spatial Resolution (m)
1	0.433 – 0.453	30
2	0.450 – 0.515	
3	0.525 – 0.60	
4	0.630 – 0.680	
5	0.845 – 0.885	
6	2.10 – 2.30	
7	0.500 – 0.680	15
8	2.08 – 2.35	
9	1.36 – 1.39	



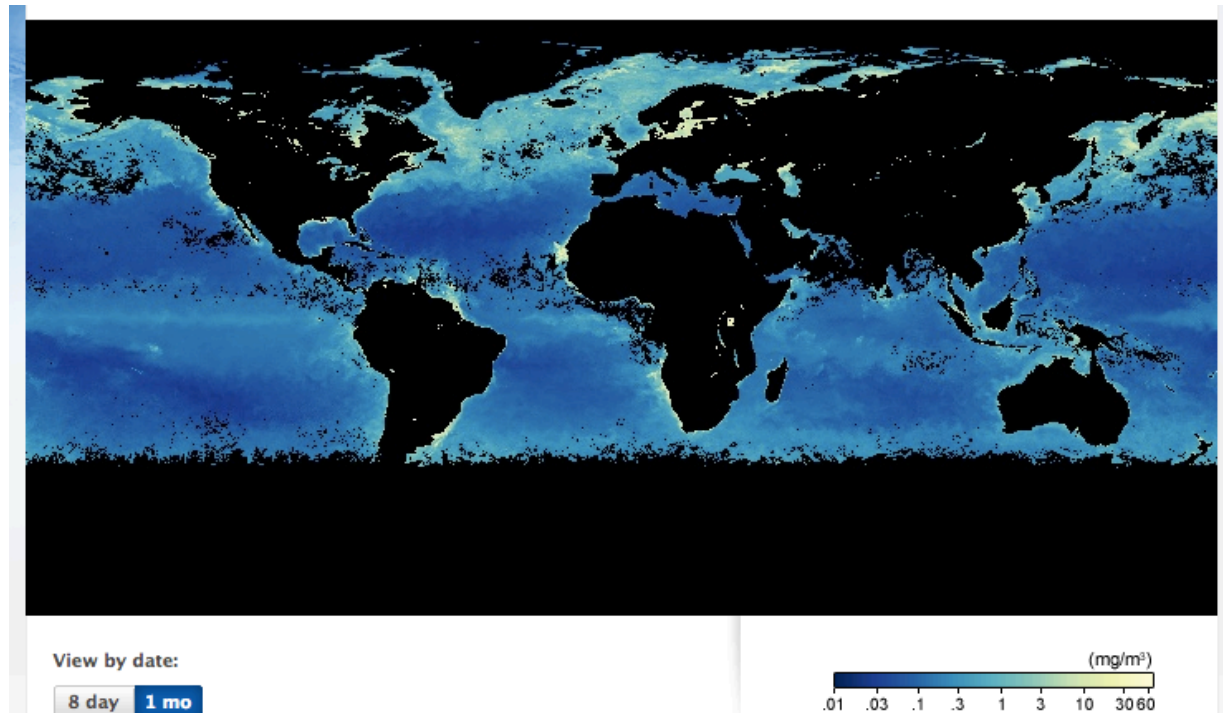


# MODIS Bands Relevant for HAB Monitoring

Band	Band Range $\mu\text{m}$
8	0.405-0.420
9	0.438-0.448
10	0.483-0.493
11	0.526-0.536
12	0.546-0.556
13	0.662-0.672
14	0.673-0.683
15	0.743-0.753

Spatial resolution: 1 km

Chlorophyll Concentration from Aqua  
MODIS, June 2017



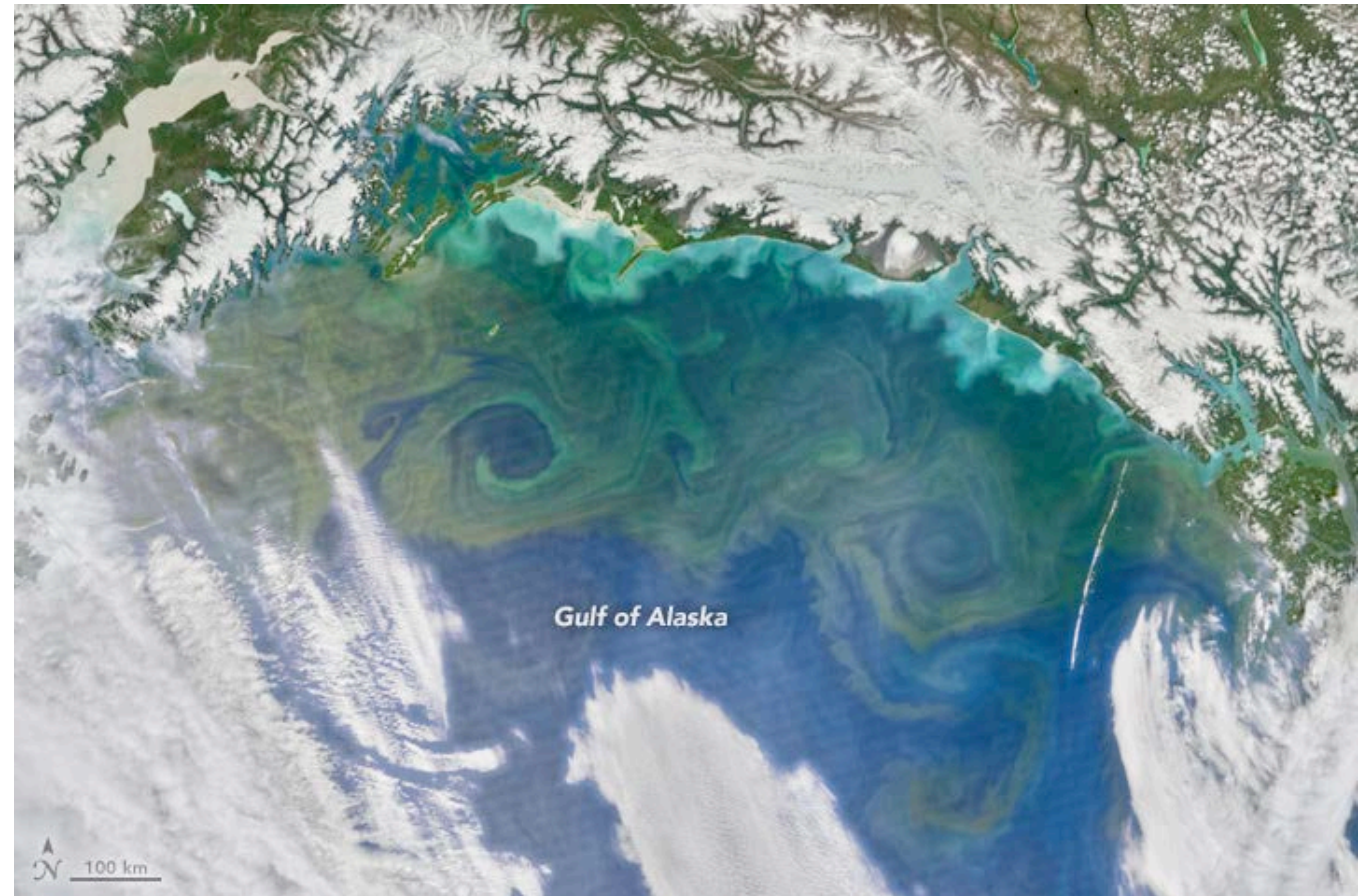


# VIIRS Bands Relevant for HAB Monitoring

Phytoplankton Bloom in the Gulf of Alaska, from VIIRS, June 9, 2016

Band	Band Range $\mu\text{m}$
M1	0.402-0.422
M2	0.436-0.454
M3	0.478-0.488
M4	0.545-0.565
M5	0.662-0.682
M6	0.739-0.745

Spatial Resolution: 750 m



# MSI bands

<https://earth.esa.int/web/sentinel/user-guides/sentinel-2-msi>

Band Number	S2A		S2B		Spatial resolution (m)
	Central wavelength (nm)	Bandwidth (nm)	Central wavelength (nm)	Bandwidth (nm)	
1	443.9	27	442.3	45	60
2	496.6	98	492.1	98	10
3	560.0	45	559	46	10
4	664.5	38	665	39	10
5	703.9	19	703.8	20	20
6	740.2	18	739.1	18	20
7	782.5	28	779.7	28	20
8	835.1	145	833	133	10
8a	864.8	33	864	32	20
9	945.0	26	943.2	27	60
10	1373.5	75	1376.9	76	60
11	1613.7	143	1610.4	141	20
12	2202.4	242	2185.7	238	20

Algal Bloom in the Middle of the Baltic Sea, Sentinel-2 MSI, Aug 7, 2015

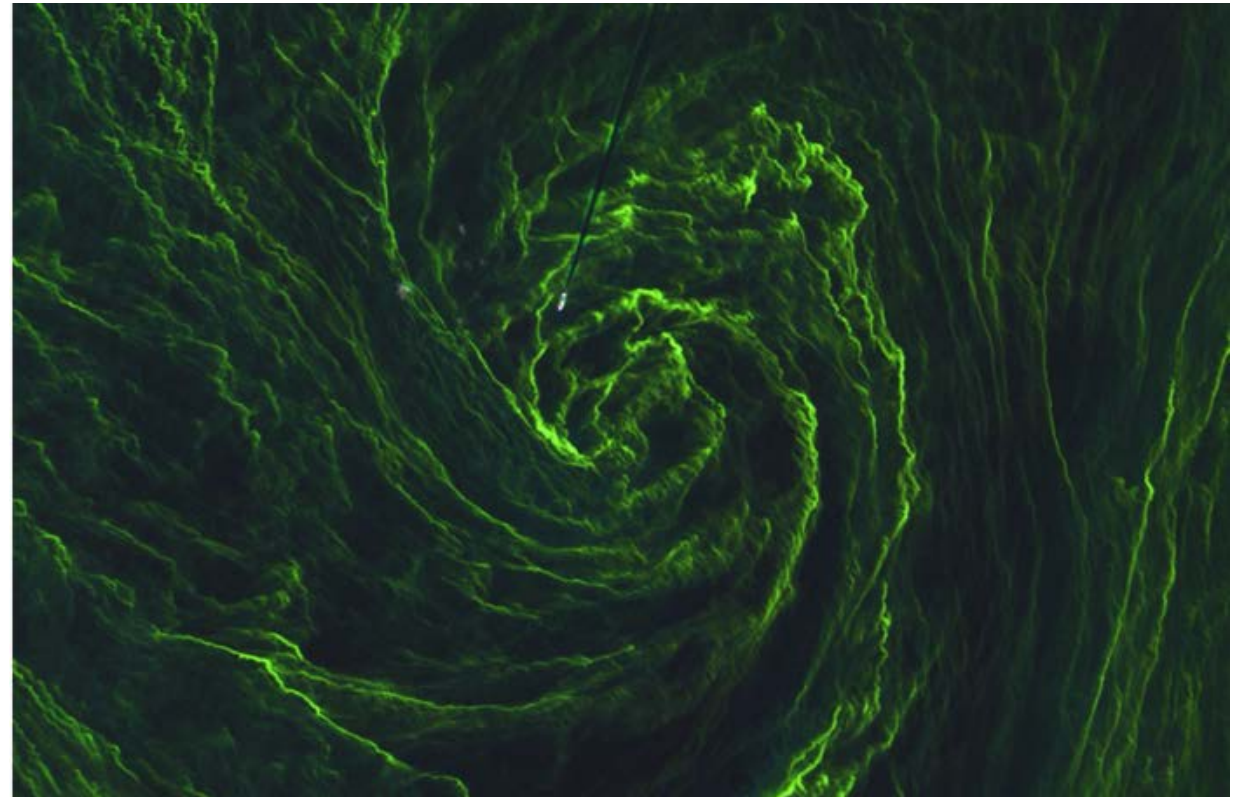


Image: Copernicus Sentinel data (2015)/ESA, [CC BY-SA 3.0 IGO](https://creativecommons.org/licenses/by-sa/3.0/)



# OLCI Bands

<https://sentinel.esa.int/web/sentinel/user-guides/sentinel-3-olci>

Band	$\lambda$ centre (nm)	Width (nm)
Oa1	400	15
Oa2	412.5	10
Oa3	442.5	10
Oa4	490	10
Oa5	510	10
Oa6	560	10
Oa7	620	10
Oa8	665	10
Oa9	673.75	7.5
Oa10	681.25	7.5
Oa11	708.75	10
Oa12	753.75	7.5

Band	$\lambda$ centre (nm)	Width (nm)
Oa13	761.25	2.5
Oa14	764.375	3.75
Oa15	767.5	2.5
Oa16	778.75	15
Oa17	865	20
Oa18	885	10
Oa19	900	10
Oa20	940	20
Oa21	1 020	40

## Sentinel-3 OCL-Based Chlorophyll Concentration

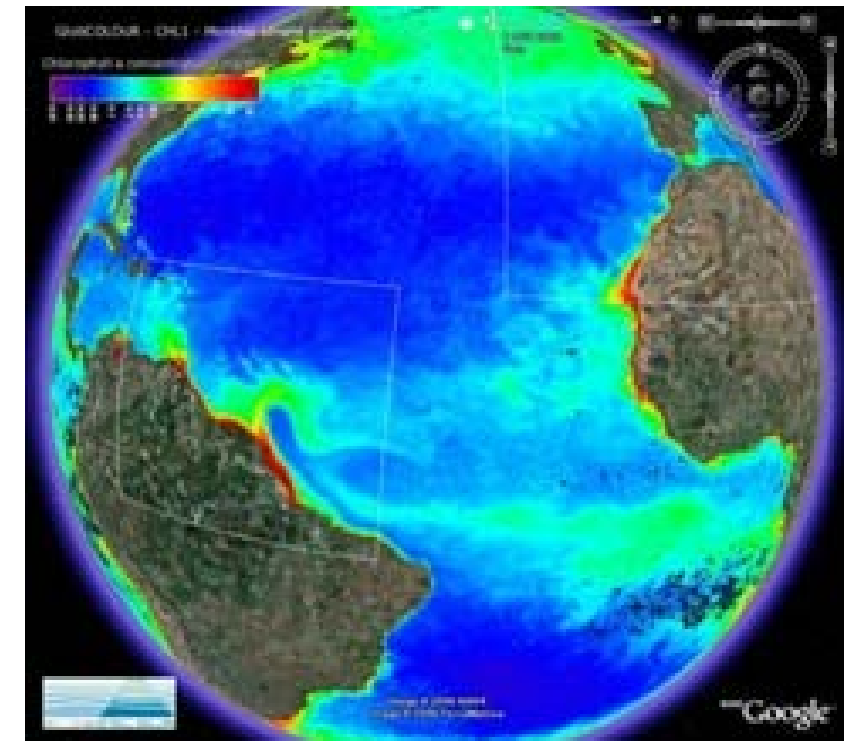


Image Credit: ESA/ACRI-ST





# Lake Clarity from Landsat in Wisconsin

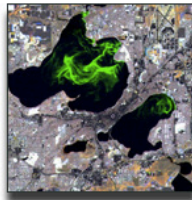
<https://www.lakesat.org/>



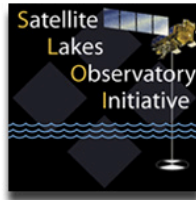
## Lake Water Clarity Monitoring and Analysis With Satellite Remote Sensing at the University of Wisconsin-Madison



**Field Spectroradiometry**  
Online library of **lake reflectance spectra**



**Statewide Wisconsin Lake Clarity Landsat Imagery**  
Results of first Statewide Composite Mapping



**SLOI (historical) Volunteer Network**  
Information Technical Center

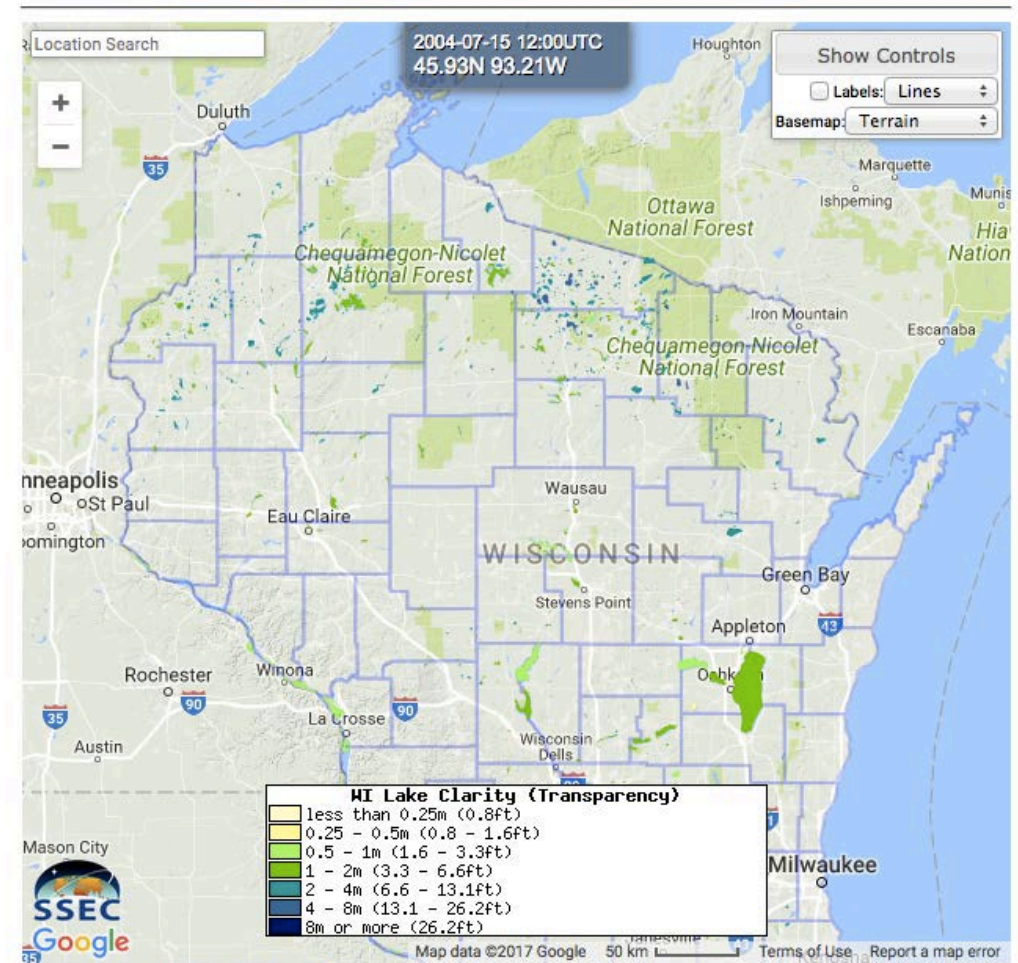


**Wisconsin-Today Imagery SSEC MODIS-Today Daily MODIS Imagery**  
of Wisconsin and the United States

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Environmental Remote Sensing Center :: University of Wisconsin-Madison  
1225 W Dayton St, Floor 12 :: Madison, WI 53706  
LakeSat Questions: [Sam Batzli](#)



Two dates are available: 2000, and 2004. Use your keyboard's left and right arrow keys to move between them.



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