National Aeronautics and
Space Administration

ARSET

Applied Remote Sensing Training

http://arset.gsfc.nasa.gov

@NASAARSET

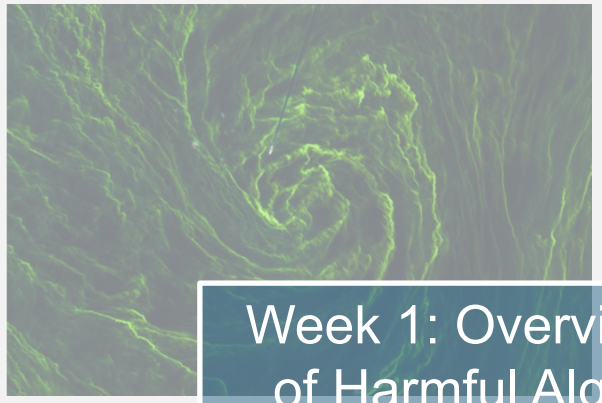
Platforms and Sensors for Ocean Observations, Data Access, and Processing Tools

Week 2, September 12, 2017

Trainers: Sherry Palacios

Amita Mehta

Course Outline



Week 1: Overview of Harmful Algal Blooms

Week 2: Platforms & Sensors, Data Access, and Processing

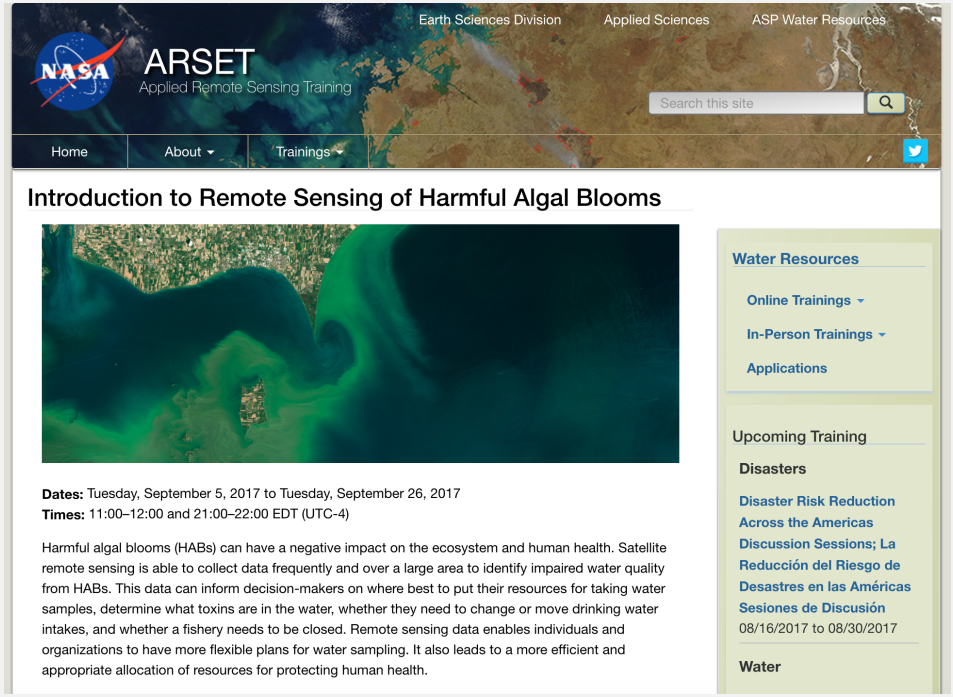
Credit: Paul Hillman/NOAA

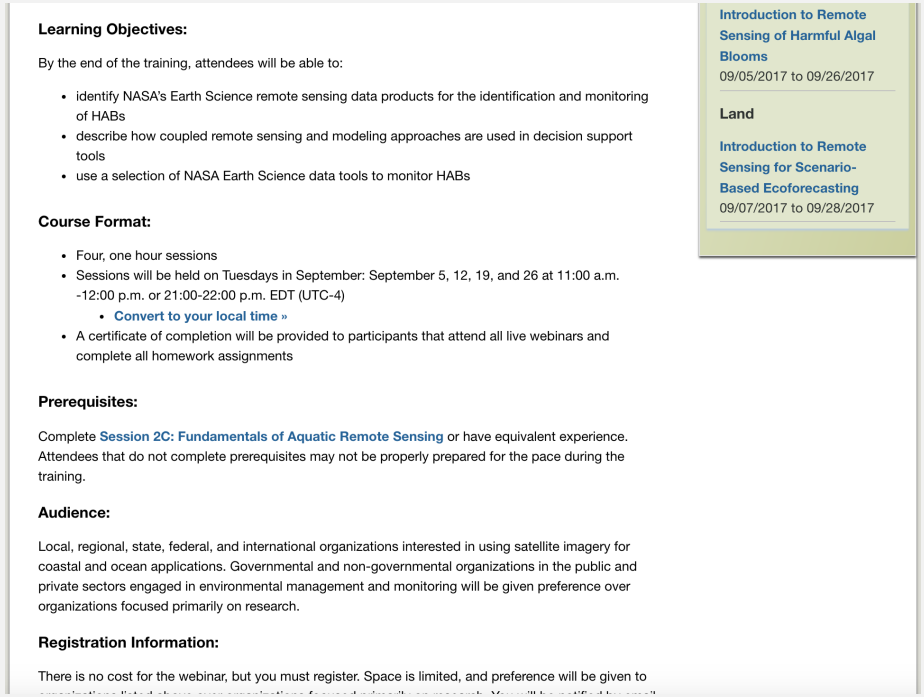
Week 3: HABs in the Coastal Environment

Week 4: Large Scale Monitoring

Course Material

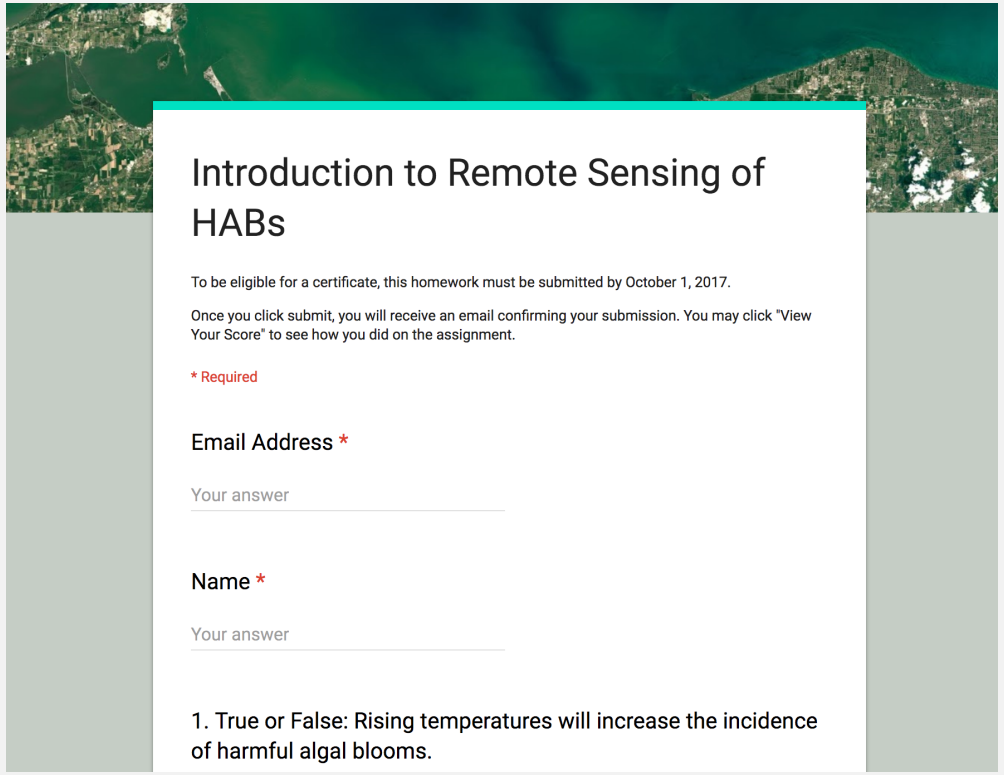
Webinar recordings, presentations, in class exercises, and homework are available at: https://arset.gsfc.nasa.gov/water/webinars/HABs17





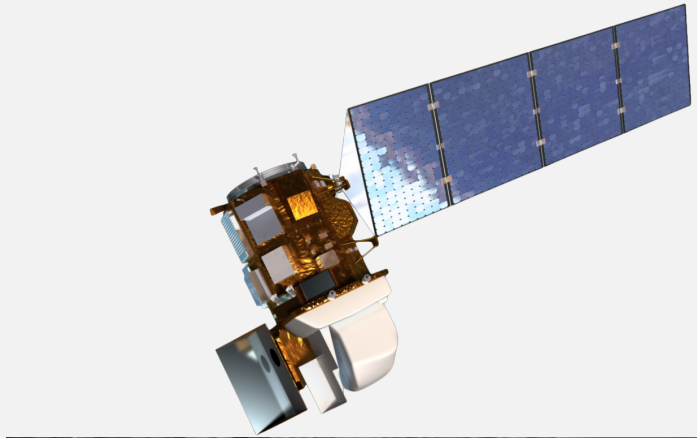
Homework and Certificates

- Homework
  - **Answers must be submitted via Google Form**
- Certificate of Completion:
  - Attend all webinars
  - Complete homework assignments by the deadline (access from ARSET website)
    - **HW Deadline: August 2nd**
  - You will receive certificates approx. two months after the completion of the course from: marines.martins@ssaihq.com



Outline: Session 2

- Week 1 Review
- HAB Detection Using Remote Sensing
- Overview of Satellites and Sensors for Monitoring HABs
- Overview of Satellite-Based Ocean Color Data Access Tools
- Examples of HAB Monitoring Tools



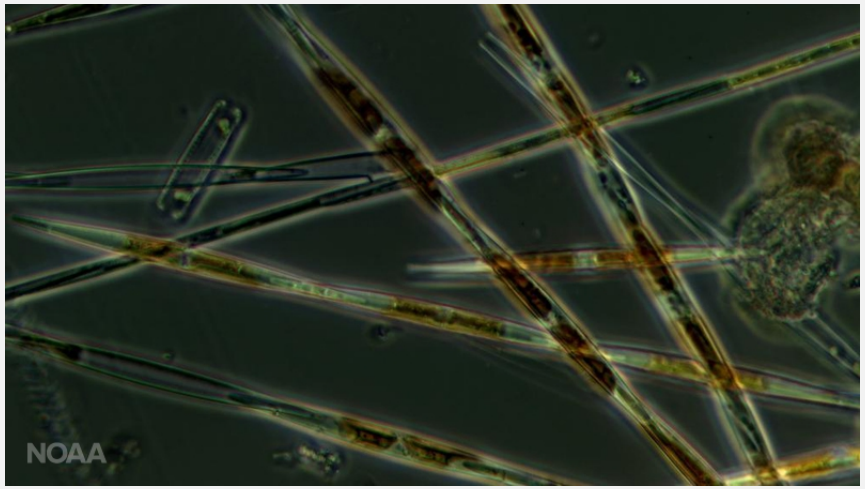
A Landsat 8 image acquired on Aug. 1, 2014 showing algal blooms in Lake Erie just north of Toledo, Ohio.

Image credit: USGS/NASA Earth Observatory

Week 1 Review

What is a Harmful Algal Bloom?

"Harmful algal blooms, or HABs, occur when colonies of algae — simple plants that live in the sea and freshwater — grow out of control and produce toxic or harmful effects on people, fish, shellfish, marine mammals and birds. The human illnesses caused by HABs, though rare, can be debilitating or even fatal."



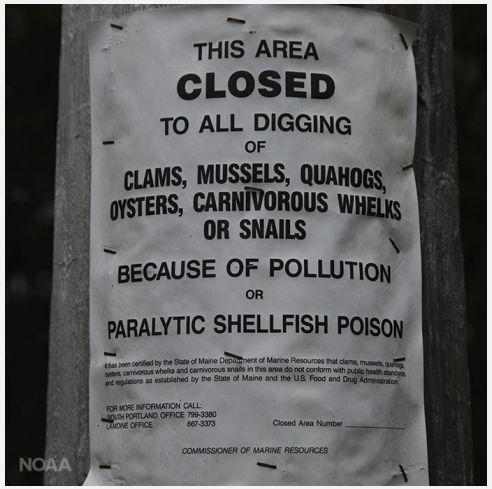


Image credit: http://www.noaa.gov/what-is-harmful-algal-bloom

How HABs Can Be Harmful

- Produce toxins
- Cause economic losses
- Impair drinking water
- Smother benthic organisms
- Deplete oxygen
- Impede visual predators
- Attenuate light to benthic submerged aquatic vegetation or corals

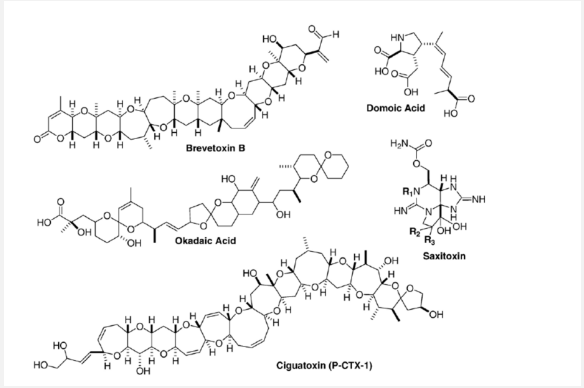


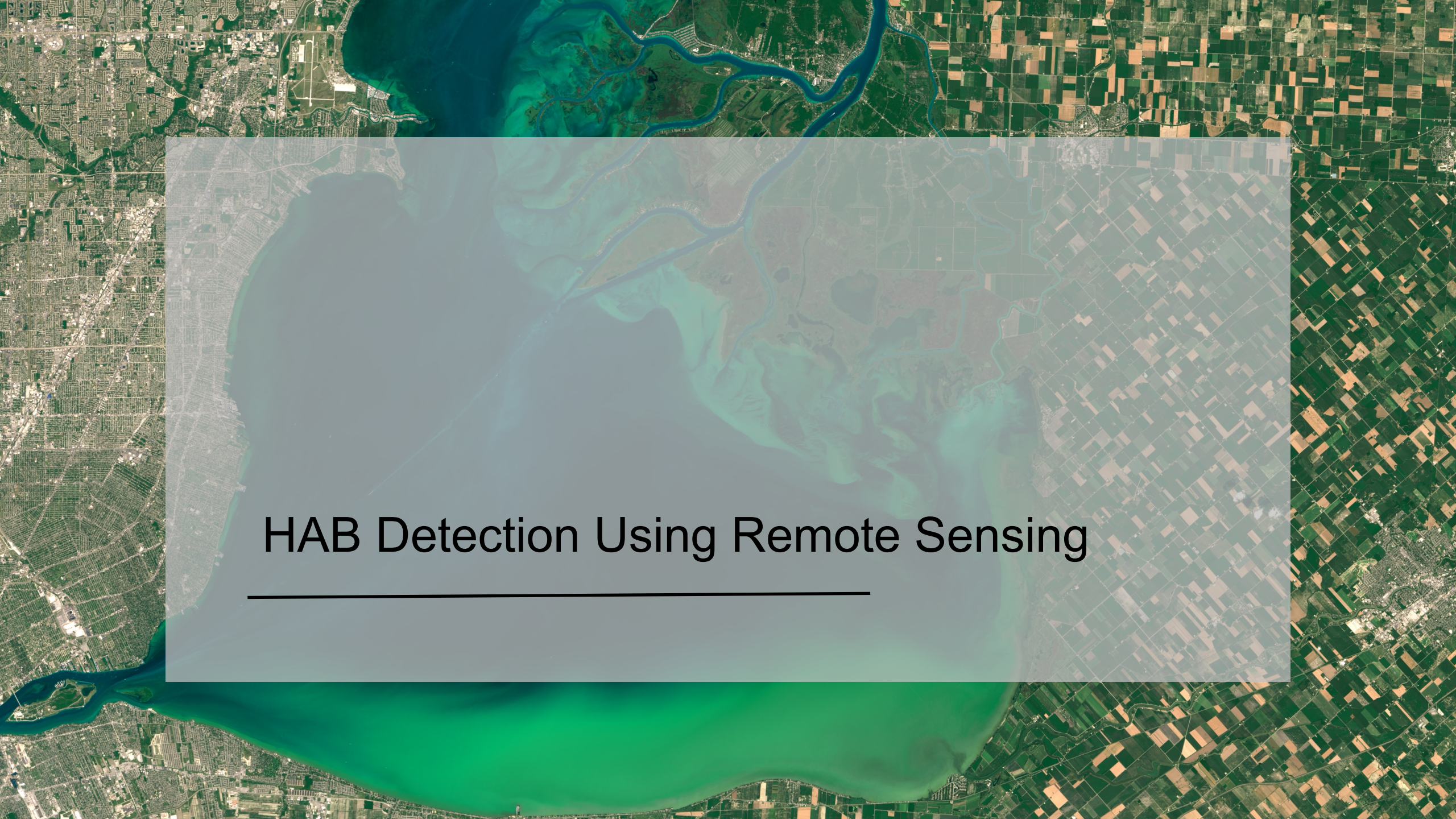
Photo Credits (clockwise from top left) Karina Cardozo (Cardozo et al., 2007); NASA Earth Observatory; NOAA Northwest Fisheries Science Center; Linda Preskitt

What Causes HABs?

- Nutrient loading “eutrophication”
- Pollution
- Warm water
- Food web changes
- Introduced species
- Changes in water flow
  – e.g., after major events like hurricanes, drought, or floods
- Other, yet unknown, factors

Optical Properties of HABs

- Some HAB species have unique properties that affect their optics – and therefore the remote sensing of blooms (e.g., *Microcystis aeruginosa* and *Karenia brevis*)
- HABs can sometimes change the color of the water (e.g., red tides), but not all red tides are harmful and not all harmful blooms discolor the water
- Chlorophyll anomalies can be used to detect and monitor HAB events for blooms that produce high biomass

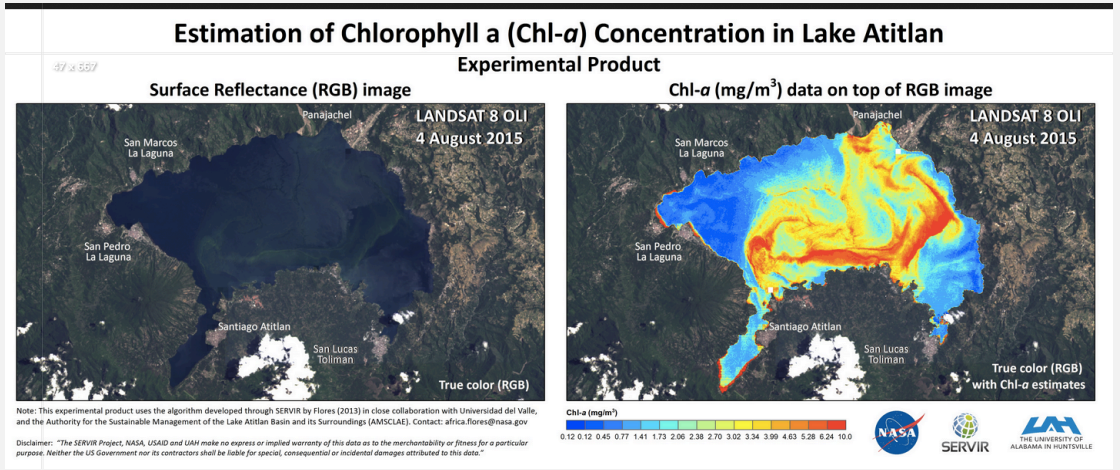


HAB Detection Using Remote Sensing

Parameters Relevant for HAB Detection

- The following parameters, available from remote sensing observations, are commonly used to detect the presence of algal blooms:
  - Chlorophyll-a Concentration (Chl-a)
  - Chlorophyll-a Concentration Anomalies*
  - Sea Surface Temperature (SST)
  - Optical Characteristics (absorption, backscattering)

*Usually taken with respect to 2-3 months means Chl-a can help detect new HABs



Source: SERVIR

Remote Sensing for HAB Detection

- Reflected solar radiation in various visible to near-infrared (NIR) bands are used to derive the properties of optically-active water constituents, including Chl-a

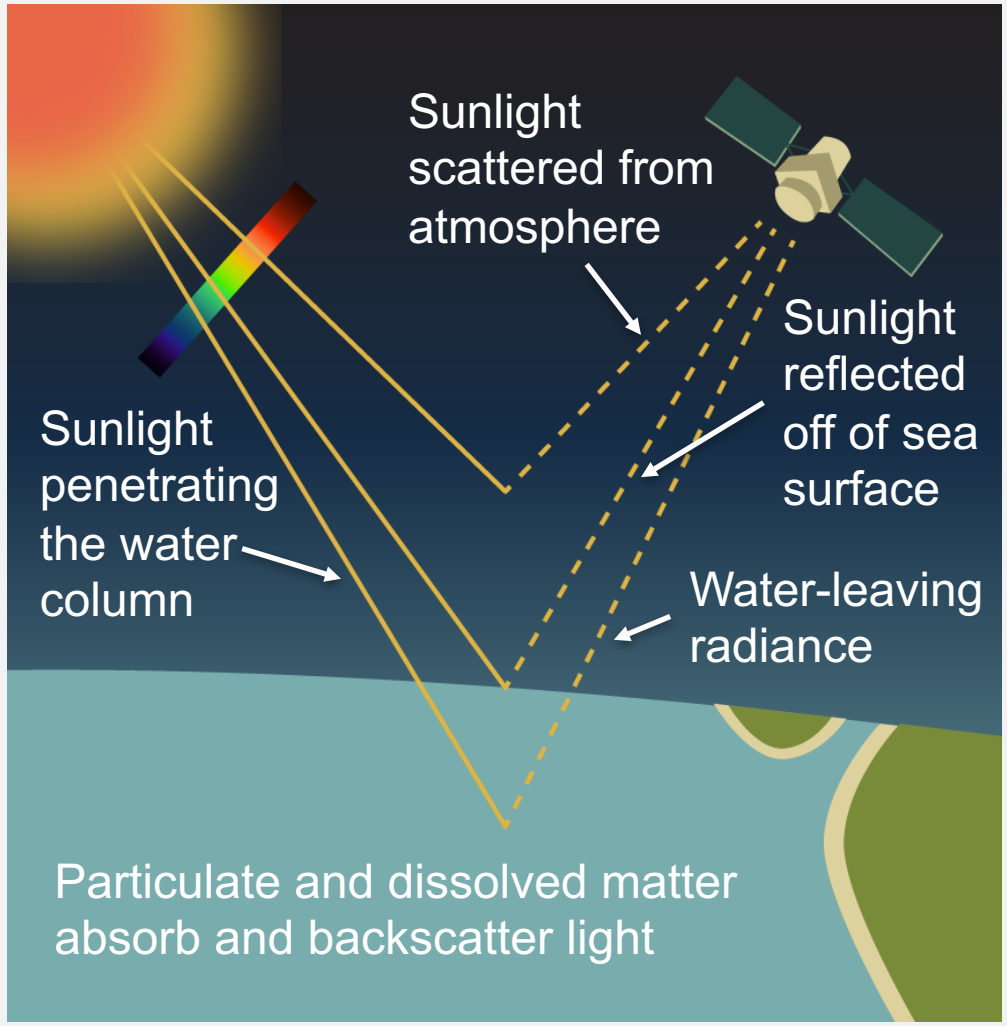
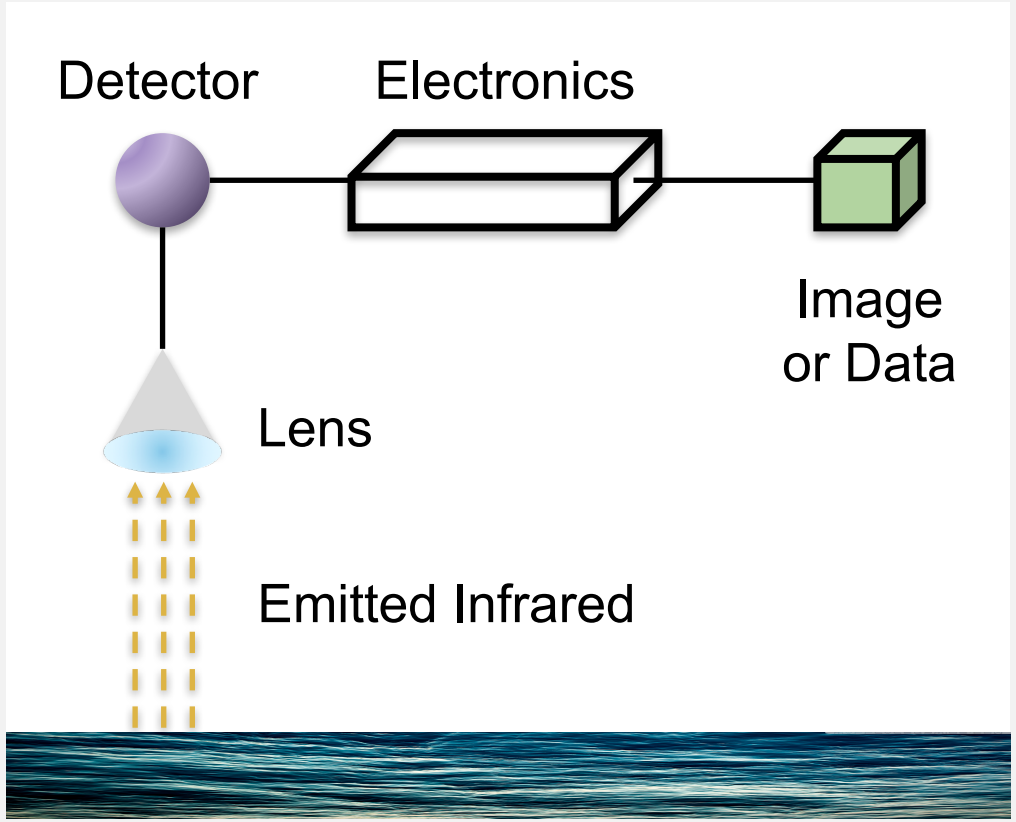


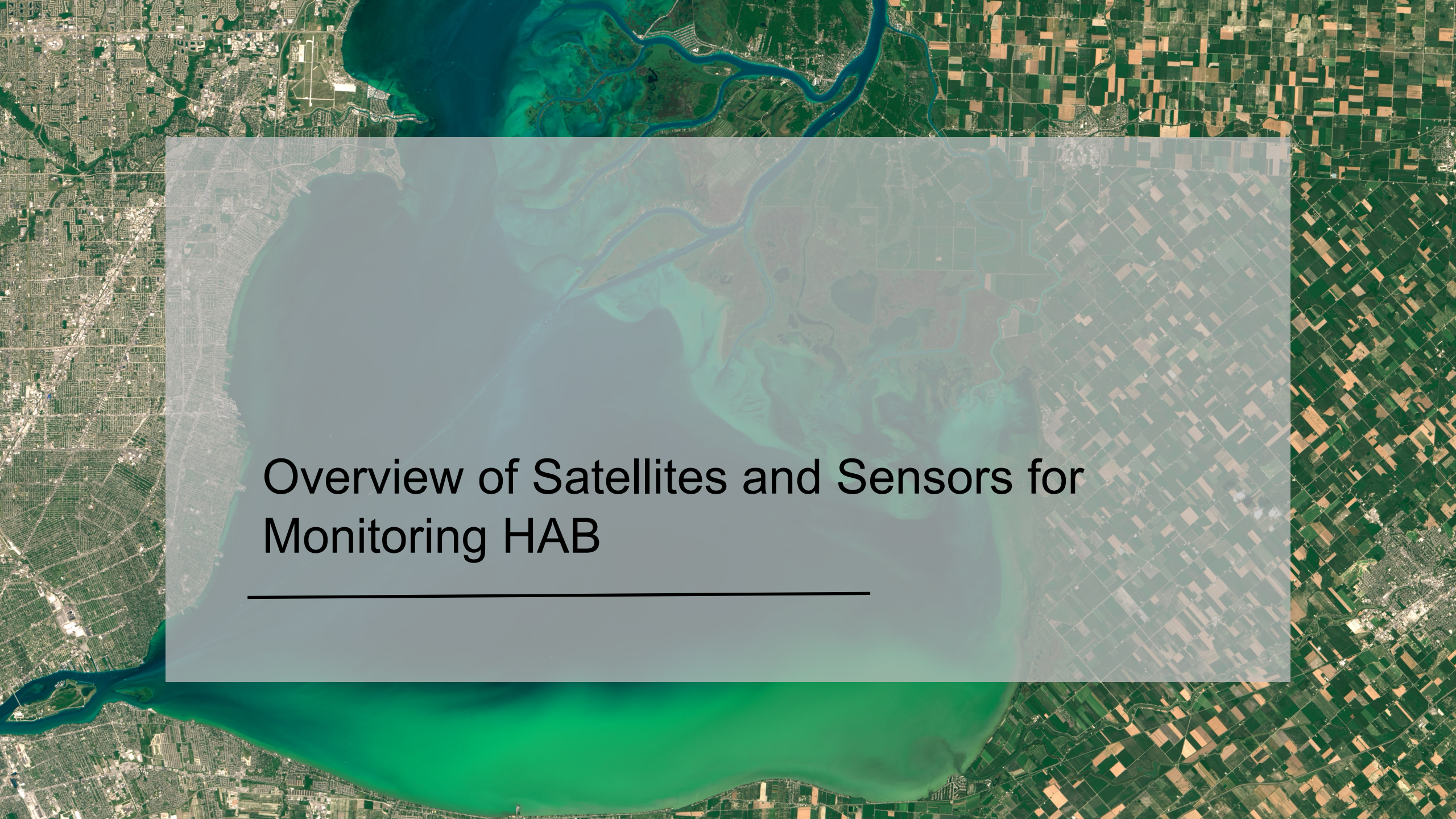
Image based on image from X

Remote Sensing for HAB Detection

- Emitted thermal infrared radiation TIR) is used to derive surface temperature of water bodies
- A number of NASA & European Space Agency (ESA) satellites carry sensors that measure reflected radiation in VIS-NIR (band reflectance) and emitted TIR



Based on an image from CCRS/CCT



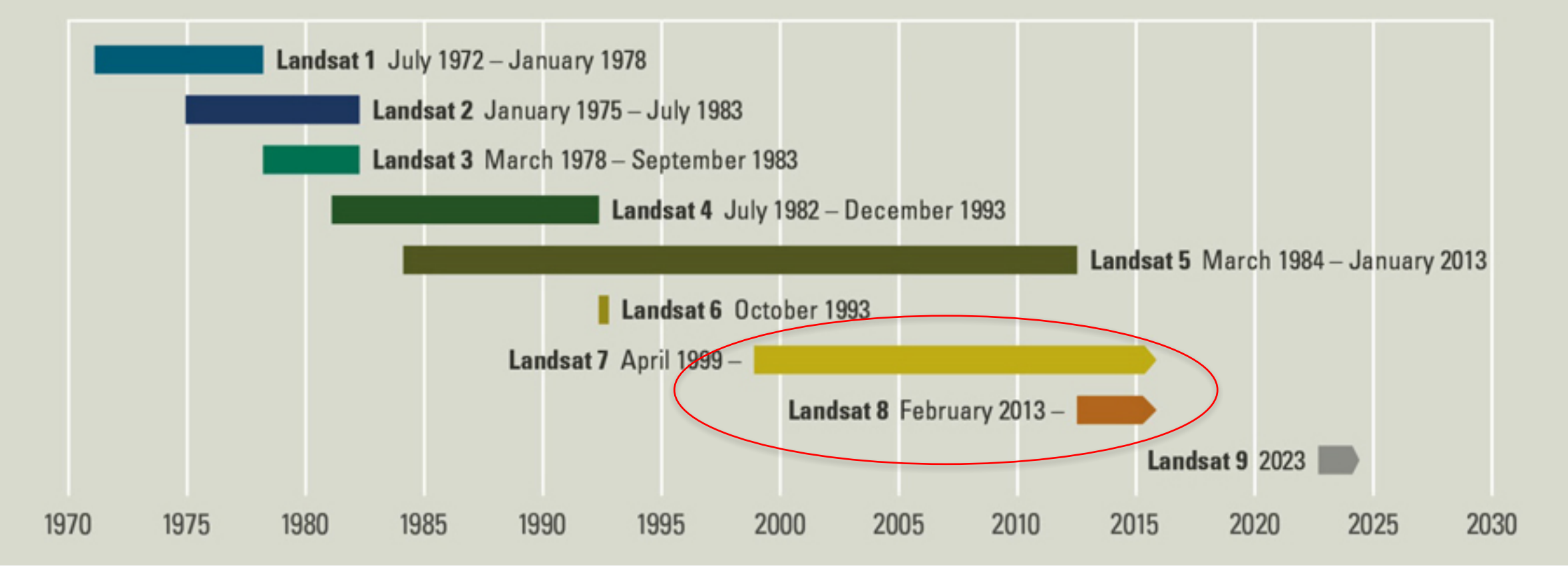
Overview of Satellites and Sensors for Monitoring HAB

Satellites for HAB Monitoring

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

Landsat Satellites and Sensors

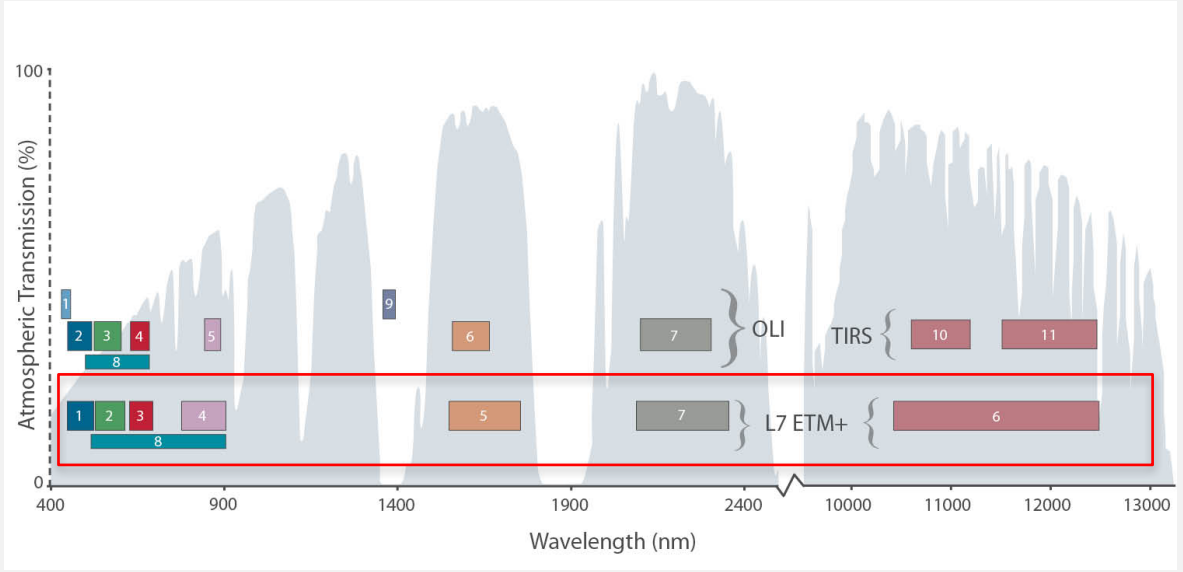
http://landsat.gsfc.nasa.gov/



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



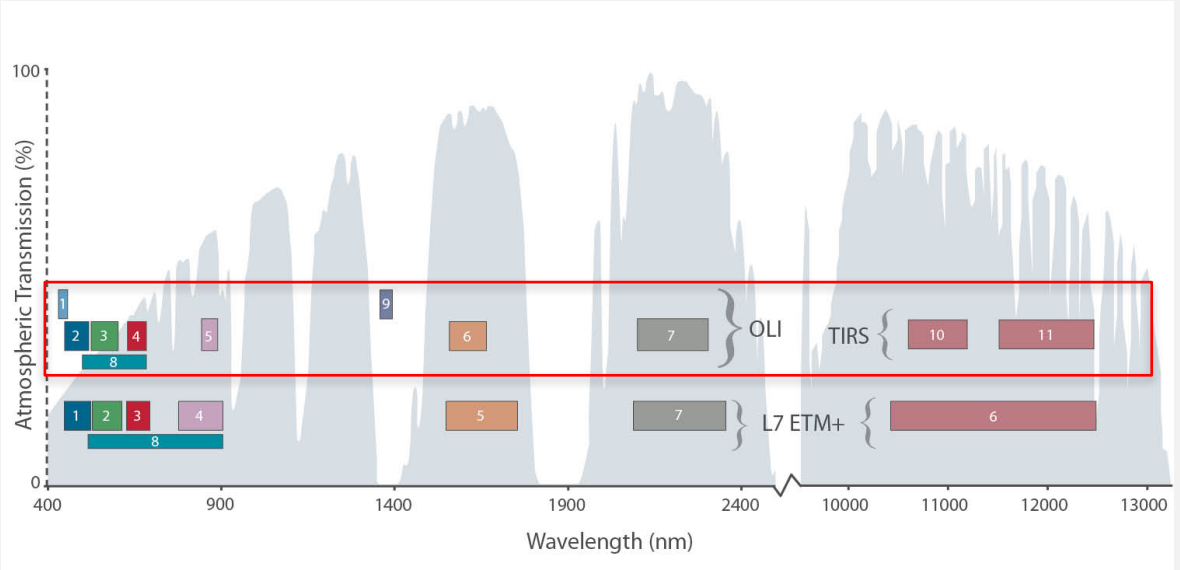
Spectral Bands: 8

- 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

Landsat Bands

Landsat 7 ETM+

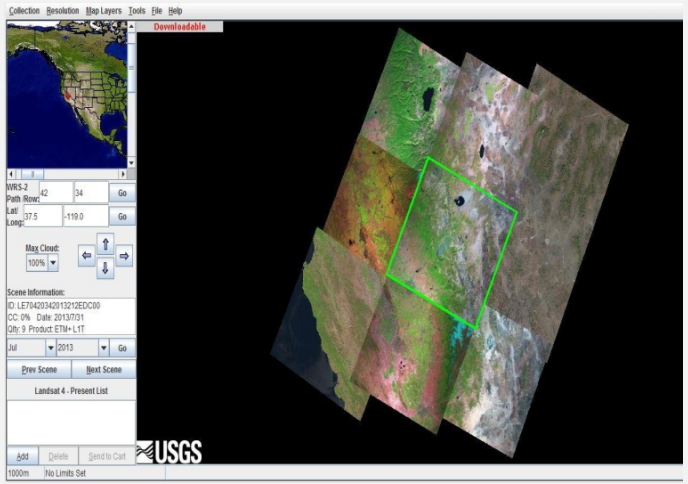
Band	Band Range (µm)	Spatial Resolution (m)
1	0.45 – 0.515	30
2	0.525 – 0.605	
3	0.63 – 0.69	
4	0.775 – 0.90	
5	1.55 – 1.75	
6	10.4 – 12.5	60
7	2.08 – 2.35	30
8	0.52 – 0.9	15

Landsat 8 OLI

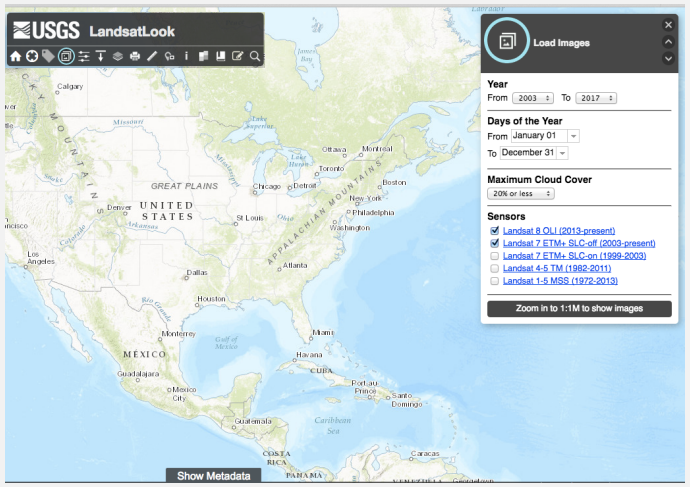
Band	Band Range (µm)	Spatial Resolution (m)
1	0.433 – 0.453	30
2	0.450 – 0.515	
3	0.525 – 0.60	
4	0.630 – 0.680	
5	0.845 – 0.885	
6	2.10 – 2.30	
7	0.500 – 0.680	
8	2.08 – 2.35	15
9	1.36 – 1.39	30

Get Landsat Images and Band Reflectance Data

Earth Explorer:
http://earthexplorer.usgs.gov/



GloVis
http://glovis.usgs.gov/



LandsatLook Viewer:
http://landsatlook.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

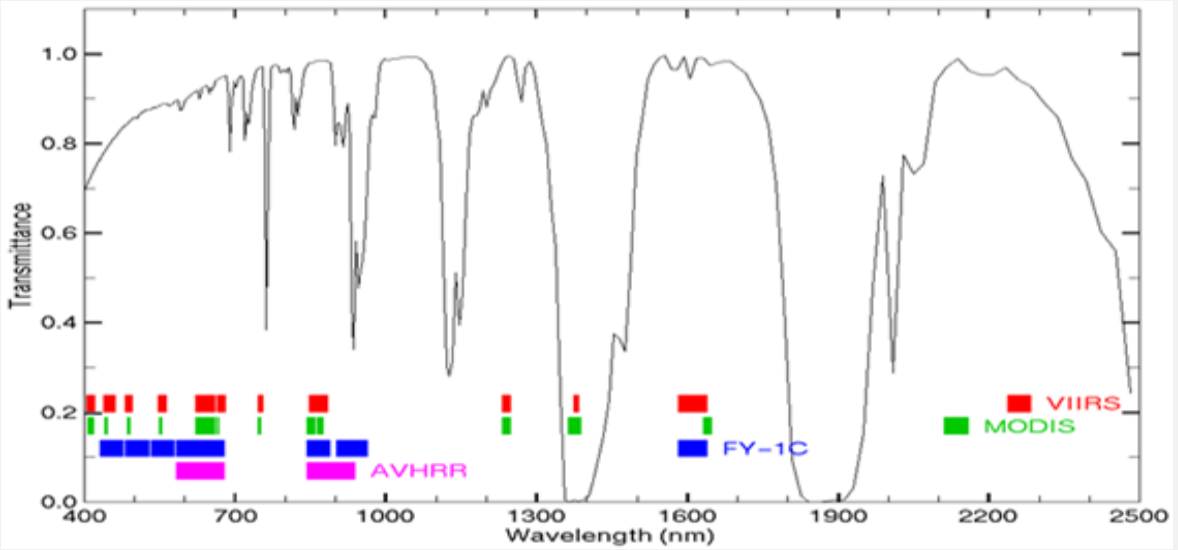
Aqua, http://aqua.nasa.gov/

- 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

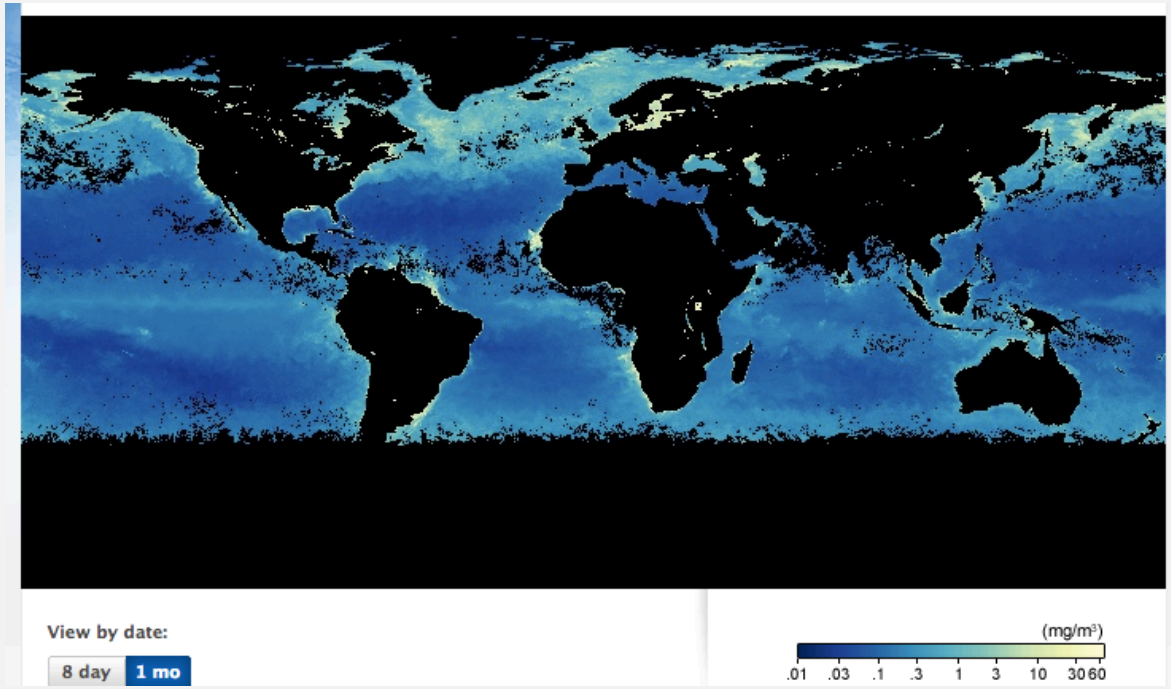
- Reflection and Emission Bands (Major Bands: red, blue, IR, NIR, MIR)
- Bands 1-2: 250 m; Bands 3-7: 500 m; Bands 8-36: 1,000 m

MODIS Bands Relevant for HAB Monitoring

Band	Band Range µm
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

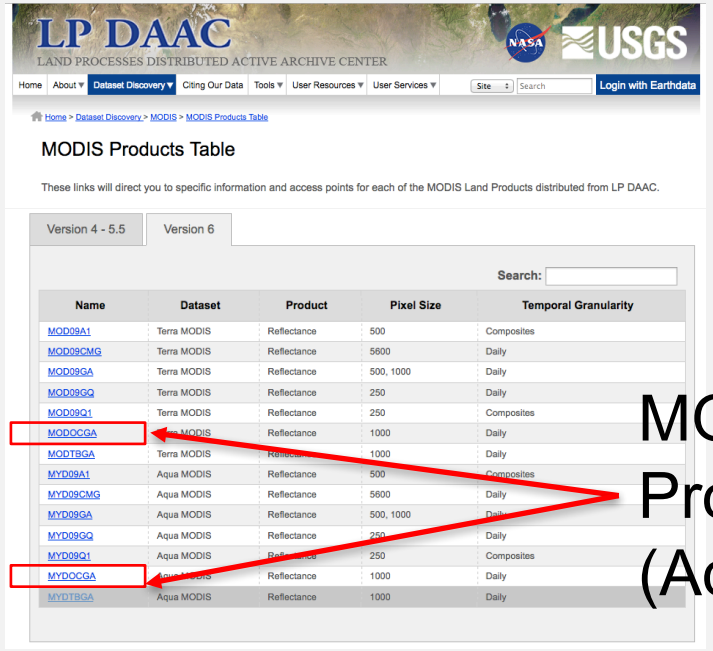
Chlorophyll Concentration from Aqua MODIS, June 2017



Get MODIS Band Reflectance Data

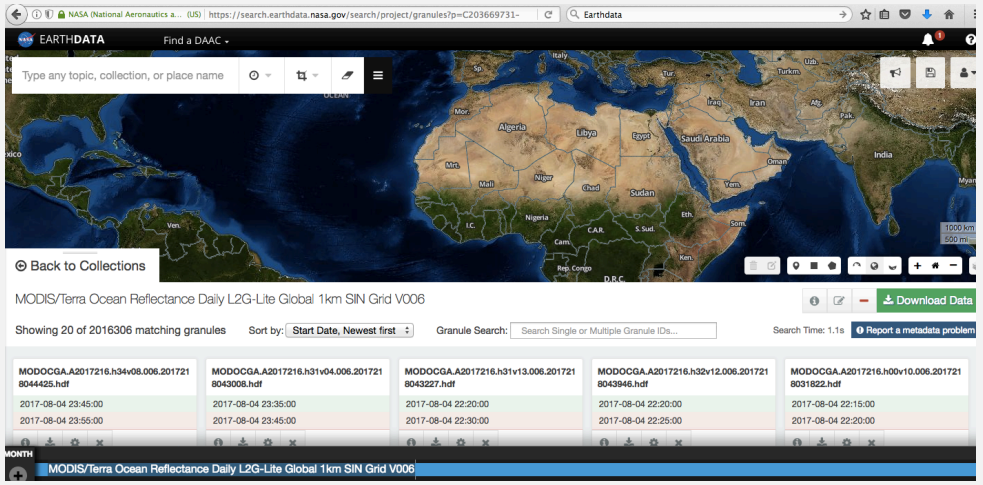
Land Processing Distributed Active Archive Center

http://lpdaac.usgs.gov/dataset_discovery/modis/modis_products_table/



NASA Earthdata

http://earthdata.nasa.gov/

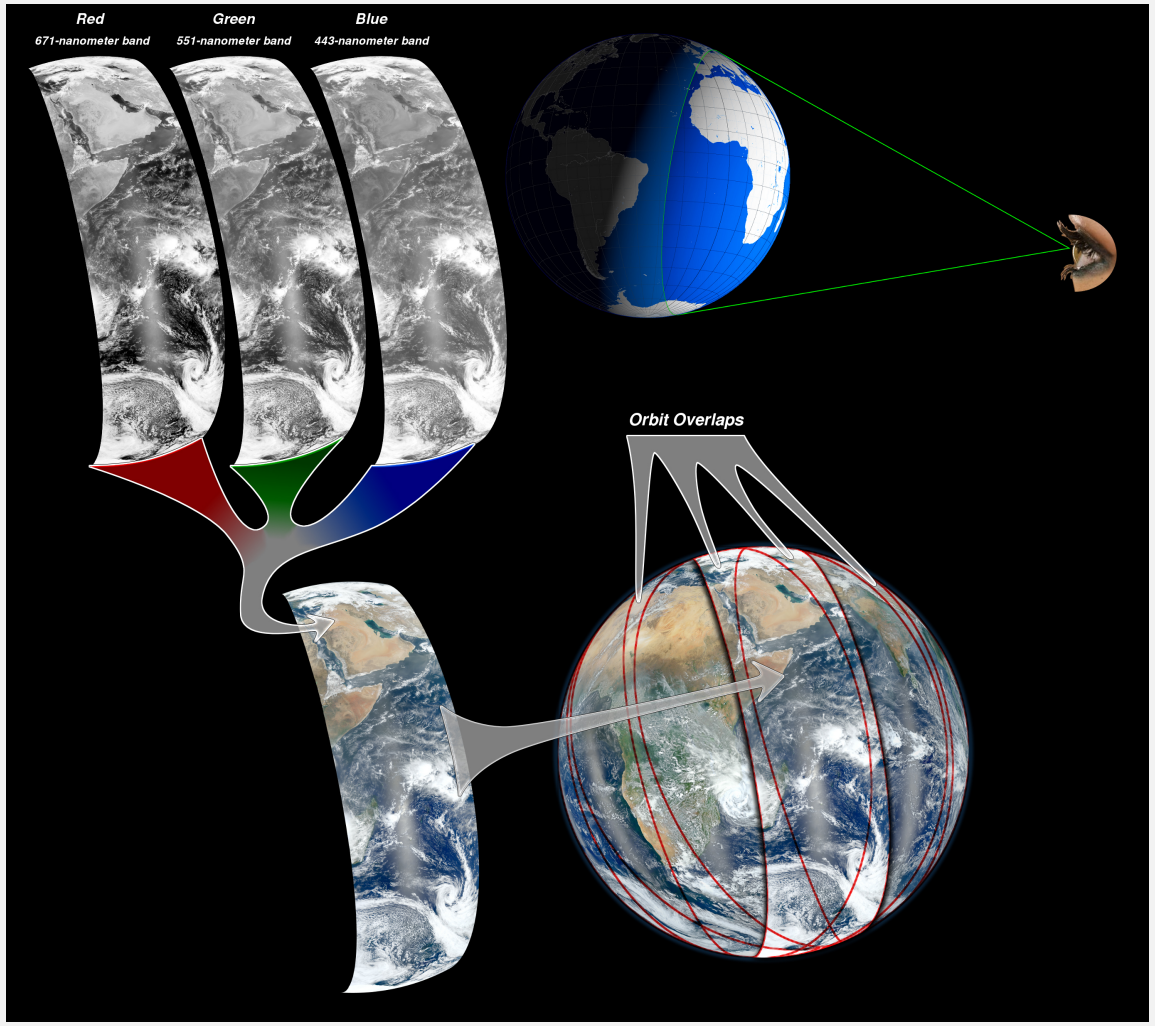


MODIS Band Reflectance for Oceans, Bands 8-16
Product Name: MODOCGA (Terra), MYDOCGA (Aqua)

Suomi National Polar Partnership (SNPP)

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, CERCES



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

VIIRS True Color Image Showing Algae in the Caspian Sea, May 18, 2014

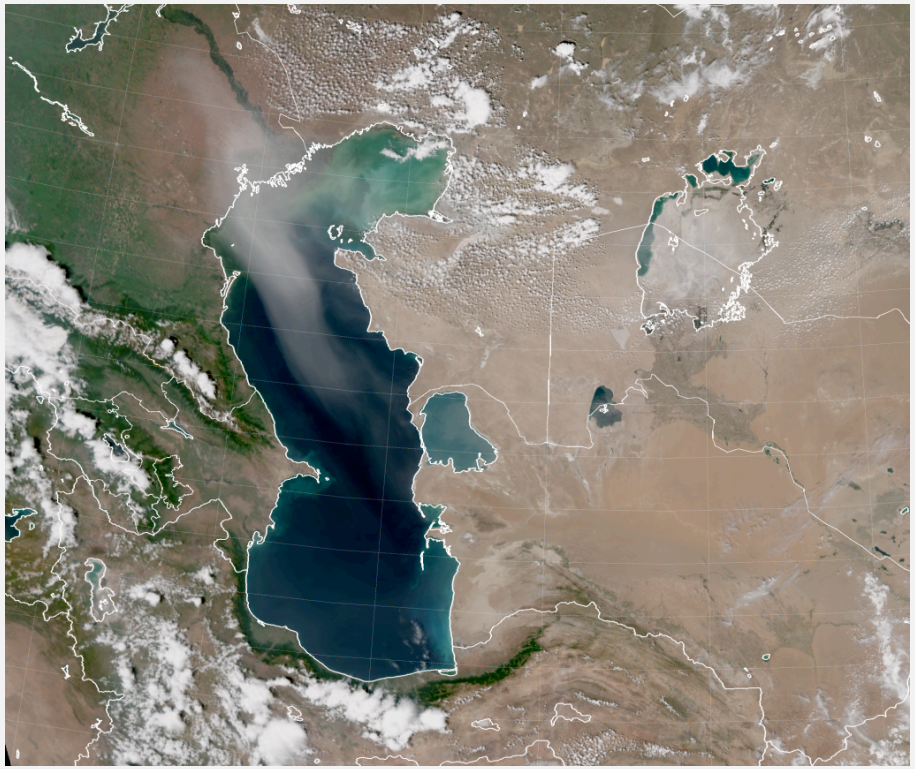


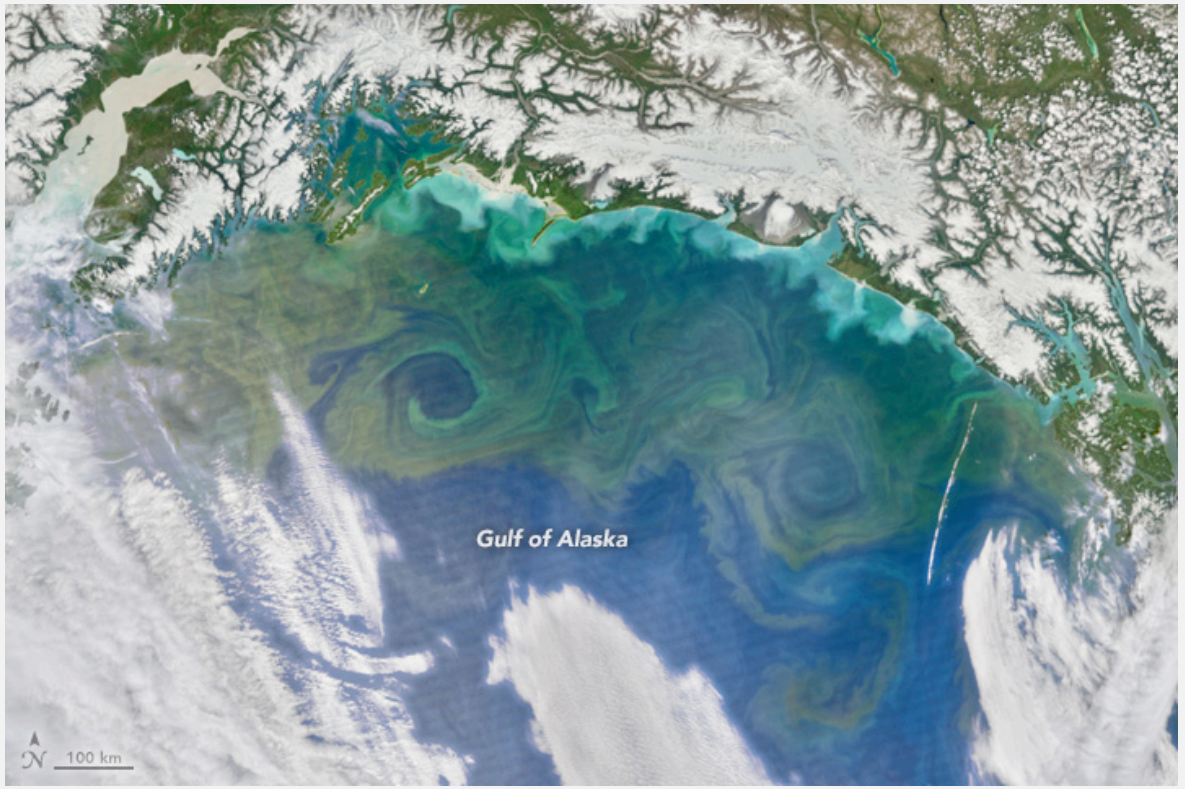
Image Credit: VIIRS Imagery and Visualization Team Blog

VIIRS Bands Relevant for HAB Monitoring

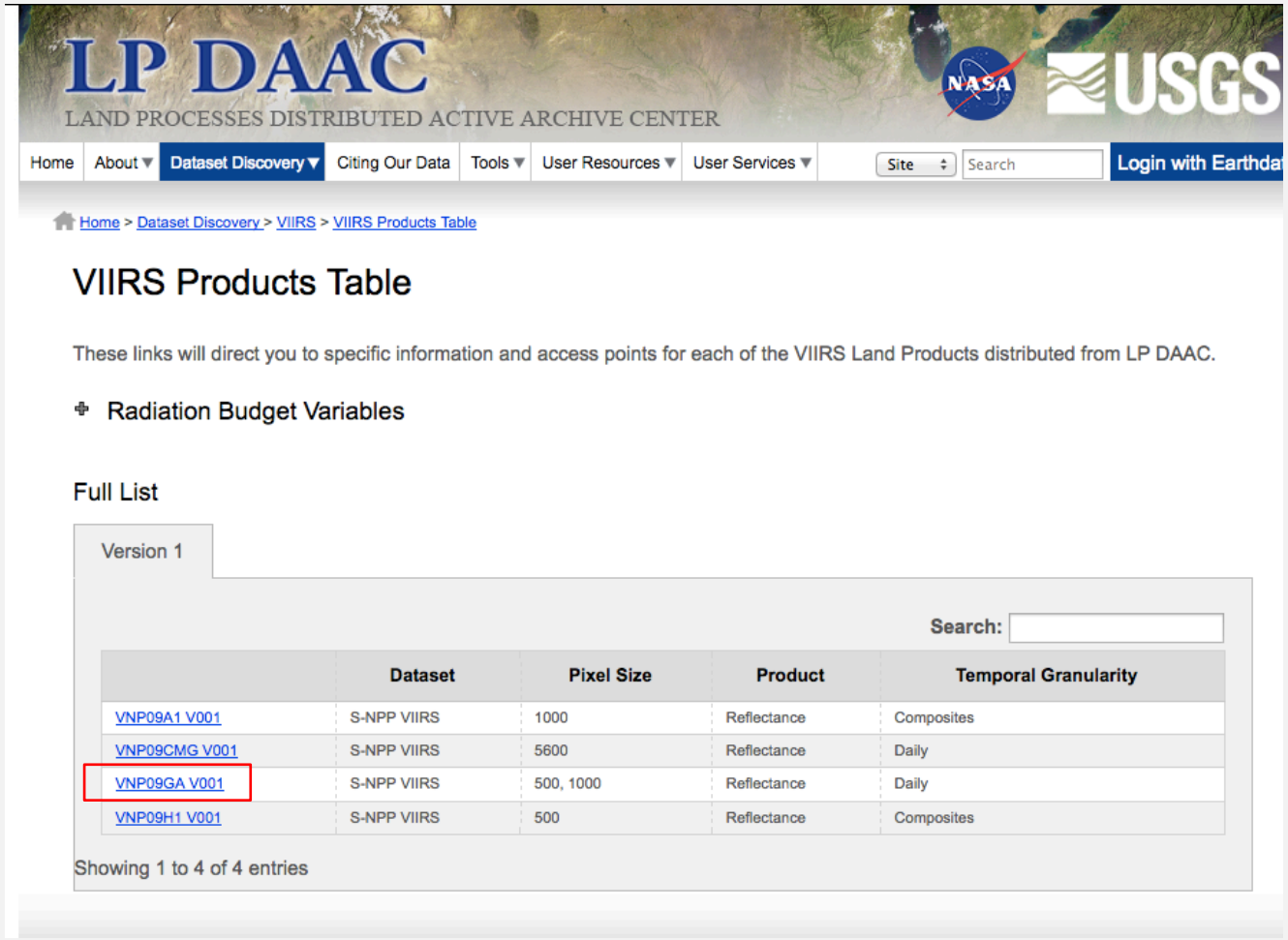
Band	Band Range µm
M1	0.402-0.422
M2	0.436-0.454
M3	0.478-0.488
M4	0.545-0.565
M5	0.662-0.682
M6	0.739-0.745

Spatial Resolution: 750 m

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



Get VIIRS Band Reflectance Data



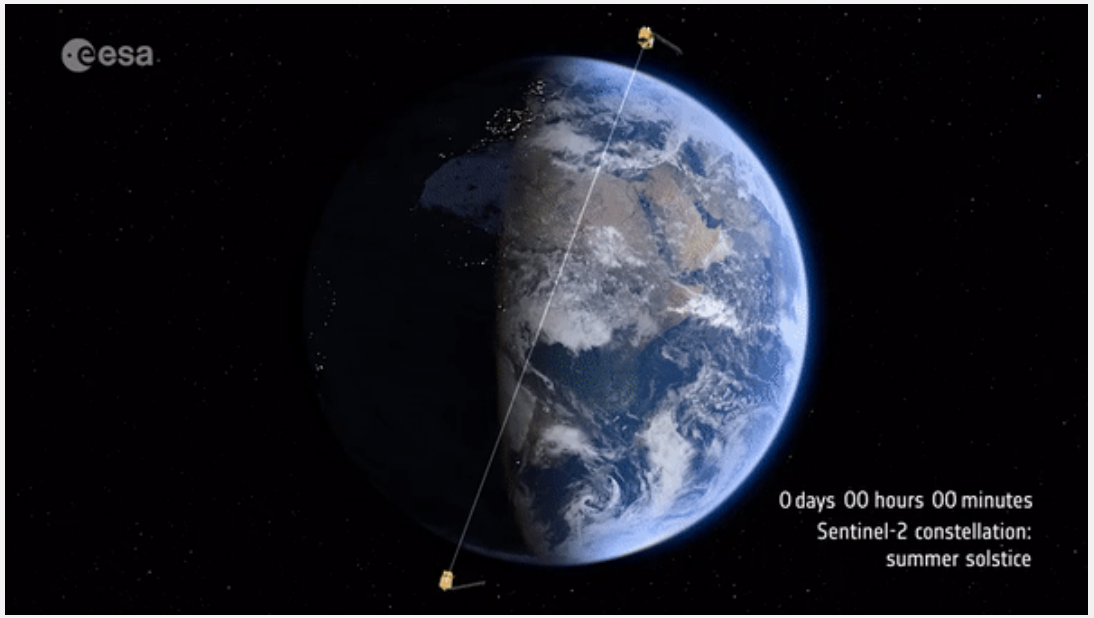
Land Process Distributed Active Archive Center

- 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/

- 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**
- Designed for land and ocean surface observations
- Spatial Coverage and Resolution:
  - Global, swath: 290 km
  - Spatial resolution varies with bands: 10 m, 20 m, 60 m
- Temporal Coverage and Resolution:
  - June 2015 & March 2017 – present
  - 5 day revisit time

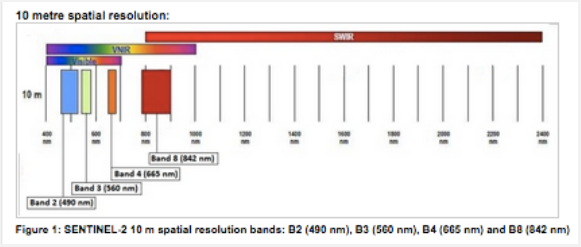


Figure 1: SENTINEL-2 10 m spatial resolution bands: B2 (490 nm), B3 (560 nm), B4 (665 nm) and B8 (842 nm)

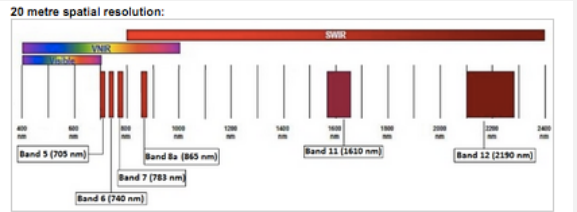


Figure 2: SENTINEL-2 20 m spatial resolution bands: B5 (705 nm), B6 (740 nm), B7 (783 nm), B8a (865 nm), B11 (1610 nm) and B12 (2190 nm)

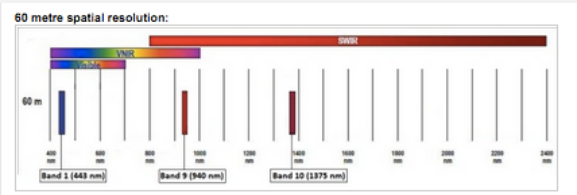


Figure 3: SENTINEL-2 60 m spatial resolution bands: B1 (443 nm), B9 (940 nm) and B10 (1375 nm)

Spectral Bands: 13

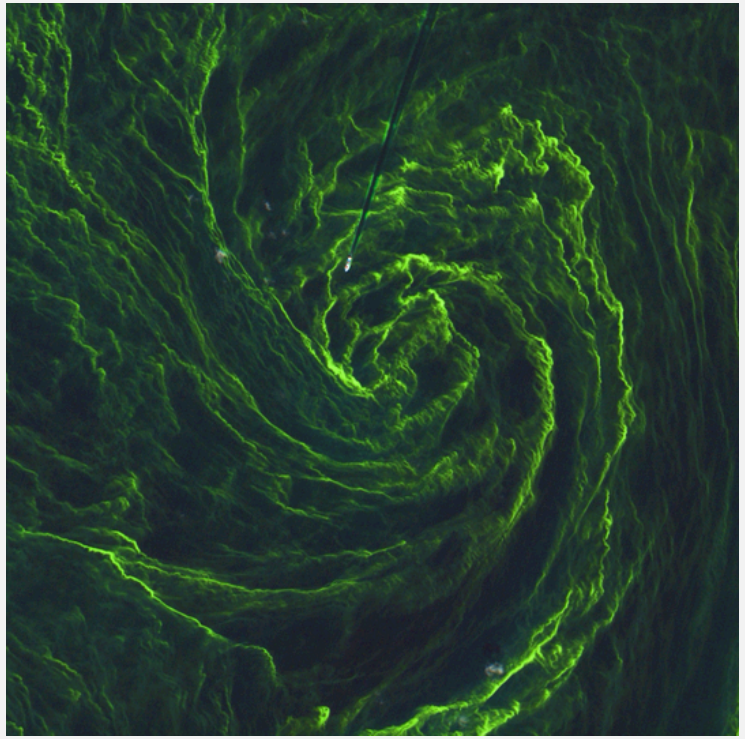
- 4 visible and NIR: 10 m
- 6 red-edge/shortwave infrared: 20 m
- 3 atmospheric correction: 60 m

MSI bands

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

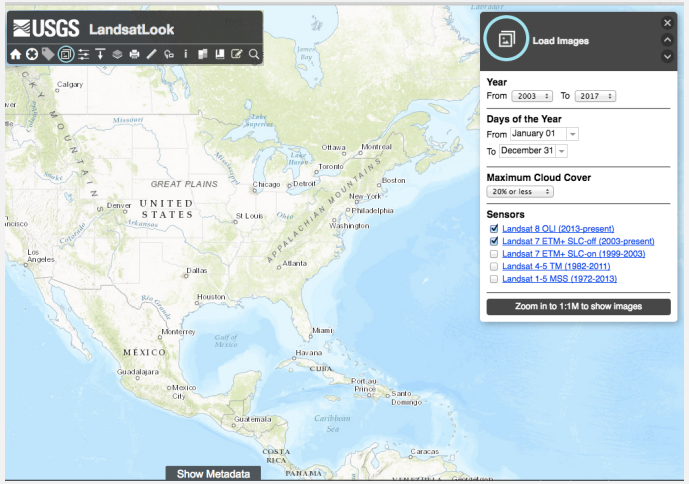
	S2A		S2B		
Band Number	Central wavelength (nm)	Bandwidth (nm)	Central wavelength (nm)	Bandwidth (nm)	Spatial resolution (m)
1	443.9	27	442.3	45	60
2	496.6	98	492.1	98	10
3	560.0	45	559	46	10
4	664.5	38	665	39	10
5	703.9	19	703.8	20	20
6	740.2	18	739.1	18	20
7	782.5	28	779.7	28	20
8	835.1	145	833	133	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



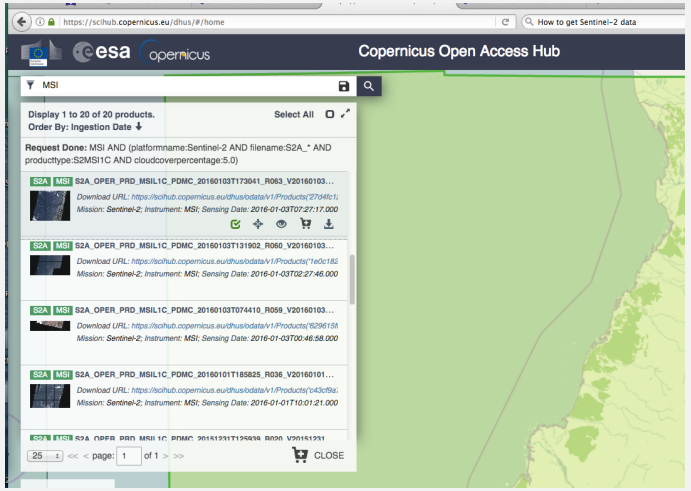
Copernicus data (2015)/ESA

Get MSI Data



USGS Sentinel-2 Look Viewer
https://landsatlook.usgs.gov/sentinel2/viewer.html

Earth Explorer:
http://earthexplorer.usgs.gov/

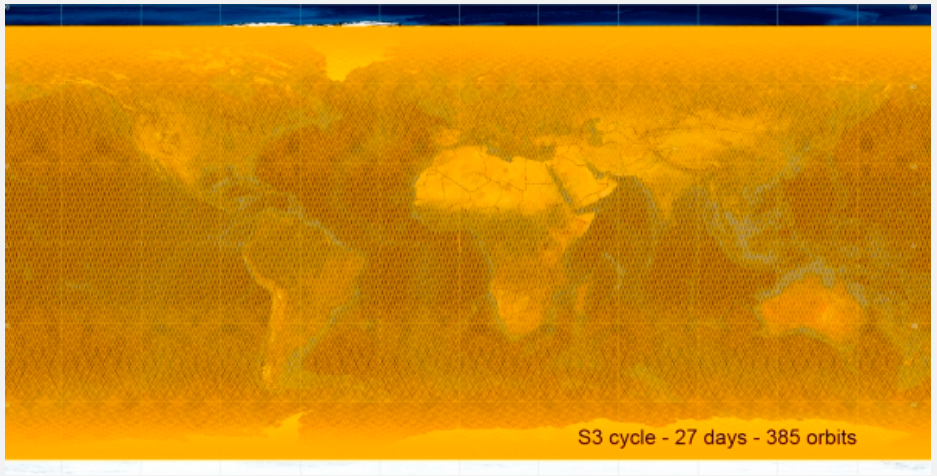


ESA Copernicus Open Hub
http://sentinel.esa.int/web/sentinel/sentinel-data-access

Sentinel-3

www.esa.int/Our_Activities/Observing_the_Earth/Copernicus/Sentinel-3/

- 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

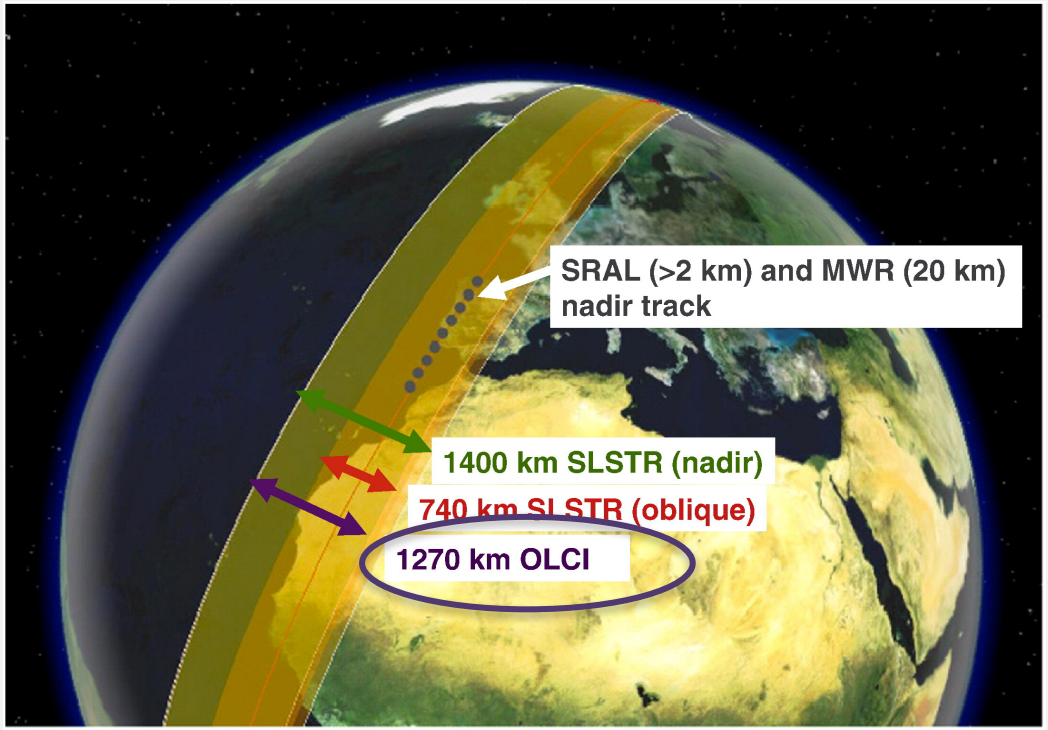


Image Credit: ESA

Spectral Bands: 21

- 4 visible to near-infrared: 300m

OLCI Bands

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

Band	λ 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	λ 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

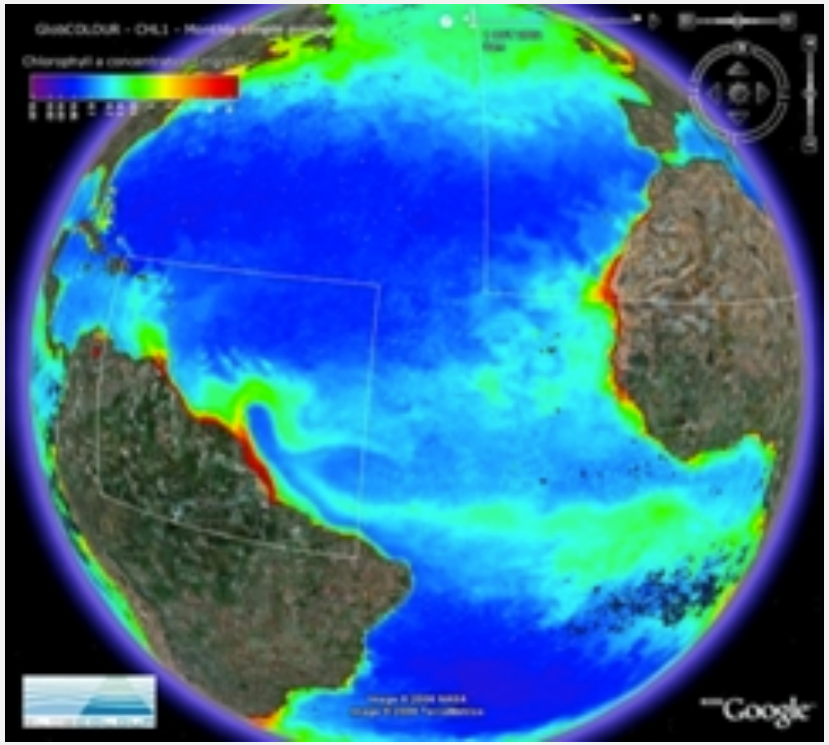
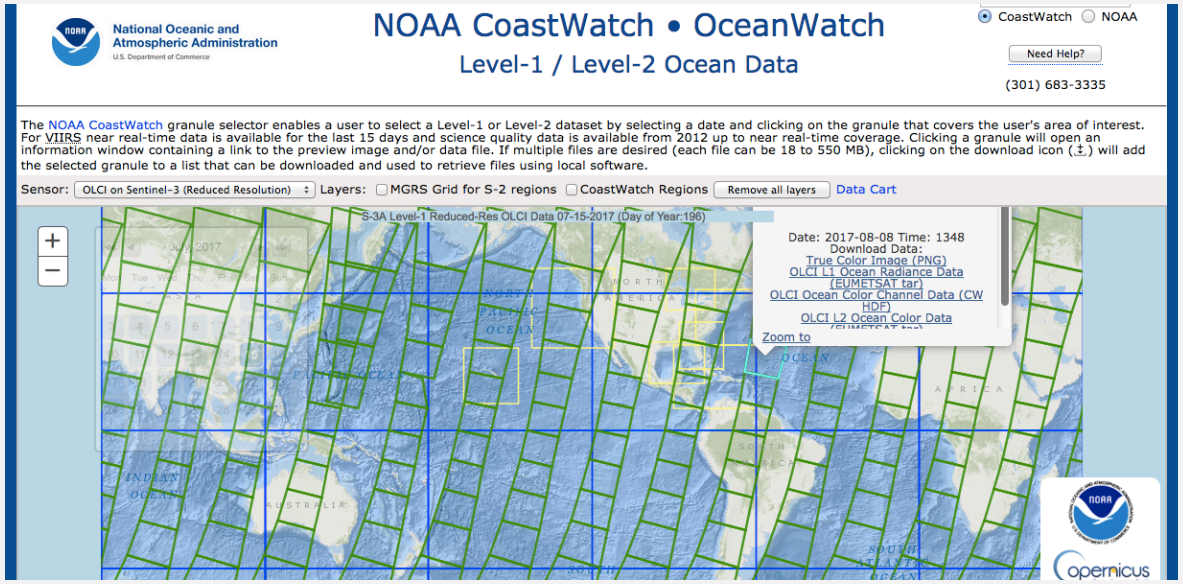
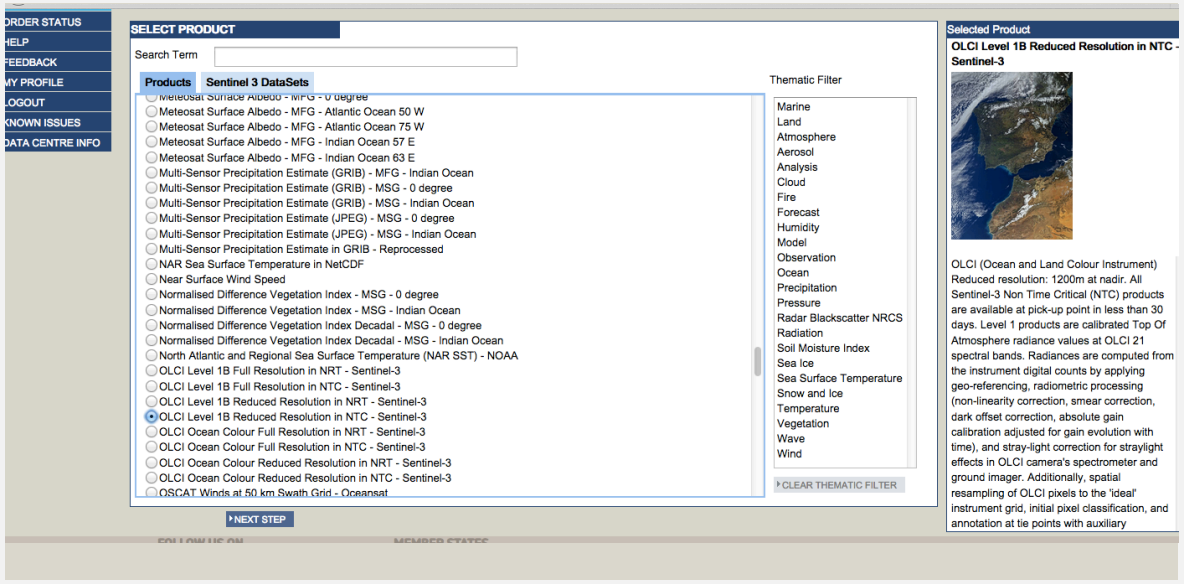


Image Credit: ESA/ACRI-ST

Get OLCI Data





NOAA CoastWatch

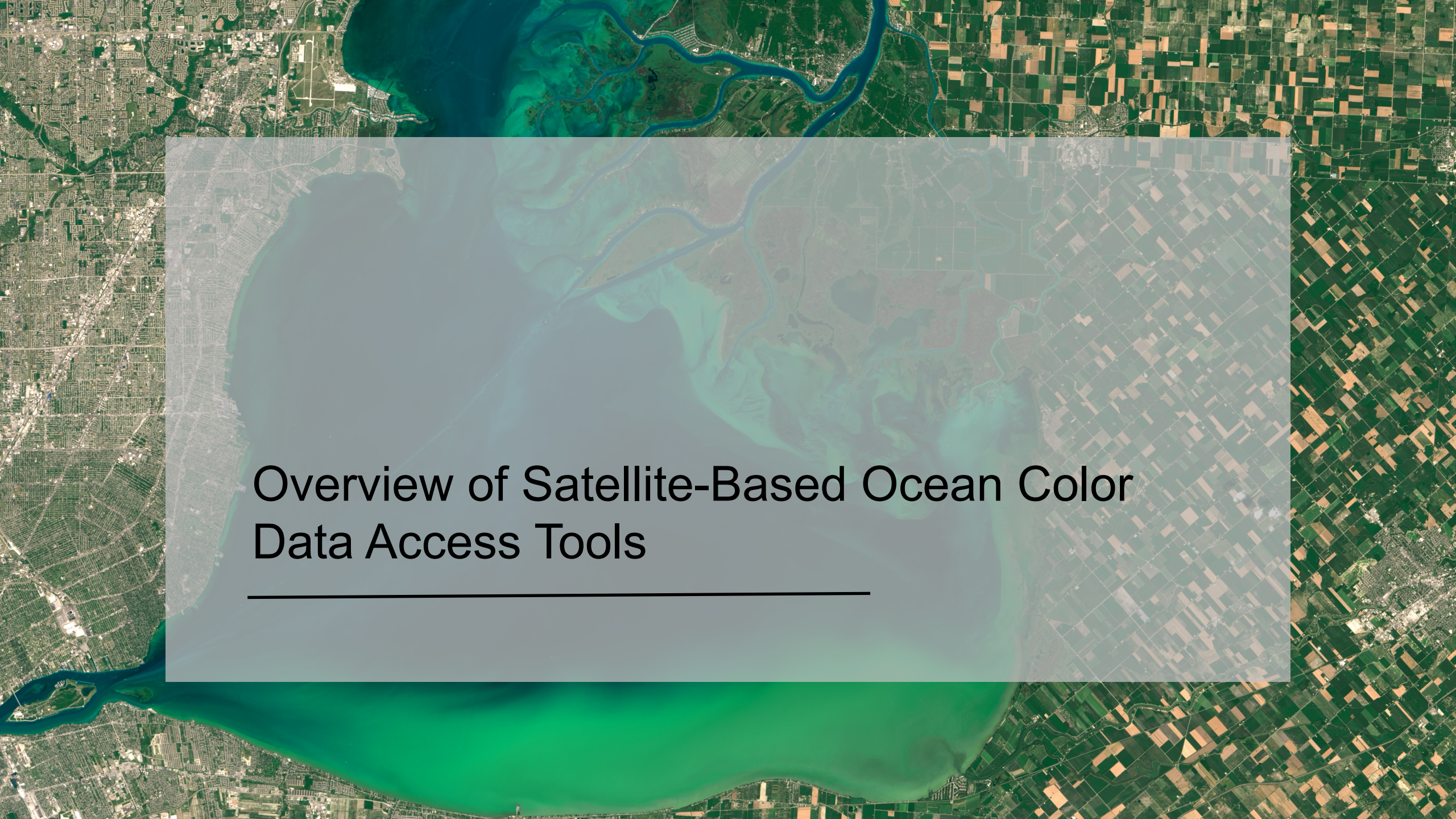
https://coastwatch.noaa.gov/cw_html/cw_granule_selector.html?sensor=OLCI

EUMETSAT

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

Limitations of Remote Sensing Observations for HAB Monitoring

- For accurate and quantitative HAB monitoring analysis of spatially and temporally co-located, *in situ* measurements and satellite observations is required
- Difficult to separate ocean color changes from sediments, dissolved matter, and Chl-a when all are present
- It is not possible to characterize algal types or toxins only from remote sensing observations
- Feasibility of HAB monitoring in coastal and inland water bodies depends on spatial, temporal, and spectral resolutions of 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



Overview of Satellite-Based Ocean Color Data Access Tools

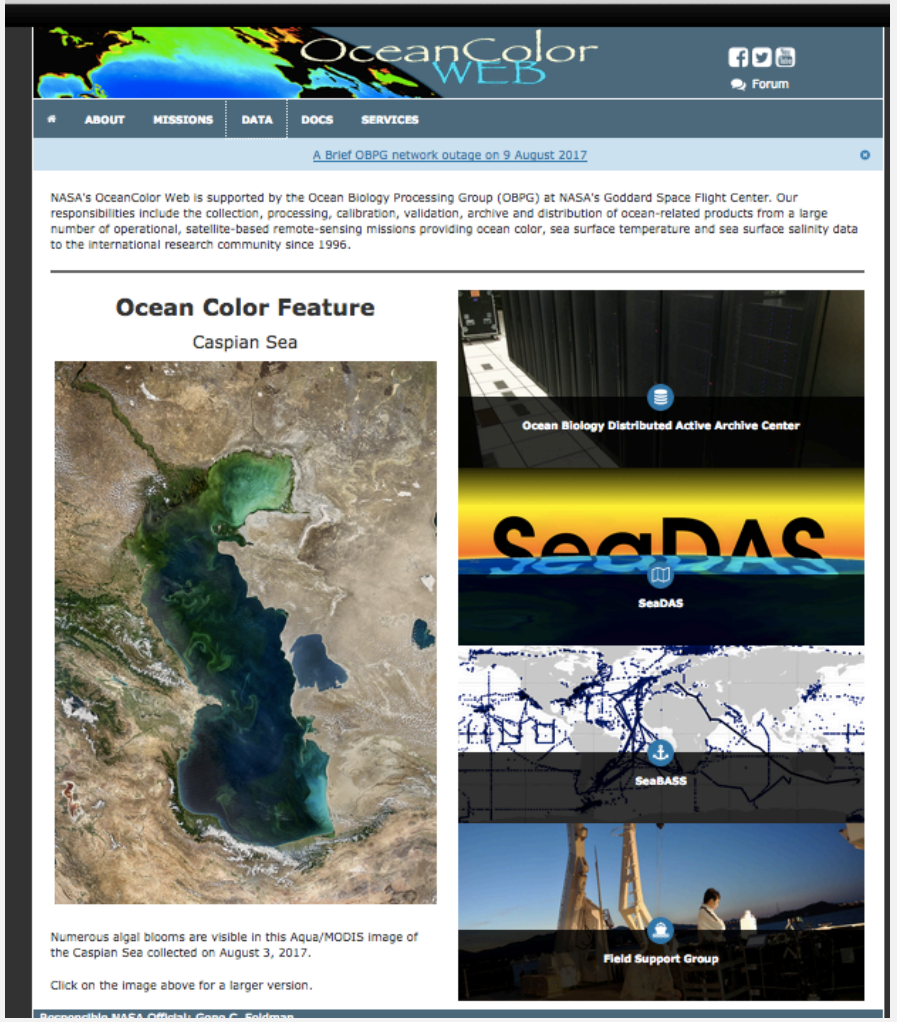
Chl-a and SST Data Access for HAB Monitoring

- 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/

OceanColor Web

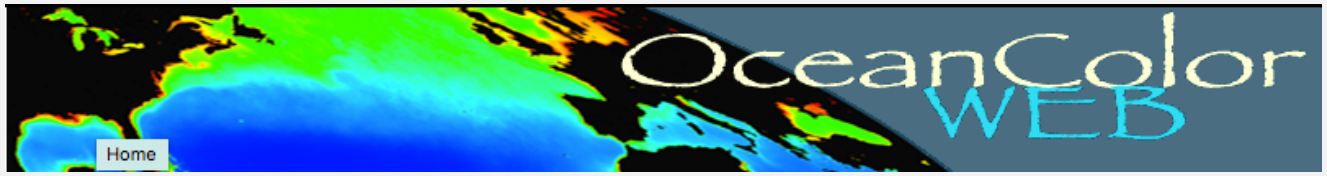
https://oceancolor.gsfc.nasa.gov/

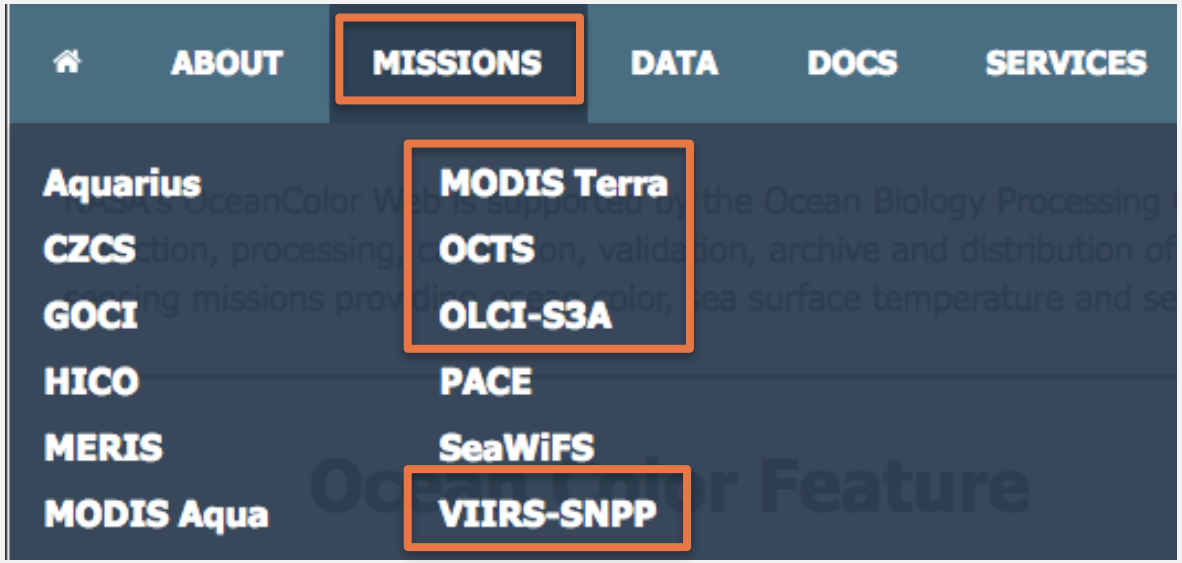
- Developed for collection, processing, validation, and distribution of ocean related products from remote sensing and in situ observations
- Useful for monitoring costal and inland water bodies and estuaries
- Provides visual data browsing capability for L1, L2, and L3 data (Chlorophyll Concentration, Sea Surface Temperature) from selected sensors
- Advances the capability of processing remote sensing images by using SeaDAS

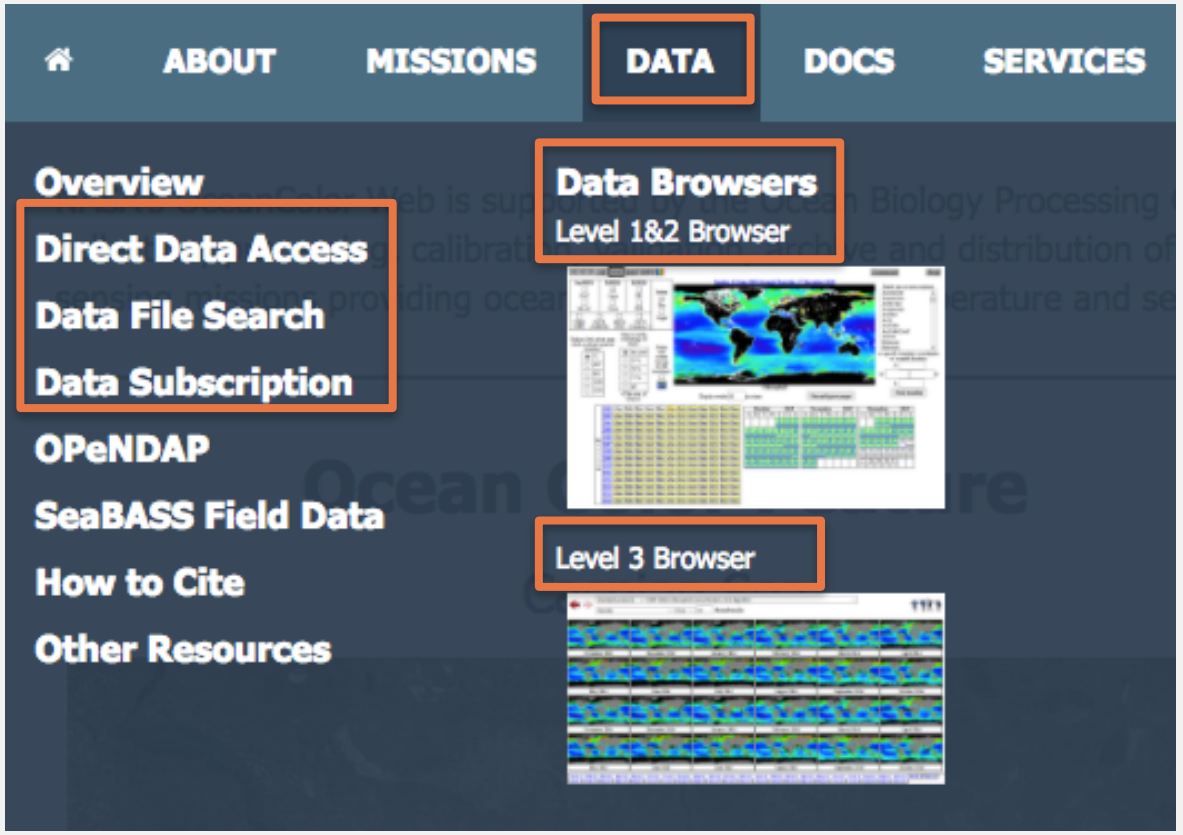


OceanColor Web: Data Search and Access

https://oceancolor.gsfc.nasa.gov/

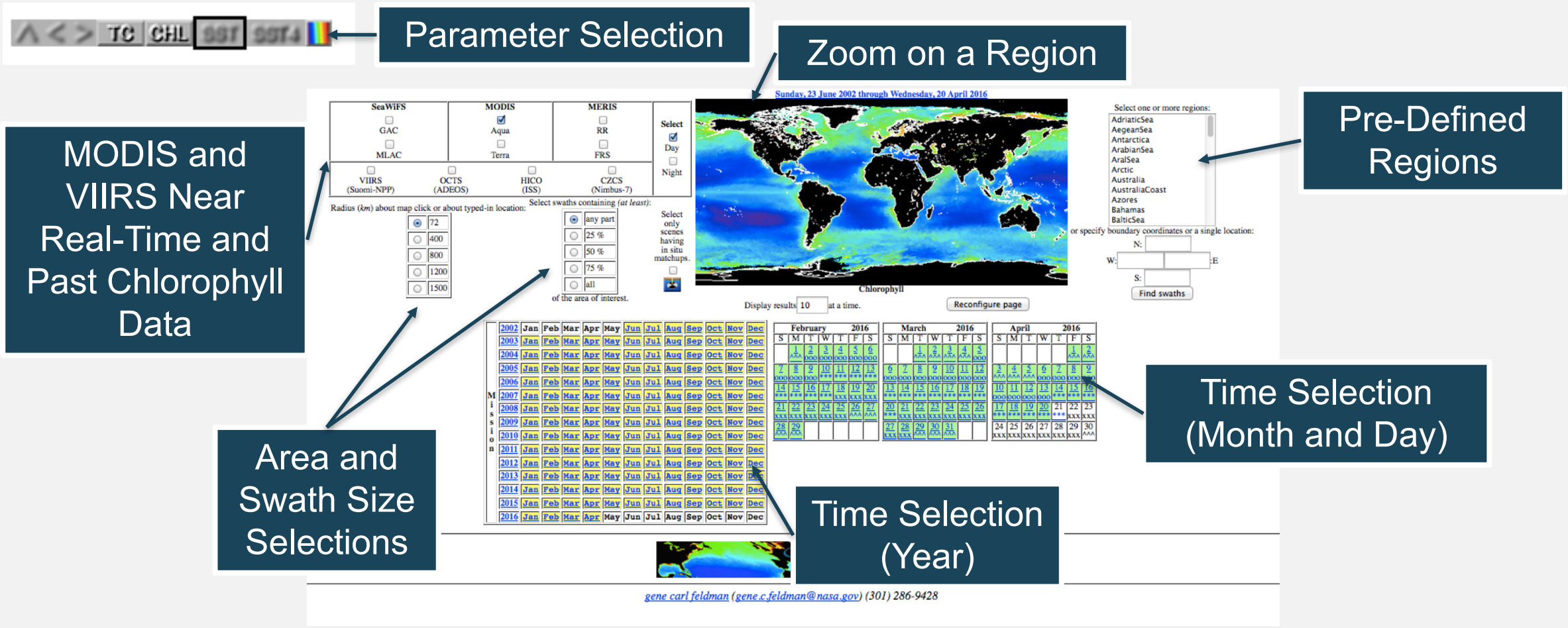






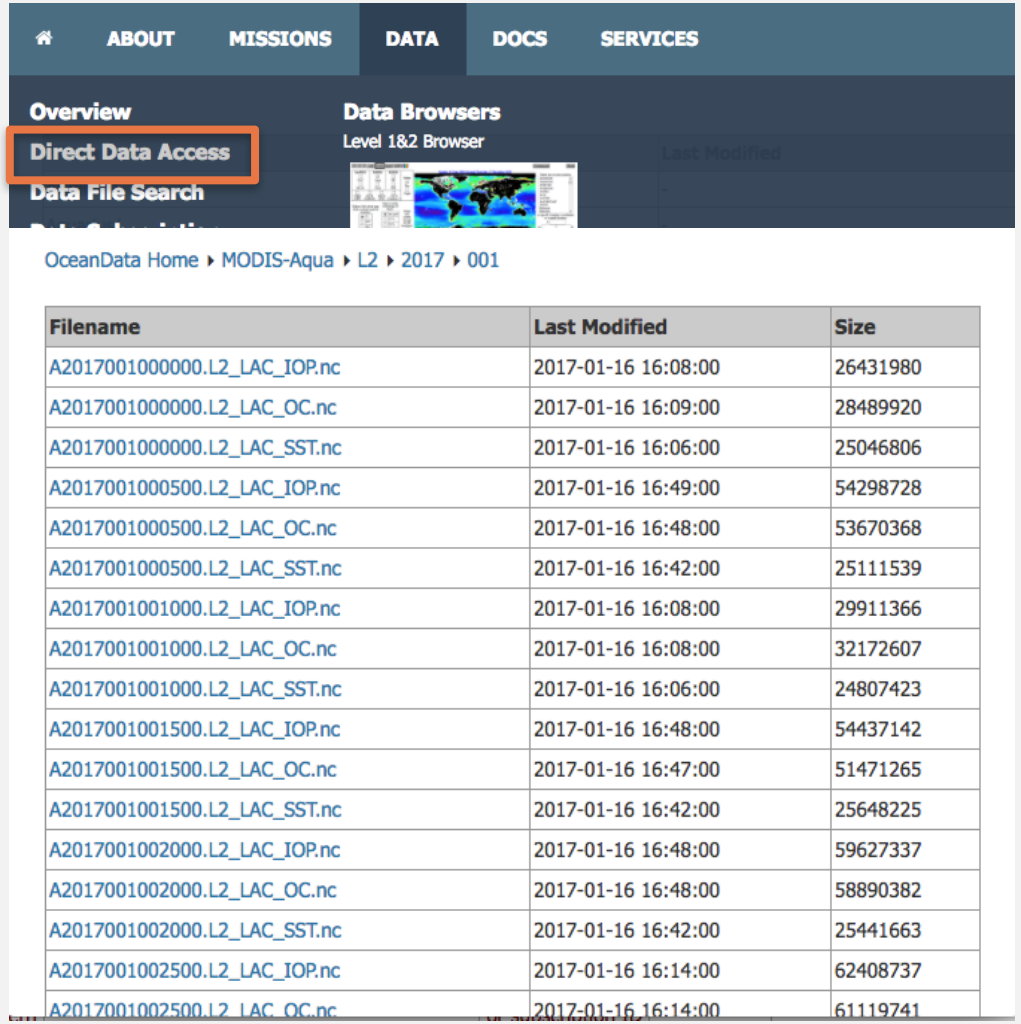
OceanColor Web: L1 Images and L2 Data Visualization

https://oceancolor.gsfc.nasa.gov/



OceanColor Web: L1 Images and L2 Data Download

https://oceancolor.gsfc.nasa.gov/



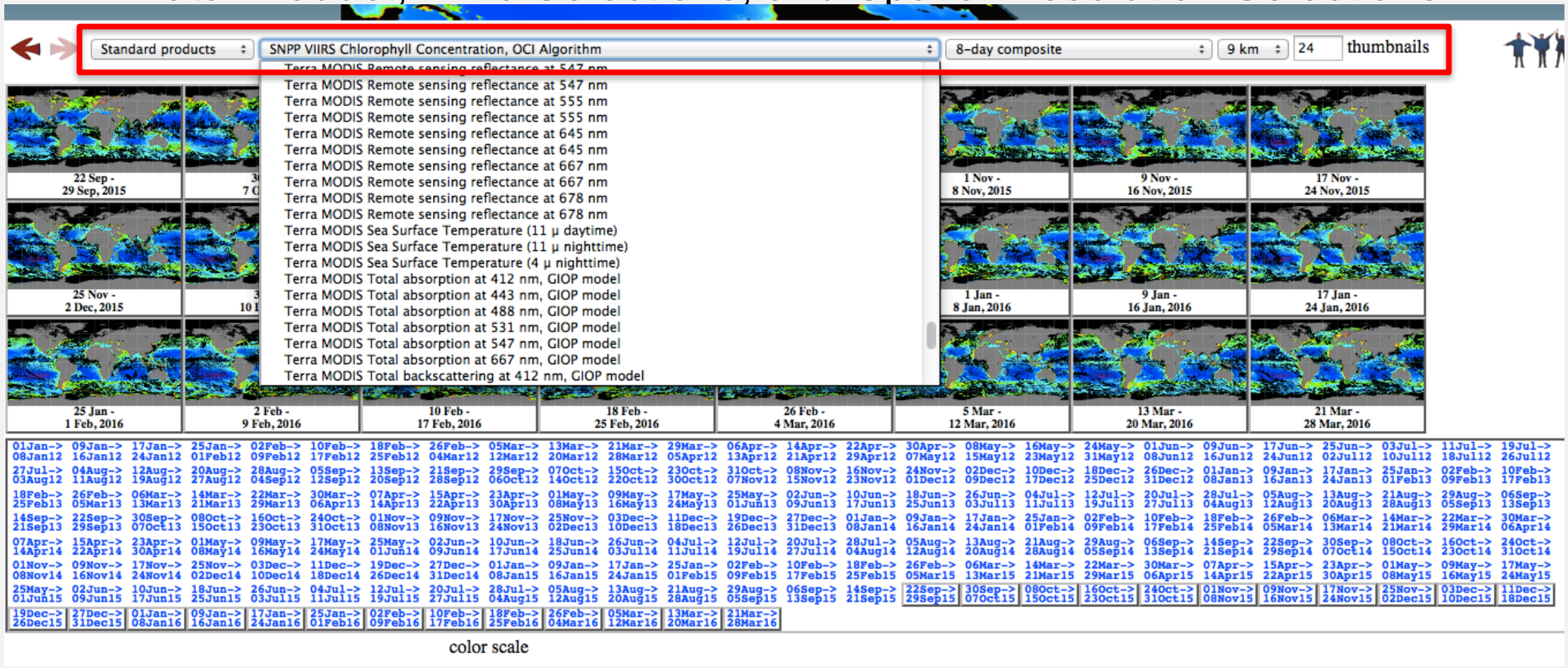
Filename	Last Modified	Size
A2017001000000.L2_LAC_IOP.nc	2017-01-16 16:08:00	26431980
A2017001000000.L2_LAC_OC.nc	2017-01-16 16:09:00	28489920
A2017001000000.L2_LAC_SST.nc	2017-01-16 16:06:00	25046806
A2017001000500.L2_LAC_IOP.nc	2017-01-16 16:49:00	54298728
A2017001000500.L2_LAC_OC.nc	2017-01-16 16:48:00	53670368
A2017001000500.L2_LAC_SST.nc	2017-01-16 16:42:00	25111539
A2017001001000.L2_LAC_IOP.nc	2017-01-16 16:08:00	29911366
A2017001001000.L2_LAC_OC.nc	2017-01-16 16:08:00	32172607
A2017001001000.L2_LAC_SST.nc	2017-01-16 16:06:00	24807423
A2017001001500.L2_LAC_IOP.nc	2017-01-16 16:48:00	54437142
A2017001001500.L2_LAC_OC.nc	2017-01-16 16:47:00	51471265
A2017001001500.L2_LAC_SST.nc	2017-01-16 16:42:00	25648225
A2017001002000.L2_LAC_IOP.nc	2017-01-16 16:48:00	59627337
A2017001002000.L2_LAC_OC.nc	2017-01-16 16:48:00	58890382
A2017001002000.L2_LAC_SST.nc	2017-01-16 16:42:00	25441663
A2017001002500.L2_LAC_IOP.nc	2017-01-16 16:14:00	62408737
A2017001002500.L2_LAC_OC.nc	2017-01-16 16:14:00	61119741

- Data Available
  - Chl-a
  - SST
  - Inherent Optical Properties

OceanColor Web: L3 Data Visualization

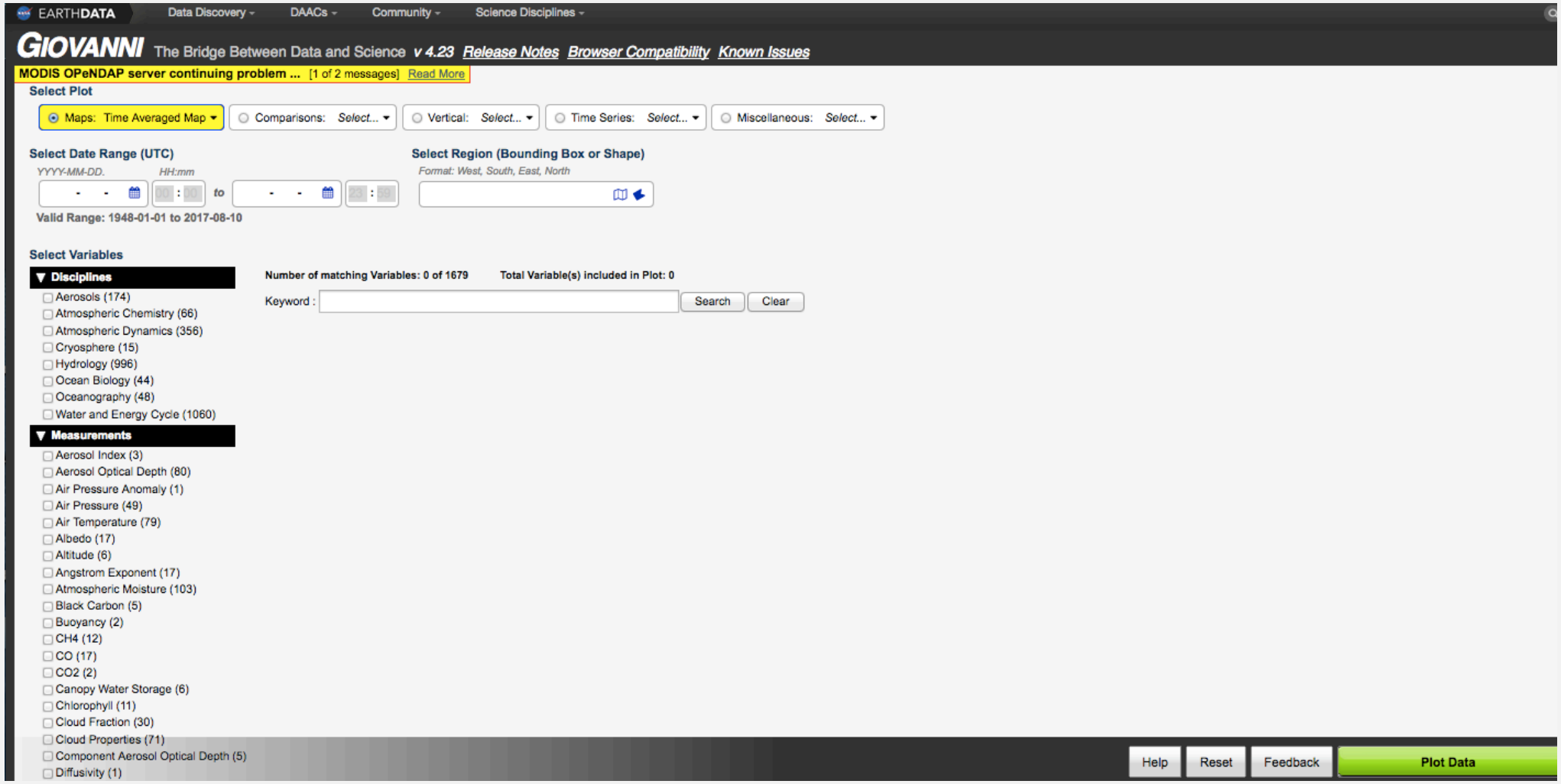
http://oceancolor.gsfc.nasa.gov/

Data Product, Time Selections, and Spatial Resolution Selections



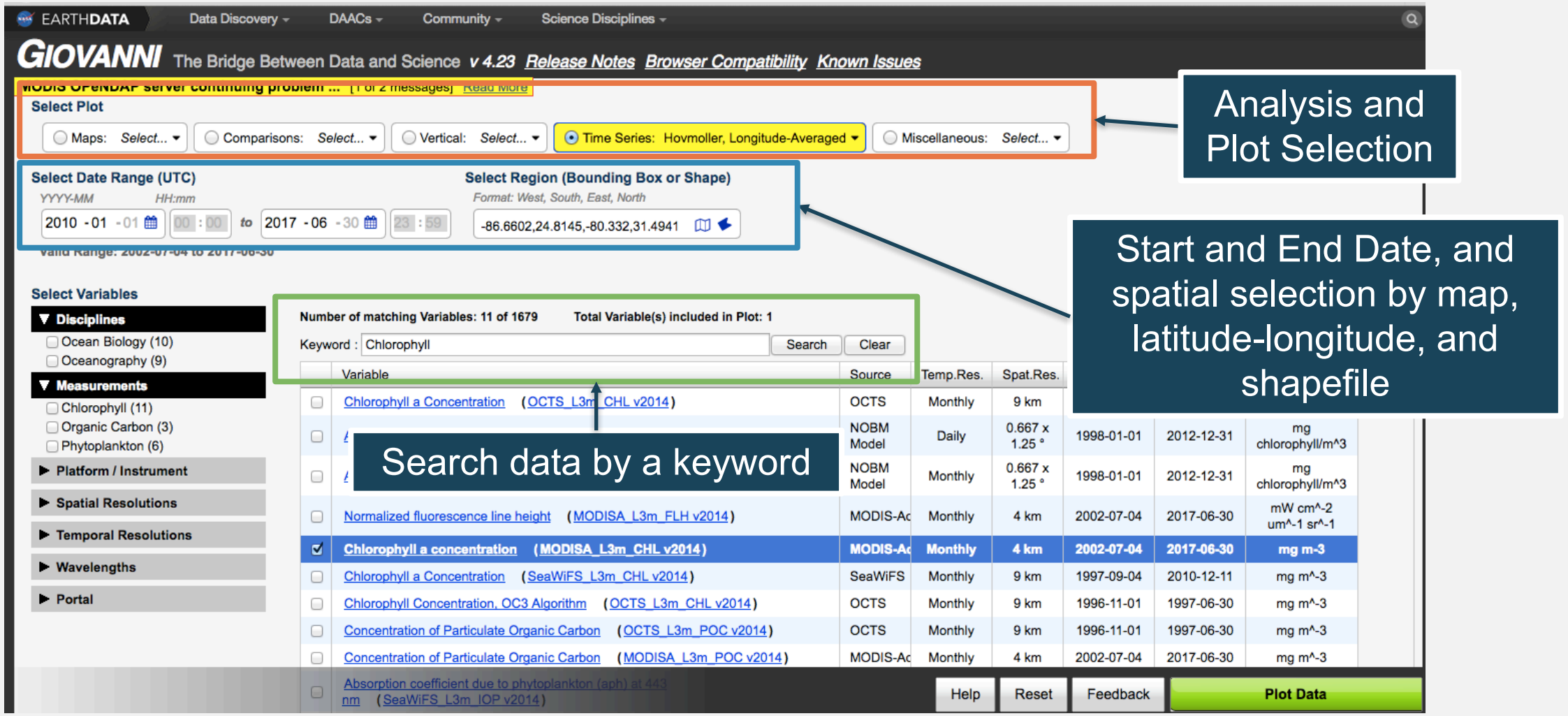
Giovanni: **G**eospatial **I**nteractive **O**nline **V**isualization **AN**d a**N**alysis **I**nfrastructure

http://giovanni.gsfc.nasa.gov/giovanni/



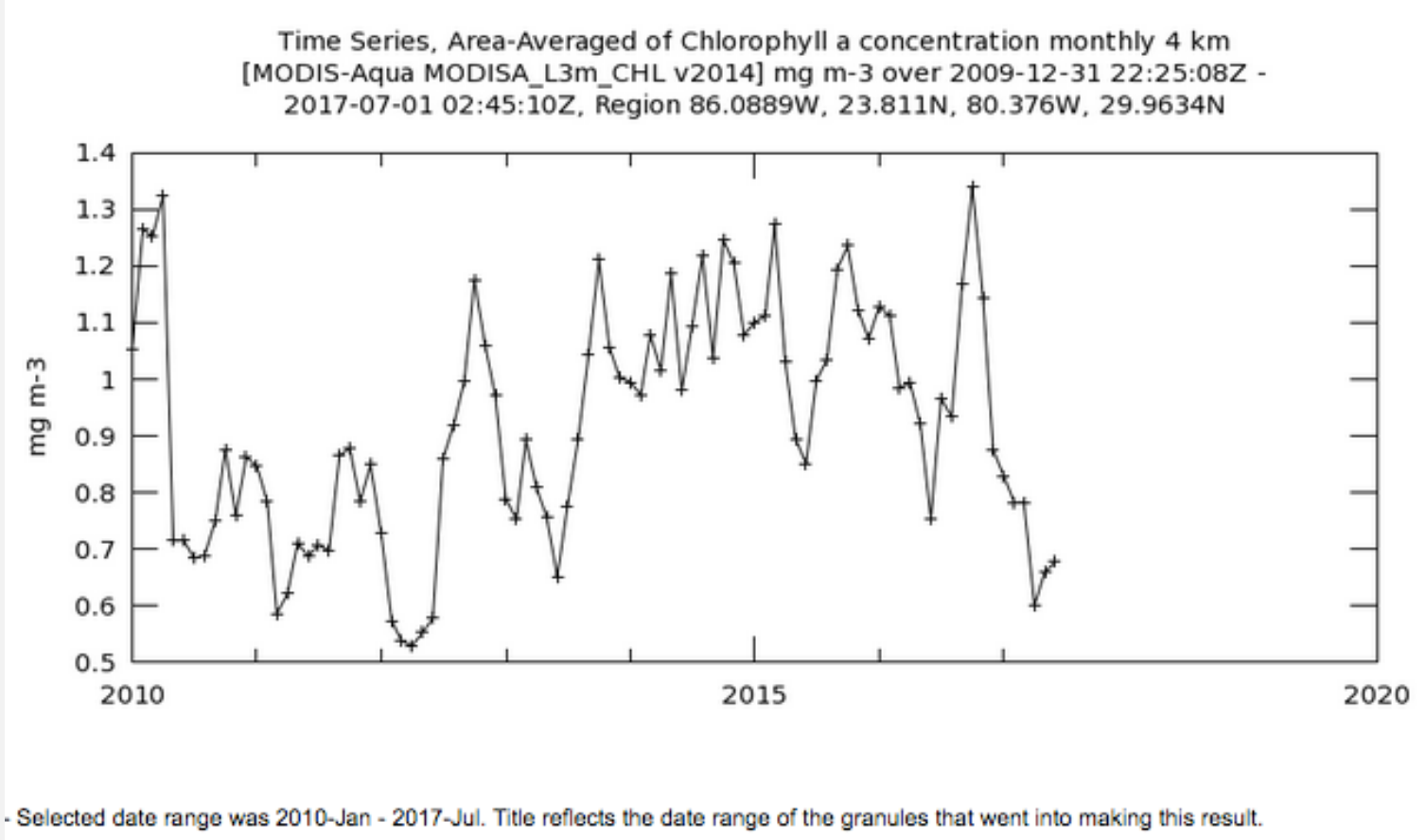
Giovanni: **G**eospatial **I**nteractive **O**nline **V**isualization **AN**d a**N**alysis **I**nfrastructure

http://giovanni.gsfc.nasa.gov/giovanni/

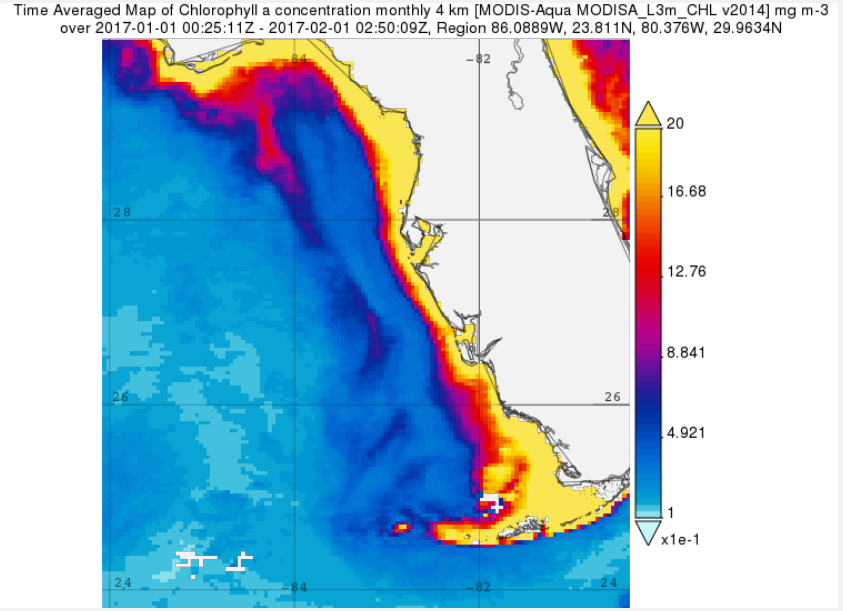


Giovanni: Chlorophyll Concentration in the Gulf of Mexico

http://giovanni.gsfc.nasa.gov/giovanni/

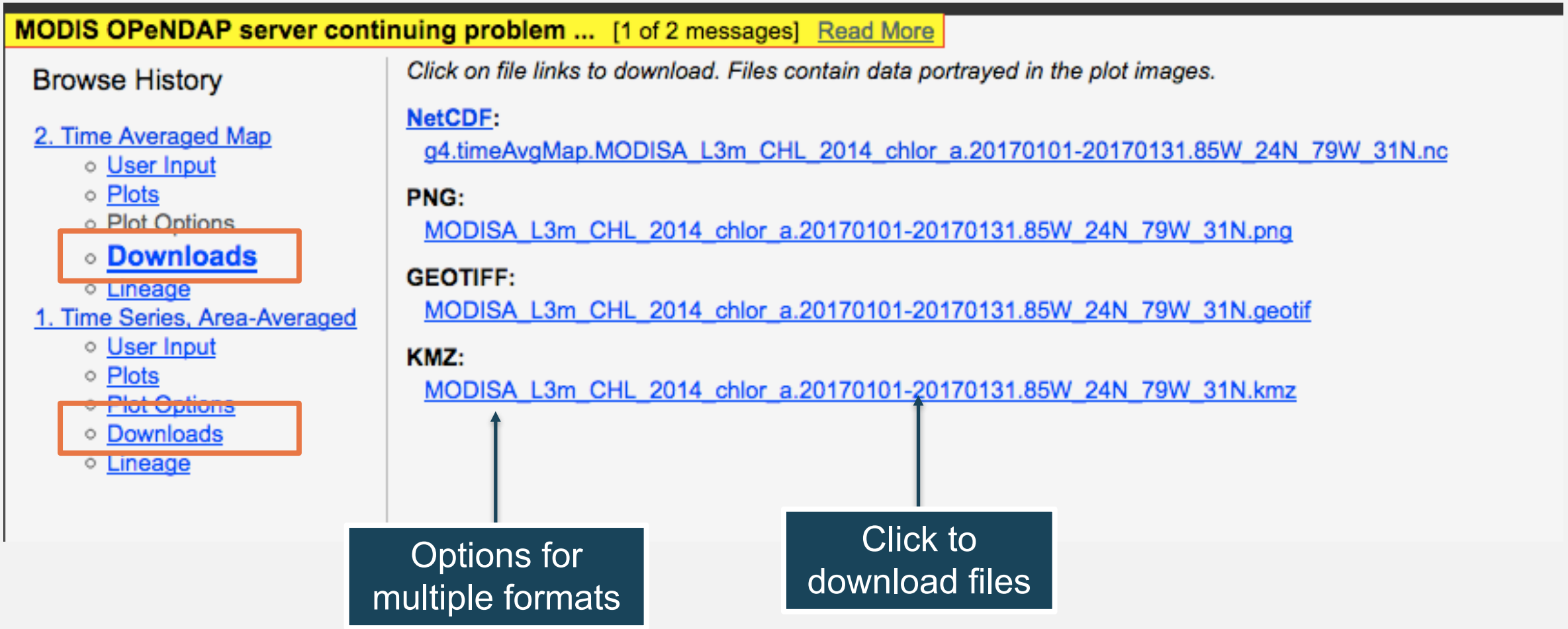


January 2017



Giovanni: Data Download

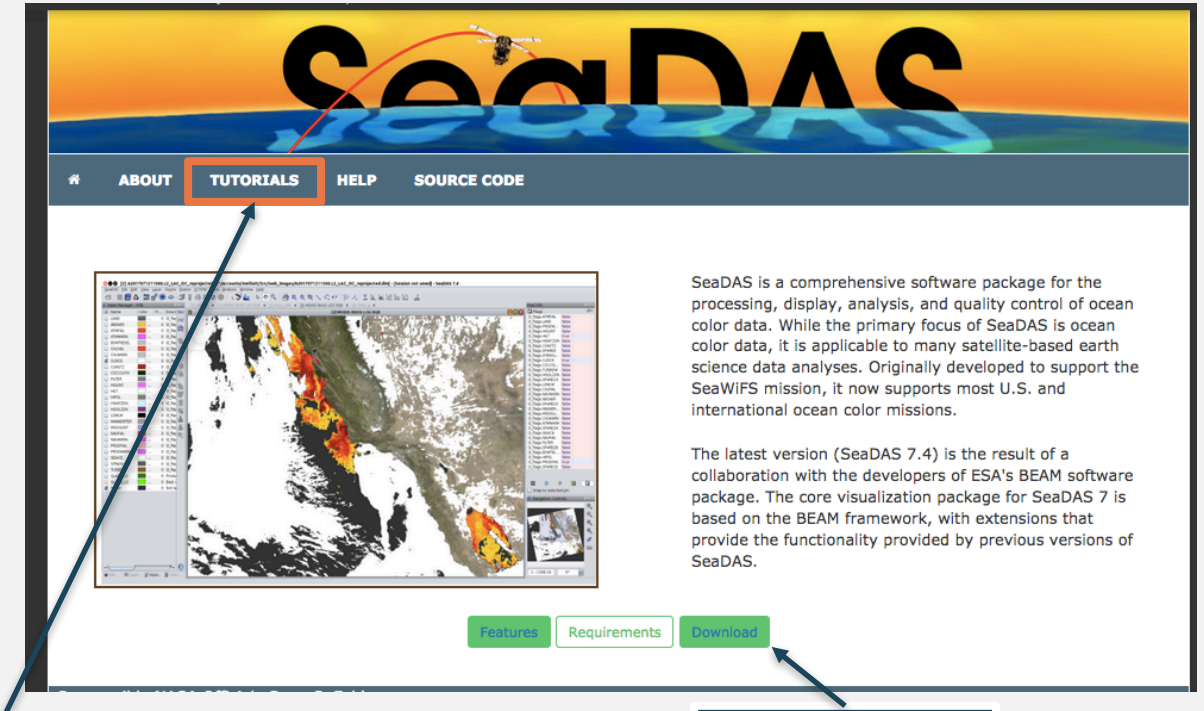
http://giovanni.gsfc.nasa.gov/giovanni/



SeaDAS: Data Analysis Package

http://seadas.gsfc.nasa.gov/

- SeaDAS is a comprehensive image analysis package developed for the processing, display, analysis, and quality control of ocean color data
- The latest version (SeaDAS 7.4) is developed in a collaboration with the developers of ESA's BEAM software package



Video tutorial and presentations about SDAS

Software download

SeaDAS: Features

http://seadas.gsfc.nasa.gov/

Visualization

- Very fast image display and navigation even of giga-pixel images
- Advanced layer management allows adding and manipulation of new overlays such as images of other bands, images from WMS servers or ESRI shapefiles
- Rich region-of-interest definitions for statistics and various plotting funtions
- Easy bitmask definition and overlay
- Flexible band arithmetic using arbitrary mathematical expressions
- Accurate reprojection and ortho-rectification to common map projections
- Geo-coding and rectification using ground control points
- Coastline, land/water masking for navigated data
- Store and restore the current session including all opened files, views and layers

Data Processing

SeaDAS offers the ability for users to process satellite data from a number of ocean color missions (both U.S. and International) through the various processing levels:

- Level 0 to Level 1 processing is offered for the MODIS sensors onboard the Terra and Aqua spacecraft
- Level 1 to Level 2 (l2gen)
- Level 2 to Level 3 binned (l2bin)
- Temporal binning of Level 3 (l3bin)
- Mapping of Level 1 data (l1mapgen)
- Mapping of Level 2 data (l2mapgen)
- Mapping of Level 3 binned data (smigen)
- Browse file creation (l1brsgen,l2brsgen)

SeaDAS: System Requirement

http://seadas.gsfc.nasa.gov/

- Visualization-only version
- Visualization and data processing version
- Multiple mission data can be analyzed
- SeaDAS download, installation, and usage require advance training

SeaDAS Configuration and Requirements

SeaDAS is currently available for Linux, Mac OS X, and Windows. The Windows version currently does not support the science data processing code. The SeaDAS source code is publicly available.

Suggested Hardware Requirements:

Platforms:	Linux Intel Mac OS X
Memory:	256MB minimum, 1GB+ suggested
Disk:	SeaDAS software package (display only version): ~200MB SeaDAS software package (with processing capabilities for all sensors): ~5GB 10GB of free space is also suggested for rudimentary data processing and storage.
Display:	15" Console or X-terminal with 20MB memory 1280x1024 resolution 24-bit X display plane depth 256 colors display minimum

Requirements:

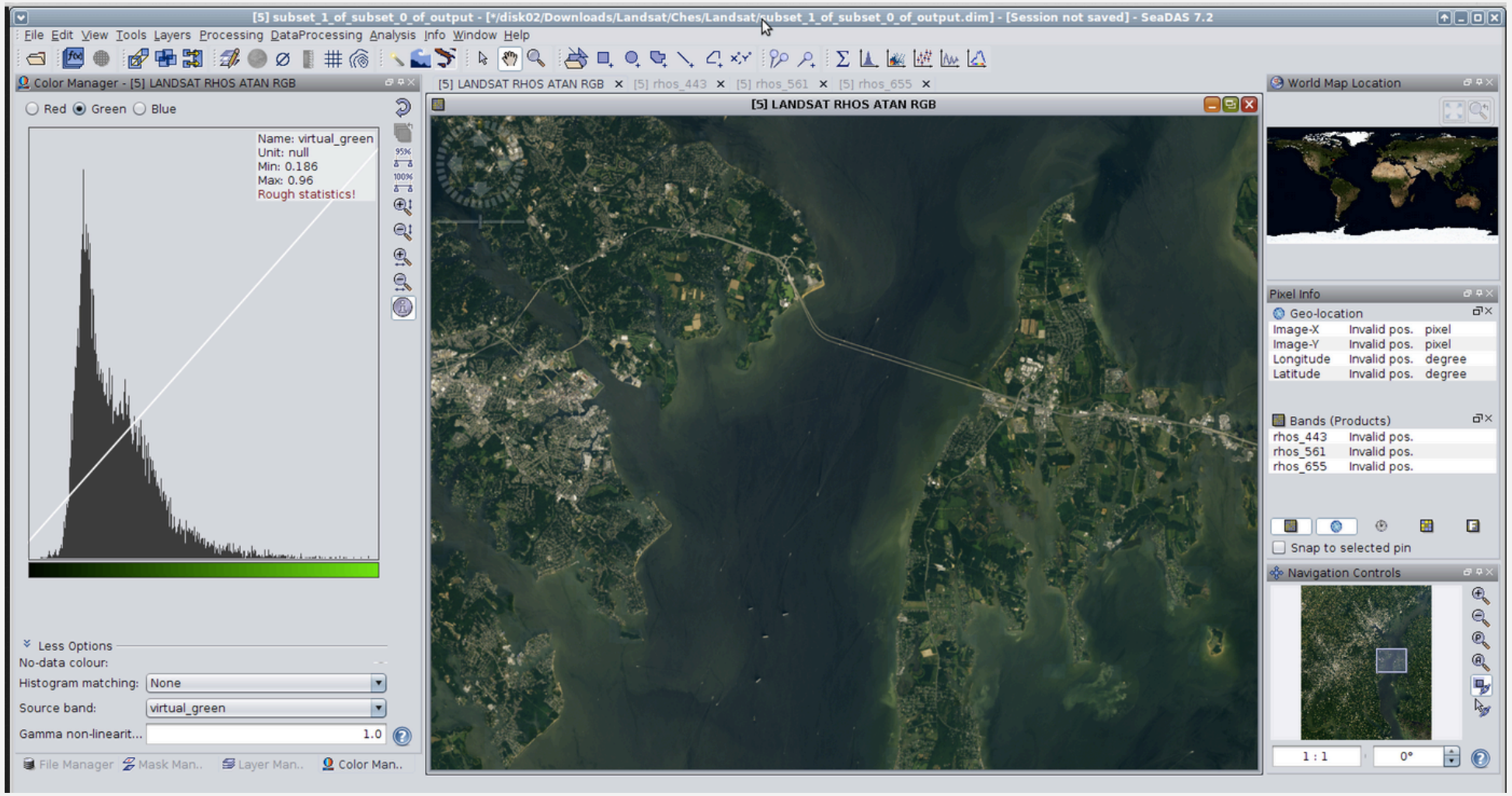
The core visualization package of SeaDAS is written in Java. A minimum Java JRE of version 1.7 is required. A suitable JRE is packaged with the Windows and MacOSX distributions. Linux users will need to separately install a suitable JRE.

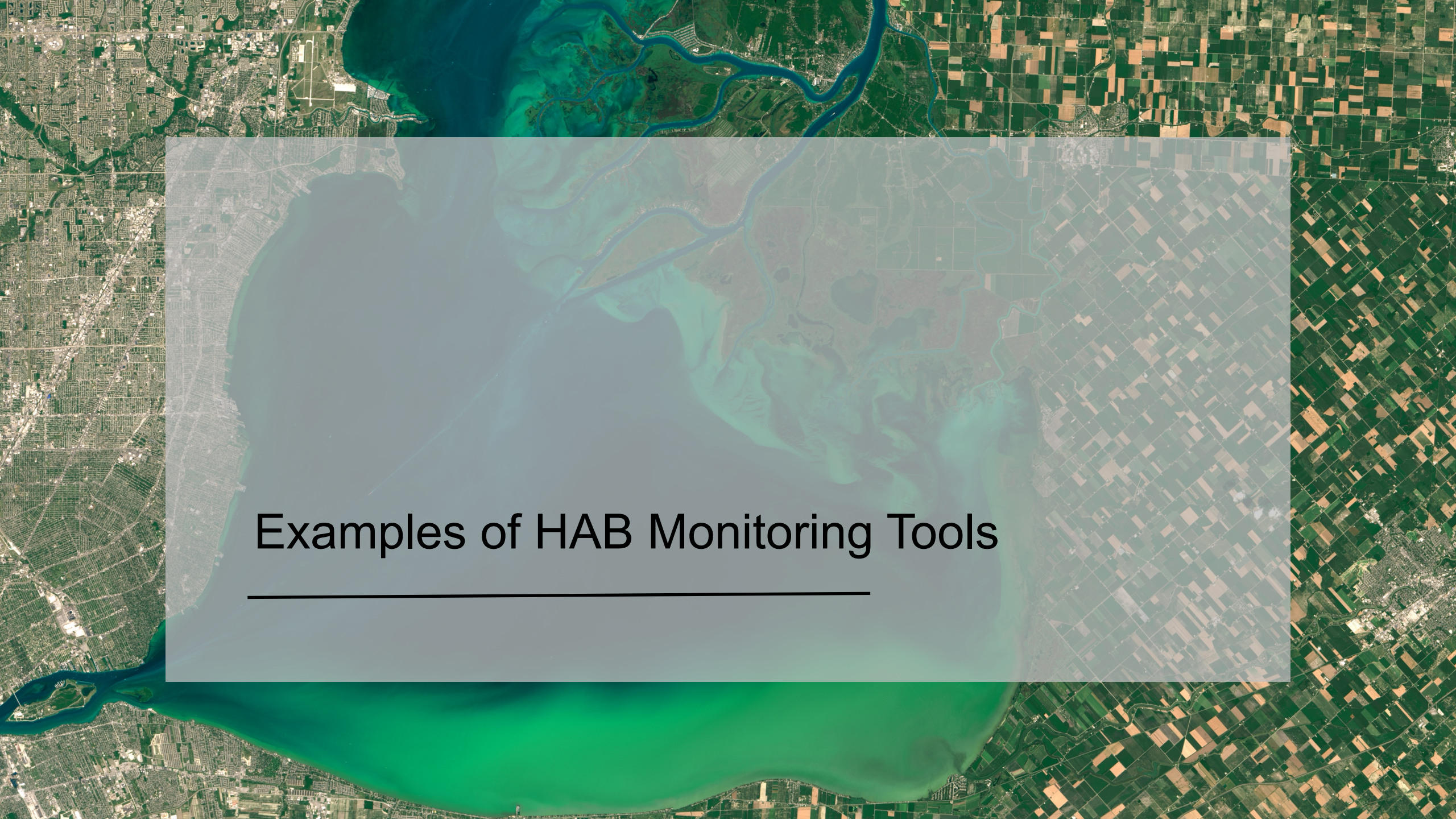
Operating Systems:	**Linux:** tested on various versions of CentOS, Fedora, and Ubuntu **Intel Mac:** OS X 10.10
Optional Compilers:	gcc/g++/gfortran (version 4.5 or higher) or Intel Compilers

Program	*Version*	*Notes*
Java	JRE 1.7 or above	Windows and MacOSX distributions come with a suitable JRE Linux users will need to separately install a suitable JRE
Bash	4.x	version 3.x should work, but not tested necessary only for science code, thus not required for Windows distributions
Python	2.6.5 or above	necessary only for science code, thus not required for Windows distributions; not (yet) compatible with version 3 and above
Git	1.7.9 or above	necessary only for science code install/update option, thus not required for Windows distributions
cURL	7.x or above	necessary only for science code install/update option, thus not required for Windows distributions

SeaDAS: Example

http://seadas.gsfc.nasa.gov/

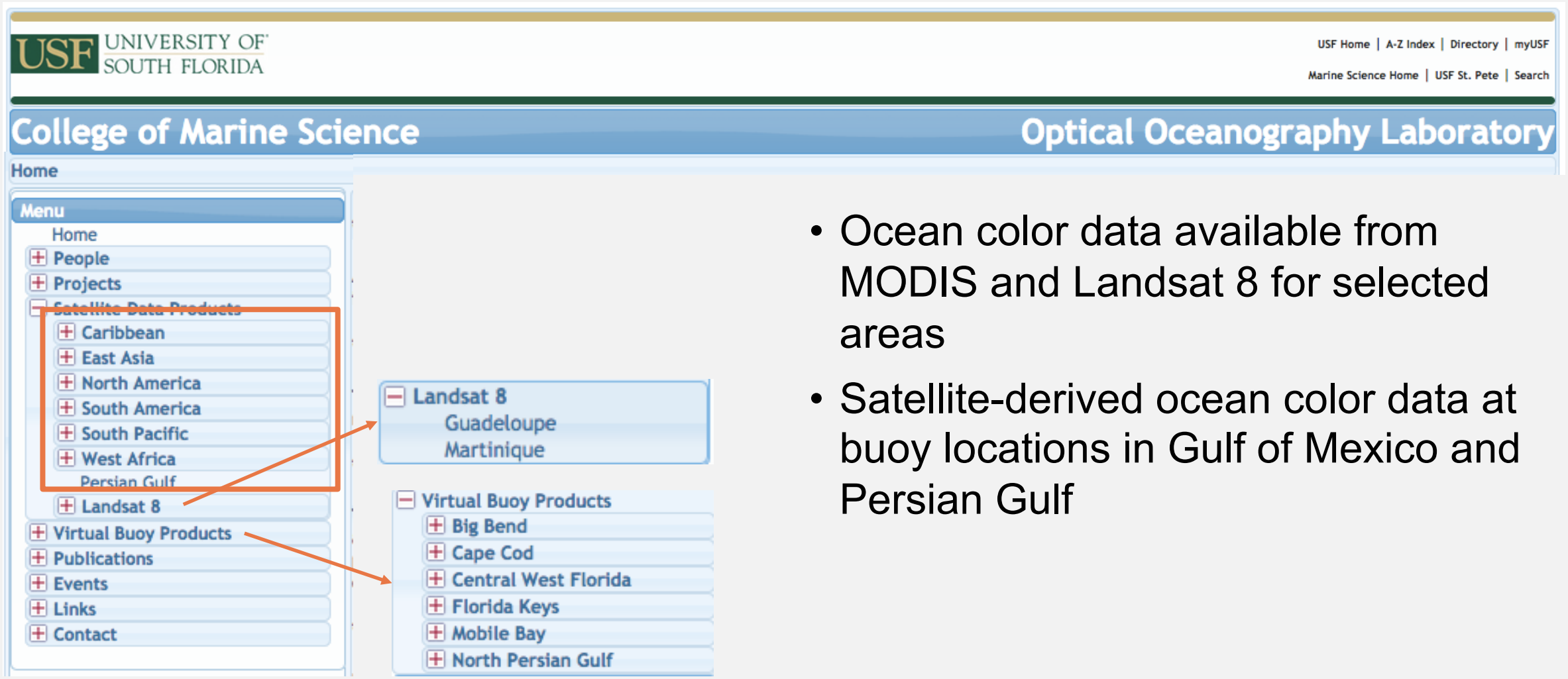




Examples of HAB Monitoring Tools

Chl-a and SST Monitoring Using MODIS and Landsat 8

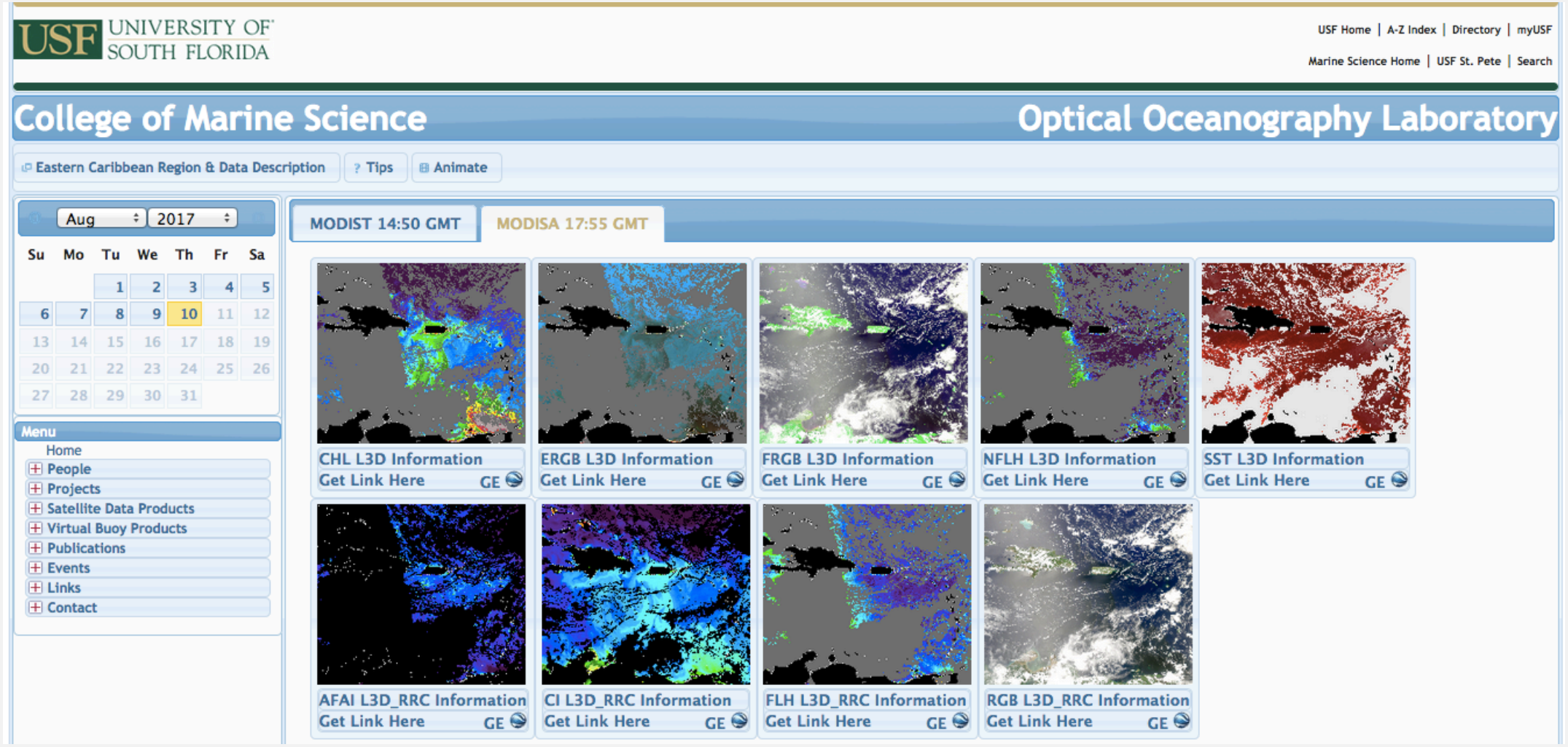
http://optics.marine.usf.edu/



- Ocean color data available from MODIS and Landsat 8 for selected areas
- Satellite-derived ocean color data at buoy locations in Gulf of Mexico and Persian Gulf

Ocean Color Data from Aqua and Terra MODIS

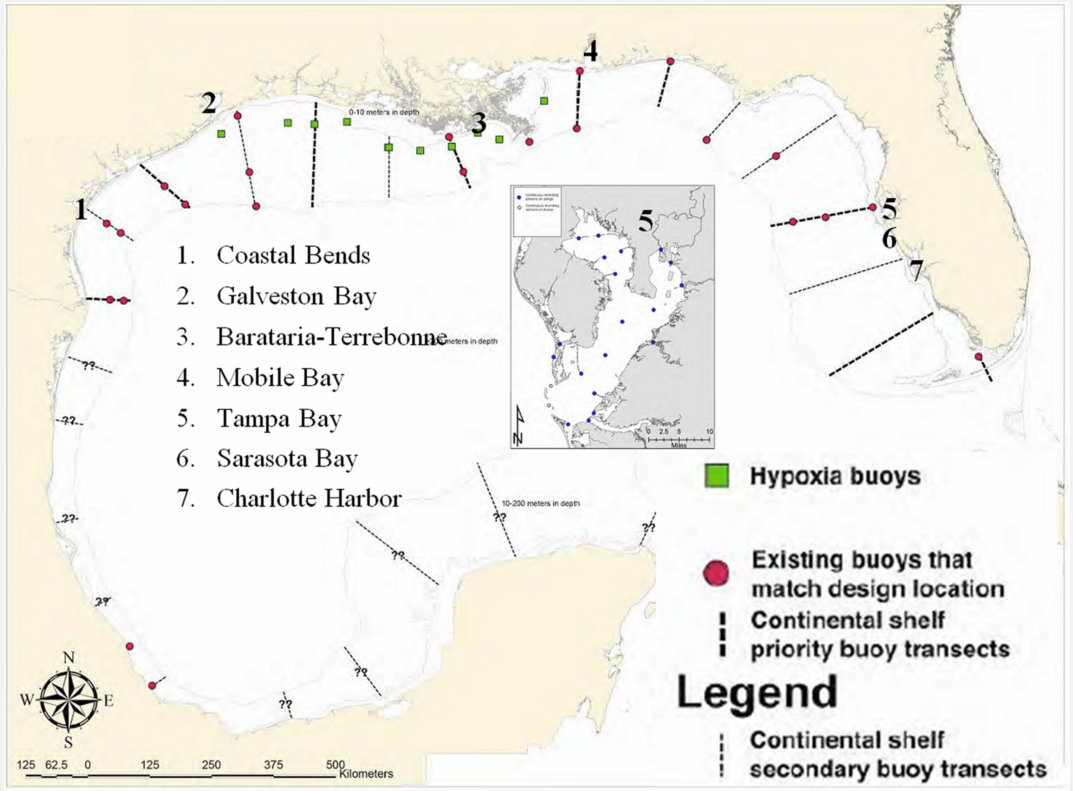
http://optics.marine.usf.edu/cgi-bin/optics_data?roi=ECARIB&current=1/

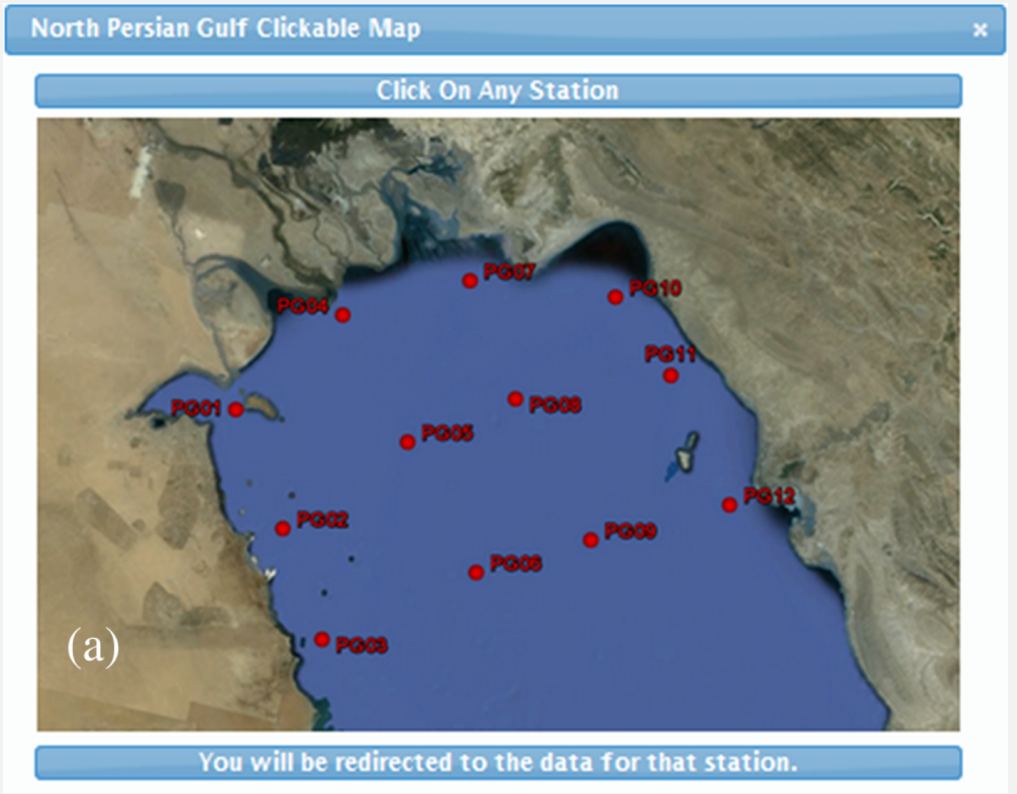


Chl-a and SST Monitoring Using MODIS and Landsat 8

http://optics.marine.usf.edu/

Buoy Locations in the Gulf of Mexico and Persian Gulf from Hu et al. (2014)





Reference: Hu ei al. 2014, Satellite-based virtual buoy system to monitor coastal water quality, Opt. Eng. 2013;53(5):051402. doi:10.1117/1.OE.53.5.051402.

Ocean Color Data from MODIS

http://optics.marine.usf.edu/

At a Buoy Location in Tampa Bay

Station Name: TB 01 Tampa Bay Clickable Map

Latitude: 27.9002

Longitude: -82.5920

Depth in Meters: 2.5

Current Imagery: /cgi-bin/optics_data?roi=CWFL&current=1

The table below shows the current conditions (most recent weekly and monthly means) at station TB 01, derived from MODIS data. Also included are conditions for the current week and month from last year, as well as the long term means (climatologies).

Current conditions which exceed one standard deviation from the climatological mean are considered "anomalies" and are color coded. Positive chlorophyll anomalies, for example, may indicate phytoplankton bloom conditions at the station. Negative SST anomalies in winter might adversely affect several marine organisms (e.g., manatees, fish, corals, and sea turtles).

Summary Table Guide

Severe Positive Anomaly	Current data ≥ 2 st. dev. above climatology
Moderate Positive Anomaly	Current data ≥ 1 st. dev. above climatology
No Anomaly	Current data within 1 st. dev. of climatology
Moderate Negative Anomaly	Current data ≤ 1 st. dev. below climatology
Severe Negative Anomaly	Current data ≤ 2 st. dev. below climatology

This table is intended to provide a visual guide to current and developing conditions at this station. However, caution must be used in interpreting anomaly data. Due to limitations of MODIS measurements, the normal climatological conditions for certain stations or time spans may not be fully characterized. As such, truly anomalous conditions may not be identified. Alternatively, detected anomalies may actually be within the climatological norm.

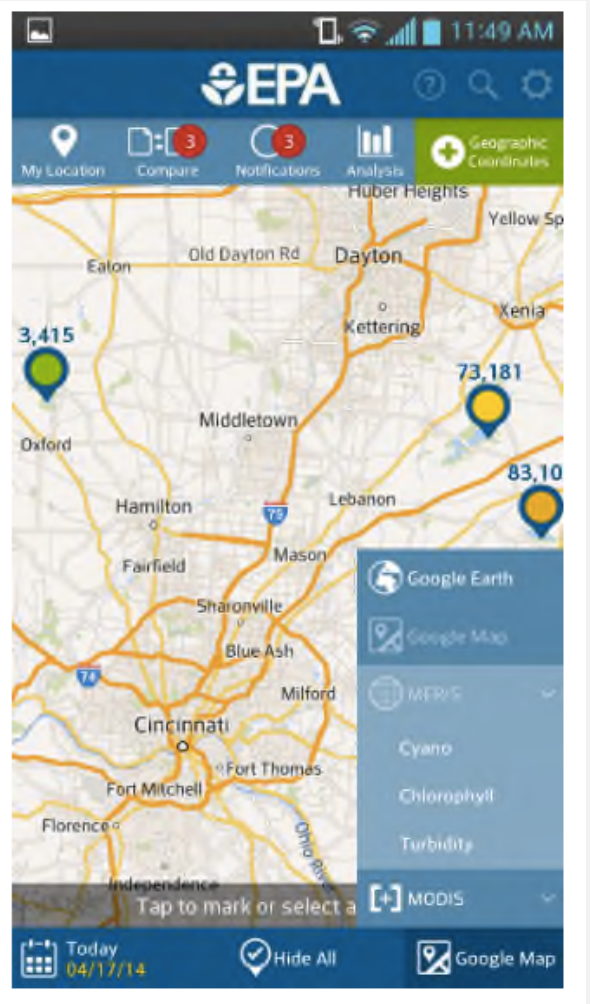
Current week number 31 in the table below is 7/30/2017 through 8/5/2017, current month is July of 2017.

Product	Weekly Mean	Monthly Mean	Weekly Last Year	Monthly Last Year	Weekly Climatology	Monthly Climatology
SST (C°)	27.56	29.94	29.80	30.11	30.41	29.85
Chlorophyll-a (mg m^{-3})	No Data	3.72	No Data	6.67	7.31	5.43
Turbidity (NTU)	No Data	1.47	No Data	3.18	2.58	2.60
Secchi Disk Depth (m)	No Data	1.91	No Data	1.51	1.12	1.44
$K_d(488)$ (m^{-1})	No Data	0.50	No Data	0.65	1.13	0.73
Light Penetration (%)	No Data	28.32	No Data	19.17	5.62	15.43

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

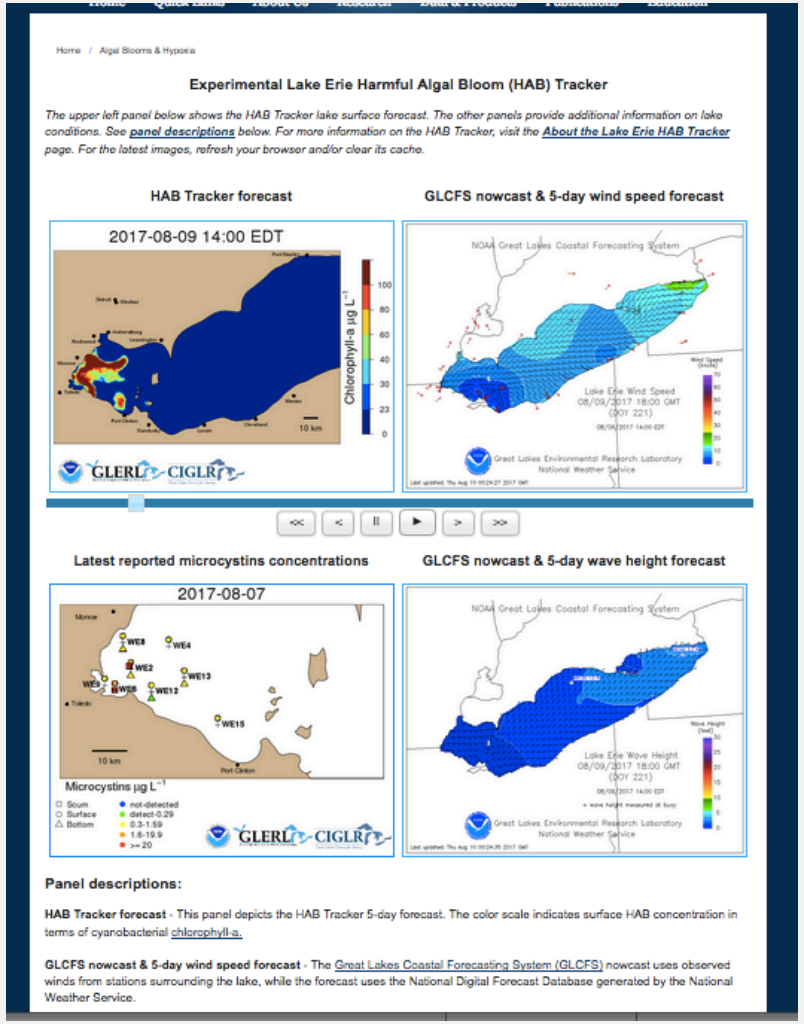


More information about CyAN will be presented in week 4

Lake Erie HAB Tracker

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

MODIS-Derived Cyanobacterial Density

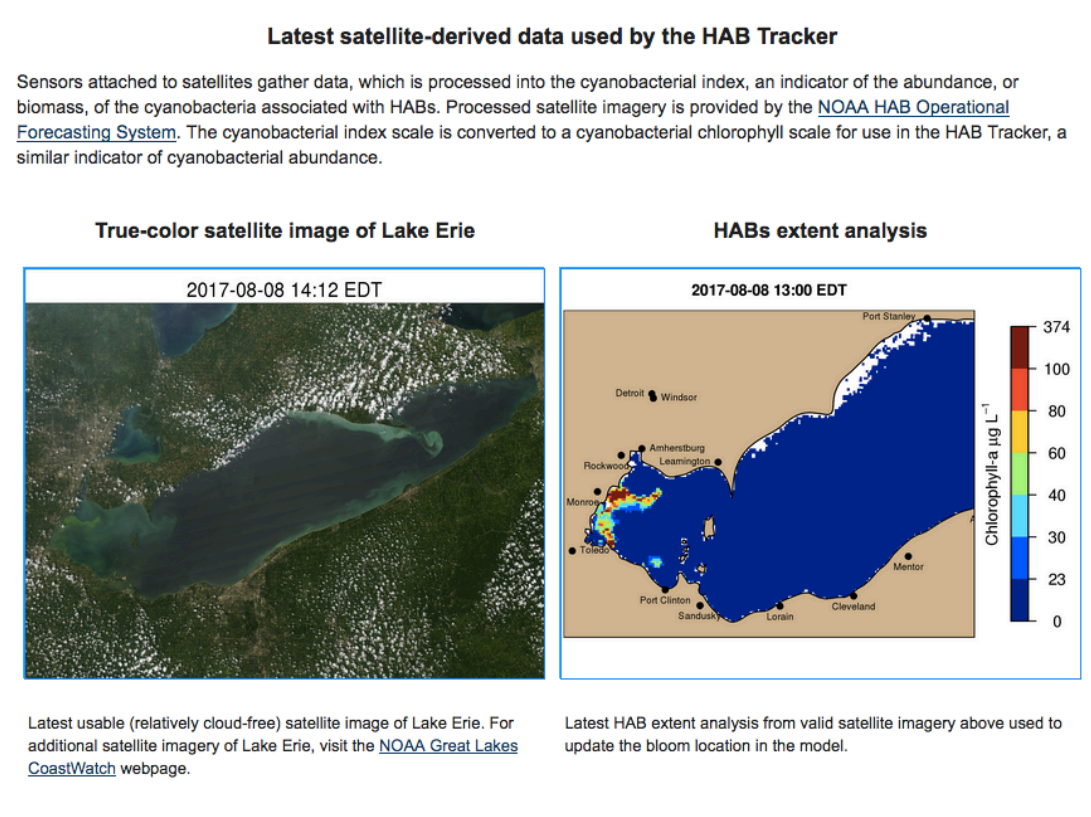
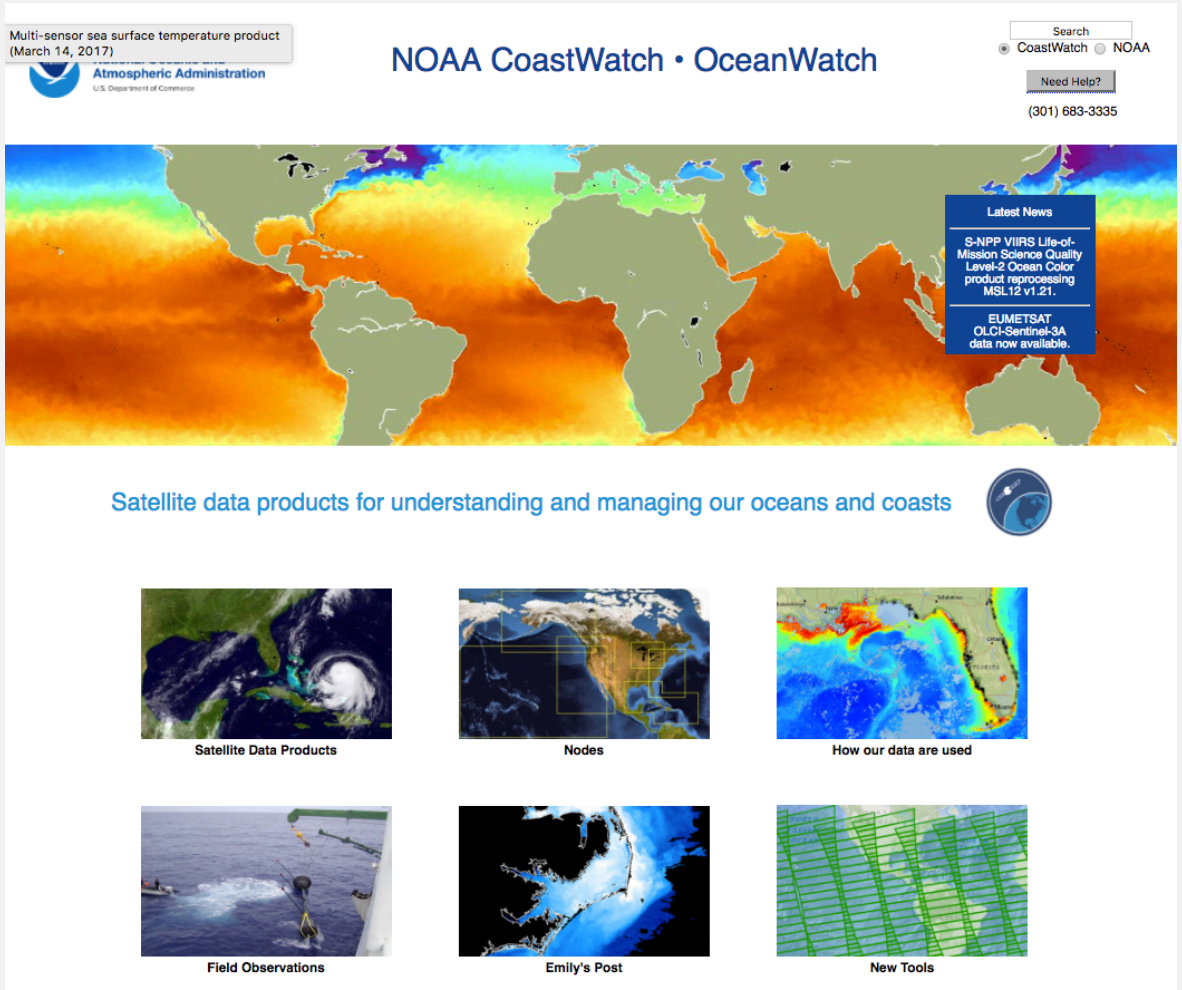


Photo Credit: NOAA GLERL

NOAA Coast Watch

https://coastwatch.noaa.gov/cw_html/index.html

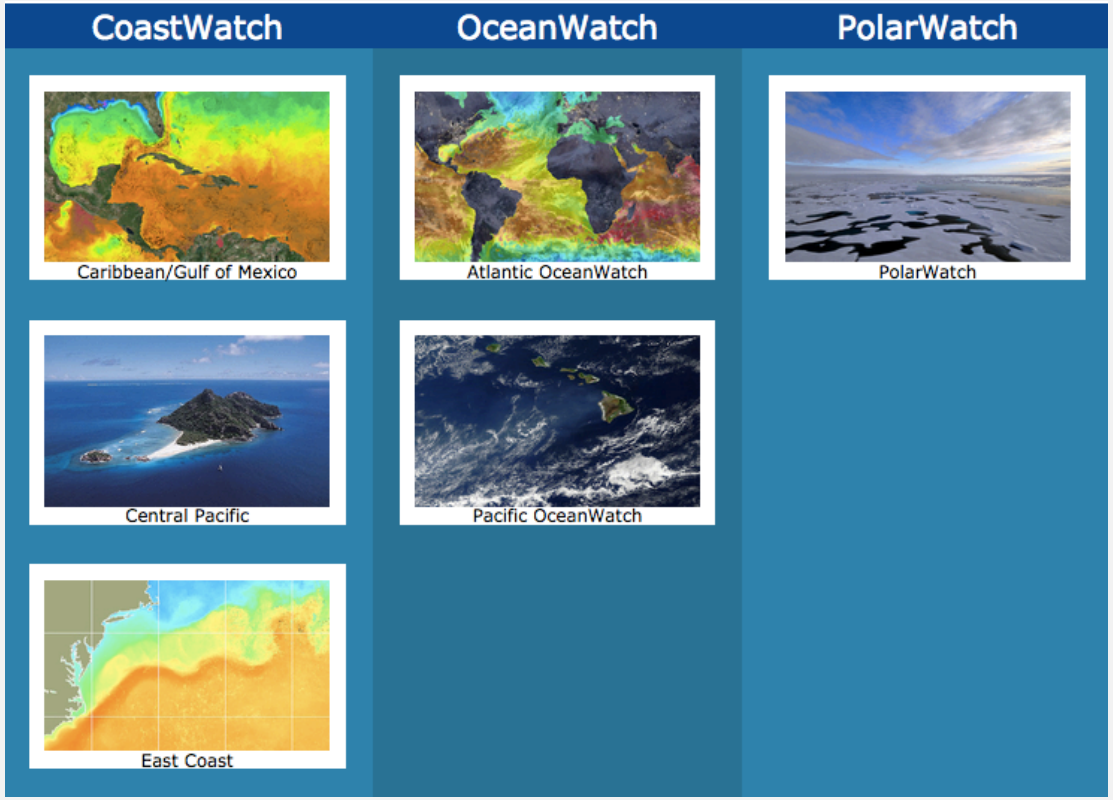


- Using remote sensing for understanding and managing oceans
- Provides HAB monitoring over coastal oceans

NOAA Coast Watch

https://coastwatch.noaa.gov/cw_html/index.html

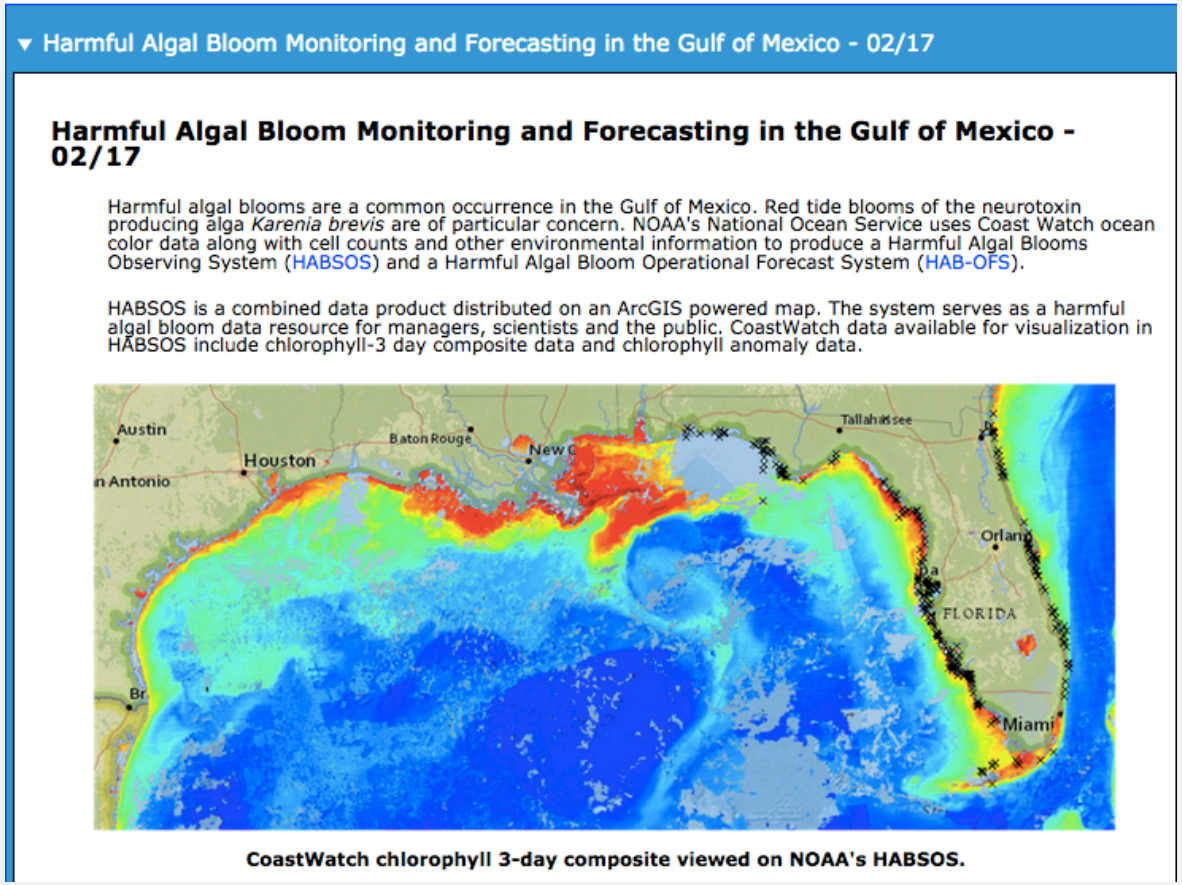
- Information provided for multiple coastal areas



- 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

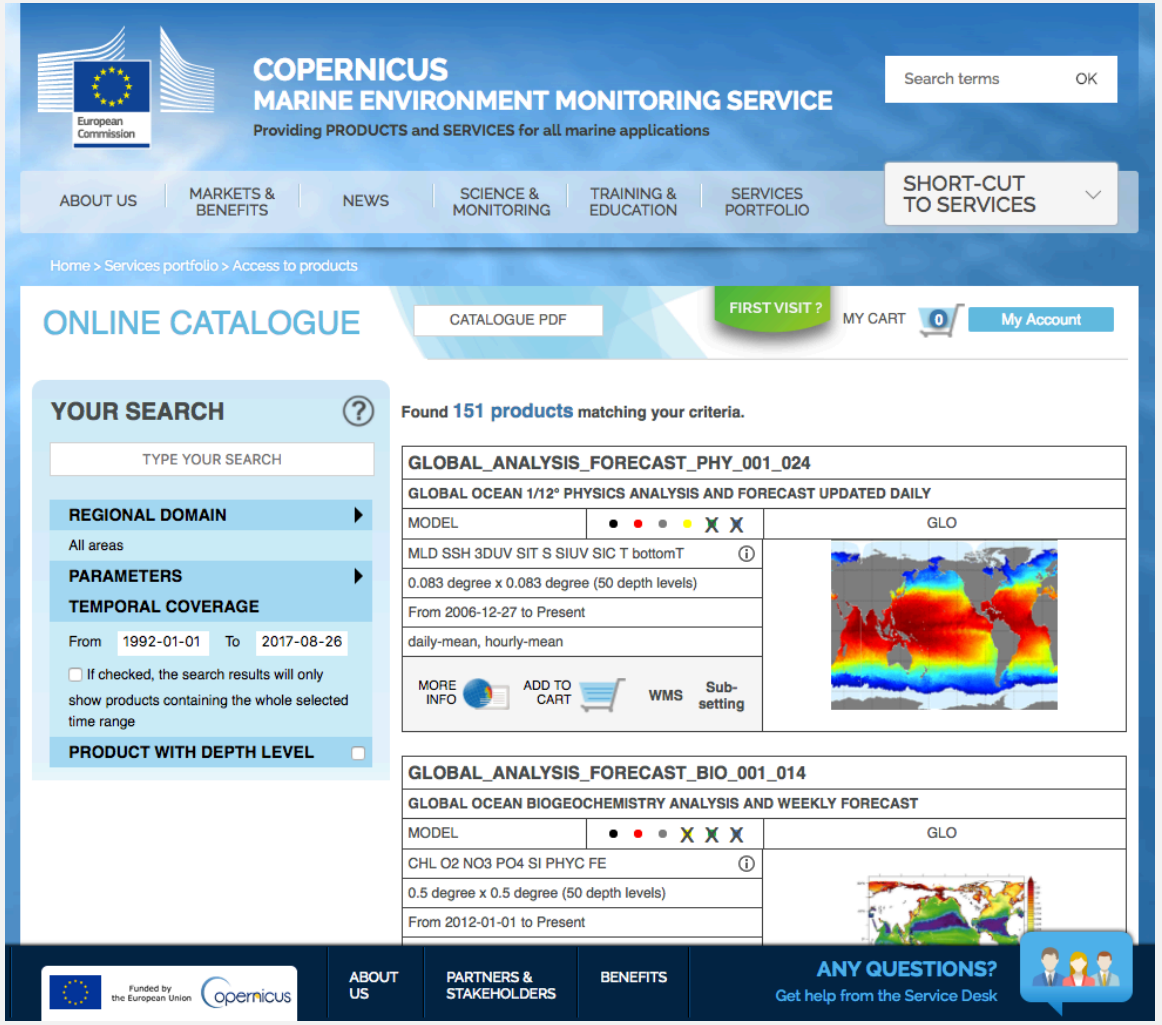


- Satellite-based HAB monitoring
- Near real-time remote sensing data used from:
  - MODIS Aqua
  - VIIRS S-NPP
  - OLCI Sentinel-3

Copernicus Marine Environment Monitoring Service

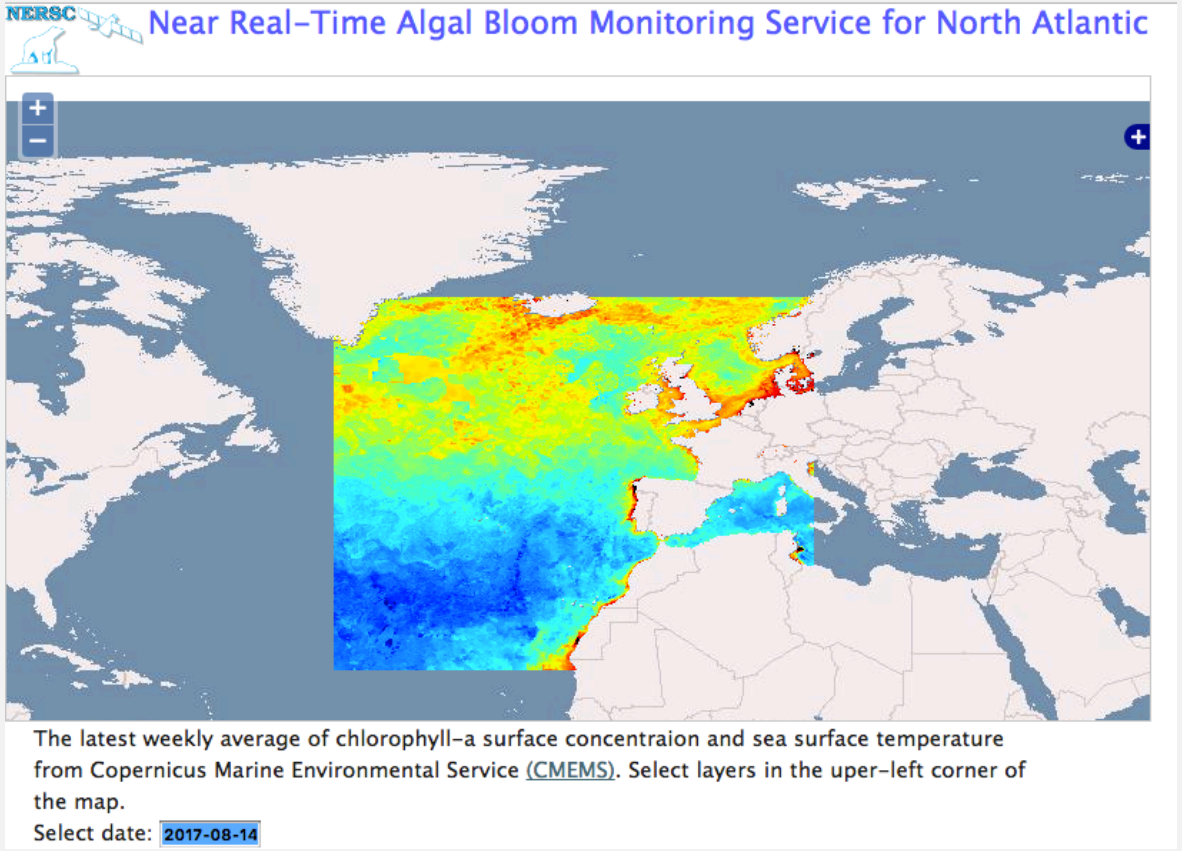
http://marine.copernicus.eu/

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



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

http://hab.nersc.no/



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

Summary

- Remote sensing provides continuous global coverage with consistent observations compared to limited point measurements from surface or ship-based water sampling
- Optical and NIR remote sensing observations from Landsat, Terra/Aqua MODIS, SNPP VIIRS, Sentinel-2 MSI and Sentinel-3 OLCI are used operationally for qualitative and quantitative HAB (Chl, and SST) monitoring

National Aeronautics and
Space Administration

ARSET

Applied Remote Sensing Training

http://arset.gsfc.nasa.gov

@NASAARSET

Thank you!

Next Week:

Understanding HABs in the Coastal Environment