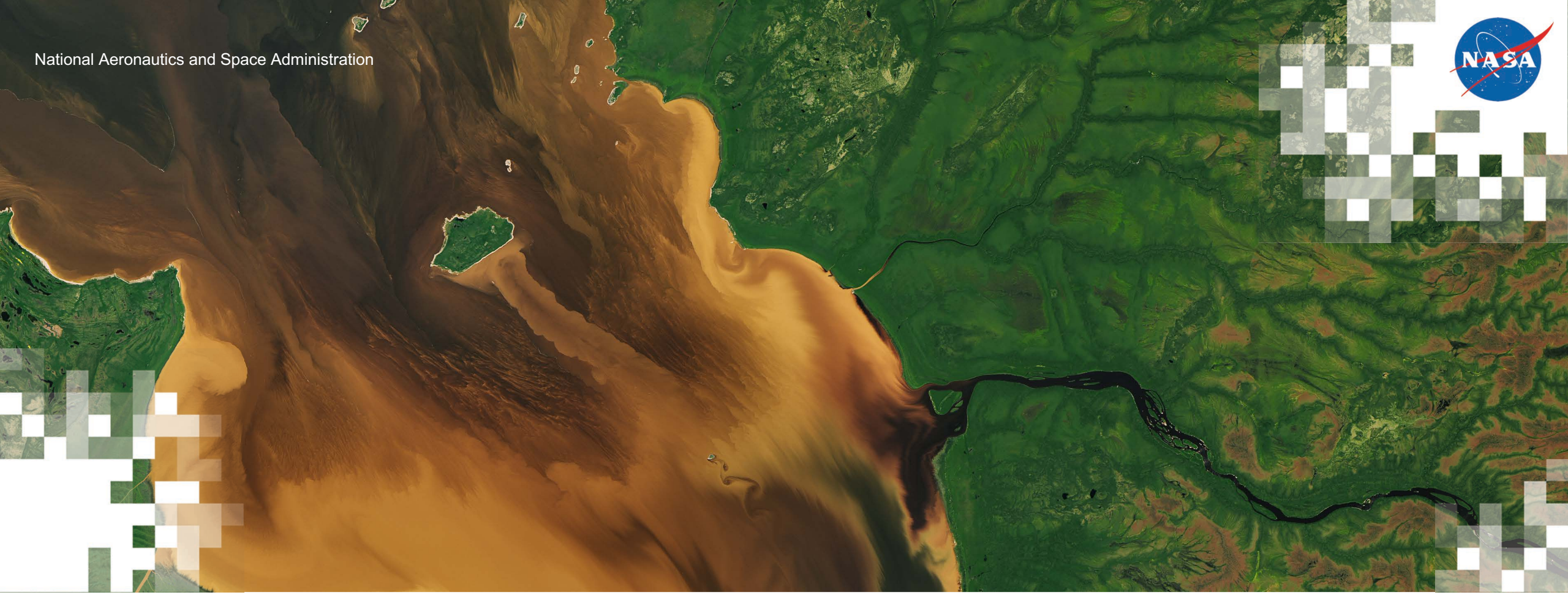
National Aeronautics and Space Administration



Monitoring Coastal and Estuarine Water Quality Using Remote Sensing and In Situ Data

Instructors: Amita Mehta, Sean McCartney, and Juan Torres-Pérez

30 November 2021

Training Objectives

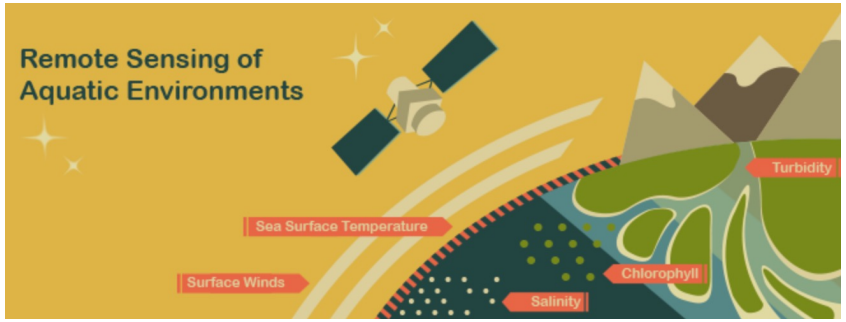
By the end of this training attendees will be able to:

- Select in situ water quality data from [1]SeaBASS
- Validate chlorophyll-a data from [2]MODIS and [3]VIIRS imagery using [4]SeaDAS and in situ measurements
- Prepare your own in situ data to use along with satellite images in SeaDAS for algorithm development
- Validate/derive water quality parameters for a selected coastal/estuarine region

[1]SeaBASS: In situ data from the SeaWiFS* Bio-optical Archive and Storage System
[2]MODIS: Moderate Resolution Imaging Spectroradiometer
[3]VIIRS: Visible Infrared Imaging Radiometer Suite
[4]SeaDAS: SeaWiFS Data Analysis System
*SeaWiFS: Sea-viewing Wide Field-of-view Sensor

Prerequisites

- Fundamentals of Remote Sensing, Session 2C:
  - https://appliedsciences.nasa.gov/join-mission/training/english/arset-fundamentals-remote-sensing



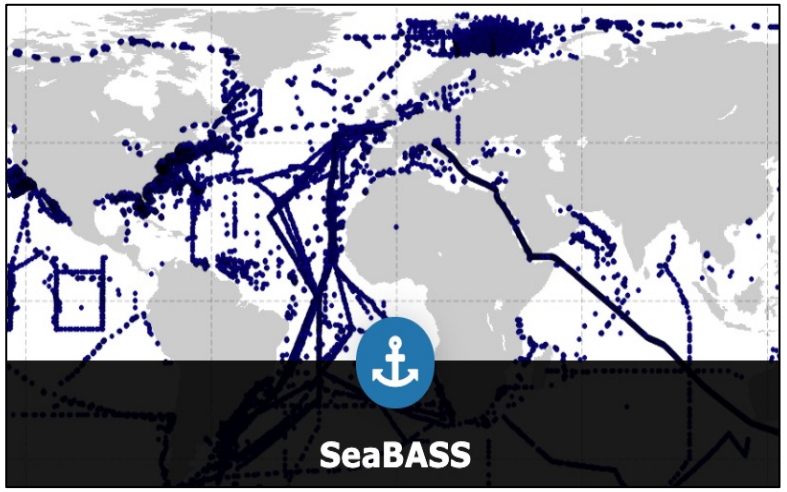
- Monitoring Coastal and Estuarine Water Quality: Transitioning from MODIS to VIIRS:
  - https://appliedsciences.nasa.gov/join-mission/training/english/arset-monitoring-coastal-and-estuarine-water-quality-transitioning

- Install SeaDAS:
  - https://appliedsciences.nasa.gov/sites/default/files/2021-11/Install_SeaDAS_Edited_AM_SC_JO.pdf

Training Outline

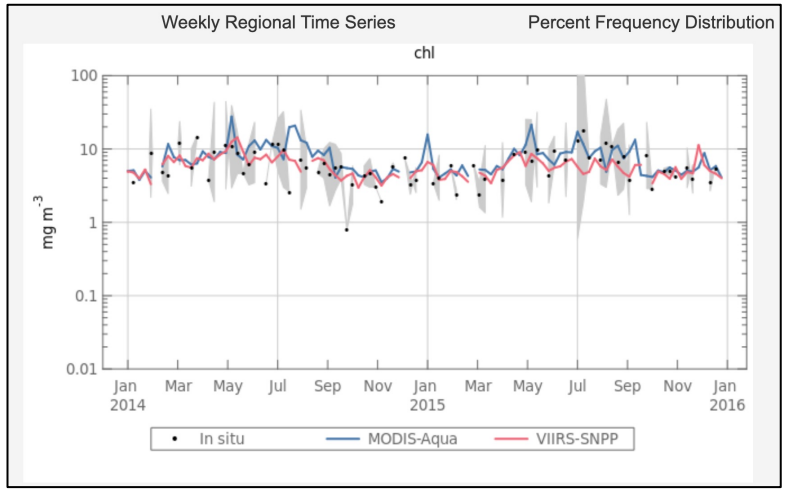
Two 2-hour sessions offered in English with materials available in Spanish.

Part 1: November 30, 2021



In Situ and Remote Sensing Data Acquisition

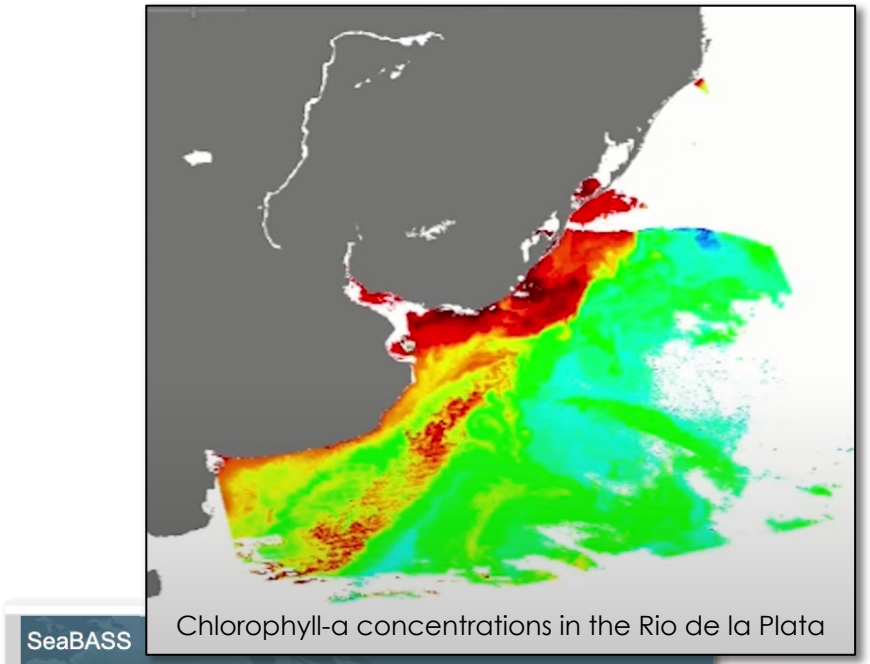
Part 2: December 7, 2021



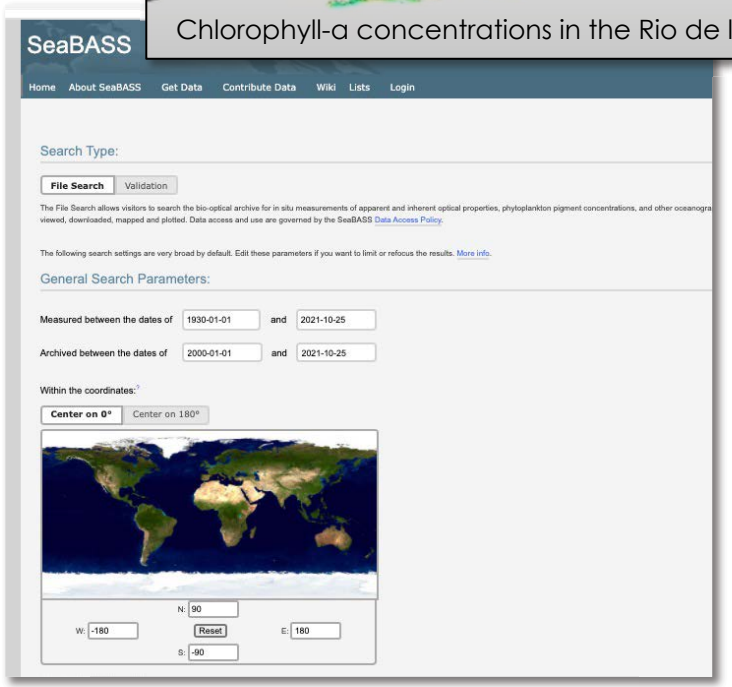
Derive MODIS- and VIIRS-Based Water Quality and In Situ Data for a Selected Estuary/Coastal Region

Outline for Session 1

- About ARSET
- Review: Water Quality Monitoring using Remote Sensing
- Overview: In Situ Data from SeaBASS
- Demonstration: Coastal Gulf of Mexico
  - In Situ Data Acquisition and Preparation
  - MODIS and VIIRS Data Acquisition
- Lab Time: Work on **Exercise 1**



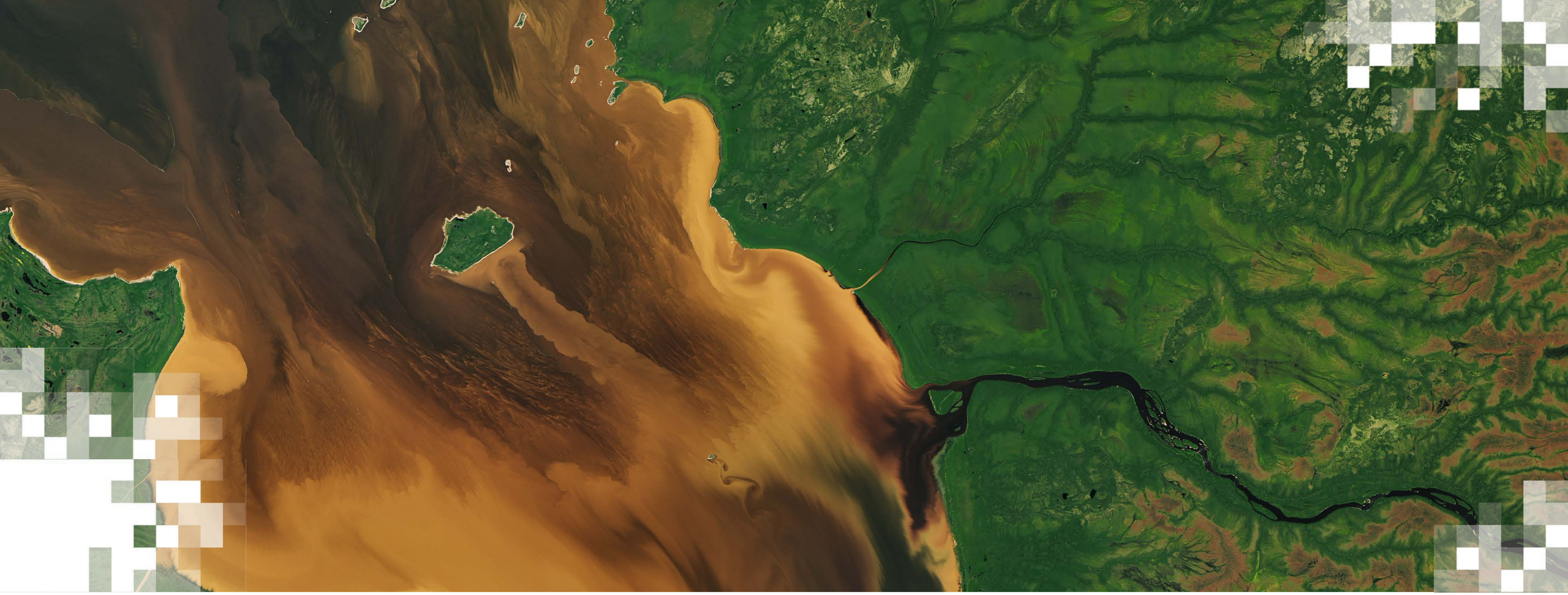
Chlorophyll-a concentrations in the Rio de la Plata



Homework and Certificate

- One homework assignment:
  - Answers must be submitted via Google Form accessed from the ARSET website, and via ARSET email address
  - Homework will be made available on December 7, 2021.
  - Due date for homework: January 5, 2022.

- A certificate of completion will be awarded to those who:
  - Attend both live webinars and complete exercise
  - Complete the homework assignment by the deadline
  - You will receive a certificate approximately two months after the completion of the course from: marines.martins@ssaihq.com



About ARSET

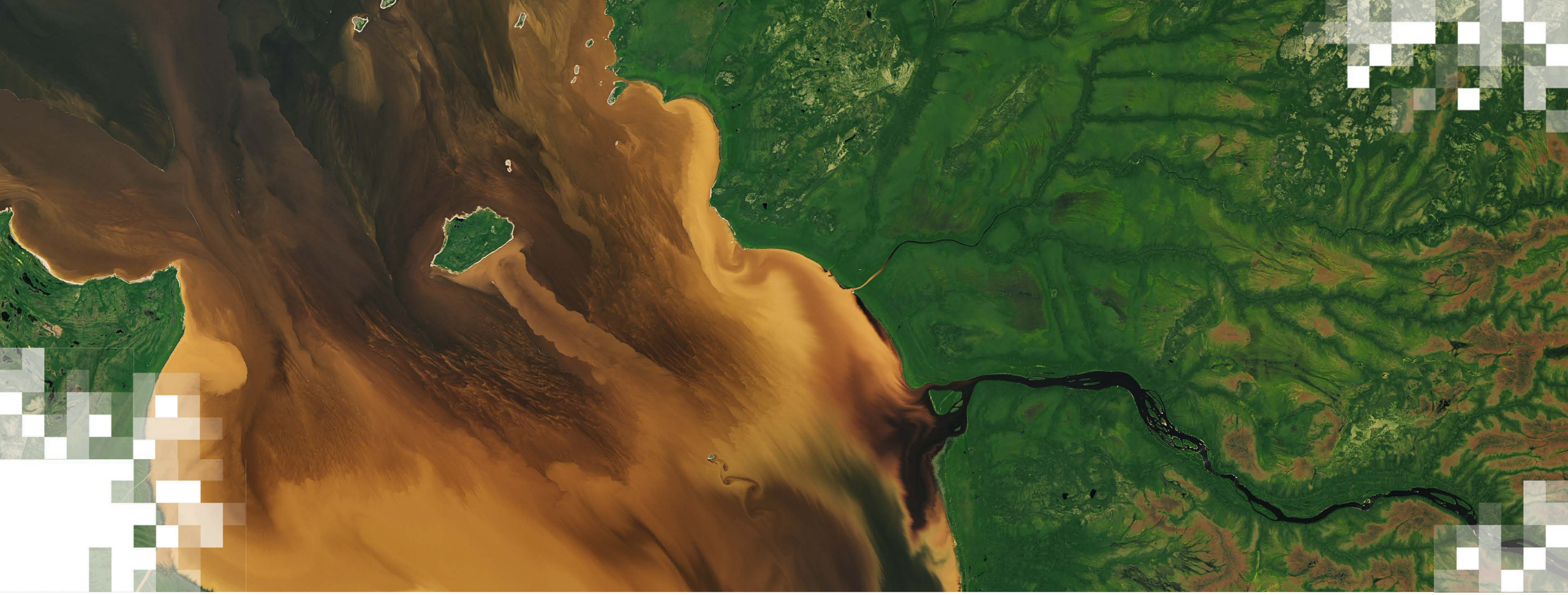
About ARSET

- *ARSET provides accessible, relevant, and cost-free training on remote sensing satellites, sensors, methods, and tools.*
- Our trainings are:
  - Online and *in-person
  - Open to anyone
  - Live, instructor-led or self-guided
  - Tailored to those with a range of experience in remote sensing, from **introductory** to **advanced**

- ARSET offers trainings for:
  - Disasters
  - Health & Air Quality
  - Land Management
  - Water Resources

For more information, visit appliedsciences.nasa.gov/arset

*ARSET is not currently offering in-person trainings due to the COVID-19 pandemic.



Review: Water Quality Monitoring Using Remote Sensing

Satellites & Sensors for Water Quality Monitoring

Satellites	Sensors	Resolution
Landsat 7	Enhanced Thematic Mapper (ETM+)	185 km swath; 15 m, 30 m, 60 m; 16-day revisit
Landsat 8	Operational Land Imager (OLI)	185 km swath; 15 m, 30 m, 60 m; 16-day revisit
Terra & Aqua	MODerate Resolution Imaging Spectroradiometer (MODIS)	2330 km swath; 250 m, 500 m, 1 km; 1–2-day revisit
SNPP[1] and JPSS[2]	Visible Infrared Imaging Radiometer Suite (VIIRS)	3040 km swath; 375 m – 750 m; 1–2-day revisit
Sentinel 2A and 2B	Multi Spectral Imager (MSI)	290 km swath; 10 m, 20 m, 60 m; 5-day revisit
Sentinel 3A and 3B	Ocean and Land Color Instrument (OLCI)	1270 km swath; 300 m; 27-day revisit

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

Current Satellite Missions for Water Quality Monitoring

- Landsat 7 (4/15/1999 – Present)
- Landsat 8 (2/1/2013 – Present)
- Terra (12/18/1999 – Present)
- Aqua (5/4/2002 – Present)
- SNPP (11/21/2011 – Present)
- JPSS (11/18/2017 – Present)
- Sentinel-2A (6/23/2015 – Present)
- Sentinel-2B (3/7/2017 – Present)
- Sentinel-3A (2/16/2016 – Present)
- Sentinel-3B (4/25/2018 – Present)

MODIS and VIIRS Data Products

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

Level 1A Data: Unprocessed instrument data at full resolution, time-referenced, and annotated with ancillary information, including radiometric and geometric calibration coefficients and georeferencing parameters (e.g., platform ephemeris data).

Level 1B Data: Level 1A data that have had instrument/radiometric calibrations applied.

Level 2 Data: Derived geophysical variables at the same resolution as the source Level 1 data.

Level 3 Data: Derived geophysical variables that have been aggregated/projected onto a well-defined spatial grid over a well-defined time period.

Remote Sensing of Water Quality

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

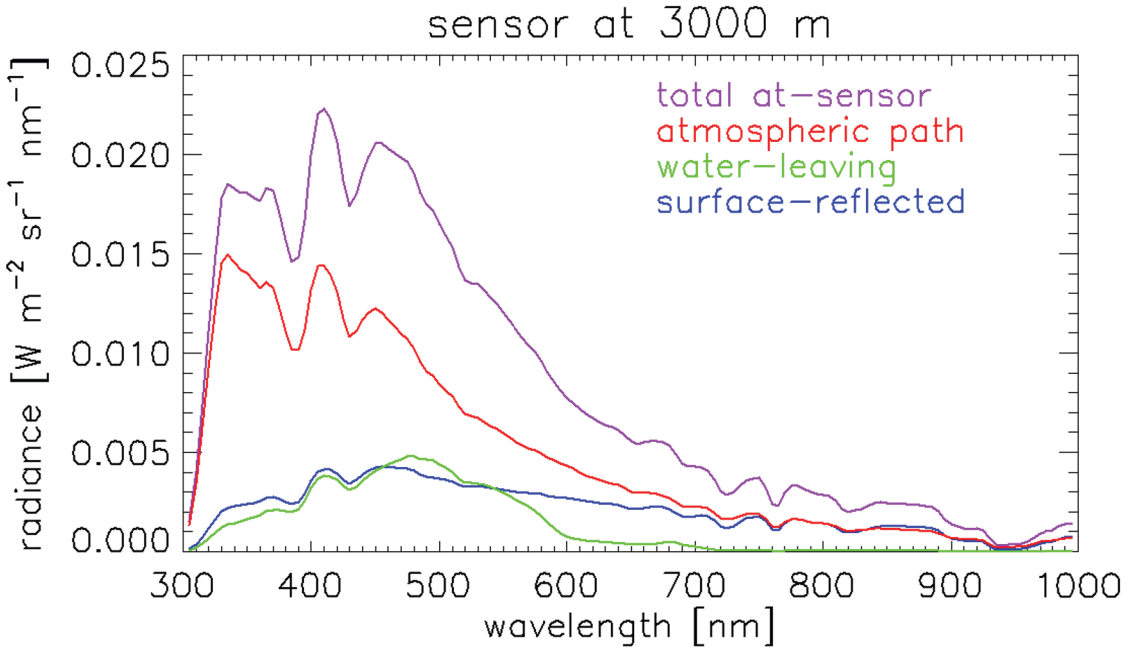
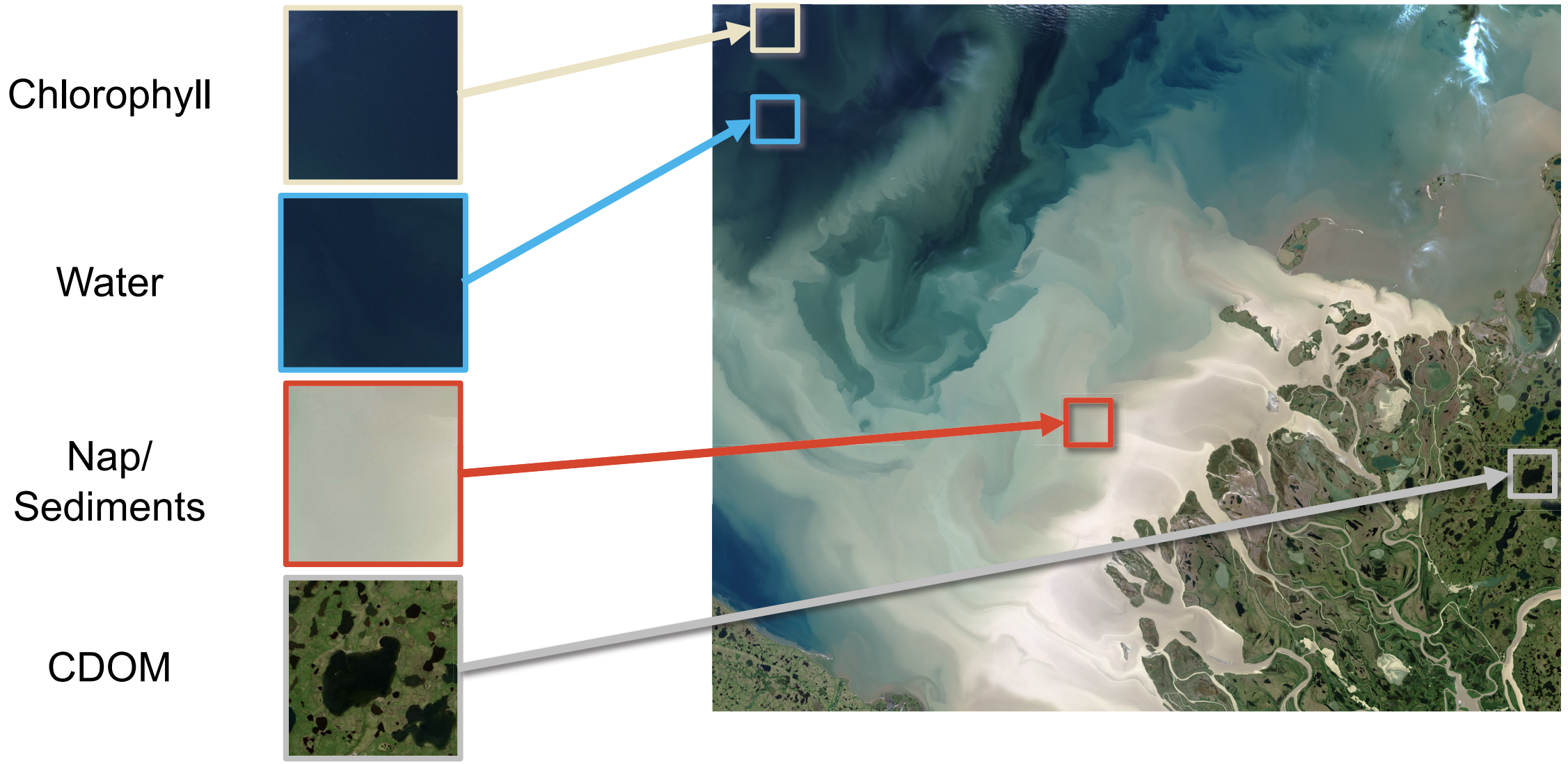


Image Credit:
http://www.oceanopticsbook.info/view/remote_sensing/the_atmospheric_correction_problem

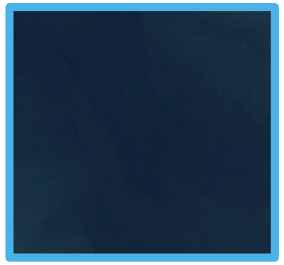
Inherent Optical Properties (IOPs) and the 'Color' of Water



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

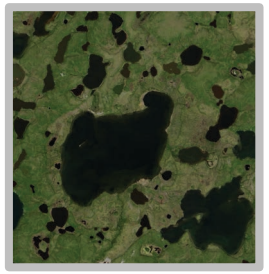
Chlorophyll

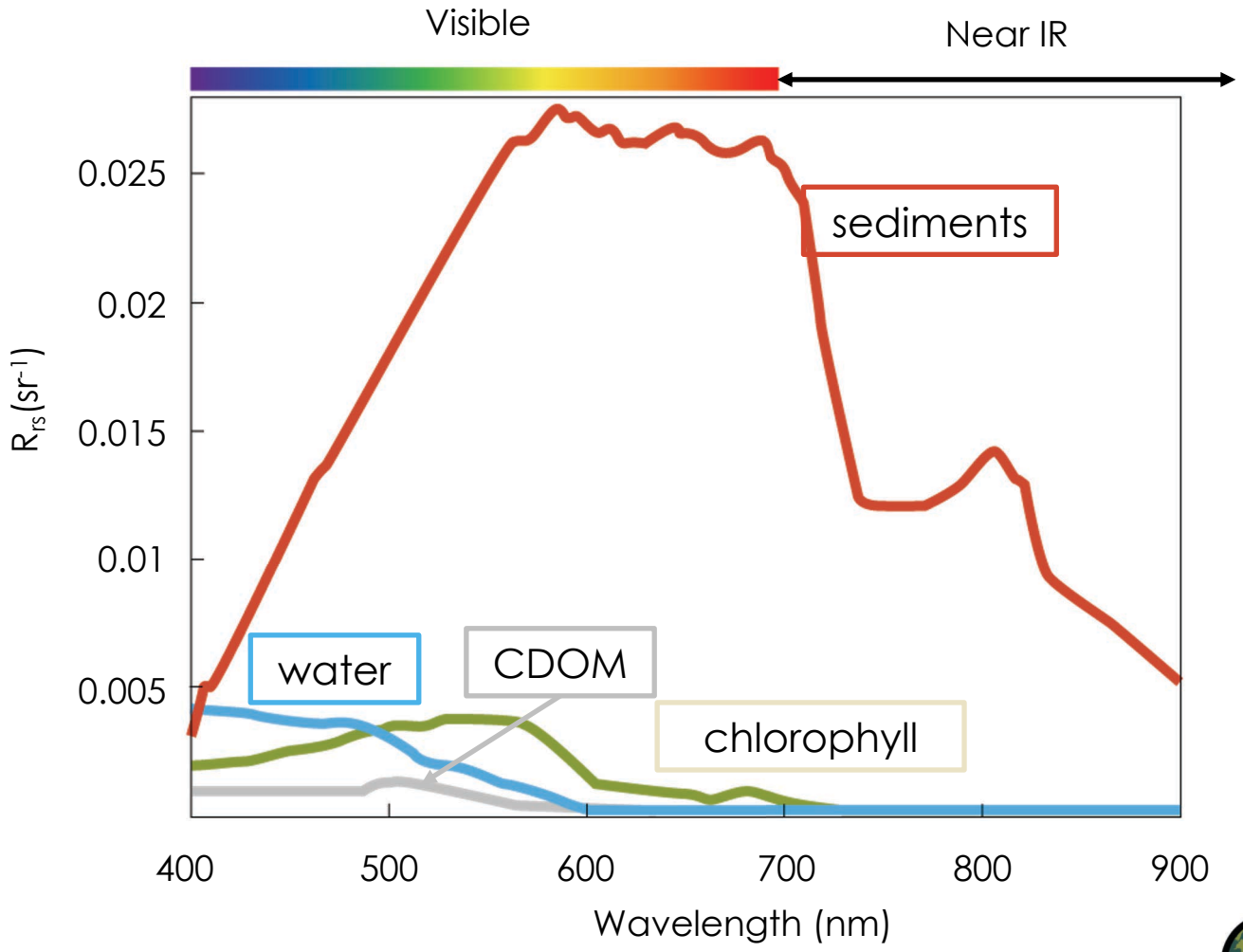
Water



Non-Algal Sediments

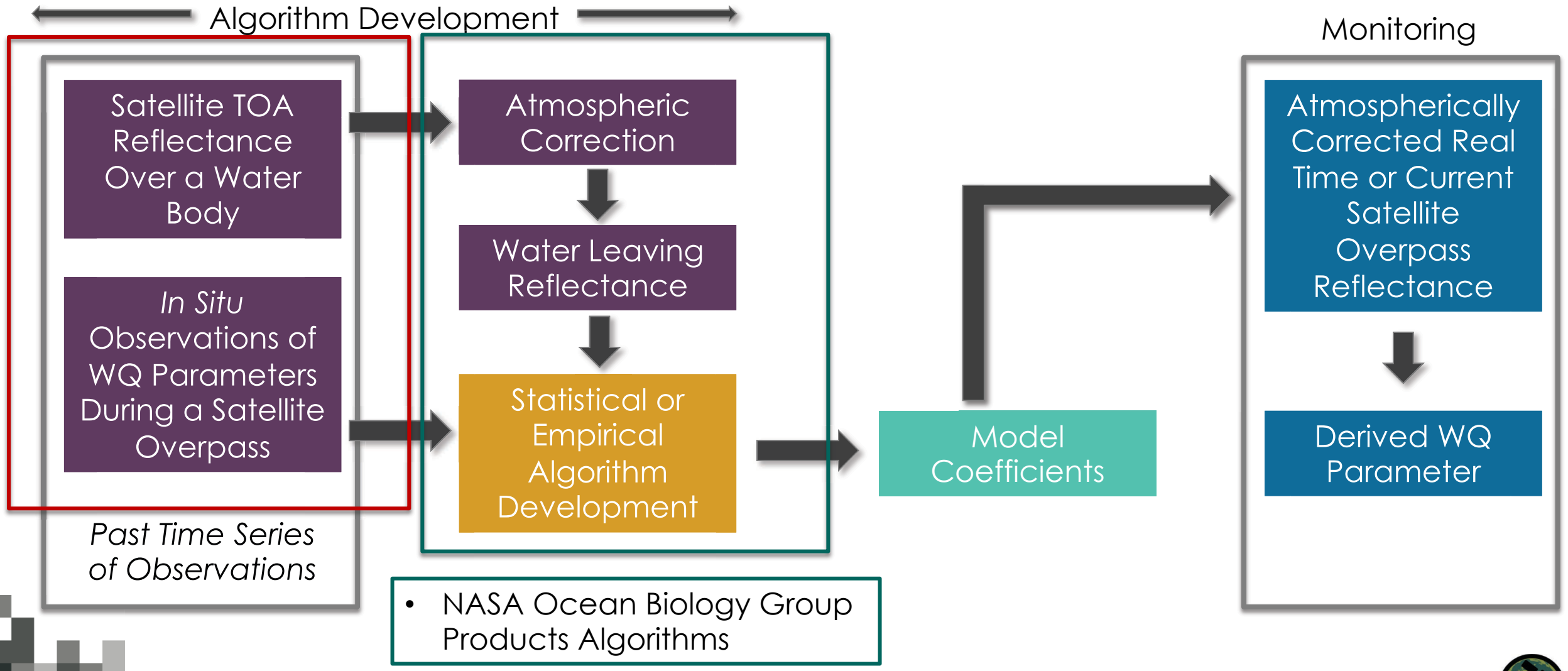
CDOM





Water Quality Parameters from Remote Sensing Observations

Quantitative Technique



NASA Ocean Color MODIS and VIIRS Processing Algorithms for Water Quality Monitoring

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

- Ocean color algorithms derive Level-2 water leaving remote sensing reflectance collocated with in situ measurements to develop algorithms to derive quantitative water quality parameters.

Algorithm Descriptions

The Ocean Biology Processing Group (OBPG) produces and distributes a standard suite of ocean color products for all compatible sensors at Level-2 and Level-3, plus sea surface temperature (SST) products from MODIS and VIIRS. The OBPG also produces a suite of Level-3 evaluation products. The descriptions and references for these standard and evaluation products (provided below) are intended to satisfy the Algorithm Theoretical Basis Document (ATBD) requirement as defined by the NASA Earth Observing System Project Science Office.

Ocean Color Products

Flags: View quality indicators of Level-2 Ocean Color products.

Standard

Remote Sensing Reflectance (Rrs; sr^{-1})
The at-surface spectral remote-sensing reflectances observed by the satellite instrument after atmospheric correction. The aerosol optical thickness and aerosol Ångström exponent products are also described.

Chlorophyll *a* (chlor_a; mg m^{-3})
The concentration of the photosynthetic pigment chlorophyll a

Diffuse attenuation coefficient for downwelling irradiance at 490 nm (Kd_490; m^{-1})
The diffuse attenuation coefficient for downwelling irradiance over the first optical attenuation layer

Particulate Organic Carbon (POC; mg m^{-3})
The concentration of particulate organic carbon

Particulate Inorganic Carbon (PIC; mol m^{-3})
The concentration of particulate inorganic carbon

Photosynthetically Available Radiation (PAR; Einstein m^{-2} d^{-1})
Daily mean photosynthetically available radiation at the ocean surface

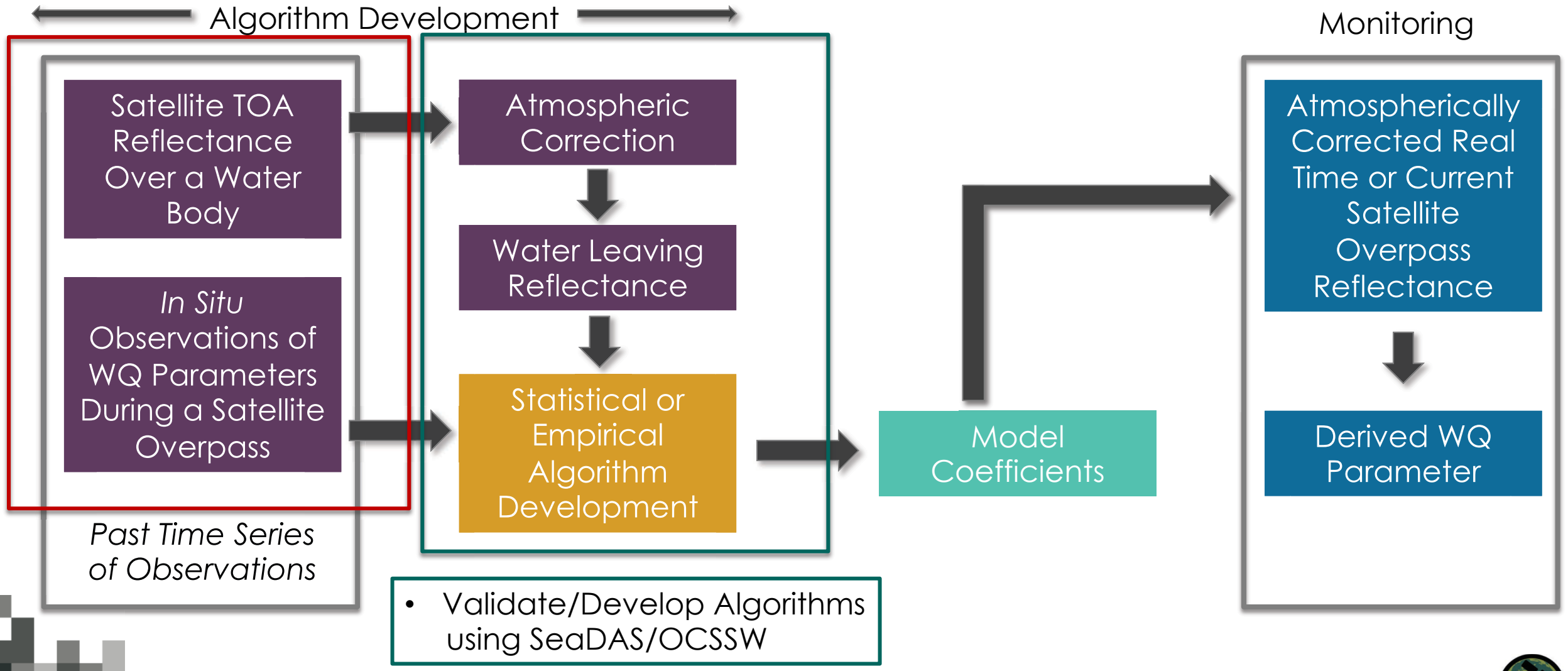
Instantaneous Photosynthetically Available Radiation (iPAR; Einstein m^{-2} s^{-1})
PAR at the ocean surface at the time of the satellite observation

Normalized Fluorescence Line Height (nFLH; mW cm^{-2} μm^{-1} sr^{-1})
Relative measure of water-leaving radiance associated with chlorophyll fluorescence

Inherent Optical Properties from GIOP Algorithm (IOP, m^{-1})
Spectral marine absorption and backscattering coefficients of water column constituents

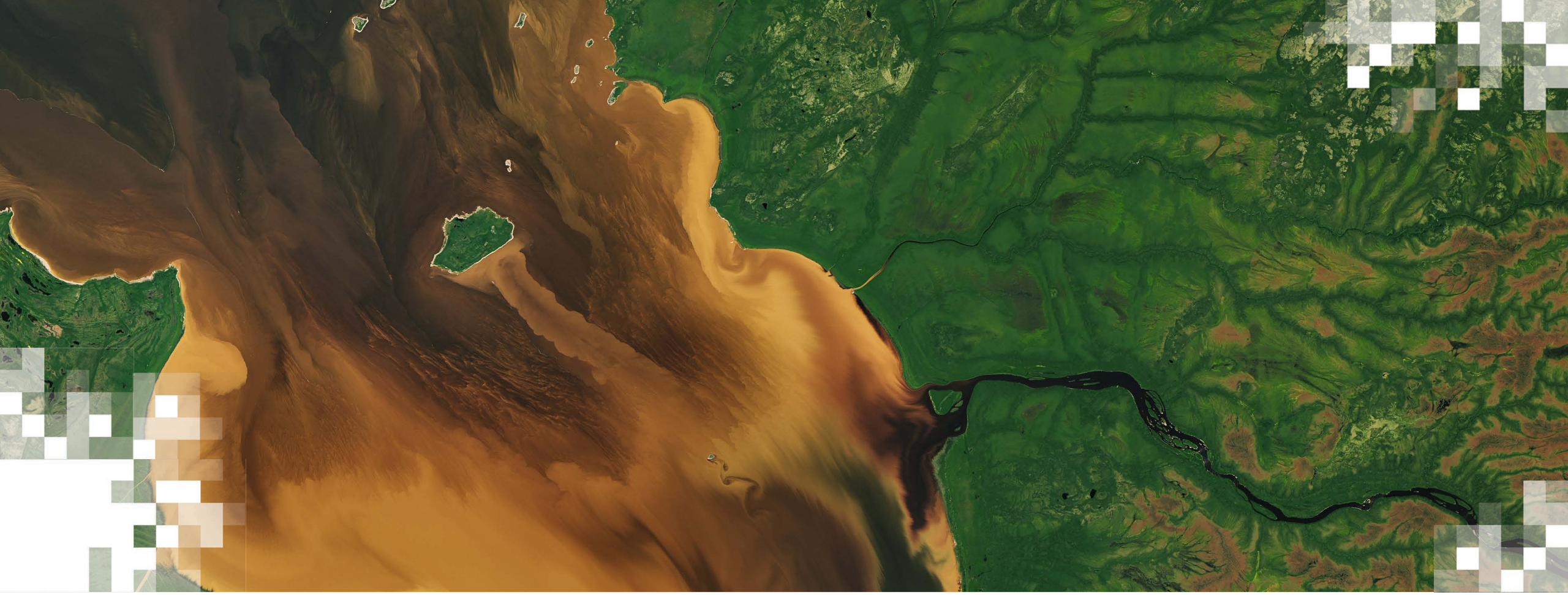
Water Quality Parameters from Remote Sensing Observations

Quantitative Technique



Requirements for Algorithm Development

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



Overview: In Situ Data from SeaBASS

About SeaBASS

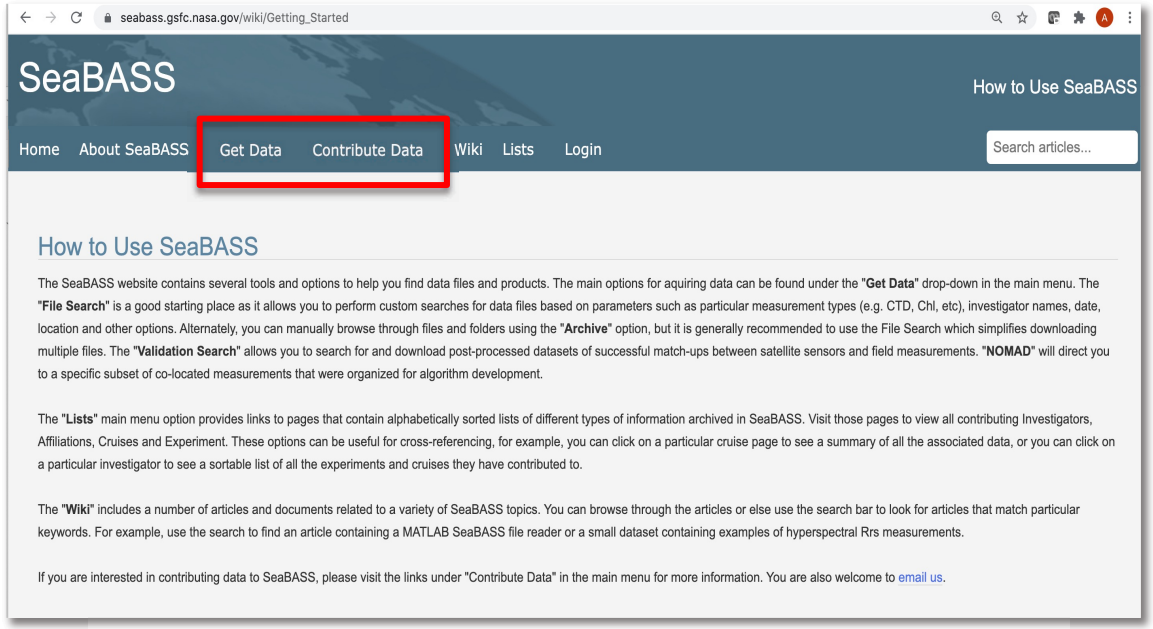
https://seabass.gsfc.nasa.gov/wiki/System_Description

- The NASA Ocean Biology Processing Group (OBPG) maintains a repository of *in situ* oceanographic data to support satellite data validation.
- The SeaWiFS Project originally developed SeaBASS to collect in situ data used for calibration and validation activities.
- SeaBASS data include measurements of inherent optical properties, phytoplankton pigment concentrations, and other related data such as water temperature, salinity, stimulated fluorescence, and aerosol optical thickness.
- Data are collected using a variety of platforms including ships and moorings.
- Different instrument packages include profilers, buoys, and hand-held instruments.

SeaBASS Data

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

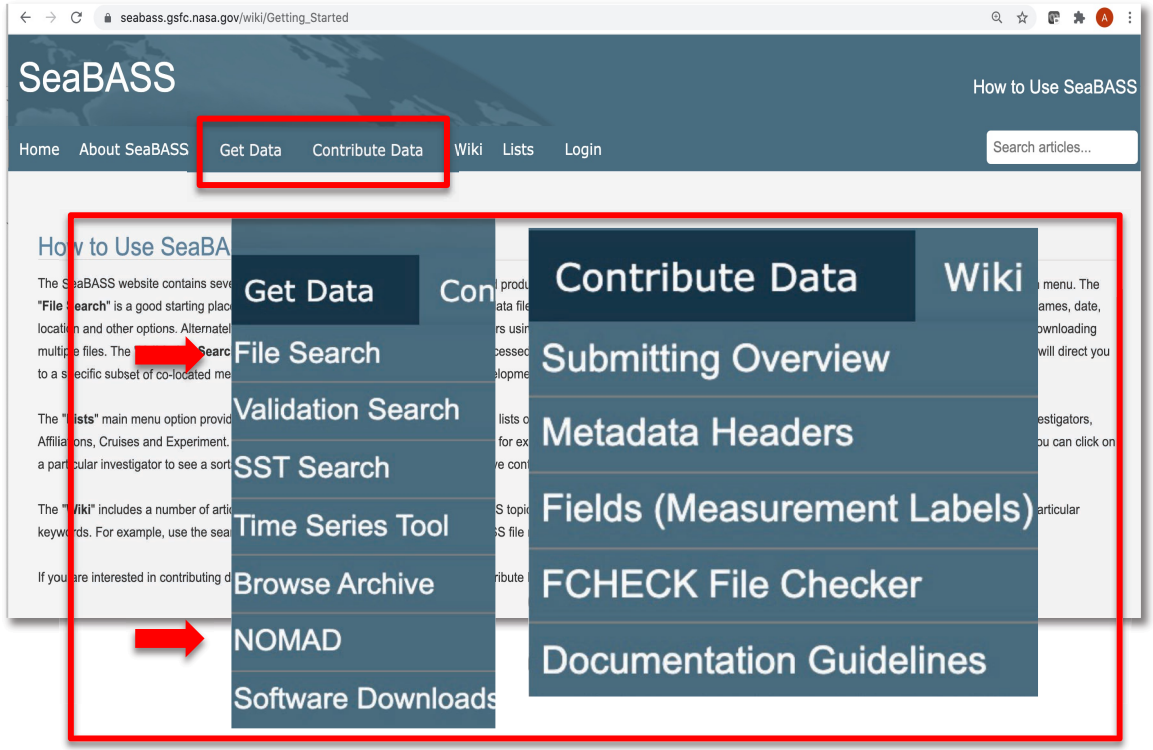
- In situ measurements data from SeaBASS can be downloaded.
- Your own in situ measurements can also be contributed.
- SeaBASS data have a specific file format.



SeaBASS Usage and Data Access

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

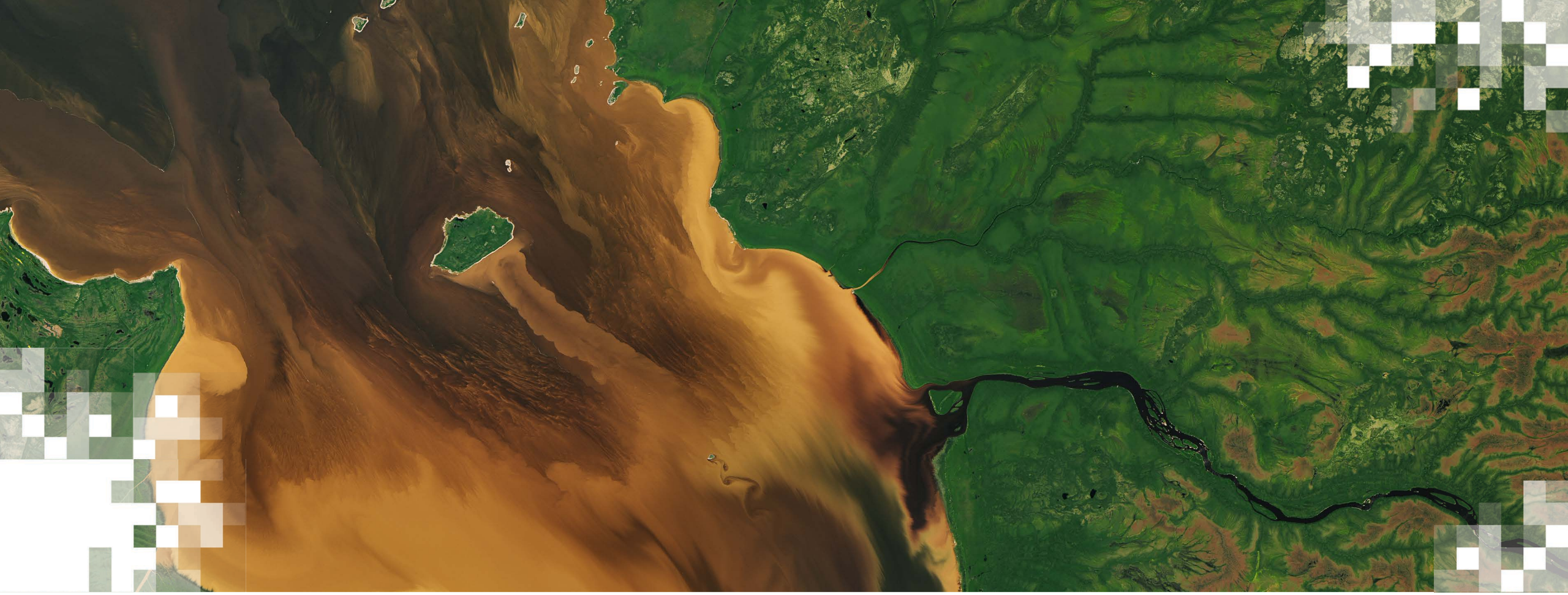
- In situ measurements data from SeaBASS can be downloaded
- Your own in situ measurements can also be contributed
- Data files have specific naming convention and format
- SeaBASS data can be imported into SeaDAS



SeaBASS File Format

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

- A text file name ending in .sb or .txt is required.
- Data file requires a header and the measured data in columns, separated by a delimiter.



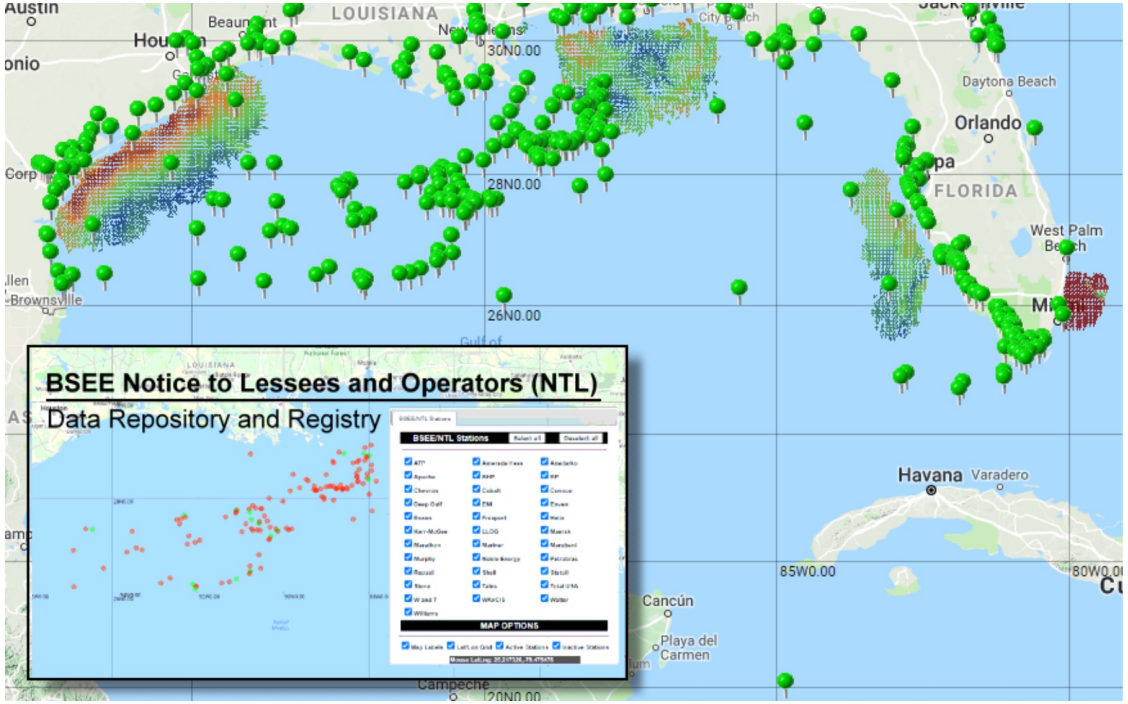
Demonstration of SeaBASS In Situ Data Access for Validation and Algorithm Development

Region: Gulf of Mexico

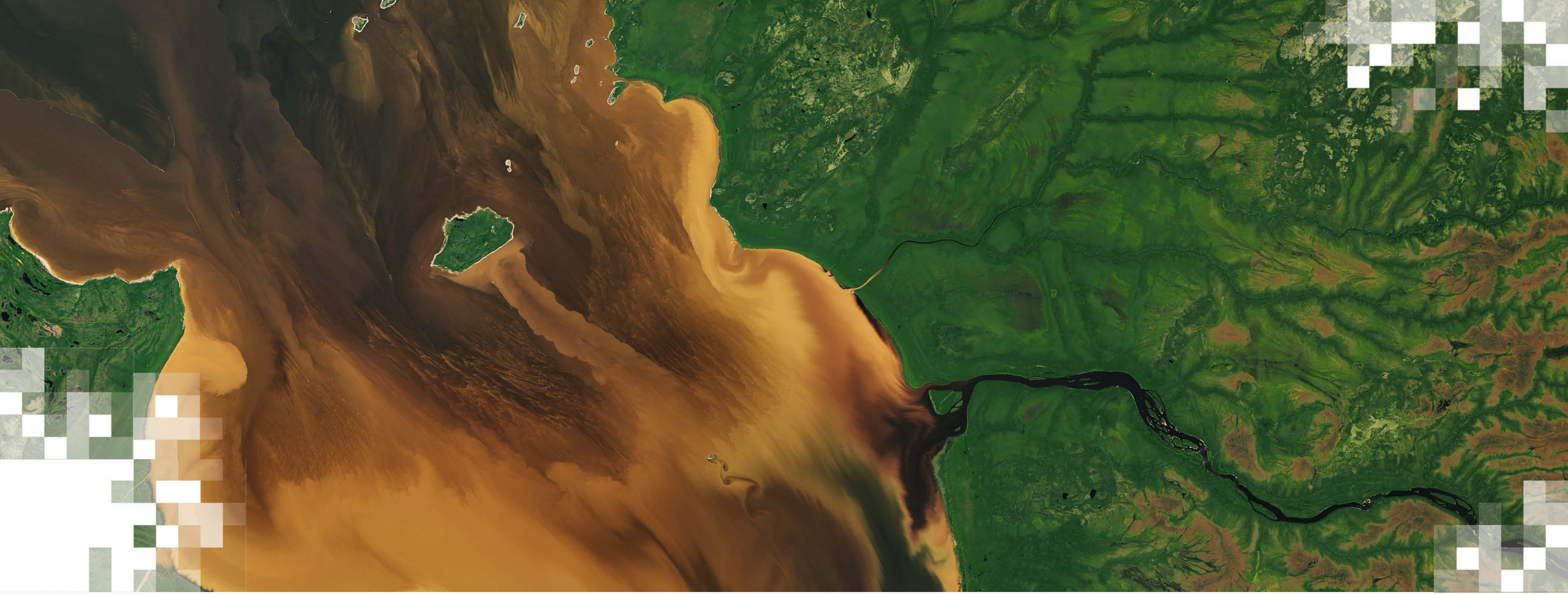
In Situ Data

- Select geographic region – Gulf of Mexico (GM)
- Select temporal range
- Download SeaBASS files and view the format
- Get independent measurements for the region of interest
  - We will use the Gulf of Mexico Coastal Ocean Observing System (GCOOS) for the GM region
- Prepare GCOOS data in SeaBASS format

GCOOS Measurement Sites



https://data.gcoos.org/



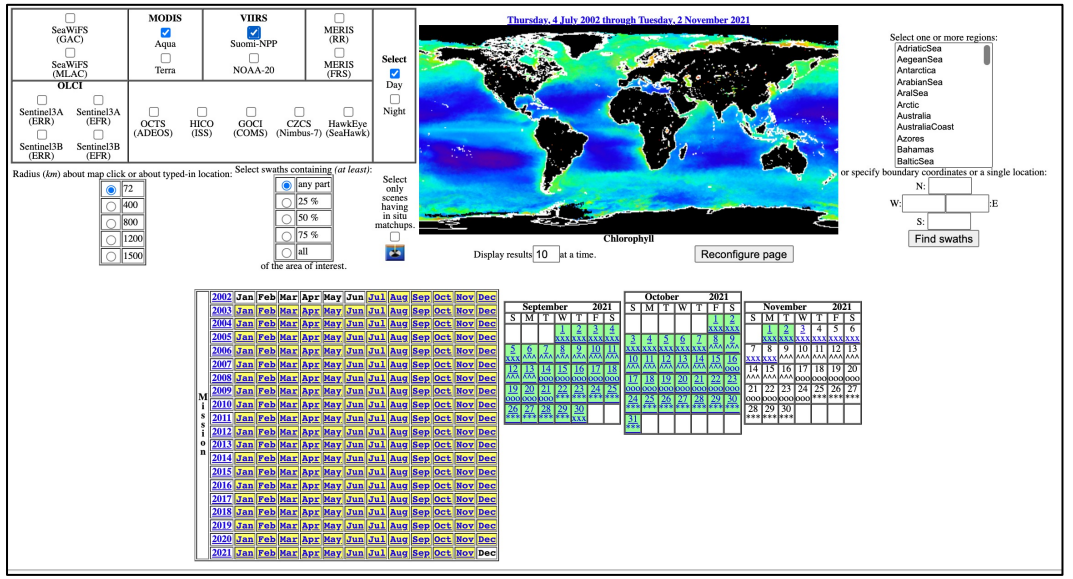
Demonstration of MODIS and VIIRS Data Acquisition

Region: Gulf of Mexico

MODIS and VIIRS Data

- Find cloud-free images:
  - For MODIS, use NASA Worldview
  - For VIIRS, use NOAA STAR Ocean Color

- *Select and download Level-2 MODIS and VIIRS images using NASA OceanColor Web



https://oceancolor.gsfc.nasa.gov/cgi/browse.pl?sen=amod

*Monitoring Coastal and Estuarine Water Quality: Transitioning from MODIS to VIIRS: https://appliedsciences.nasa.gov/join-mission/training/english/arset-monitoring-coastal-and-estuarine-water-quality-transitioning

Demonstration and Exercise Next Week

- Using MODIS and VIIRS Level-1 images, prepare Level-2 satellite data using SeaDAS/OCSSW (focus on chlorophyll-a)

- Import in situ data prepared in Session-1 into SeaDAS and compare chlorophyll-a data with Level-2 and learn to: 1) validate remote sensing data, and 2) revise algorithm

Lab Time: Exercise-1