Monitoring Coastal and Estuarine Water Quality: Transitioning from MODIS to VIIRS

Image Processing using SeaDAS

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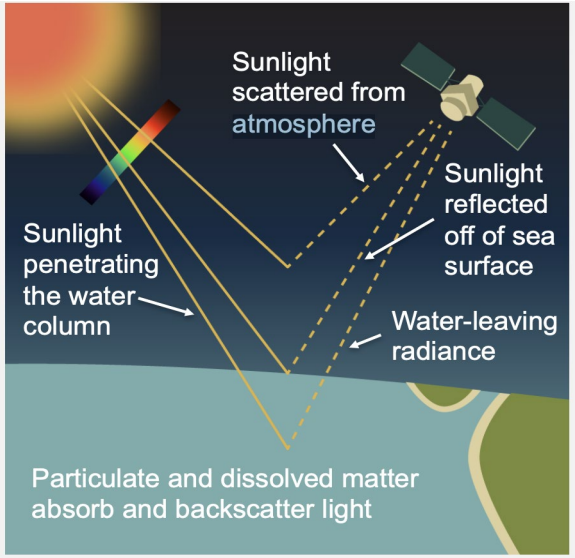
September 16, 2021

Training Outline

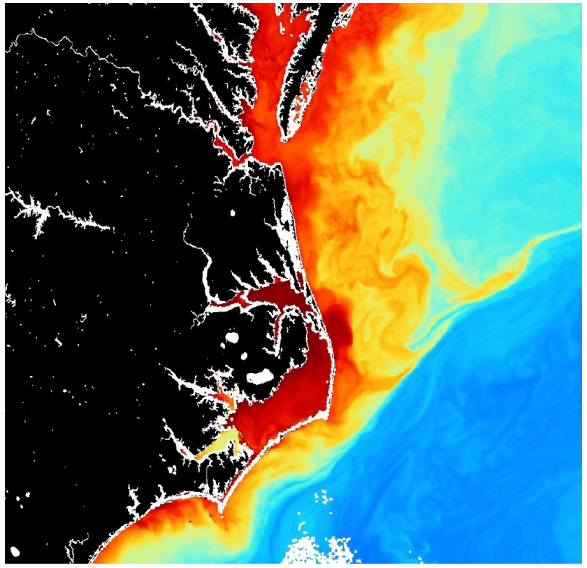
Three 1.5-hour sessions offered in both English and Spanish

Overview of Remote Sensing Observations for Water Quality Monitoring in Estuaries



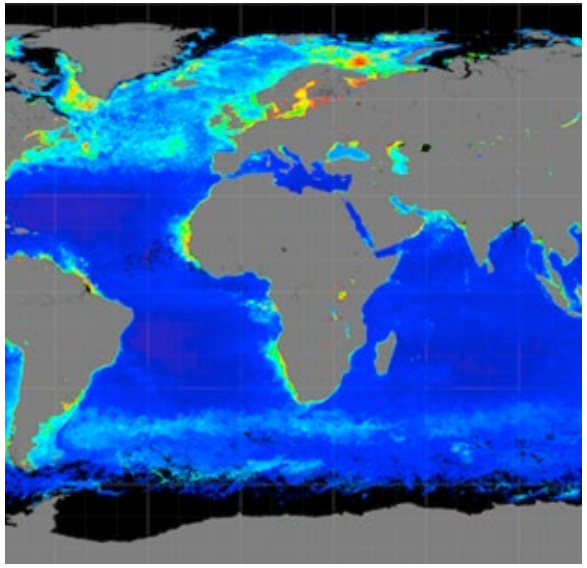
September 14, 2021

Image Processing using SeaDAS



September 16, 2021

Monitoring MODIS- and VIIRS-Based Water Quality



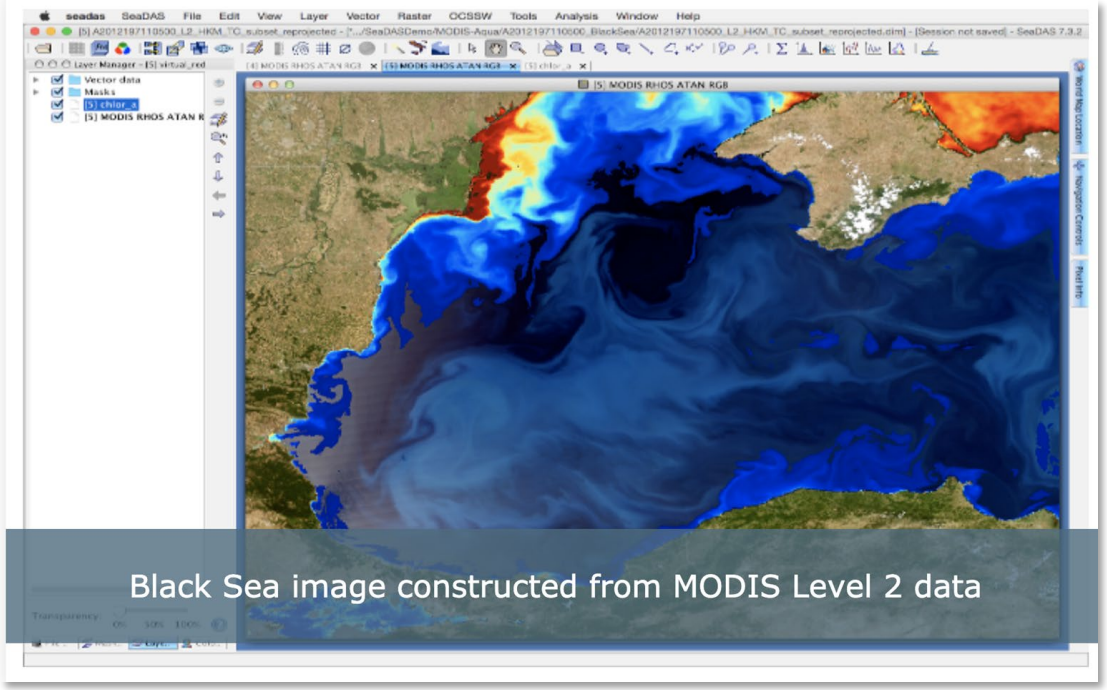
September 21, 2021

Homework and Certificate

- One homework assignment:
  - Answers must be submitted via Google Form, accessed from the ARSET website.
  - Homework will be made available on September 21, 2021.
  - Due date for homework: October 5, 2021
- A certificate of completion will be awarded to those who:
  - Attend all live webinars
  - 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

Outline for Part 2

- Review of Part 1
- Installation overview of SeaDAS and Ocean Color Science SoftWare (OCSSW)
- Processing MODIS and VIIRS Level-1 Images to Level-2
- Demonstration of SeaDAS Processing and Visualization of MODIS and VIIRS Images for the Chesapeake Bay and Río de la Plata



Black Sea image constructed from MODIS Level 2 data

Review of Part 1

Brief Summary of Part 1

- Coastal water and estuaries are transition regions from land to open ocean, support a variety of ecosystems, and are important for regional and global economies.
- Increasing nutrients and sediments in coastal/estuarine water is a major concern as it leads to low dissolved oxygen in the water – hypoxia – a major cause of destruction of benthic organisms and fish.
- For sustainable aquatic ecosystems in these regions, monitoring water quality (WQ) allows us to understand how to mitigate the impacts of land use change, eutrophication, and contamination in coastal/estuarine systems.
- Remote sensing provides regular and consistent observations over a large area, with a consistent revisit time.

Brief Summary of Part 1

- MODIS provides ~20 years of moderate resolution and frequent (daily) observations for WQ monitoring.
- VIIRS will provide an adequate follow-on to and replacement of MODIS for ocean color monitoring.

MODIS & VIIRS QAA Total Backscattering @551/547nm – MissBight – 2/15/2014

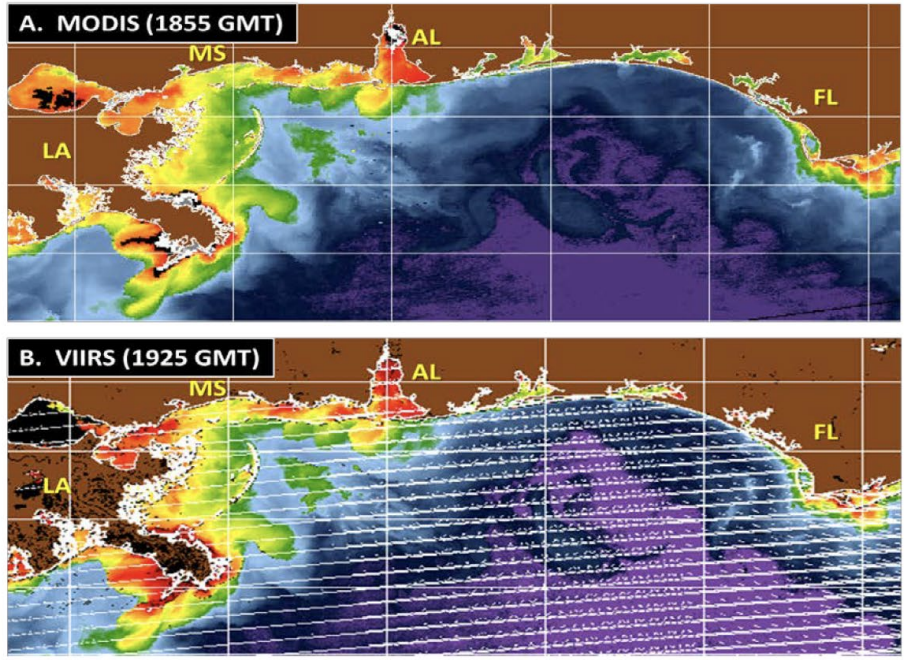


Figure 1 shows a comparison between VIIRS and MODIS Aqua derived total backscatter QAA @ 551nm (VIIRS) and 547nm (MODIS Aqua) product for November 20, 2013 covering the Mississippi Sound in the Northern Gulf of Mexico. Note that the derived total backscattering for both sensors is very similar and a small resolution improvement for VIIRS at 750m as compared to MODIS Aqua is at 1 kilometer. Blue dots represent flowthru data sample locations and red dots above water rrs.

Learn to Use MODIS and VIIRS Data for WQ Monitoring

Case Studies:

- Study Regions:
  - Chesapeake Bay
  - Río de la Plata
- Search and Obtain MODIS and VIIRS Level-1 Data from NASA Ocean Color Web
- Derive MODIS and VIIRS Level-2 Data
  - Spectral Reflectance
  - Geophysical Parameters (e.g., sea surface temperature, chlorophyll-a concentration, vertical attenuation coefficient)

Chesapeake Bay

Rio de la Plata

Credit: NASA

Installation and Overview of SeaDAS and Ocean Color Science SoftWare (OCSSW)

SeaDAS

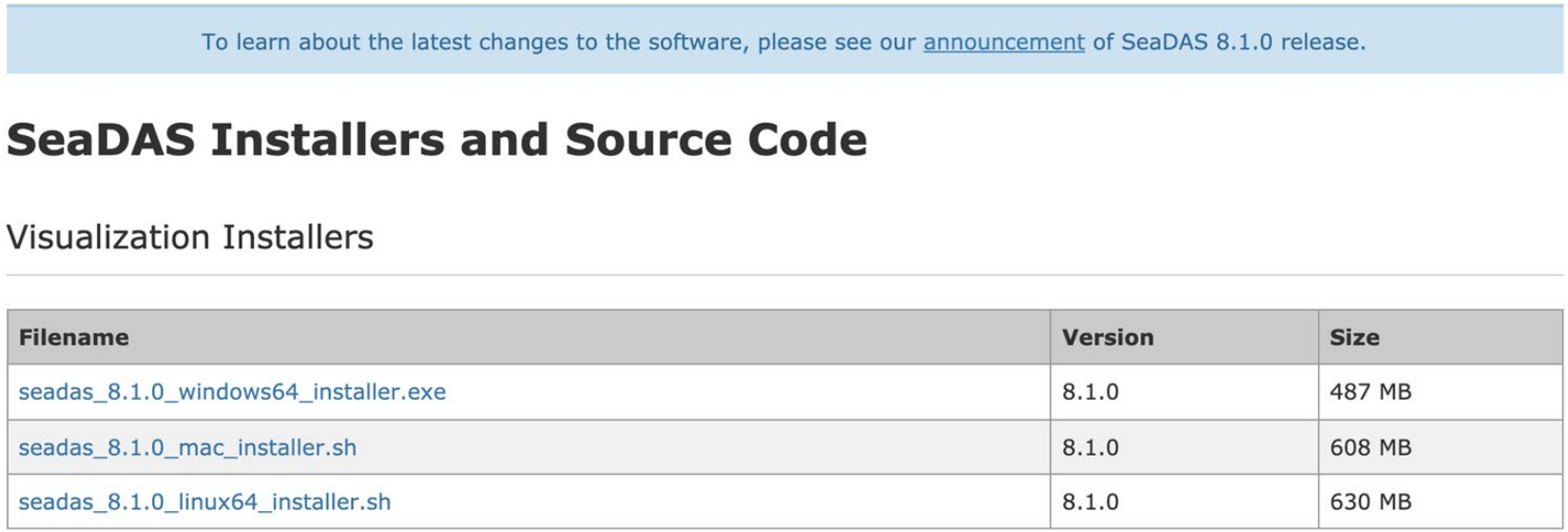
https://seadas.gsfc.nasa.gov/

- NASA Ocean Biology official data processing and analysis software
- Latest Version: 8.1.0
- There is a Graphical User Interface (GUI) version.
- It is open source and can be downloaded from https://seadas.gsfc.nasa.gov/downloads/
- Can also download code and use the command line version

SeaDAS

https://seadas.gsfc.nasa.gov/

- Available for Windows, Mac OS, and Linux operating systems
- **Requires:**
  - Bash
  - Python 3.6 or later
  - Python requests package v2.18.0 or later



To learn about the latest changes to the software, please see our announcement of SeaDAS 8.1.0 release.

SeaDAS Installers and Source Code

Visualization Installers

Filename	Version	Size
seadas_8.1.0_windows64_installer.exe	8.1.0	487 MB
seadas_8.1.0_mac_installer.sh	8.1.0	608 MB
seadas_8.1.0_linux64_installer.sh	8.1.0	630 MB

SeaDAS

https://seadas.gsfc.nasa.gov/

- The SeaDAS GUI can be used for:
  - Visualization, processing, and analysis of images[1]
  - Installation of OCSSW
  - Running OCSSW to get Level-2 and Level-3 data from Level-1
  - Accessing available in situ data from SeaBASS[2]
- SeaDAS 8.1.0 contains SeaDAS Toolbox that includes Sentinel-3 Toolbox
- This session will focus on using SeaDAS GUI on Mac OSX

[1]**Currently, the processing components can only be installed on Linux or MacOSX (Intel) systems.** The Linux binaries were compiled on a system with CentOS 6.10 and gcc-6.3.1. If your system is not the same, you *might* need to build the binaries from source.

[2]The SeaWiFS Bio-optical Archive and Storage System (SeaBASS), is publicly shared archive of in situ oceanographic and atmospheric data maintained by the NASA Ocean Biology Processing Group (OBPG). (https://seabass.gsfc.nasa.gov/)

Processing MODIS and VIIRS Level-1 Images to Level-2

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 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).

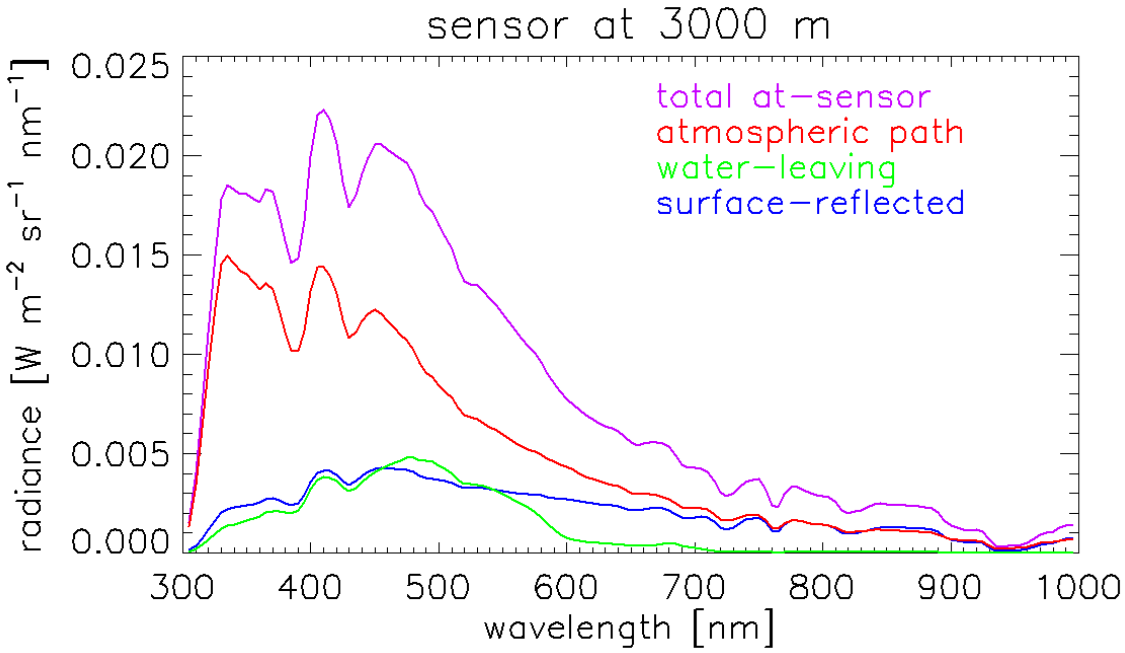
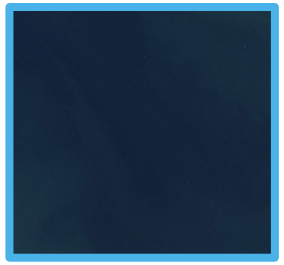


Image Credit:
http://www.oceanopticsbook.info/view/remote_sensing/the_atmospheric_correction_problem

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

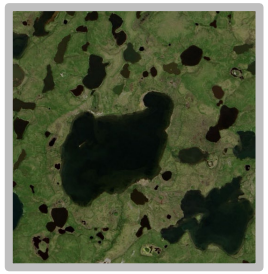
Chlorophyll

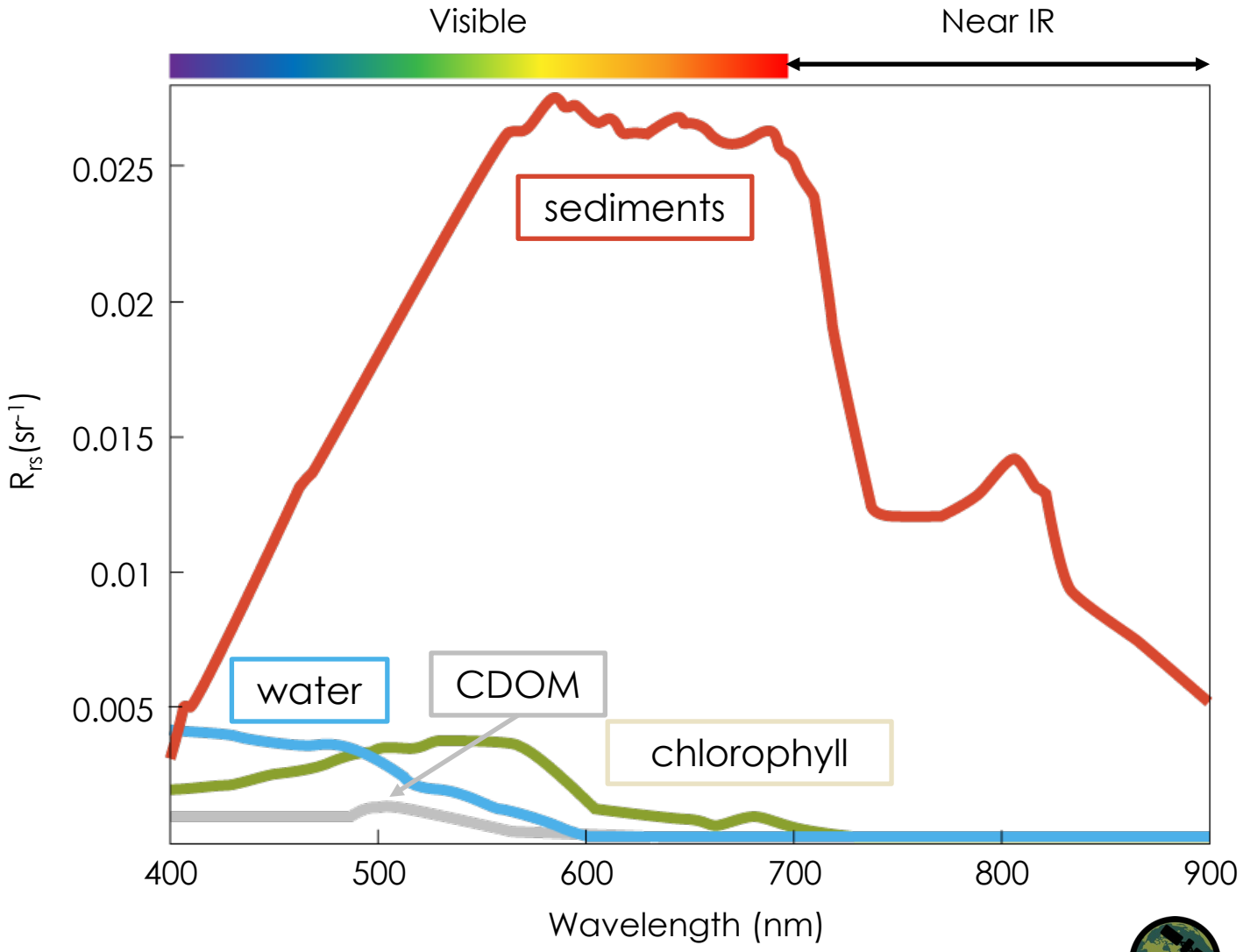
Water



Non-Algal Sediments

CDOM



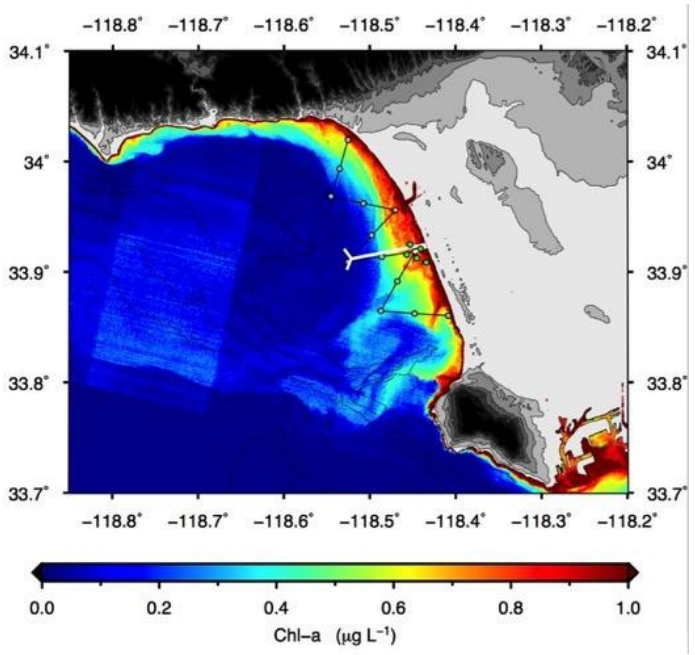


Remote Sensing of Water Quality

Techniques

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

2. Different algorithms combine atmospherically-corrected satellite images and in situ measurements to derive **quantitative information** about water quality.



In situ observations required

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

Atmospheric Correction for Water Quality Monitoring

- Satellite observations of reflectance have to be corrected for atmospheric effects for getting water surface reflectance.
- Various techniques exist for the atmospheric corrections.
- Requires radiative transfer modeling along with atmospheric conditions, clouds, and aerosol information.

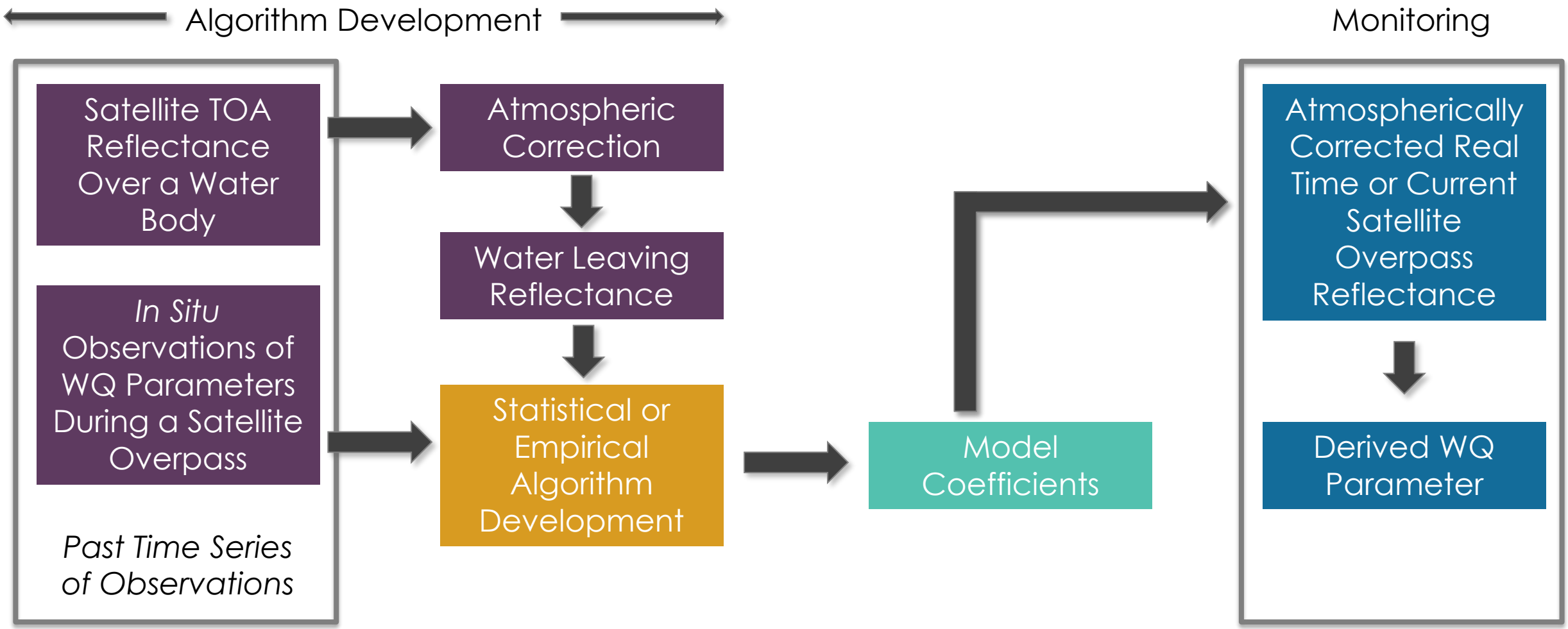
Examples:

- NASA Ocean Biology Processing Group Algorithm: https://oceancolor.gsfc.nasa.gov/docs/technical/NASA-TM-2016-217551.pdf
- ***6S**: **S**econd **S**imulation of the **S**atellite **S**ignal in the **S**olar **S**pectrum: http://6s.ltdri.org/#
- ACOLITE: https://odnature.naturalsciences.be/remsem/software-and-data/acolite
- HydroLight: http://www.oceanopticsbook.info/view/radiative_transfer_theory/level_2/hydrolight

*Vermote, E.E., D. Tanré, J.L. Deuzé, M. Herman and J.-J. Morcrette, Second Simulation of the Satellite Signal in the Solar Spectrum, 6S: An Overview, *IEEE Transactions on Geoscience and Remote Sensing, Vol. 35, No. 3, p. 675-686., 1997.* r12_Stumpf_Tomlinson.pdf

Water Quality Parameters from Remote Sensing Observations

Quantitative Technique



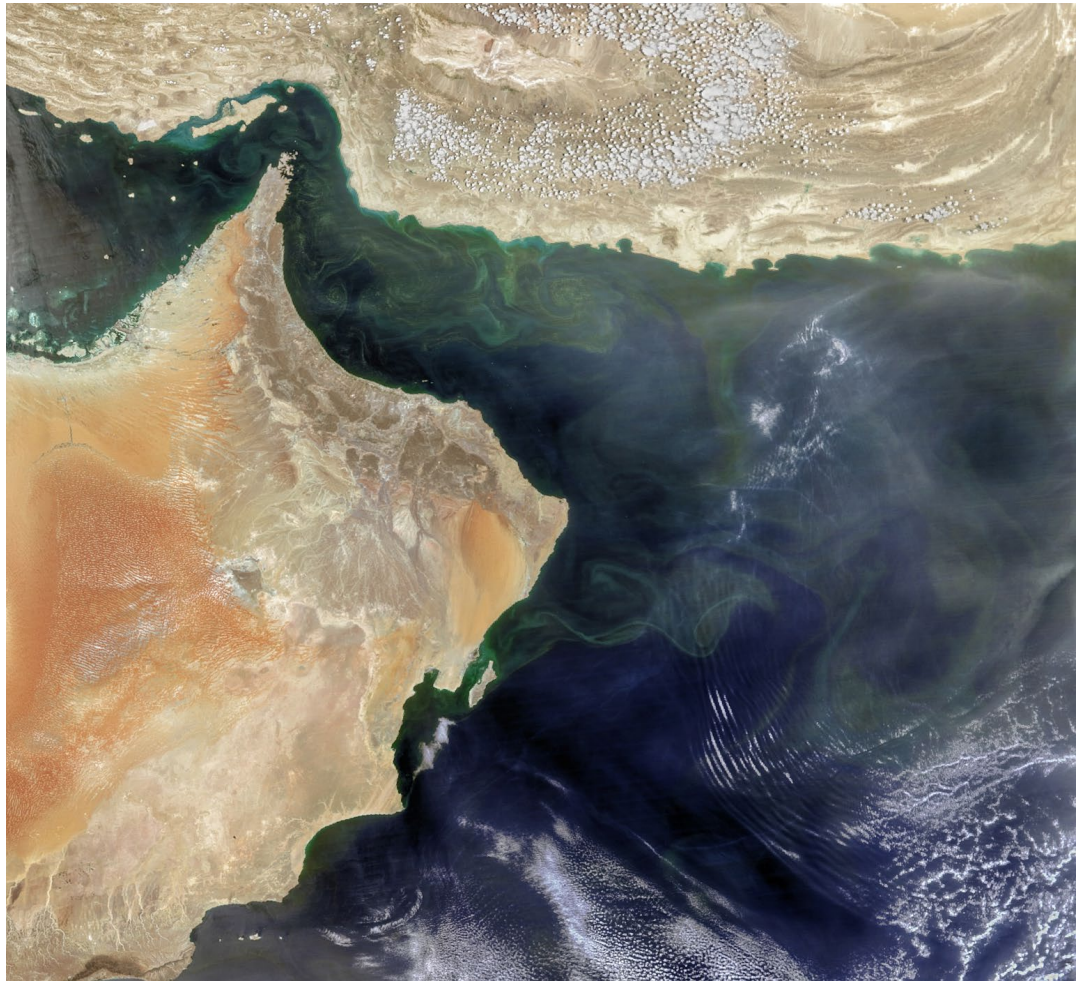
Demonstration of SeaDAS/Processing and Visualization for MODIS and VIIRS Images for the Chesapeake Bay and Río de la Plata

National Aeronautics and Space Administration

Demonstration of VIIRS Water Quality Products Available for Coastal Waters from NOAA NESDIS

Questions

- Please enter your questions in the Q&A box. We will answer them in the order they were received.
- We will post the Q&A to the training website following the conclusion of the webinar.



Credit: NASA

Contacts

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  - Sean McCartney: sean.mccartney@nasa.gov
- Training Webpage:
  - https://appliedsciences.nasa.gov/join-mission/training/english/arset-monitoring-coastal-and-estuarine-water-quality-transitioning
- ARSET Website:
  - https://appliedsciences.nasa.gov/what-we-do/capacity-building/arset


APPLIED REMOTE SENSING TRAINING PROGRAM
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Thank You!