National Aeronautics and Space Administration

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

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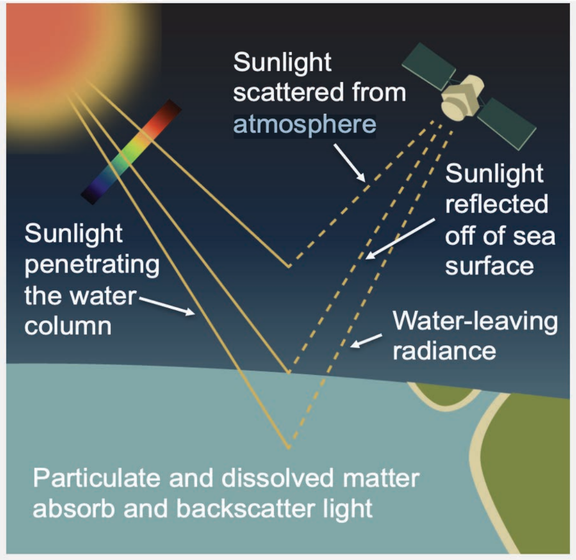
September 21, 2021

Training Outline

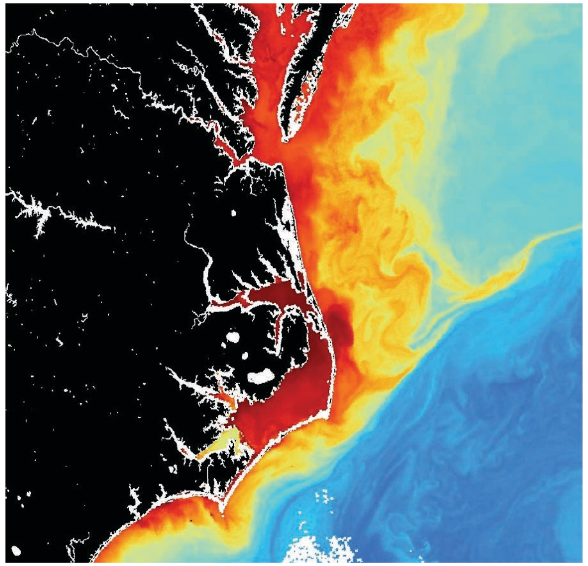
Three 1.5-hour sessions offered in both English and Spanish

Overview of Remote Sensing Observations for Water Quality Monitoring in Estuaries



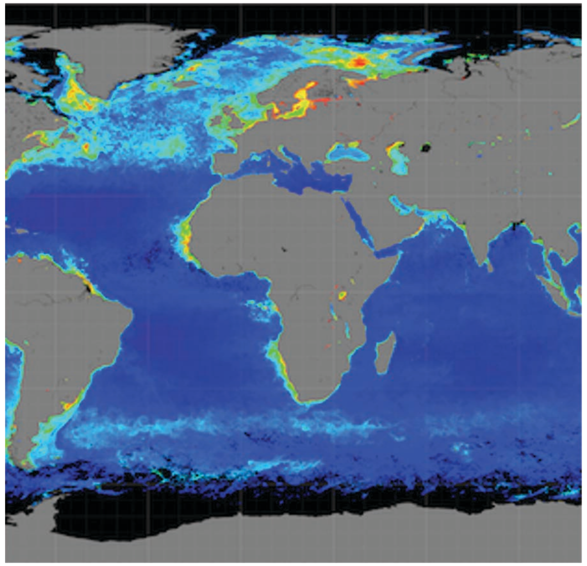
September 14, 2021

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 3

- Background: Chesapeake Bay and Río de la Plata
- Demonstration of MODIS- and VIIRS-based water quality monitoring in the Chesapeake Bay and Río de la Plata

Credit: NASA

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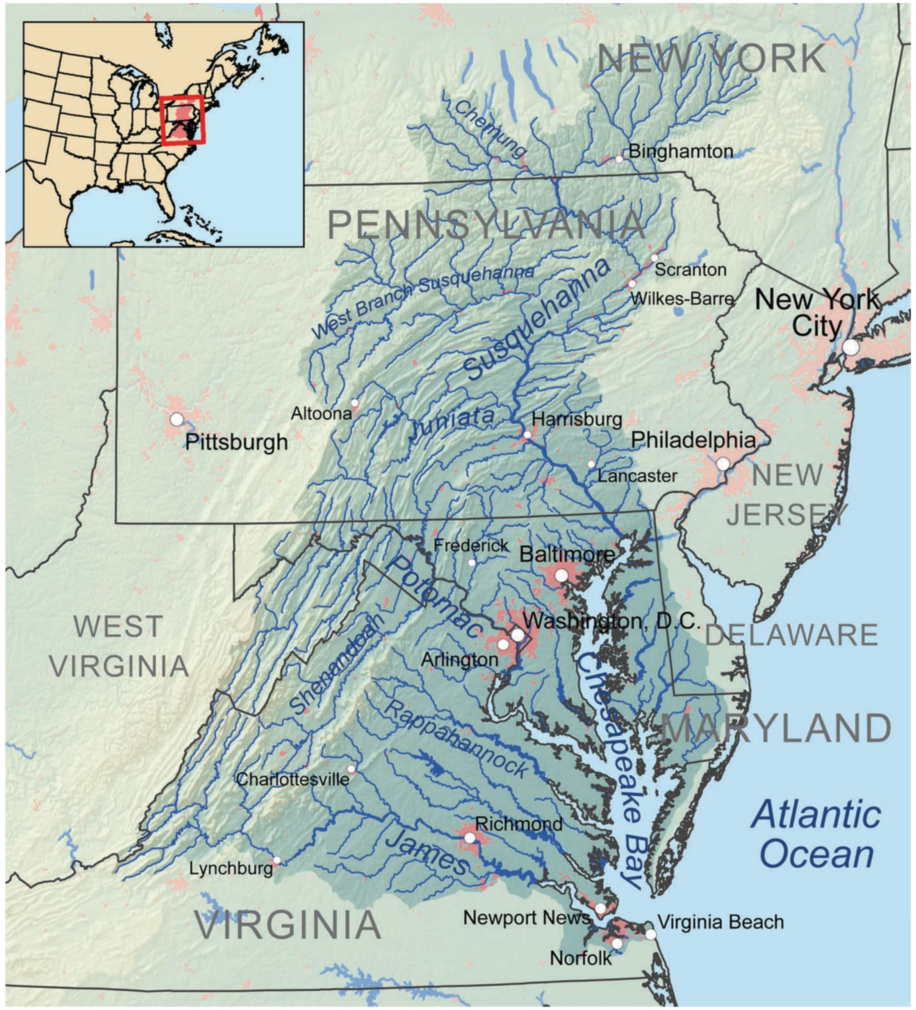
Background: Chesapeake Bay

Chesapeake Bay

- Largest estuary in the United States
- Bay is 322 kilometers (200 miles) long, stretching from Havre de Grace, Maryland, to Virginia Beach, Virginia
- Average depth is 6.4 m (21 ft)
- Watershed covers parts of 6 states and the District of Columbia
  - Delaware
  - Maryland
  - New York
  - Pennsylvania
  - Virginia
  - West Virginia

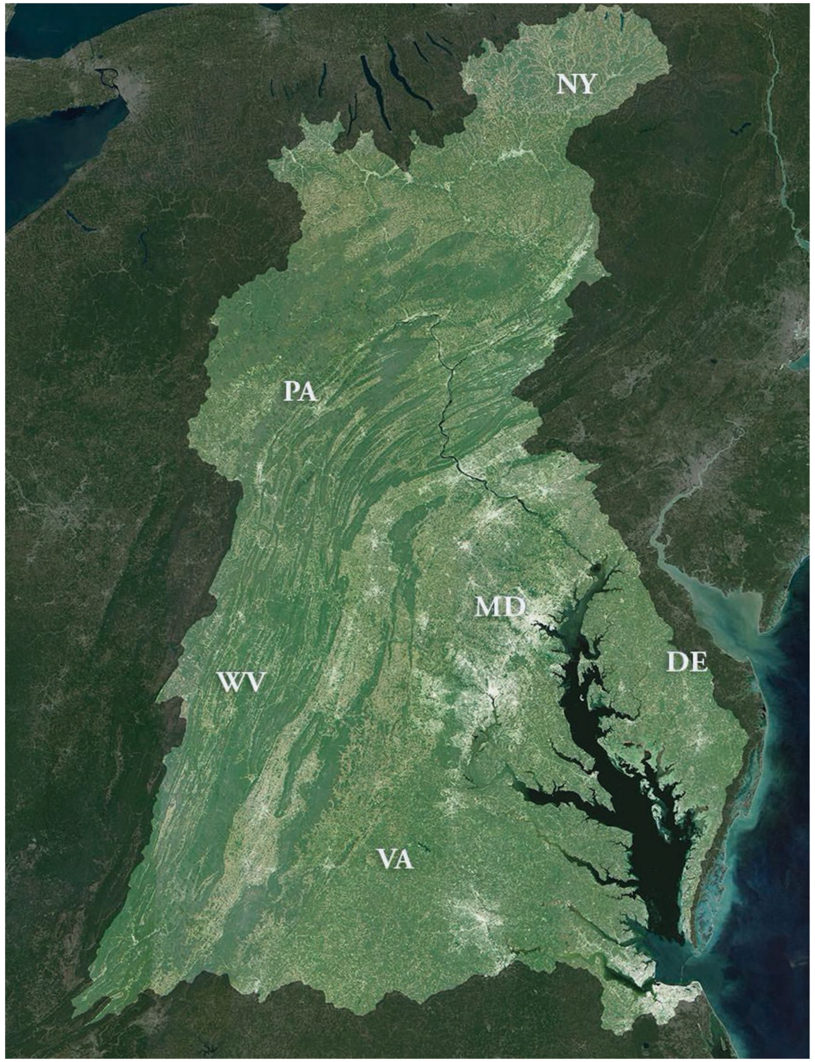


Chesapeake Bay Watershed
Credit: Kmusser

Chesapeake Bay

- Area of watershed: ~165,760 km^2 (64,000 mi^2)
- Watershed drains 5 geologic provinces: Appalachian Plateau, Valley and Ridge, Blue Ridge, Piedmont, and Coastal Plain
- Largest rivers in the watershed: Susquehanna, Potomac, James, Rappahannock, and York
- More than 18 million people live in the Chesapeake Bay watershed.

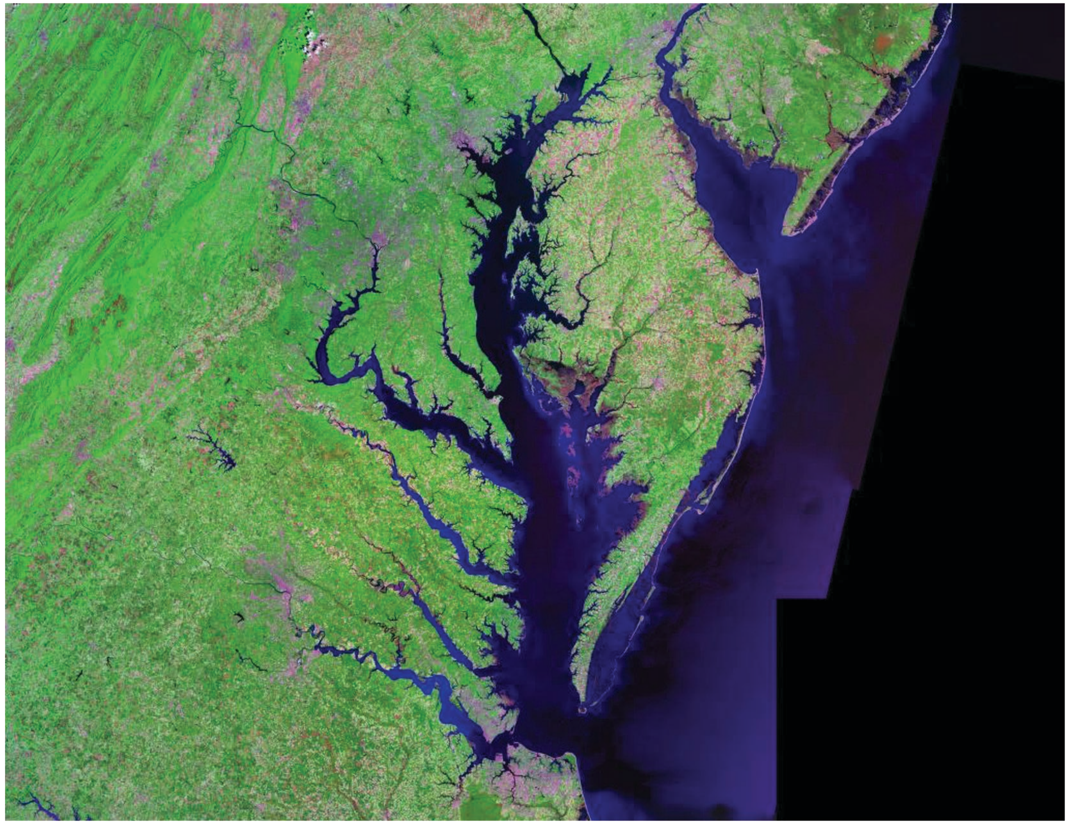
https://www.chesapeakebay.net/discover/watershed



Chesapeake Bay Watershed
Credit: NOAA

Chesapeake Bay

- Before Europeans arrived, there were several confederations of tribes in the region and the dominant group were eastern-Algonquian speakers.
- The word *Chesepiooc* is an Algonquian word referring to a village "at a big river."
- Communities lived close to water bodies where they hunted, fished, and farmed beans, maize, tobacco, and squash.
- Tens of thousands of people who identify as American Indian live in the Chesapeake region today.



Landsat Imagery of the Chesapeake Bay
Credit: NASA

Chesapeake Bay

- The Bay supports more than 300 species of fish, shellfish, and crab.
- During the winter, the Bay supports 87 species of waterbirds.
- Nearly one million waterfowl winter on the Bay – approximately one-third of the Atlantic coast's migratory population.
- Approximately 284,000 acres of tidal wetlands grow in the Chesapeake Bay region.

https://www.chesapeakebay.net/discover/facts

The Choptank Wetlands Preserve on the Choptank River (MD)
Credit: Chesapeake Bay Program

Chesapeake Bay

- Submerged aquatic vegetation (SAV) is a critical part of the Bay ecosystem. It provides wildlife with food and habitat, oxygenates water, absorbs nutrient pollution, traps sediment, and reduces erosion.
- Higher than average precipitation can push nutrient and sediment pollution into the Bay and its tributaries, impacting SAV growth.
- SAV acts as a measure of Bay health.

Submerged aquatic vegetation on the Susquehanna Flats (MD)
Credit: Chesapeake Bay Program

https://www.chesapeakebay.net/issues/bay_grasses

Chesapeake Bay

- Agricultural lands comprise nearly 30 percent of the watershed.
- Agriculture is the single largest source of nutrient and sediment pollution.
- Excess nutrients and sediment adversely affect water quality in the bay and its tributaries.
- Agricultural practices – including over-irrigating, over-tilling, and over-applying fertilizers and pesticides contributes nitrogen, phosphorus, and sediment to the Bay.

Sediment Runoff in Agricultural Field
Credit: USDA

https://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/national/programs/initiatives/?cid=stelprdb1047323
https://www.chesapeakebay.net/issues/agriculture

Chesapeake Bay

- Nitrogen and phosphorous are the two nutrients of concern in the watershed. They reach the Bay from three sources: wastewater treatment plants; urban, suburban, and agricultural runoff; and air pollution.
- Nutrients that run off the land and into the water through urban, suburban, and agricultural runoff come from a range of sources, including lawn fertilizers, septic systems, and livestock manure.
- Air pollution emitted by cars and trucks, industries, gas-powered lawn tools, and other sources contribute significantly to the total nitrogen load entering Chesapeake waterways.

https://www.chesapeakebay.net/issues/nutrients

Discharge Pipe
Credit: USDA

Chesapeake Bay

- More than three-quarters of the Chesapeake Bay's tidal waters are considered impaired by chemical contaminants.
- A 2010 report from the U.S. Environmental Protection Agency (EPA) found the extent and severity of mercury contamination to be widespread in the watershed.
- Chemical contaminants into the Bay and its tributaries come from agricultural runoff, stormwater runoff, wastewater, and air pollution.

Water Pollution
Credit: Lamiot

https://federalleadership.chesapeakebay.net/ChesBayToxics_finaldraft_11513b.pdf
https://www.chesapeakebay.net/issues/nutrients

Chesapeake Bay

- Since the seventeenth century, watershed-wide changes in land use and land cover have disrupted the natural processes of erosion.
- In the watershed, river basins with the highest percentage of agricultural lands yield the highest amount of sediment each year.
- Eroding shorelines and nearshore areas are also contributing to higher amounts of sediment discharge into the Bay.
- Sediment blocks light from reaching submerged aquatic vegetation, impacting aquatic health.

https://www.chesapeakebay.net/issues/sediment

Influx of Sediment from the Susquehanna River into the Chesapeake Bay
Credit: NASA

Chesapeake Bay

- Between 1982 and 1997, the watershed lost more than 750,000 acres of forestland to development – a rate of about 100 acres per day.
- 60% of the region's forests have been divided by roads and subdivisions. Fragmented forests are less resilient to disturbances and more prone to wildfires and invasive species.
- Development is linked to air and water quality. As we build more roads and homes and disturb more parcels of land, we create more pathways that send pollutants into our air and water.

Suburban Sprawl in Baltimore, MD
Credit: David Wilson

https://www.chesapeakebay.net/issues/development

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Background: Río de la Plata

Río de la Plata

- Formed by the confluence of the Uruguay River and the Paraná River
- Widest estuary in the world, with a maximum width of 220 km (140 mi)
- Principal sub-basins in the watershed: Paraná River, Paraguay River, and Uruguay River
- Transboundary river basin covers parts of 5 countries:
  - Bolivia
  - Brazil
  - Paraguay
  - Uruguay
  - Argentina

Río de la Plata drainage basin
Credit: Kmusser

Río de la Plata Basin

- Area of basin: 3,170,000 km^2 (1,220,000 mi^2)
- Second largest drainage basin in South America (after Amazon)
- Bounded to the west by the Andes Mountains and to the northeast and the east by the Brazilian Plateaus and the Serra do Mar, respectively
- Itaipu Reservoir in the Paraná River is the largest dam in the basin and has largest hydroelectric plant in the world
- Groundwater system from within the Basin provides recharge for the Guarani Aquifer, one of the largest groundwater reservoirs in the world

Río de la Plata Drainage Basin

Río de la Plata Basin (Pre-European History)

- Before Europeans arrived, the northern basins of the Alto Paraná and Paraguay rivers were inhabited primarily by Guayacurú- and Bororo-speaking peoples.
- Nomadic hunter-gatherers roamed Mato Grosso and the Pantanal.
- To the south, along the Paraguay and Alto Paraná rivers, the Guaraní occupied semi-permanent villages and cleared patches of surrounding forest for the cultivation of maize, cassava, and other crops.

Iguazu Falls, Misiones Province, Argentina
Credit: Enaldo Valadares

Chapada dos Guimarães, Mato Grasso, Brazil
Credit: Edmilson Sanches

Río de la Plata Basin (Pantanal)

- Pantanal is a region in the upper Paraguay basin encompassing the world’s largest tropical wetland area, and world's largest flooded grasslands.
- Pantanal supports a biologically diverse collection of aquatic plants and animal species.
- Approximately 99% of the land in the Pantanal is privately owned for agriculture and ranching.
- Sediment run-off from deforested highlands alters soil hydrology.
- Pollution from sewage systems and pesticides runoff to the flood plains.

Pantanal (highlighted area), South America
Credit: NASA World Wind

Pantanal highlands, Mato Grasso, Brazil
Credit: Filipefrazao

Río de la Plata Basin (Gran Chaco)

- Gran Chaco is the second largest biome in South America.
- It is a hot and arid alluvial plain located east from the Andes mountain range, formed by the deposit of sediments.
- One of the continent's last frontiers; agricultural expansion, driven by cattle and soy production, is the biggest threat to the natural ecosystems of the Gran Chaco.
- From 2010 to 2012, the Chaco lost native vegetation at an average rate of more than an acre per minute.

https://www.worldwildlife.org/places/gran-chaco

Gran Chaco
Credit: Terpsichores

Río de la Plata Basin (Pampas)

- Pampas plains have the most fertile soils in the Río de la Plata basin.
- It is one of the most extensive grassland regions in the world.
- Pampas area: 1,200,000 km ^{2} (460,000 mi^2)
- Most native vegetation has been replaced by agriculture and cattle ranching.
- It contains 90% of Argentina's grain production and 48% of the cattle stock.

Pampas (highlighted in green)
Credit: GumSkyloard

Ares, Varni, & Chagas, 2020. https://doi.org/10.1002/hyp.13782

Río de la Plata

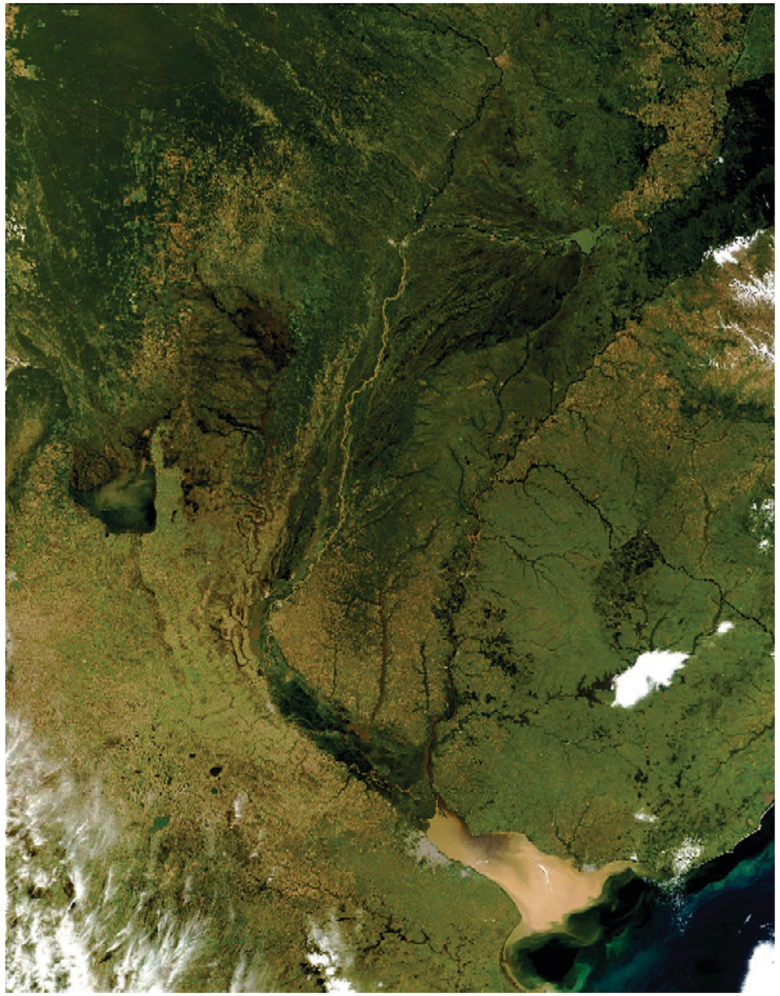
- Urban centers of Argentina and Uruguay are set along the shores of the Río de la Plata, where 12.8 million people live in Buenos Aires and its metropolitan area.
- High urbanization and industrialization concentrated on the inner zone of the estuary generates pollutants (e.g., nutrients, organic matter, effluent sewage) that pose a threat to biota and human health.
- Dredging and modification of coastal wetlands have altered the morphology of the coast, interfering with the integrity of the physical habitat and biological processes.

Río de la Plata
Credit: NASA

Sathicq et al., 2017. https://doi.org/10.1016/j.csr.2016.08.009

Río de la Plata

- Main drivers impacting aquatic ecosystems in Río de la Plata:
  - Industry
  - Deforestation
  - Sedimentation
  - Nutrient Runoff
  - Irrigation Projects
  - Population Growth
  - Intensive Agriculture
  - Construction of Dams & Reservoirs



Credit: NASA

FAO, 2016. Transboundary River Basin Overview – La Plata.
http://www.fao.org/3/ca2141en/CA2141EN.pdf

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Demonstration of MODIS and VIIRS Water Quality Monitoring for the Chesapeake Bay and Río de la Plata

Summary

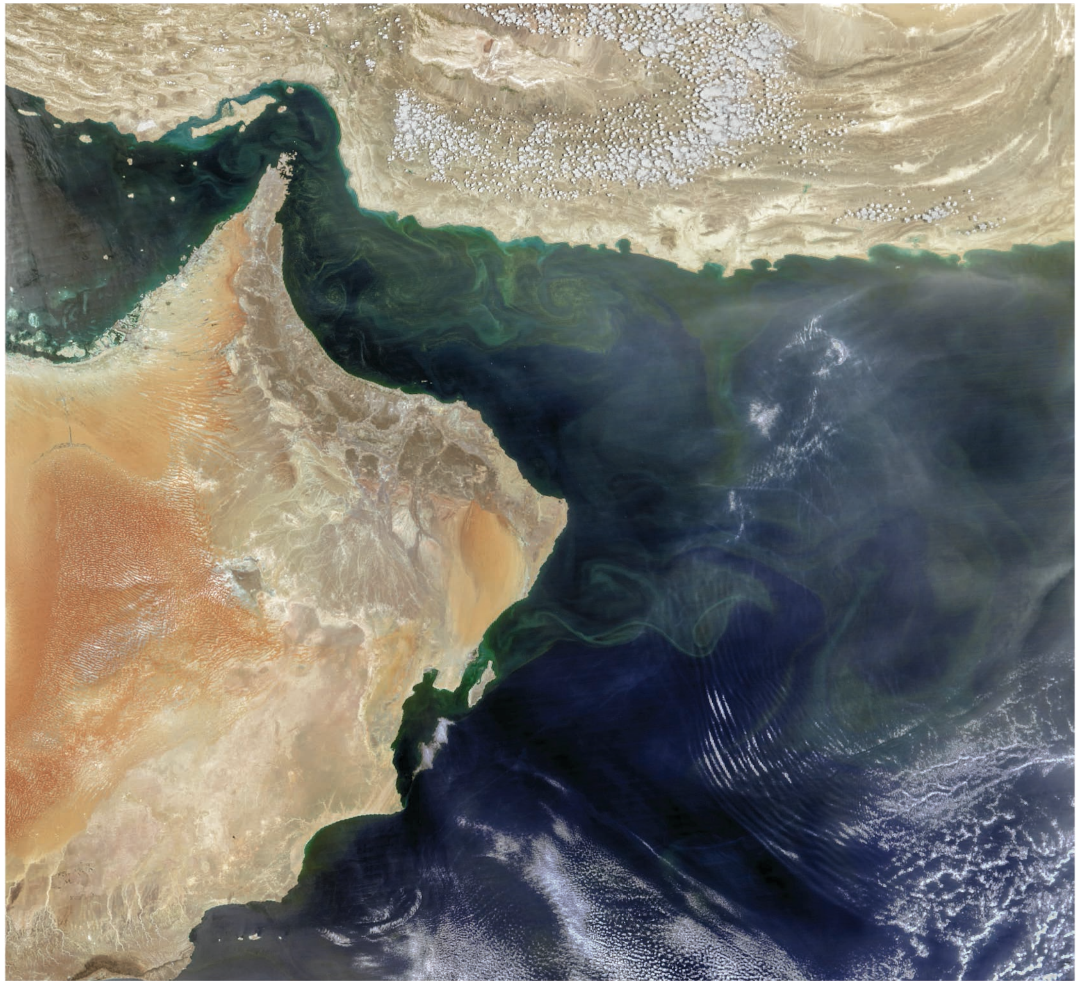
- This training focused on learning:
  - MODIS and VIIRS image processing for water quality monitoring using NASA SeaDAS/OCSSW software.
  - Comparison of selected water quality parameters from MODIS and VIIRS for two regions, the Chesapeake Bay and Rio de la Plata.
  - From MODIS and VIIRS Level-1 images chlorophyll-a concentration, SST, PIC, POC, and CDOM Index (Morel and Gentili, 2009) were obtained using OCSSW/l2gen.
  - SeaDAS image processing features to geolocate, calibrate, spatial subset, collocate, and to conduct band math were introduced.
  - MODIS and VIIRS chlorophyll-a concentration and SST were compared, as indicators of algal bloom that may lead to hypoxia.
- Sample images from July 2021 showed that MODIS and VIIRS chlorophyll-a and SST in the Chesapeake Bay and Rio de la Plata show reasonable overall agreement, but in shallow, turbid waters the differences are substantial and require further investigation and understanding.

Summary

- VIIRS images show striping due to "bow tie" deletion and image striping, associated with multidetector arrangement (Liu et al., 2013) and images must be corrected (Mikelsons et al., 2014) before use.
- Primarily, water quality data retrievals are missing due to presence of clouds, and also in shallow and turbid waters.
- Detailed comparison of MODIS and VIIRS water quality parameters on daily to seasonal time scales are required for assessing, adjusting, and extending the MODIS water quality time series with VIIRS water quality parameters.
- The current algorithms use global coefficients. For better estimation of water quality, accurate algorithm development and validation with systematic, regional in situ data and proper atmospheric correction are required.
- ARSET is planning an advanced webinar with hands-on exercises to develop regional algorithms for retrieving water quality parameters from MODIS and VIIRS together with available in situ data.

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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- 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

Thank You!