Chesapeake Community Research Symposium 2024
Session 10: Applications of remote sensing for water quality management

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Assessing Satellite Ocean Color Datasets in the Chesapeake Bay: A Comparative Study with AERONET-OC

Satellite remote sensing can provide resource managers with an additional tool for monitoring water quality over broad areas. However, these products are limited by how accurately measurements of variables at the water's surface can be derived from satellite observations. Coastal, turbid water bodies such as the Chesapeake Bay are especially challenging targets due to frequent cloud cover, complicated atmospheric correction, and land adjacency, which limits the availability of valid aquatic data at the land-water interface. We employ above water radiometry measurements from the new Chesapeake Bay node of the Aerosol Robotic Network with Ocean Color (AERONET-OC). We compare these data with diverse satellite ocean color datasets, considering variations in spatial resolution, atmospheric correction algorithms, and other processing techniques to evaluate the impact of these factors on the quality and consistency of ocean color retrievals. These findings will contribute to a larger project that fuses multiple in situ and satellite data products in a machine learning architecture for coastal water quality application.

Michelle C. Tomlinson, Elizabeth A. Staugler, Jennifer Maucher Fuquay, Nia Rene, Catherine E. Wazniak, Richard P. Stumpf and Kaytee L. Pokrzywinski

Monitoring Harmful Algal Blooms, improving resolution through remote sensing and community scientists

A SeaGrant workshop, “Applying novel techniques to assess and forecast harmful algal blooms to protect fisheries, aquaculture and human health” was conducted in January 2023. The goals were to better understand how HABs affect agency and industry operations, explore how satellite imagery is currently being used, and what needs could be met via satellite and forecasting information. To improve monitoring and forecasting information on HABs in Chesapeake Bay, the next steps include: 1) exploring citizen science monitoring opportunities, 2) involving interested industry partners in community science to collect samples, and 3) improving spatial resolution of satellite products, to improve monitoring in narrow coastal regions.
The National Centers for Coastal Ocean Science (NCCOS) has been delivering satellite imagery to resource managers in MD and VA since 2016. Several algorithms applied to the Sentinel-3 Ocean and Land Colour Imager (OLCI) have improved bloom detection at 300 m spatial resolution, however, species-level information is reliant on state phytoplankton monitoring programs. Budget constraints and limited temporal/spatial resolution have

constrained sampling and the data are often insufficient for real-time validation of satellite and modeling efforts. As a result, NCCOS has increased efforts to collect additional phytoplankton samples through the expansion of NOAA's Phytoplankton Monitoring Network to Chesapeake Bay. Collaboration with Maryland DNR and the Bay's aquaculture community has extended sampling in important coastal regions affected by HABs. Efforts are underway to improve satellite observing capabilities by evaluating the use of higher spatial and spectral resolution satellites, such as Sentinel-2, which will provide more information on blooms in narrow coastal regions where aquaculture activities are located. NCCOS is also exploring the use of higher spectral resolution to separate phytoplankton groups, to improve information about potential toxicity of blooms in anticipation of new hyperspectral satellite products.

Xin Yu, Michelle C. Tomlinson, Jian Shen, Yizhen Li, Alexandria G. Hounshell, Kimberly S. Reece

Combining satellite imagery and numerical modeling to simulate Margalefidinum polykrikoides blooms in the York River estuary

Remote sensing technology for detecting harmful algal blooms (HABs) provide a robust approach to combine numerical modeling and satellite data to track and predict HABs in estuarine and coastal waters. We developed a particle-tracking model using a high-resolution hydrodynamic model capable of simulating algal growth and respiration, to successfully simulate the spatial distribution and intensity of a Margalefidinium polykrikoides (M. polykrikoides) bloom in the lower York River, USA, where HABs have occurred almost every year over the past decade. Particle release location and density were determined using chlorophyll-a concentrations obtained from Ocean Land Colour Imager (OLCI) satellite imagery. We used summer of 2022 (August to September) to assess model performance as the bloom lasted for nearly two months and numerous high-quality low-cloud cover satellite images were available for model initiation and validation. We found that the use of satellite data as initial conditions for simulating the HAB in the particle tracking model was crucial for model performance. In addition, a series of model experiments were carried out to understand model sensitivity to different optimal growth temperature and phytoplankton subsurface aggregation. Overall, model results show that a combined numerical modeling and satellite remote sensing approach is an effective way to track HABs in coastal and estuarine waters. The approach provides a framework to forecast HAB movements and intensities for coastal managers in the future.

Morgaine McKibben, Stephanie Schollaert Uz, Sherry Palacios

Testing a hyperspectral, bio-optical approach for identification of phytoplankton groups in estuarine waters

The multi- to hyperspectral evolution of satellite ocean color sensors is anticipated to enable satellite-based identification of phytoplankton biodiversity, a key factor in aquatic ecosystem functioning and upper ocean biogeochemistry. In this work the bio-optical Phytoplankton Detection with Optics (PHYDOTax) approach for deriving taxonomic (class-level) phytoplankton community composition (PCC, e.g. diatoms, dinoflagellates) from hyperspectral information is evaluated in the Chesapeake Bay and Long Island Sound estuaries on the U.S. East Coast. PHYDOTax is among relatively few optical-based PCC differentiation approaches available for optically complex waters, but it has not yet been evaluated beyond the California coastal regime where it was developed. Study goals included: 1) developing approaches to adapt PHYDOTax to turbid estuarine waters; and 2) performance and sensitivity assessments with both synthetic mixture and field datasets. Sensitivity to three hyperspectral resolutions (1nm, 5nm, 10nm) was low for all field and synthetic datasets. Algorithm skill was robust on synthetic mixture datasets but variable on field datasets. Project results are summarized and the implications of variability in performance across the field datasets are discussed.

Nima Pahlevan, William Wainwright, Akash Ashapure, Navid Golpayegani, Akash Ashapure, Brandon Smith, Ryan O'Shea, Sakib Kabir, Arun Saranathan

STREAM – A satellite-based water-quality monitoring system for effective assessment of water quality

Coastal resources are prone to intertwined effects of climate variability and anthropogenic stressors. With their massive societal and economic benefits through fisheries, aquaculture, and recreation, it is imperative for decision-making entities to integrate the highest-quality data and observations into decision support systems, thereby enhancing coastal management and monitoring. This is particularly critical in resource-constrained regions and areas frequently struck by extreme weather patterns for pre- and post-event recovery. To further enrich existing observational capabilities, we have developed a near-real-time data processing system that ingests, processes, and displays water quality (WQ) maps (i.e., chlorophyll-a, transparency, total suspended solids) from high-resolution imagery (10 – 30 m) of Landsat and Sentinel-2 missions. This web-based platform, STREAM (a satellite-based analysis tool for rapid evaluation of aquatic environments), offers globally validated WQ products developed using a processing engine that relies on a machine-learning model. For its interface, we harness various tools and capabilities that have already been developed as part of NASA's near-real-time data processing systems (e.g., Fire Information for Resource Management System). It allows end-users to visualize WQ maps, identify pixel values, and view time-series plots for a given pixel or a region. STREAM will enable low-latency (< 6 hours) detection of anomalous WQ conditions for robust and timely decision-making. The system is currently live and supports processing at select regions.

David Parrish, Cassia Pianca, Carl Friedrichs, William Reay

Exploring the Use of Dataflow Water Quality Monitoring Platform to Calibrate Multispectral Satellite Imagery to Estimate Surface Water Clarity and Turbidity

Since 2003, the Chesapeake Bay National Estuarine Research Reserve in Virginia (CBNERR-VA) has deployed its Dataflow platform for measuring surface water quality conditions in cooperation with the Virginia Department of Environmental Quality (VADEQ).

Dataflow operates effectively on small boats moving at speeds of approximately 25 KT, enabling sampling every 2-3 seconds and generating samples at intervals of about 25m. Each Dataflow cruise yields thousands of water quality measurements.

In 2024, CBNERR-VA is partnering with VADEQ to strategically target the timing of Dataflow measurements to align with overpasses by multispectral satellites. This effort aims to calibrate satellite imagery, enhancing our capability to more broadly characterize spatial variations in surface water turbidity and clarity within the tidal regions of the Chesapeake Bay. In support of this effort, this presentation explores empirical relationships between water quality measurement and paired multispectral data using the historical CBNERR-VA Dataflow record.

Suzanne Bricker, Varis Ransibrahmanakul, Katherine Okada, Erik Davenport, Renee Karrh, Ronald L. Vogel, Travis Briggs, and Michelle Tomlinson

Can satellite data products or state monitoring program data be substituted for on-farm in situ data for Oyster Aquaculture Modeling?

Chesapeake Bay and its tributaries have experienced moderate to severe eutrophication impacts due to nutrient inputs (nitrogen, phosphorus) from wastewater, urban and agricultural runoff, and atmospheric deposition. Oyster aquaculture is a promising innovative nutrient management strategy, in combination with traditional strategies, because bivalves remove nutrients from the water as they feed. Models are used to estimate nutrients removed by oysters; model driver requirements include monthly water quality data (temperature, salinity, chlorophyll-a (Chl), particulate organic matter, total particulate matter) for at least one year. Field sampling and lab analyses are time and resource intensive. Alternative less costly methods of data collection or use of data collected for other purposes was investigated.

Existing satellite-derived Chl products, and monthly water quality data at the closest long-term monitoring station collected by Maryland Department of Natural Resources (MD DNR) were compared with on-farm data sampled from two oyster farms in MD Chesapeake Bay in Chester River and North Tangier Sound. Satellite Chl, MD DNR, and on-farm data compared well. Model estimated oyster production (harvest) using MD DNR and on-farm data as model inputs at a Chester River farm show no significant difference in results (metric tons oysters + standard deviation: 18+4.5 on-farm, 21+3.5 MD DNR). Results with substitution of on-farm Chl with satellite Chl were also not different (17+5.3). There was also no significant difference among model estimated harvests for a North Tangier Sound oyster farm (metric tons oysters + standard deviation: 35+12.9 on-farm, 35+13.0 MD DNR, 26.3+13.1 satellite). The analysis suggests that MD DNR data and satellite Chl can be substituted for on-farm data, saving time and resources while providing needed information for resource managers and the shellfish industry on potential oyster harvest and associated nutrient removal.

Peter Tango

Options and Opportunities with Advanced Water Quality Monitoring Using Remote Sensing: A Summary of a 2022 Chesapeake Bay Program Scientific Technical Advisory Committee Workshop

The Chesapeake Bay Program measurement and reporting of bay health has depended on a fixed-point tidal water quality monitoring network of water column sampling with biweekly to monthly temporal densities in offshore habitats since 1985. High temporal density (15-minute) fixed-site nearshore monitoring intensified in the late 1990s. Underway boat sampling featuring spatially-intensive data collection with DATAFLOW technology complemented the fixed site efforts. In spite of significant opportunities to use remote sensing to support decision making on water quality management, few management decisions relied on satellite-derived products. High-resolution (i.e., <1m2 imaging) remote sensing of water quality measures for annual bay health assessments have largely been limited to the Virginia institute of Marine Science annual Submerged Aquatic Vegetation (SAV) survey using fixed-wing aircraft and hyperspectral camera imaging; satellite imagery has recently been used to complement annual surveys and filling data gaps. Barriers for EPA managers in applying satellite-based image assessment results in water quality assessments were described from a qualitative survey highlighted by Schaeffer et al. (2013) included cost, product accuracy, data continuity, and programmatic support. In the last decade these concerns have largely been addressed, however, the degree of utility for managers for baywide seasonal to annual water quality assessments using satellite-based sensor data depends on the parameter of interest. During the workshop, presentations described the status of applicability for satellite-based remote sensing data ranging from proof-of-concept demonstrations where further research and development are needed for habitat assessment (e.g., kd) to published applications showing effective monitoring capacity in diverse estuaries (e.g., submerged aquatic vegetation, chlorophyll, HABs). The workshop focused on understanding the status of accessible satellite-based remote sensing data and products to enhance habitat assessment capacity and support Chesapeake Bay Program monitoring needs with annual dissolved oxygen, water clarity (kd), SAV, and chlorophyll. The presentation will summarize workshop findings.