Advancing Monitoring Approaches to Enhance Tidal Chesapeake Bay Habitat Assessment Water Clarity and SAV, Chlorophyll a and Dissolved Oxygen

Peter Tango USGS@CBPO

on behalf of our workshop committee

STAC Workshop Summary

March 5-6, 2024

Thank you’s!

- STAC for workshop support

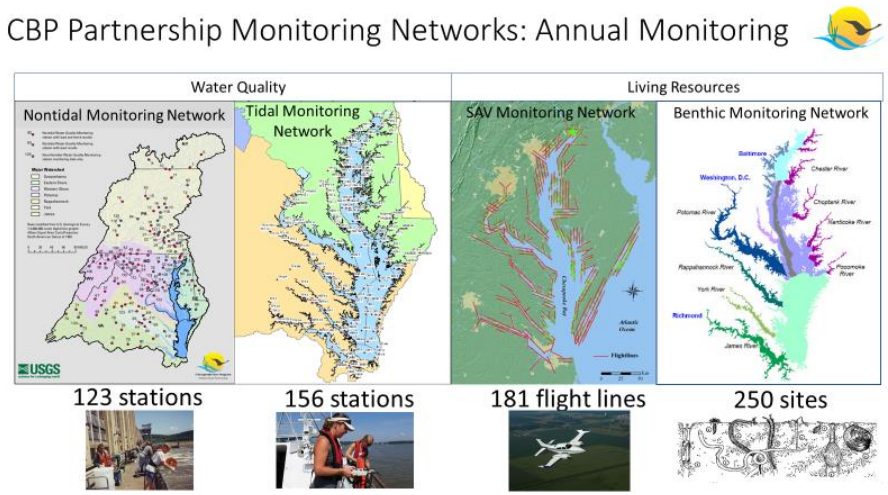
- Meg Cole, Tou Matthews for meeting organization, report support, and moral support ☺. (You rock!)

- Committee support:
  - Peter Tango USGS@CBPO Chair
  - Brooke Landry MD DND,
  - Mark Trice MD DNR,
  - Breck Sullivan USGS@CBPO,
  - Tish Robertson VADEQ
  - Bill Dennison UMCES, STAC 2023

2021 Monitoring Review Needed

- **March 2, 2021. Principal Staff Committee request:**
  - Provide information to improve CBP monitoring networks, including: (1) Current status and threats to the networks, (2) what is needed to improve the monitoring networks.

Challenges

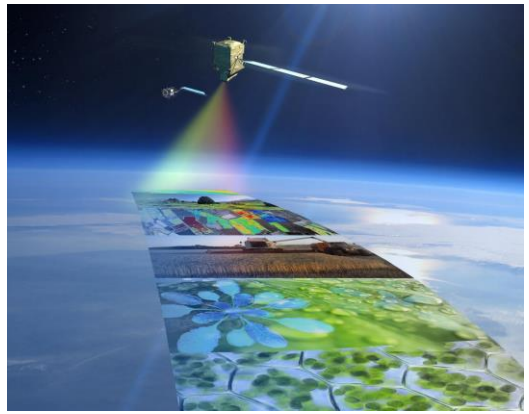


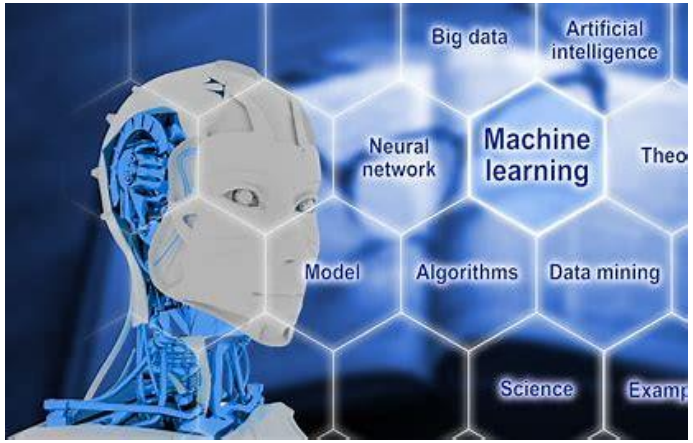
- **TMDL related, Water quality standards** – Since the publishing of Chesapeake Bay criteria on dissolved oxygen, SAV/Water Clarity and Chlorophyll *a* in USEPA (2003), **0 of 92** segments have ever been fully assessed in any assessment period with our existing investments in traditional monitoring and evaluation.

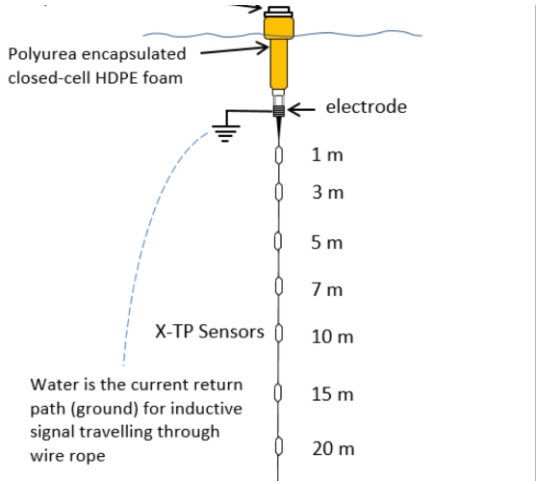
- We need to address capacity.
- We need to adapt our program.

Workshop Structure: 3 sessions

- **December 9, 2021:**
  - **SAV-focused monitoring and assessment**
- **April 22, 2022:**
  - **Water clarity/CHLA focus monitoring and assessment**
- **May 11, 2022:**
  - **Dissolved oxygen focus monitoring and assessment**







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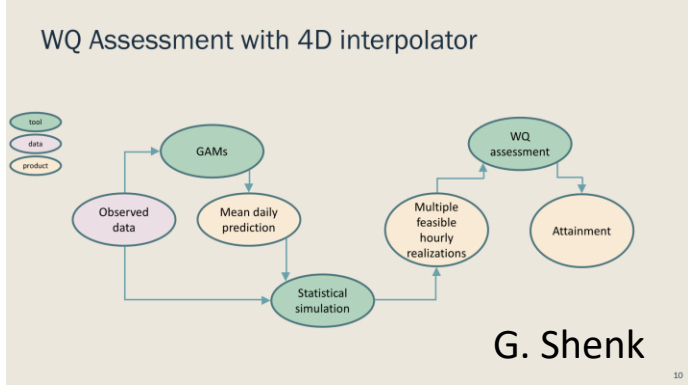
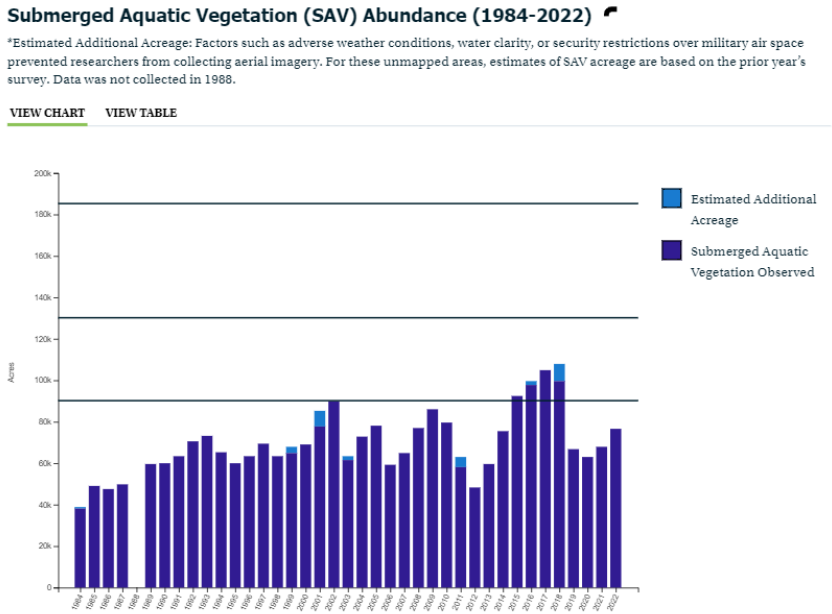


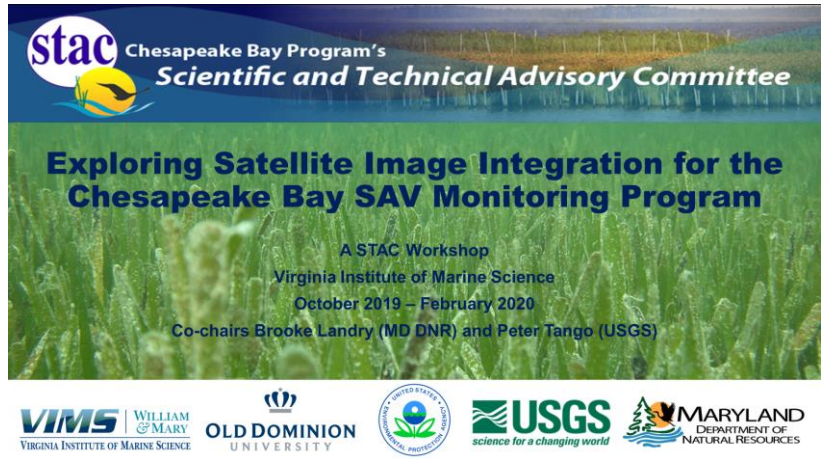
Session 1 SAV
SAV Background

- VIMS SAV survey had roots in work before the CBP was born – quintessential indicator of bay health since 1985.

- 2018 – Wet weather year – satellite imagery is used to supplement SAV survey results where transects could not be acquired with fixed wing aircraft monitoring

- 2019-20 STAC Workshop
  - Recommendations led to support for a test case of acquiring imagery where and when it was needed
    - Needed a report out venue
  - EPA and ODU researchers were making rapid advances with new satellite resources
    - Needed a report out venue





Session 1
Workshop Findings

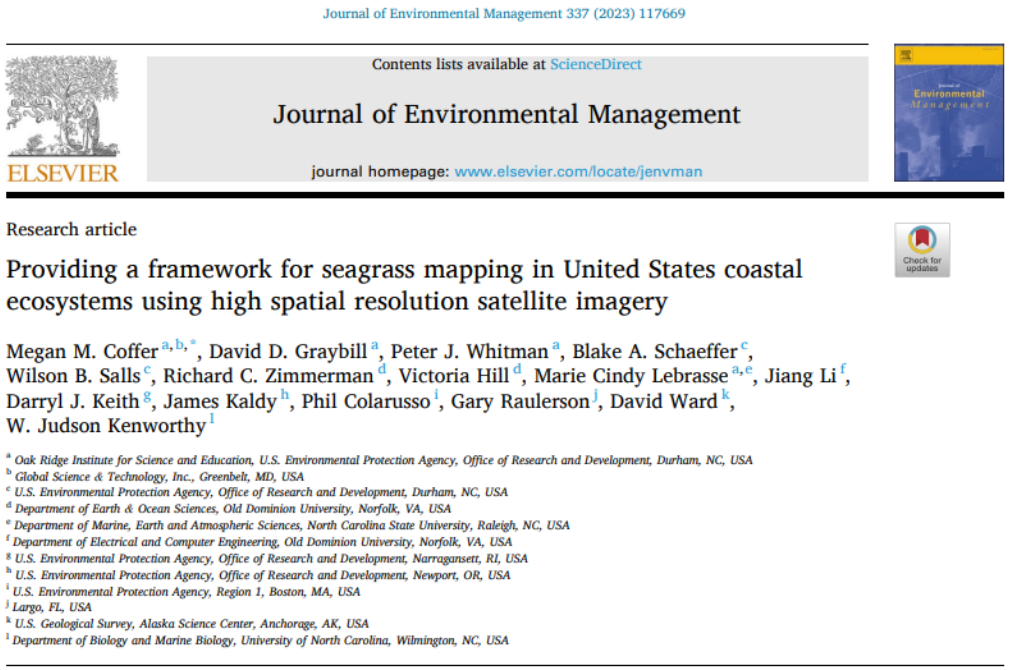
- Maxar (Digital Globe) – VIMS reports limited success in tasking the satellite for site and time specific assessment of bay grasses as a monitoring program effort.
- However, significant advances were being made using other satellite-based data with AI based interpretive algorithm support provided by these colleagues during the workshop:

Quantification of Blue Carbon Burial in Seagrass Ecosystems from High Resolution Commercial Imagery — *Victoria Hill (ODU)*

Automating the Quantification of Submerged Aquatic Vegetation from High Resolution Satellite Imagery — *Dick Zimmerman (ODU)*

- Review of new research at Old Dominion University (ODU) on the possibilities of mapping SAV in the Chesapeake Bay using satellite-acquired data and AI.

Satellite Derived Seagrass Update — *Megan Coffer, David Graybill, Cindy Lebrasse, Wilson Salls, Peter Whitman, Blake Schaeffer, Victoria Hill, Richard Zimmerman*



Journal of Environmental Management 337 (2023) 117669

Contents lists available at ScienceDirect

Journal of Environmental Management

journal homepage: www.elsevier.com/locate/jenvman

Research article

Providing a framework for seagrass mapping in United States coastal ecosystems using high spatial resolution satellite imagery

Megan M. Coffer [a,b,*], David D. Graybill [a], Peter J. Whitman [a], Blake A. Schaeffer [c], Wilson B. Salls [c], Richard C. Zimmerman [d], Victoria Hill [d], Marie Cindy Lebrasse [a,e], Jiang Li [f], Darryl J. Keith [g], James Kaldy [h], Phil Colarusso [i], Gary Raulerson [j], David Ward [k], W. Judson Kenworthy [l]

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[e] Department of Marine, Earth and Atmospheric Sciences, North Carolina State University, Raleigh, NC, USA
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[g] U.S. Environmental Protection Agency, Office of Research and Development, Narragansett, RI, USA
[h] U.S. Environmental Protection Agency, Office of Research and Development, Newport, OR, USA
[i] U.S. Environmental Protection Agency, Region 1, Boston, MA, USA
[j] Largo, FL, USA
[k] U.S. Geological Survey, Alaska Science Center, Anchorage, AK, USA
[l] Department of Biology and Marine Biology, University of North Carolina, Wilmington, NC, USA

Session 1 Workshop Recommendations (12)

Monitoring

- Continue aerial survey at this time, supplement with satellite-imagery as necessary
- Support calibration and verification for all data sources

Research

- Develop workflow for using satellite-based imagery in a monitoring framework for the bay from acquisition through interpretation and reporting with new satellite resources
- Calibrate new approaches to historic time series

Management

- Build relationships and agreements needed to access and acquire satellite imagery for low cost/free.

Policy

- With protocol development for satellite-based SAV cover assessment is achieved, developing documenting of protocols will need EPA approval
- Upon EPA approval and publication of the methods, it will be recommended for State adoption of methods for water quality standards attainment analysis by State agencies to provide options and benefits to each jurisdiction and the Bay community.

Subsequent actions 2022-23

- Workshop findings informed PSC Monitoring Review recommendations for developing satellite-based SAV survey support
- EPA developed an RFA for protocol develop of the workflow; proof of concept over a large region of Chesapeake Bay
- 2 year award was made in early 2023

Enhancing the Chesapeake Bay Program Monitoring Networks
A Report to the Principals' Staff Committee

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SAV	Gathering Satellite Imagery
Funder	
SAV	Develop SAV protocols for AI interpretation of diverse satellite imagery
Funder	
SAV	Develop SAV protocols to convert AI produced maps to layers like those manually created
Funder	
SAV	Calibrate and align the use of aerial images and satellite images

SAV	Proof of Concept: Test AI satellite-derived assessment on spring *Zannachelia* survey
Funder	
SAV	Management of Sentinel Site Monitoring Program
Funder	
SAV	SAV Monitoring Program 5% COLA
Funder	

Session 2 Water Clarity/CHLA Background

- Point sample, DataFlow, Conmon resources are used today to support water quality criterion and other habitat assessments
- **Water Clarity**: Program lacks for simultaneous high temporal and spatial resolution assessment at the bay-wide scale within a year.
    - It took >20 years to evaluate all 92 segments using water clarity measures separate from the SAV survey.
- **CHLA**: Only the James River VA and 2 bay segments in DC have quantitative criteria, most of the bay is not subject to quantitative criteria for chlorophyll *a through the published bay criteria (USEPA 2003)*
    - *Can we make baywide intra-annual chla assessments at high temporal and spatial resolution?*
    - *Can we have a quantitative translation of narrative criteria?*

Session 2 Water Clarity Workshop Findings

Water Clarity

- Baywide, satellite-based water clarity assessment is feasible
- Accuracy has high uncertainty with the then present algorithms
- Calibration and verification information is needed

State Water Clarity Assessment Review

MD and VA Water Clarity Assessment — *Mark Trice (MD DNR), David Parrish (VIMS)*

DC Water Clarity Assessment — *Nicoline Shulterbrandt (DOEE)*

Resources and Insights for Extending to Baywide Annual Clarity-related Analyses

Short and Long-term Station-specific Water Clarity Secchi Trends — *Rebecca Murphy (UMCES)*

Remote sensing of Water Clarity in the Chesapeake Bay: Advantages and disadvantages — *Jessie Turner (UConn and VIMS)*

Resources and Insights for Extending to Baywide Annual Clarity-related Analyses (Continued)

Merging Landsat-8, Sentinel-2, and in situ data to improve coastal water clarity monitoring — *Sarah Lang (University of Rhode Island)*

NOAA satellite-based Products for Chesapeake Bay Water Clarity—*Ron Vogel (NOAA Satellite Applications & Research / CoastWatch)*

Session 2 CHLA Workshop Findings

CHLA

- Research shows that chlorophyll *a* condition assessments using satellite-borne sensor data have advanced to allow for interannual change assessments at the baywide scale.
- Satellite-based time series analyses align time periods with in-situ Chesapeake Bay Program monitoring history for the first time, 1985 through to the present.
- Advances highlighted in the workshop are using free satellite-based data
- Advances in HAB species bloom detection for select species with satellite-based resources aligned with ground truthing efforts are occurring for Chesapeake Bay.

Open Access Article

Evaluating the Efficacy of Five Chlorophyll-*a* Algorithms in Chesapeake Bay (USA) for Operational Monitoring and Assessment

by Timothy T. Wynne [1,*], Michelle C. Tomlinson [1], Travis O. Briggs [1,2], Sachidananda Mishra [1,2], Andrew Meredith [1,2], Ronald L. Vogel [3,4] and Richard P. Stumpf [1]

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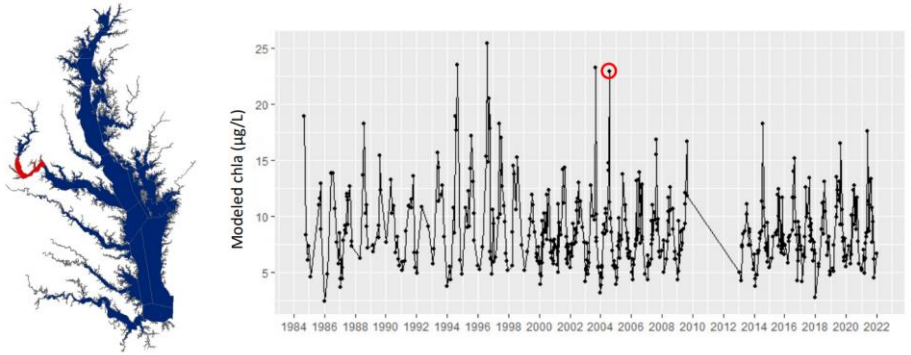
[2] Consolidated Safety Services, Inc., Fairfax, VA 22030, USA
[3] Cooperative Institute for Satellite Earth System Studies, Earth System Science Interdisciplinary Center, University of Maryland, College Park, MD 20740, USA
[4] National Oceanic and Atmospheric Administration, National Environmental Satellite, Data and Information Service, Center for Satellite Applications and Research, College Park, MD 20740, USA
* Author to whom correspondence should be addressed.

J. Mar. Sci. Eng. **2022**, *10*(8), 1104; **https://doi.org/10.3390/jmse10081104**

Submission received: 1 July 2022 / Revised: 4 August 2022 / Accepted: 6 August 2022 / Published: 12 August 2022

(This article belongs to the Special Issue **New Frontiers in Ocean Color Remote Sensing: Novel Applications, Sensor Fusion, and Hyperspectral Sensing**)

Potomac Chlorophyll Time-Series



Unpublished K. Wnuk USGS STAC Workshop, draft 2022
Landstat based CHLA
1984-2021

Session 2 Workshop Recommendations

Water Clarity

Monitoring

- Calibration and verification information is needed using increased Kd measurements across all habitats

Research

- Continue to improve the accuracy of algorithms

Session 2 Workshop Recommendations

Water Clarity

Monitoring

- Calibration and verification information is needed using increased Kd measurements across all habitats

Research

- Continue to improve accuracy of algorithms

CHLA

Monitoring and Management –

- Sustain existing long-term monitoring and shallow water monitoring program efforts that provide calibration and verification of the rapidly evolving satellite-based data products.

Research and Management –

- Given the groundbreaking work to develop annual baywide chlorophyll characterization with consistent protocols across decades, support is needed for work through workshop, action team or other venue bringing researchers, analysts and mangers together to align needs and expectations for a viable criteria assessment protocol from satellite-based data resources.

Session 2 Workshop Recommendations

CHLA continued

- **Policy**
  - Upon completion of protocol development for satellite-based chlorophyll a assessment, documentation will be provided for EPA approval of methods.

  - Upon EPA approval and publication of the methods, it will be recommended for State adoption of methods for water quality standards attainment analysis by State agencies will provide options and benefits to each jurisdiction and the Bay community.

Subsequent actions 2022-23

- Water clarity and CHLA recommendations from the STAC workshop were captured in general recommendations of the PSC Monitoring Report and acknowledged as monitoring program gaps.

- The gaps have not yet been translated with details into fundable project outlines with budget estimates

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Subsequent actions 2022-23

- It has been recognized that EPA has approved satellite-based CHLA-related protections for Ohio waters of Lake Erie, providing a road map for translating narrative to quantitative criteria using satellite-based data resources (Davis et al. 2019)

Harmful Algae 81 (2019) 59–64

Contents lists available at ScienceDirect

Harmful Algae

journal homepage: www.elsevier.com/locate/hal

Science meets policy: A framework for determining impairment designation criteria for large waterbodies affected by cyanobacterial harmful algal blooms

Timothy W. Davis[a,*], Richard Stumpf[b], George S. Bullerjahn[a], Robert Michael L. McKay[a], Justin D. Chaffin[c,e], Thomas B. Bridgeman[d], Christopher Winslow[c,e]

[a] Department of Biological Sciences, Bowling Green State University, Bowling Green, Ohio, 43403, USA
[b] National Oceanic and Atmospheric Administration, National Centers for Coastal Ocean Science, Silver Spring, MD, 20910, USA
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[d] Department of Environmental Sciences and Lake Erie Center, University of Toledo, Toledo, OH, 43606, USA
[e] Ohio Sea Grant College Program, The Ohio State University, 1314 Kinnear Rd., Research Area 100, Columbus, OH, 43212, USA

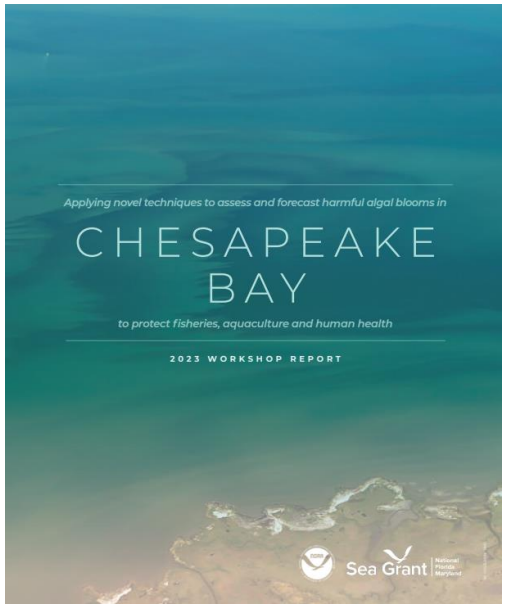
- There are notable advances by NOAA in HAB detections for Chesapeake Bay featured in the 2023 Chesapeake Bay workshop (FL Sea Grant)

SUGGESTED CITATION

Staugler, E.A., Stumpf, R.P., Tomlinson, M.C., Wakefield, K., Allen, M., Egerton, T., Musick, S., and Wazniak, C. (2023). Applying novel techniques to assess and forecast harmful algal blooms in Chesapeake Bay to protect fisheries, aquaculture and human health, workshop report. Gainesville, Fla.: Florida Sea Grant College Program.

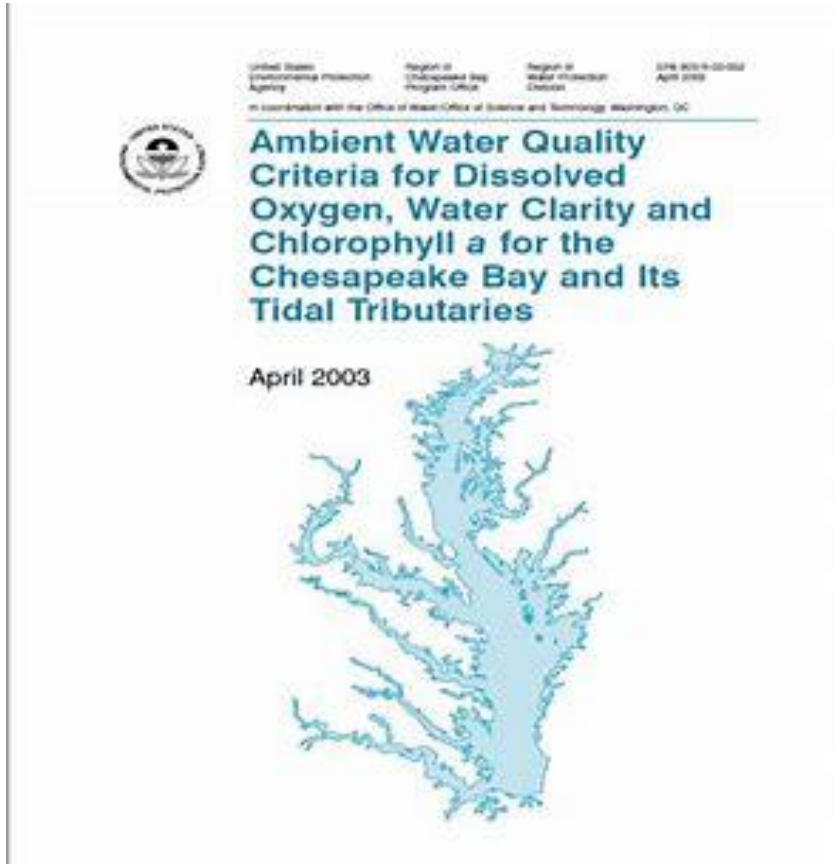
ACKNOWLEDGEMENTS

Peter Tango, USGS for helpful contributions and review



Session 3 Dissolved Oxygen Background

- USEPA 2003 – published new Chesapeake Bay dissolved oxygen criteria, recognized monitoring and assessment was not meeting all the assessment needs for the new criteria.
  - Recommended monitoring included segment based, water column monitoring in high temporal density to support short duration criteria assessment (i.e., instantaneous, 1-day means, 7-day means)
  - Diverse approaches were suggested for application to assessing the spatially and temporally diverse criteria



Why a 4D interpolator?

- **2007 STAC Workshop: Assessing the feasibility of developing a four-dimensional (4-D) interpolator for use in impaired waters listing assessment**

Why is the Chesapeake Bay Program interested in 4d interpolation?

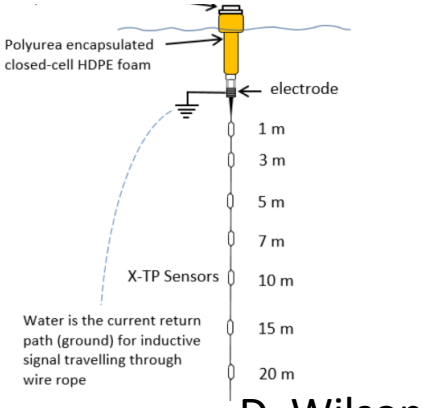
- To allow combining and integrating measurements from numerous disparate datasets
- To generate a more complete interpolation of available data in space and time.
- To improve the ability to evaluate water quality for the 303d listing process.

Curriero et al. 2008 STAC Workshop Report

2007 STAC Workshop consensus

- Sampling frequency (biweekly to monthly) is insufficient
- Spatial resolution of the existing Chesapeake Bay datasets is insufficient
  - for successful extrapolation to four dimensions.

"However, there is an on-going effort among Chesapeake Bay partners to acquire funding to deploy continuous monitoring buoys, which are equipped with vertical profilers in deep water areas of the Chesapeake Bay and tidal tributaries. If these efforts succeed, then the shortcomings of existing datasets will be greatly alleviated."



D. Wilson

Curriero et al. 2008 STAC Workshop Report

Session 3. Dissolved Oxygen Workshop Findings

Existing Dissolved Oxygen Criteria Assessment for Chesapeake Bay — *Richard Tian (UMCES), Qian Zhang (UMCES), Peter Tango (USGS)*

Future Criteria Assessment Protocol Framework Addressing All Time Scales of Chesapeake Bay Dissolved Oxygen Criteria — *Gary Shenk (USGS)*

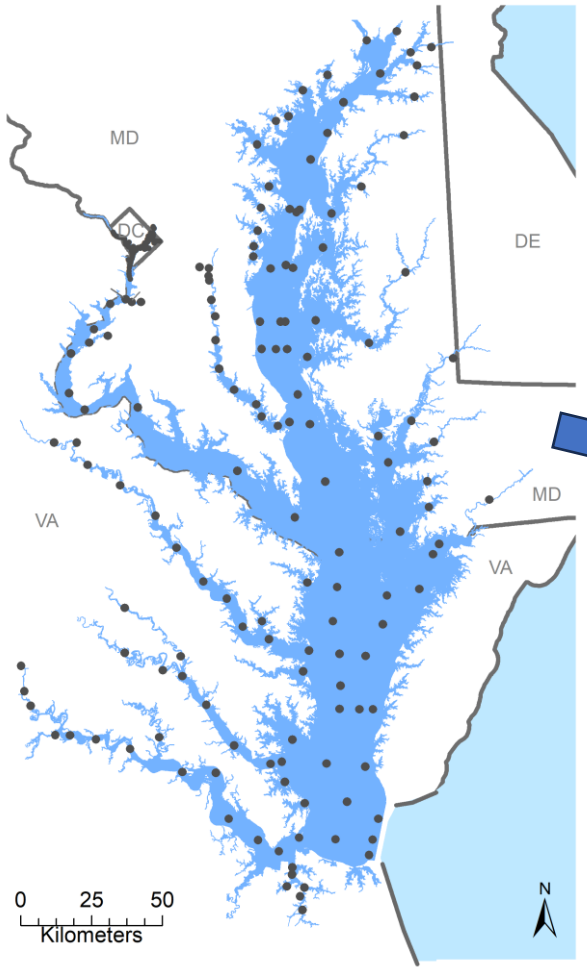
Options for Assessing Dissolved Oxygen Criteria — *Dong Liang (UMCES)*

Considerations for the Design of the 4D Water Quality Interpolator — *Rebecca Murphy (UMCES)*

Advances in development a New 4D water quality Interpolator for Chesapeake Bay — *Elgin Perry (Statistician), Rebecca Murphy (UMCES)*

New vertical sensor arrays that are robust, portable and more cost-effective than previously tested designs were successfully pilot tested on the open waters of Chesapeake Bay in a 2019-20.

Bi-weekly long-term sampling
(DOEE, MDDNR, VADEQ, CBP)



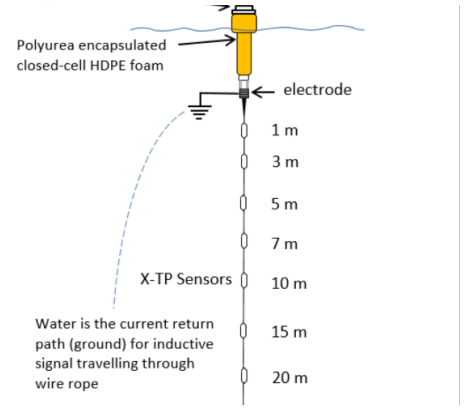
Shallow water continuous monitoring
(MDDNR and VECOS)

From https://eyesonthebay.dnr.maryland.gov/

From http://vecos.vims.edu/

Observed data

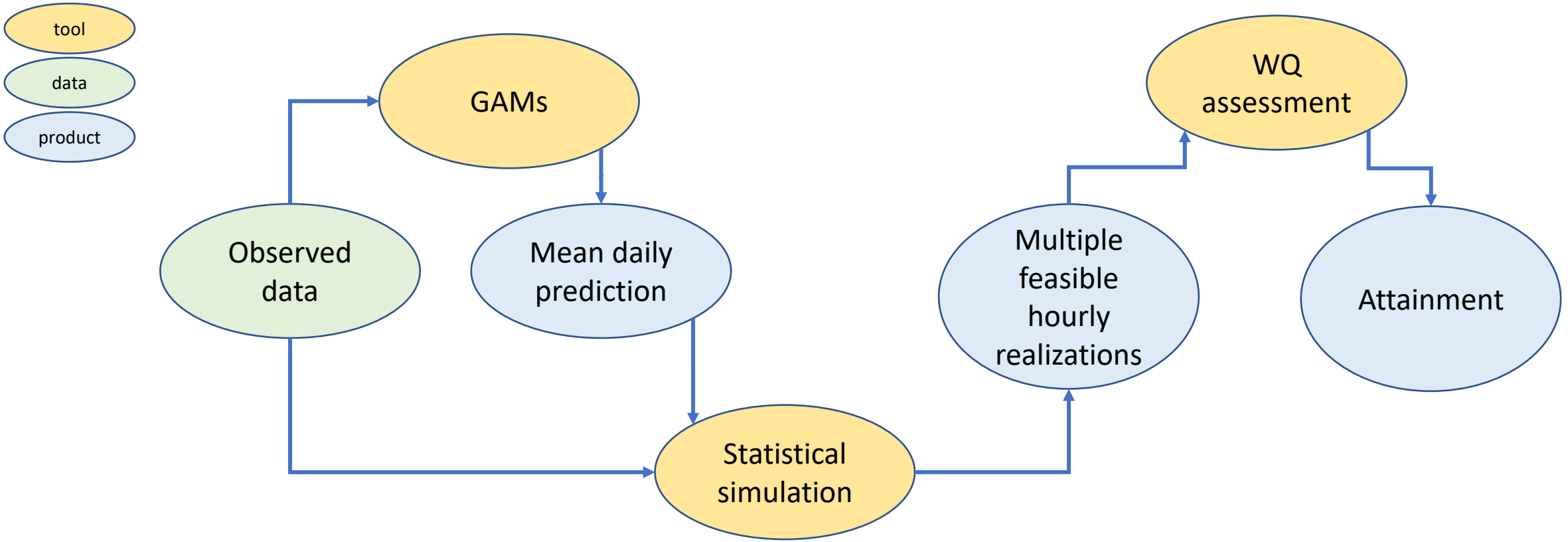
New continuous vertical arrays (NOAA & CBP)



https://www.chesapeakebay.net/who/group/hypoxia-collaborative-team

And more for validation & testing: Citizen science, data collected with fisheries studies, and research data sets

WQ Assessment with 4D interpolator – Feasibility of using GAMs has been demonstrated



Session 3. Dissolved Oxygen - Recommendations

Research, Monitoring and Management - A study design is needed for distribution of stations for habitat assessments

Monitoring and Management - At least one array should be outfitted with sensors at 1m depth intervals to serve as a reference.

Research and Management - Complete the 4D interpolator.

Management - Finalize investments into completing a 10 array system

Monitoring and Management – Sustain existing long-term monitoring and shallow water monitoring program efforts that provide spatial and temporal coverage in habitats to support 4D interpolator assessment products.

Policy –

- Upon completion of protocol development and assessment, documentation will be provided for EPA approval of methods.
- Upon EPA approval and publication of the methods, it will be recommended for State adoption of methods for water quality standards attainment analysis by State agencies will provide options and benefits to each jurisdiction and the Bay community.

Coincident and Subsequent actions 2021-23

2 STAR Workgroups formed.

- **Hypoxia Collaborative** to develop vertical array monitoring network
  - Leadership Team: Bruce Vogt, Peter Tango, Jay Lazaar, Kevin Shabow, Bailey Roberty, August Goldfischer
- **Bay Oxygen Research Group** to develop the 4D interpolator
  - Co-coordinators Rebecca Murphy, Peter Tango
  - STAR staffer August Goldfischer
  - Key developers: Elgin Perry, John Harcum
  - Key leadership: Gary Shenk, Isabella Bertani, Breck Sullivan, Richard Tian

Workshop recommendations translated to fundable packages as recommendations for the PSC Monitoring Review.

- **4D interpolator work received funding support from EPA**
- **EPA and NOAA have coordinated on investing approximately $1M** in building out a 10-station network of vertical water quality monitoring arrays.
  - In 2024, 6 arrays are expected to be in operation.

Draft Workshop Report is undergoing the USGS review process since early winter 2023-24

Enhancing the Chesapeake Bay Program Monitoring Networks
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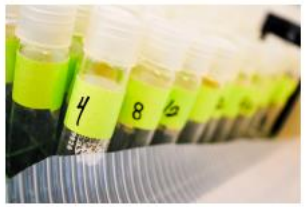

CBP Network	*Recommendation*
Tidal	Equipment and Supplies for 8 advanced vertical sensor array stations.
Tidal	Support operation and maintenance of vertical sensor arrays
Funder	
Tidal	Sustain Existing Tidal Water Quality Program
Funder	
Tidal	4D Interpolator Development
Funder	

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Thank you
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