4-Dimensional (4-D) Interpolator 101

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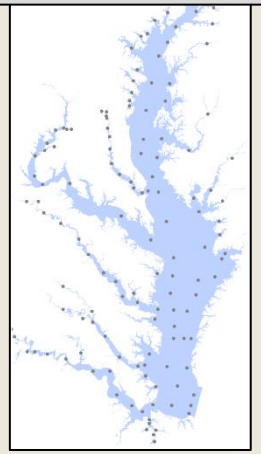
Partnership Uses of the 3D Interpolator

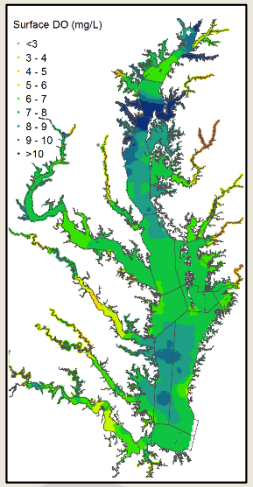
- 1) One Step In the Analysis for Annual Assessments
  - *Helps us answer how are we doing towards meeting our goals*
  - *E.g., Water Quality Standards Attainment Indicator*
- 2) Support Jurisdictions with 303(d) reporting
  - *Cycle is every two years*
- 3) CBP Modeling Suite and Developing Planning Targets
  - *Commitment in the Watershed Agreement*
  - *Develop Planning Targets to achieve Water Quality Criteria*
  - *Support Effective Watershed Implementation Plans*
- 4) Research Applications
  - *Academic partners*

WQS Criterion Assessment

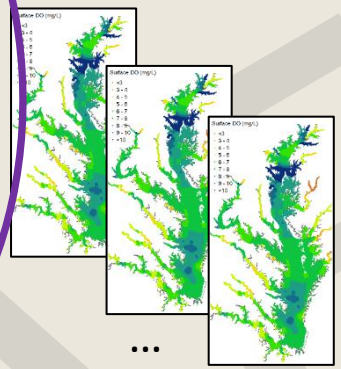
1. Collect bi-weekly to monthly data at each monitoring station



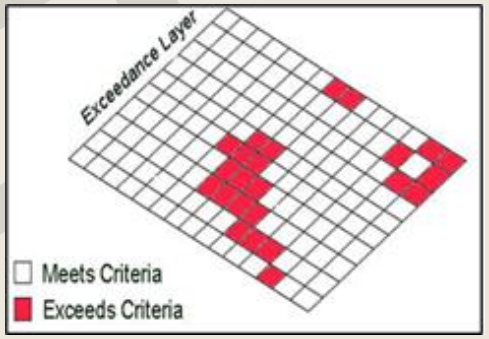
2. Interpolate bay-wide for a single cruise



3. Conduct interpolations for a season over the 3-year period

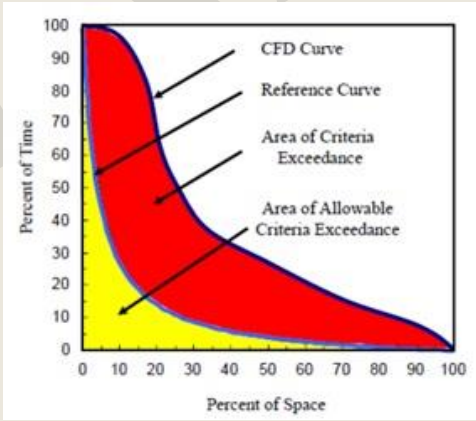


4. Average monthly if 30-day criterion, and compare the interpolated values with appropriate criterion values



5. Repeat Step 4 throughout the 3-year period

6. Calculate the cumulative frequency distribution (CFD) for extent of exceedance in space and time



7. Quantify attainment status (attaining or not) for the 3-year period

From Peter Tango

Why do we need a new method?

- The current interpolator (developed 20+ years ago) was not designed to interpolate through time or work effectively with unstructured data having mixed time scales and sampling patterns and sourced from multiple monitoring programs.

- There is more high frequency data now to fill in temporal gaps.

- A new interpolation will use all the data to fill in the gaps between data based on observed patterns to help accurately assess high frequency DO criteria.
  - Chesapeake Bay Program interest in 4D Interpolation started because water quality criteria for the 303d listing require assessments at finer space and time scales than current data can support.

Partnership History with the 4D Interpolator

2007
- Recommended a further development of spatial interpolation and statistical aspects of measuring water quality criteria attainment assessment (USEPA, 2007).

2008
- Technical Support for Criteria Assessment Protocols Addendum (USEPA, 2008)
- STAC Workshop aimed to identify key functionality requirements and coordinate ongoing development efforts of a 4D Interpolator to ensure future products meet the needs of CBP partners.

2009
- STAC review and recommendations for the application of reference curves in dissolved oxygen criteria assessment.

2010
- Technical Support for Criteria Assessment Protocols Addendum (USEPA, 2010).

2014
- 2014 Watershed Agreement Water Quality Goal includes the language “maintain and grow monitoring and assessment capacity.”

2021
- PSC request to provide information to improve CBP monitoring networks, including (1) current status and threats to the network and (2) what is needed to improve the monitoring networks.
- Bay Oxygen Research Group/4D Team start work on developing the 4D Interpolator.

2022
- PSC Monitoring Report (2022) recommended funding the development of the 4D Interpolator by the Chesapeake Bay Program, which was supported by the PSC.

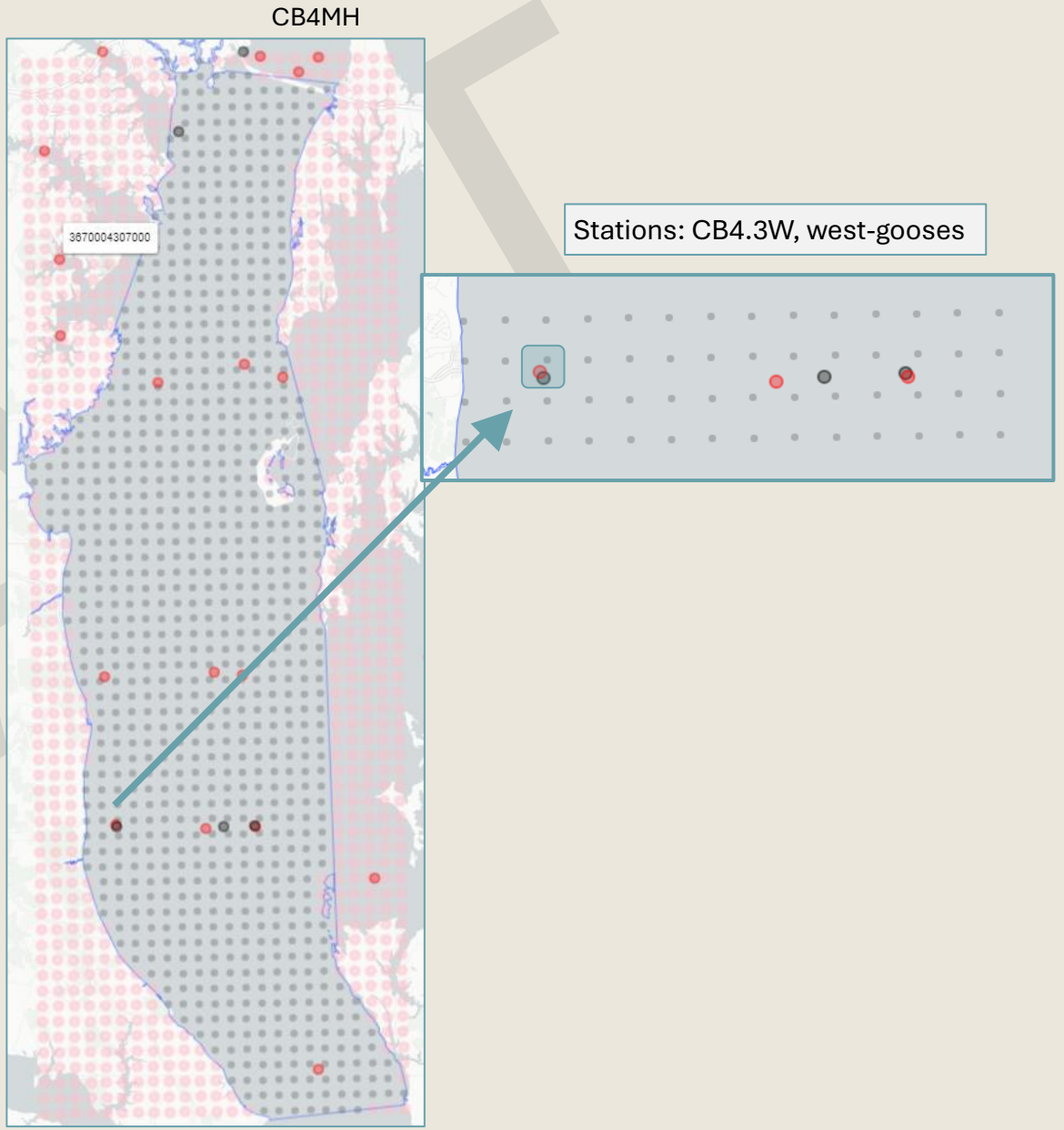
GOAL STATEMENT

To develop a spatial-and-temporal interpolation tool for water quality monitoring data collected in the tidal waters of the Chesapeake Bay, thus enabling the evaluation of both long- and short-duration water quality criteria.

The tool should:

1. *Interpolate observed dissolved oxygen in space and time (“4D”) at every node (grey dots) in the interpolation grid to fill data gaps**
2. *Provide statistical estimates of uncertainty*
3. *Reproduce daily and hourly variability of the data*
4. *Allow for post-processing of the interpolation output into designated uses (DU)*
5. *Allow for interpolation function to be different in time or space based on what the data tell us*

*Note: Focus on development so far has been on dissolved oxygen, but ultimately chlorophyll *a* and clarity may be evaluated as well.



Purpose: Build a tool for more complete criteria assessment

DO criteria that currently can be evaluated with existing approaches and data

Table 1. Chesapeake Bay dissolved oxygen criteria.

Designated Use	Criteria Concentration/Duration	Protection Provided	Temporal Application
Migratory fish spawning and nursery use *	7-day mean ≥ 6 mg liter^{-1} (tidal habitats with 0-0.5 ppt salinity)	Survival/growth of larval/juvenile tidal-fresh resident fish; protective of threatened/endangered species.	February 1 - May 31
	Instantaneous minimum ≥ 5 mg liter^{-1}	Survival and growth of larval/juvenile migratory fish; protective of threatened/endangered species.	
	Open-water fish and shellfish designated use criteria apply		June 1 - January 31
Shallow-water bay grass use	Open-water fish and shellfish designated use criteria apply		Year-round
Open-water fish and shellfish use	30-day mean ≥ 5.5 mg liter^{-1} (tidal habitats with 0-0.5 ppt salinity)	Growth of tidal-fresh juvenile and adult fish; protective of threatened/endangered species.	Year-round
	30-day mean ≥ 5 mg liter^{-1} (tidal habitats with >0.5 ppt salinity)	Growth of larval, juvenile and adult fish and shellfish; protective of threatened/endangered species.	
	7-day mean ≥ 4 mg liter^{-1}	Survival of open-water fish larvae.	
	Instantaneous minimum ≥ 3.2 mg liter^{-1}	Survival of threatened/endangered sturgeon species.[1]	
Deep-water seasonal fish and shellfish use	30-day mean ≥ 3 mg liter^{-1}	Survival and recruitment of bay anchovy eggs and larvae.	June 1 - September 30
	1-day mean ≥ 2.3 mg liter^{-1}	Survival of open-water juvenile and adult fish.	
	Instantaneous minimum ≥ 1.7 mg liter^{-1}	Survival of bay anchovy eggs and larvae.	
	Open-water fish and shellfish designated-use criteria apply		October 1 - May 31
Deep-channel seasonal refuge use	Instantaneous minimum ≥ 1 mg liter^{-1}	Survival of bottom-dwelling worms and clams.	June 1 - September 30
	Open-water fish and shellfish designated use criteria apply		October 1 - May 31

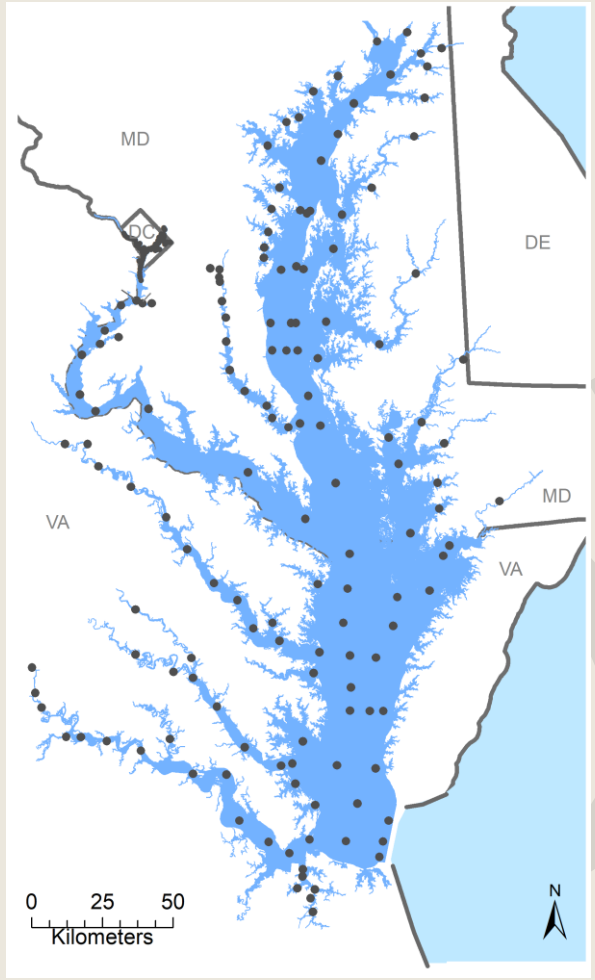
[1] At temperatures considered stressful to shortnose sturgeon (>29°C), dissolved oxygen concentrations above an instantaneous minimum of 4.3 mg liter^{-1} will protect survival of this listed sturgeon species.

*Note a 30-day mean 6 mg/L MSN value is evaluated for purpose of the WQ indicator.

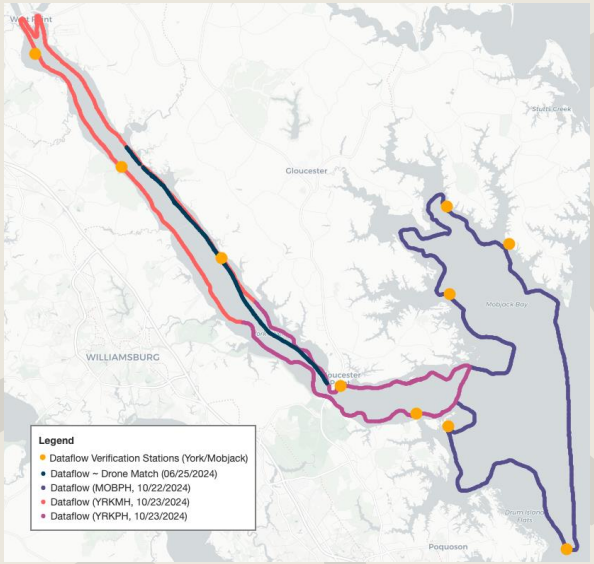
From EPA 2003 Ambient Water Quality Criteria

Dissolved Oxygen data sets

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

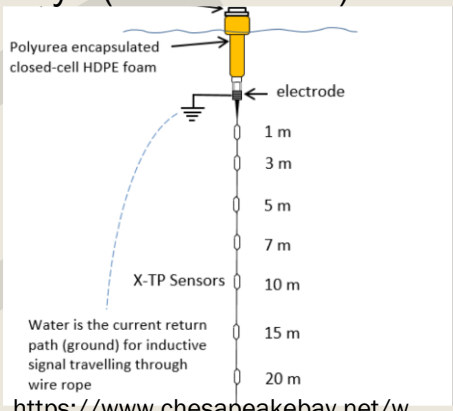


Dataflow (MDDNR and VECOS)



From http://vecos.vims.edu/

New continuous vertical arrays (NOAA & CBP)



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

Shallow water continuous monitoring (MDDNR and VECOS)

From http://vecos.vims.edu/

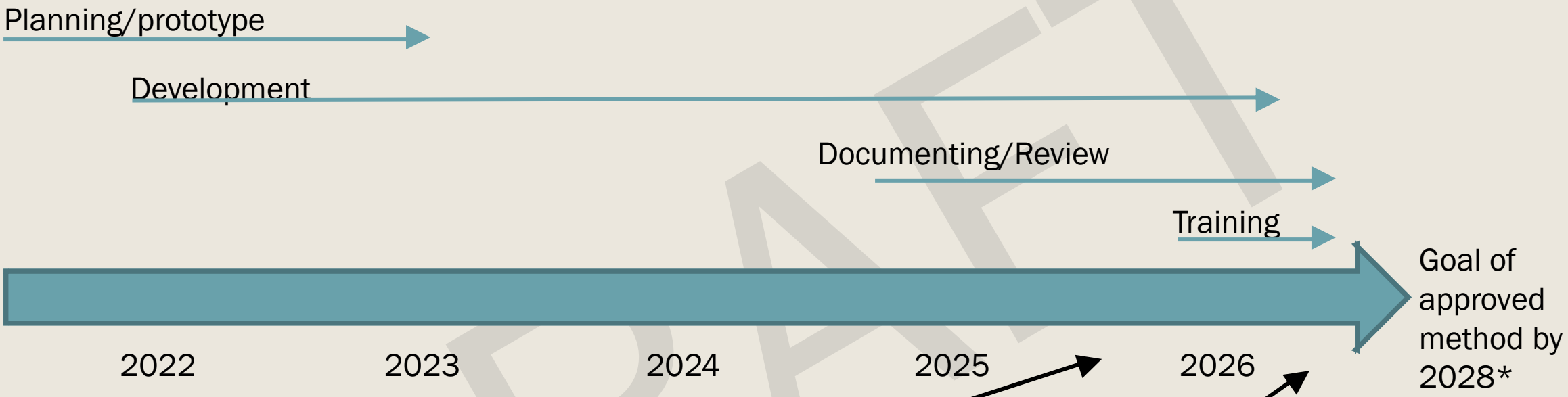
From https://eyesonthebay.dnr.maryland.gov/

And more Citizen science, riverkeepers, research data sets, and future data sets

New Features for an Updated Chesapeake Bay Interpolator

- Retain uses of 3D Interpolator
  - Annual Assessment, Support Jurisdictions with 303(d) reporting, CBP Modeling Suite and Developing Planning Targets, Research Applications
- Uses patterns in observed DO to estimate hourly DO every 1km at 1m depths
- Advanced analytical techniques that allow use of all data (of any monitoring frequency) to assess all criteria
- Quantifiable uncertainty in condition estimate
- Developed so it can run on a typical laptop

4-D interpolator development timeline



Through 2026:

- Working 4-D tool,
- Collaboration ongoing with CAP on criteria assessment methods.

In 2026-2027:

- Documenting,
- Additional functionality as needed for linking to criteria assessment,
- Preparing for training & review.

*with 2030 goal of reporting on all criteria