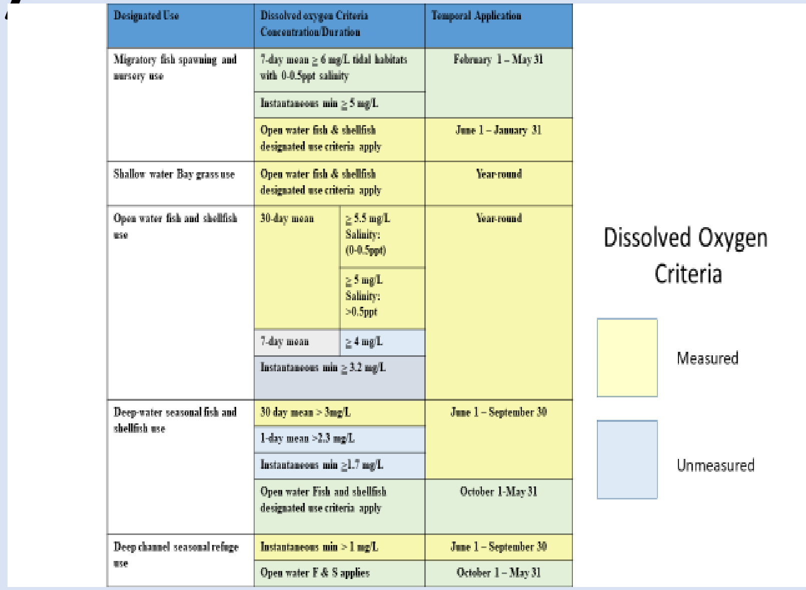
# New interpolator development to support assessment of all Chesapeake Bay dissolved oxygen water quality criteria

Peter Tango

8/13/2024

CAP WG

Colonial Beach, VA



| Designated Use | Dissolved oxygen Criteria Concentration/Duration | | Temporal Application |
|---|---|---|---|
| Migratory fish spawning and nursery use | 7-day mean ≥ 6 mg/L tidal habitats with 0-0.5ppt salinity | | February 1 – May 31 |
| | Instantaneous min ≥ 5 mg/L | | |
| | Open water fish & shellfish designated use criteria apply | | June 1 – January 31 |
| Shallow water Bay grass use | Open water fish & shellfish designated use criteria apply | | Year-round |
| Open water fish and shellfish use | 30-day mean | ≥ 5.5 mg/L Salinity: (0-0.5ppt) | Year-round |
| | | ≥ 5 mg/L Salinity: >0.5ppt | |
| | 7-day mean | ≥ 4 mg/L | |
| | Instantaneous min ≥ 3.2 mg/L | | |
| Deep-water seasonal fish and shellfish use | 30 day mean > 3mg/L | | June 1 – September 30 |
| | 1-day mean >2.3 mg/L | | |
| | Instantaneous min ≥1.7 mg/L | | |
| | Open water Fish and shellfish designated use criteria apply | | October 1-May 31 |
| Deep channel seasonal refuge use | Instantaneous min > 1 mg/L | | June 1 – September 30 |
| | Open water F & S applies | | October 1 – May 31 |

# Outline – hang in there with me ☺. Foundations of our work

- Brief intro
- What is interpolation and Why interpolate?
  - Insights from data collected from 2022 vertical array transect deployments
- The evolving path toward the new interpolator
  - Partnership interest for 4D interpolation
- Where are we relative to the 2008 STAC panel vision for the new interpolator?

# A brief intro to our Interpolator 101 session

# What monitoring programming brings to the Partnership: From planning to sample collection to actionable knowledge

ACTIONABLE KNOWLDGE


GATHER INFORMATION

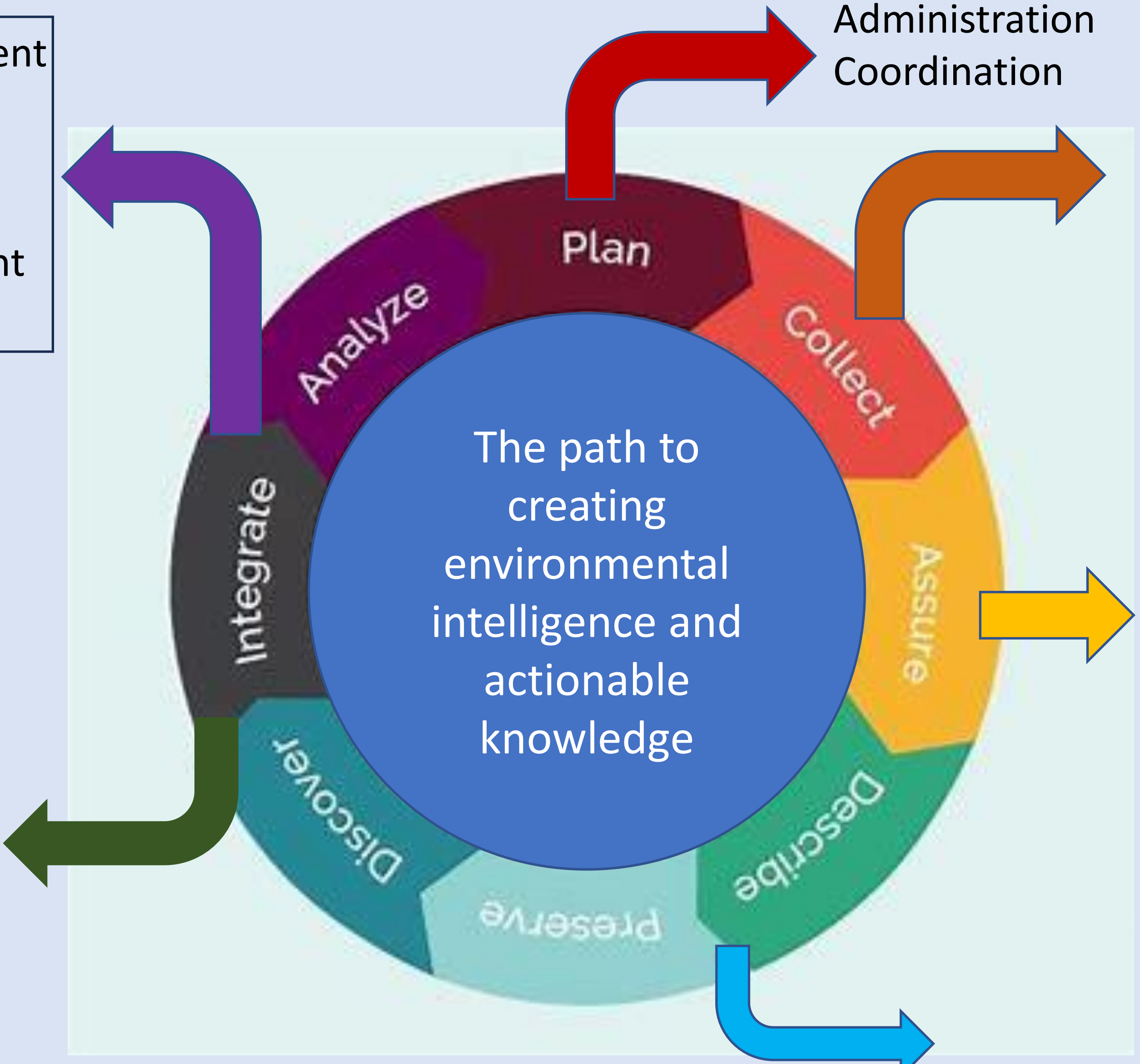
# What monitoring programming brings to the Partnership: From planning to sample collection to actionable knowledge

ACTIONABLE KNOWLDGE

- Method development
- Science synthesis
- Science translation
- Data visualization
- Report development
- Communication

Administration
Coordination

Sensors
Field measures
Lab measures



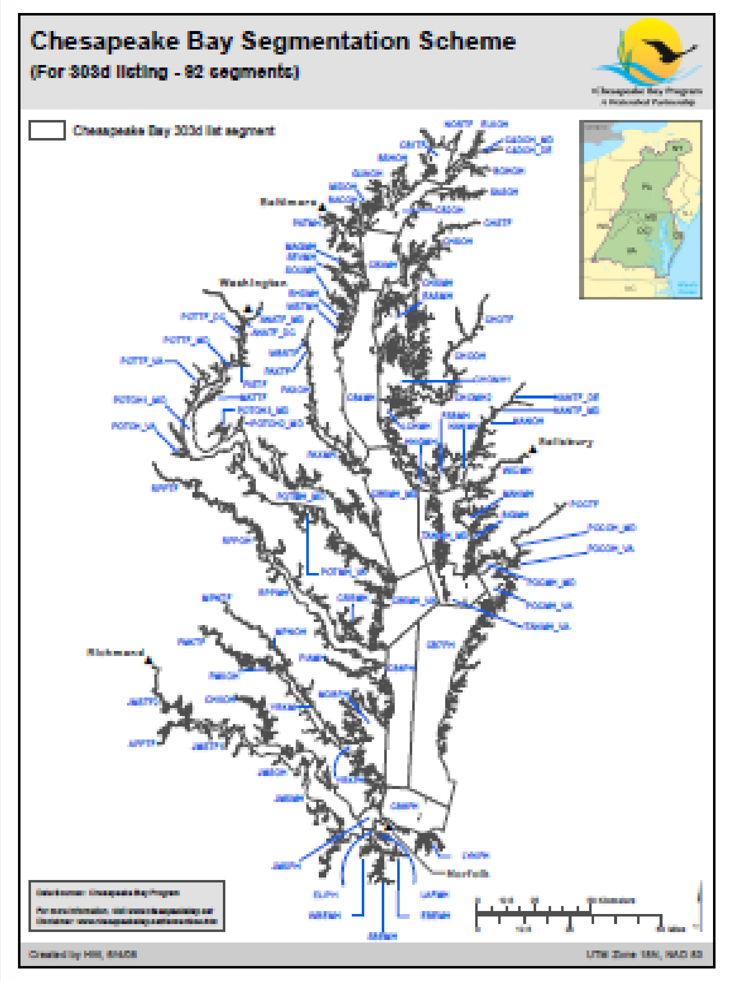

Field, lab & data management
QA program

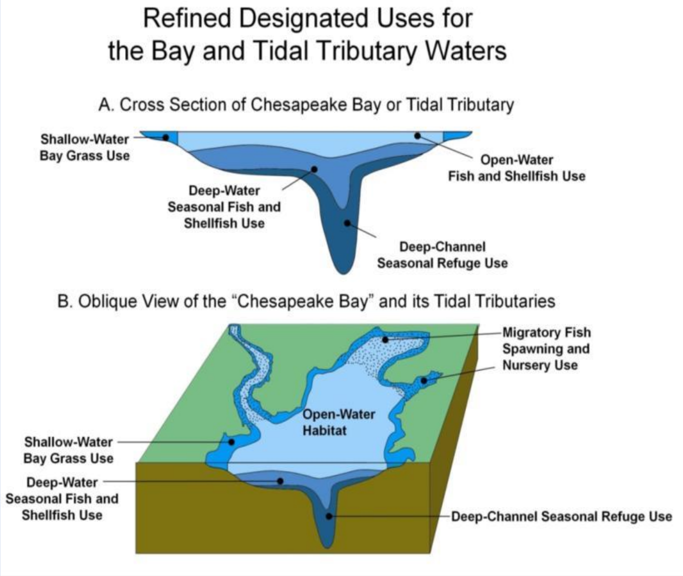
Modeling
Calibration
Verification

Metadata management
IT data input and storage management

GATHER INFORMATION

# Clean Water Act Water Quality Standards Monitoring and Assessment Issue: A segment must meet **all criteria** in **all applicable designated uses** for a decision on delisting in State water quality standards

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The number of segments we have full monitoring data accounting to support all criteria assessments needed to evaluate criteria underpinning WQ Stds

# Challenges

- Unassessed criteria remain a hurdle for delisting decisions of State-adopted water quality standards with our existing framework

= Inability to report on standard attainment

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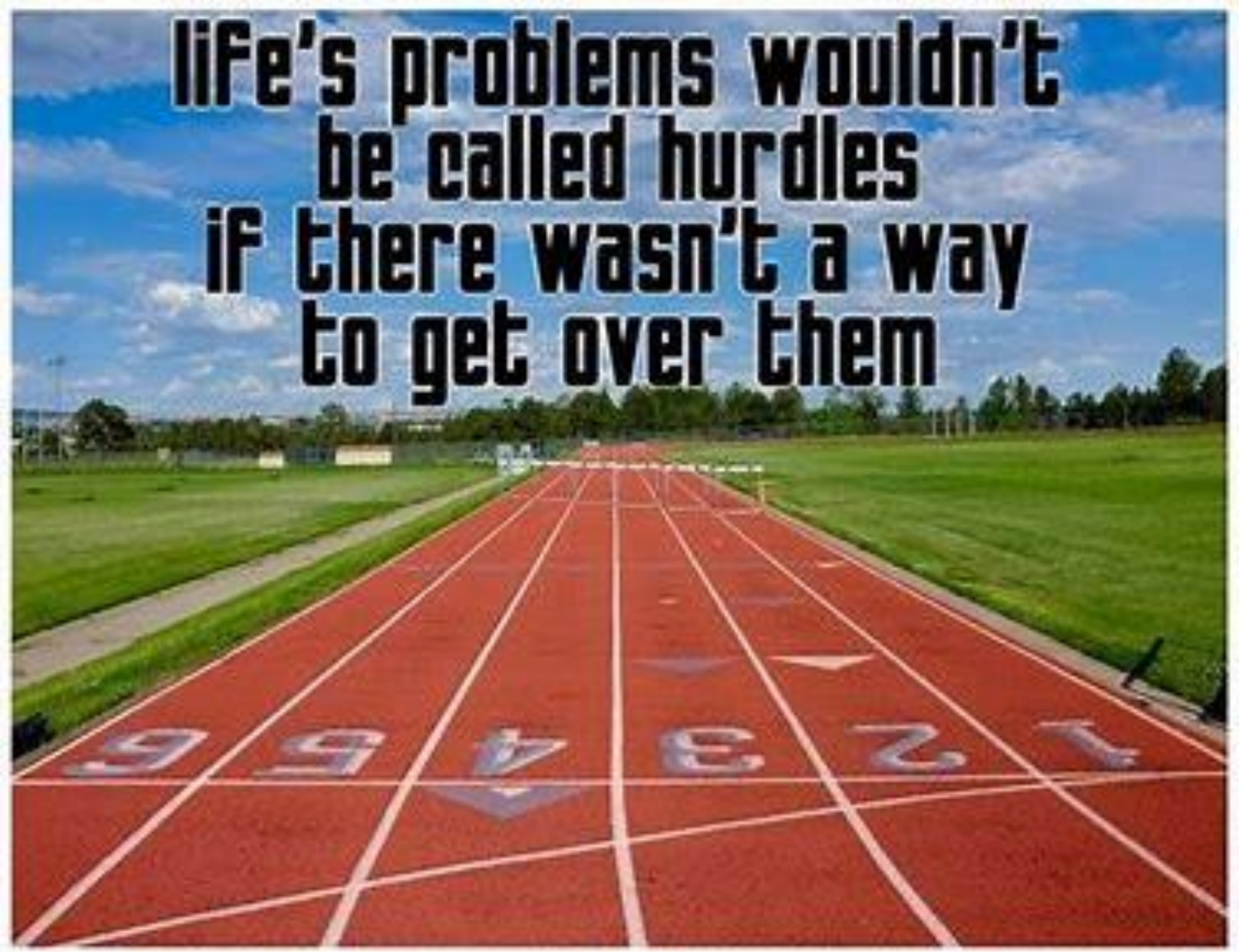
- Historically – mismatch between criteria and the monitoring and assessment to support their evaluation.



Thanks for the analogy Tish ☺

# Overcoming hurdles



# What is interpolation? Why interpolate at all?

- To estimate the values of unknown data points that fall in between existing, known data points.

- To fill in missing data based on known data points.

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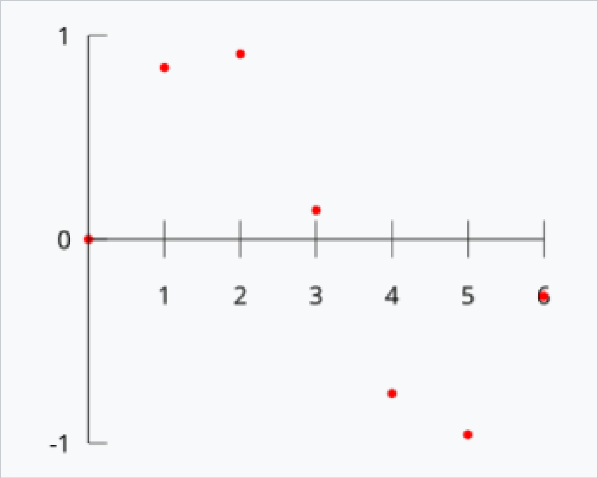
- To estimate the values of unknown data points that fall in between existing, known data points.

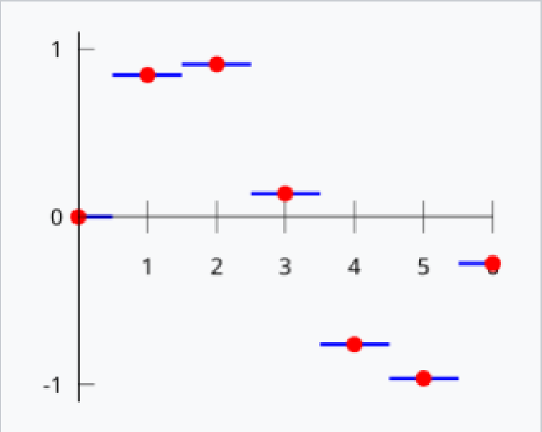
- To fill in missing data based on known data points.

- Spatial interpolation is the process of **estimating values of spatially continuous variables for spatial locations where they have not been observed, based on observations**

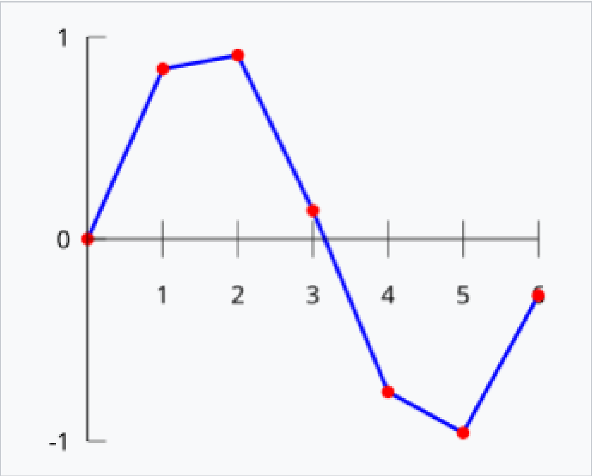
# Interpolation complexity – time series example



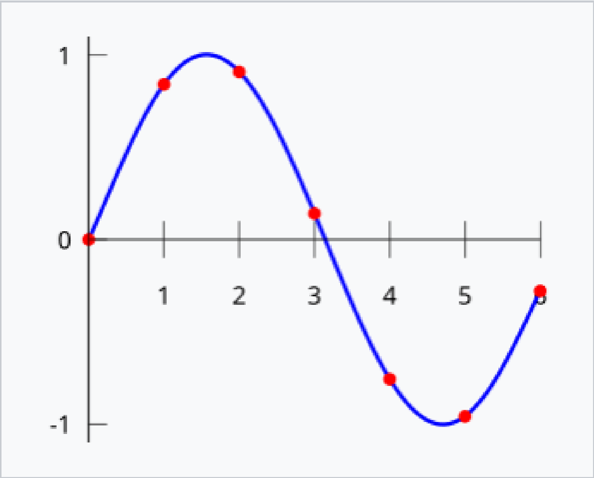

Plot of the data points as given in the table




Piecewise constant interpolation, or nearest-neighbor interpolation

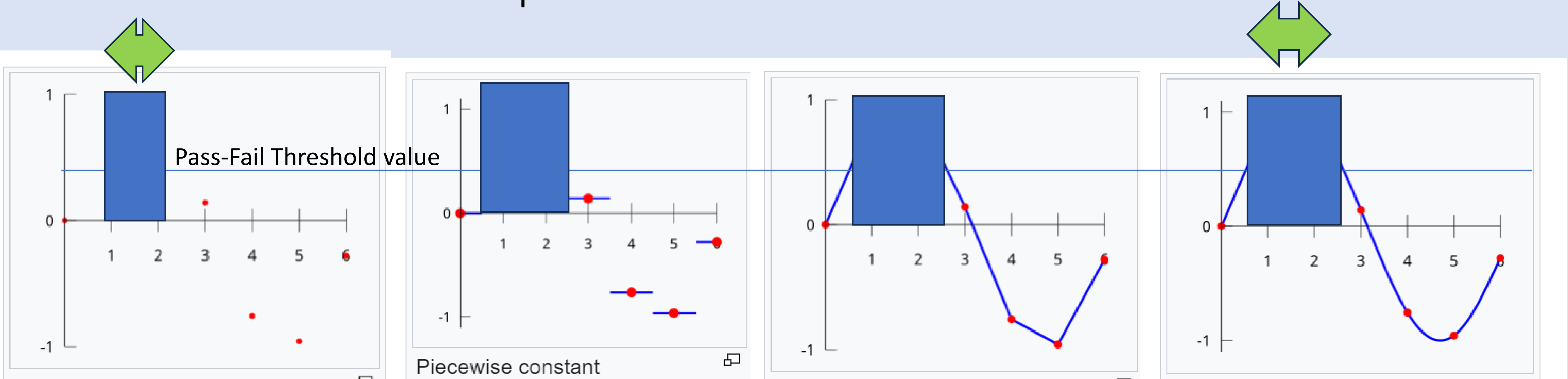



Plot of the data with linear interpolation superimposed




Plot of the data with polynomial interpolation applied

# As we improve the shape of the function and representation of the data pattern, we find there is more time in the passing region than based on the raw data alone for this example

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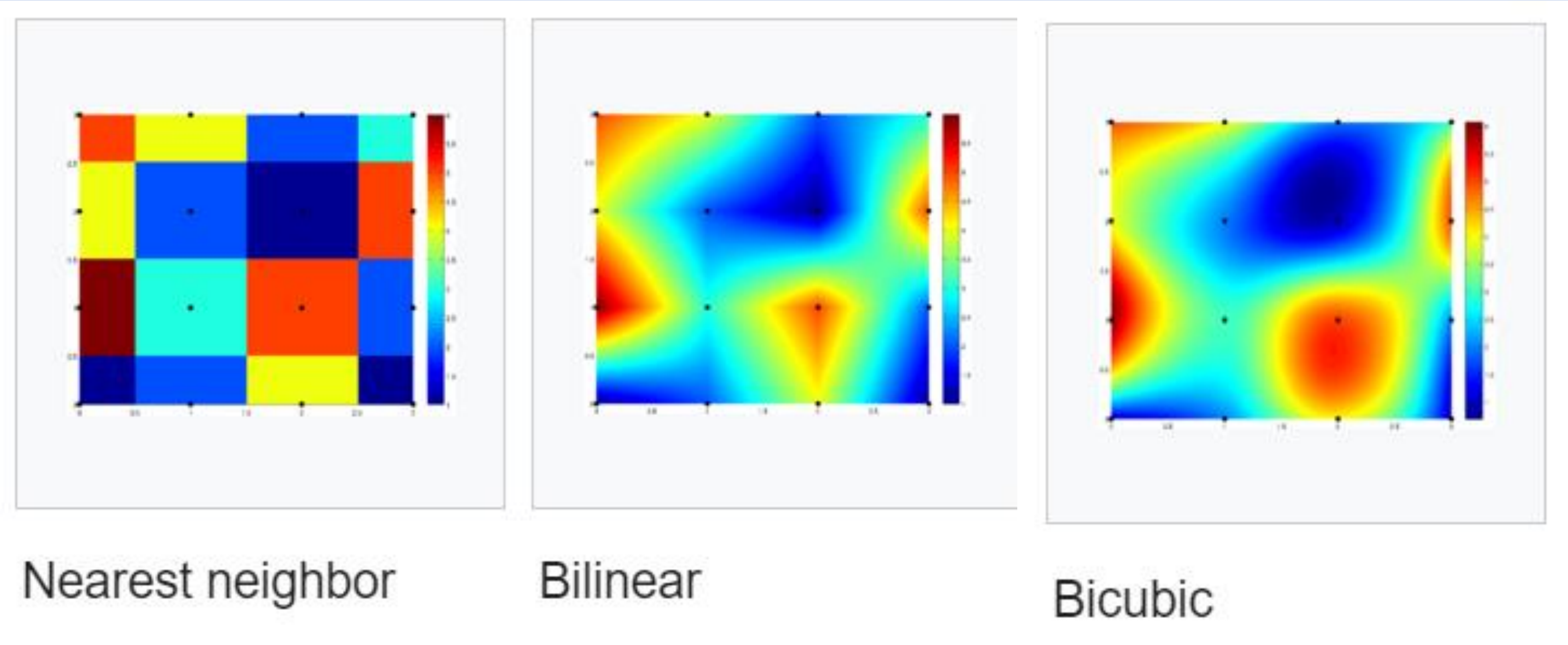
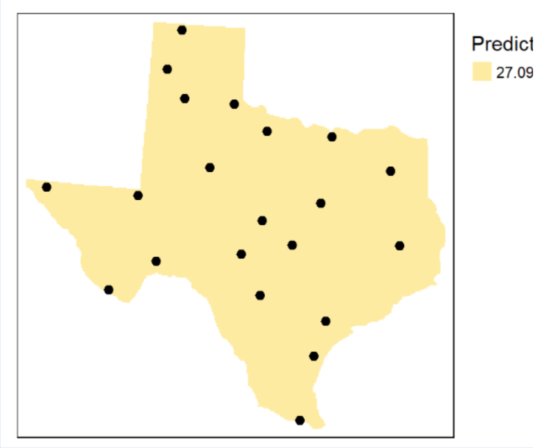
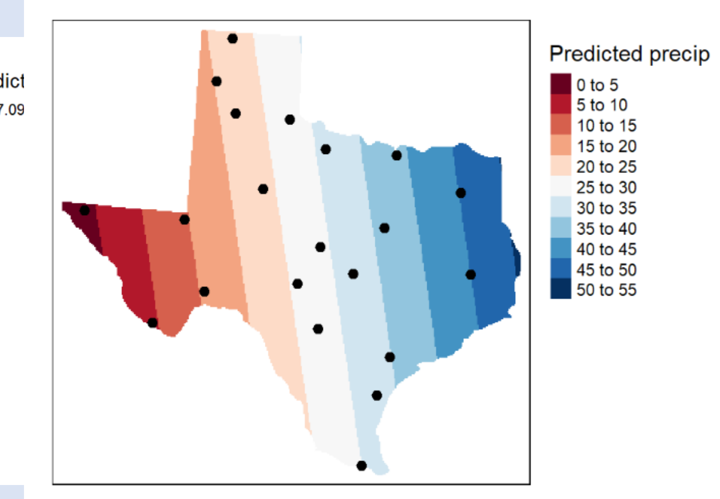
# Spatial interpolation in an example here



# Improving explanation of spatial precipitation patterns: E.g., Texas

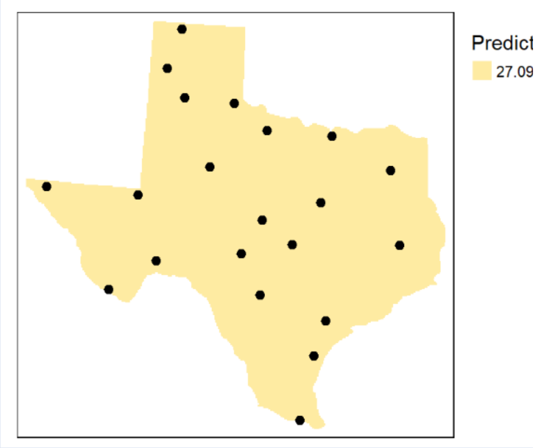



0th order interpolation (Average)




1st order interpolation

# Improving the depiction of spatial precipitation patterns: E.g., Texas

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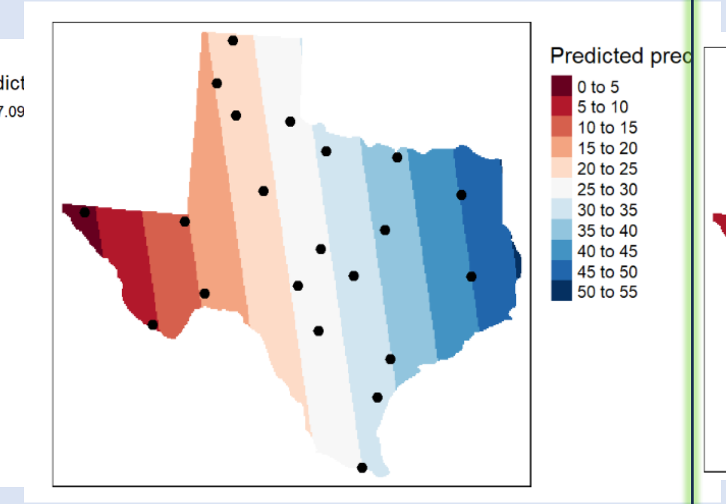
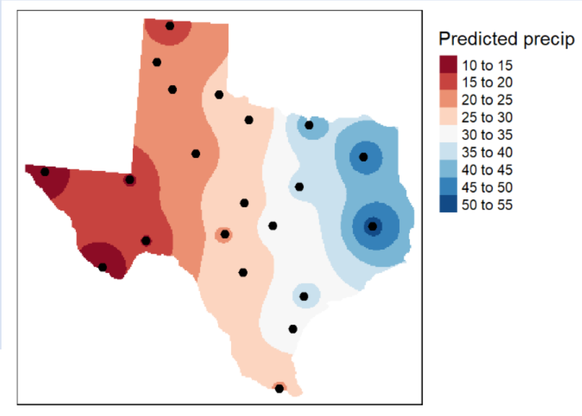
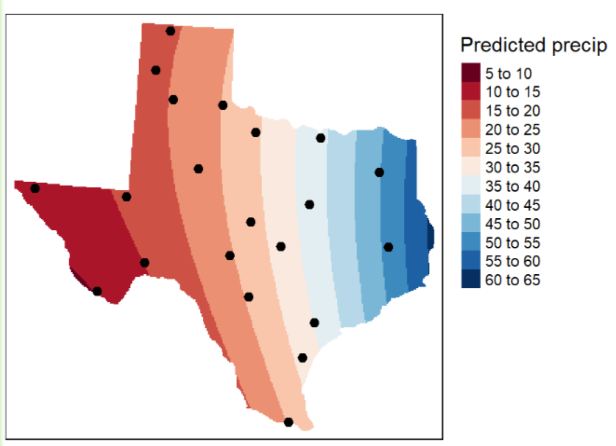



1st order interpolation

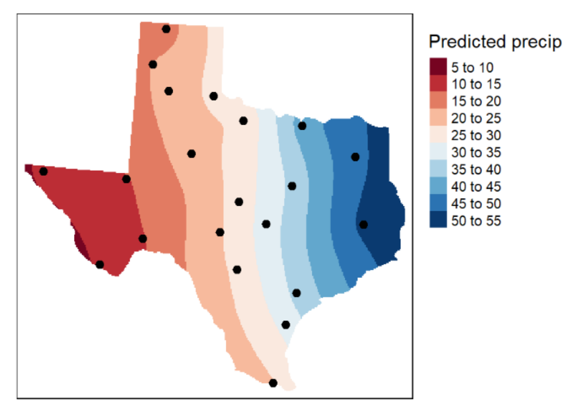
Advanced interpolation options




IDW interpolation




Polynomial 2nd order interpolation




Ordinary Kriging interpolation

# Focusing on interpolation for the Bay and our Partnership

Chesapeake Bay Program

Science. Restoration. Partnership.

# Why do interpolation with all this new data available?

- Establishing magnitude, duration and frequency of a condition is crucial for successful development and application of state water quality standards.

National Research Council 2001

- Equally important is the spatial extent of a condition.

- The spatial and temporal dimensions of attainment assessment must be defined.

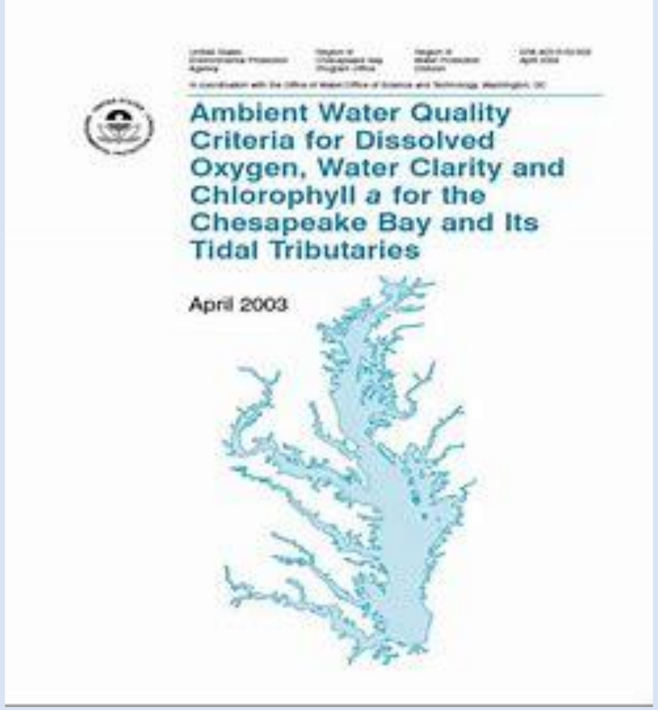
USEPA 2003


**Figure VI-2.** Chesapeake Bay Program segment boundaries, fixed monitoring station locations and summer chlorophyll *a* concentration ($\mu g\ liter^{-1}$) distribution in the Tangier Sound area of the Eastern Shore of Maryland and Virginia. Summer chlorophyll *a* concentration distribution is defined by spatial interpolation.

# Why do interpolation with all this new data available?

- “Methods currently used for assessment of criteria attainment are based only on temporal variations because measurements are usually evaluated only at individual monitoring station locations.”

- USEPA 2003 – p154. “**The use of the cumulative frequency distribution** (cfd) is recommended for assessing spatial and temporal water quality criteria exceedance in Chesapeake Bay.”



Ambient Water Quality Criteria for Dissolved Oxygen, Water Clarity and Chlorophyll a for the Chesapeake Bay and Its Tidal Tributaries

April 2003

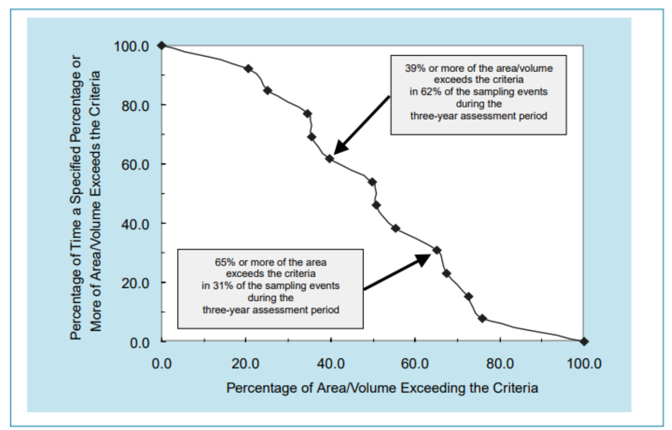
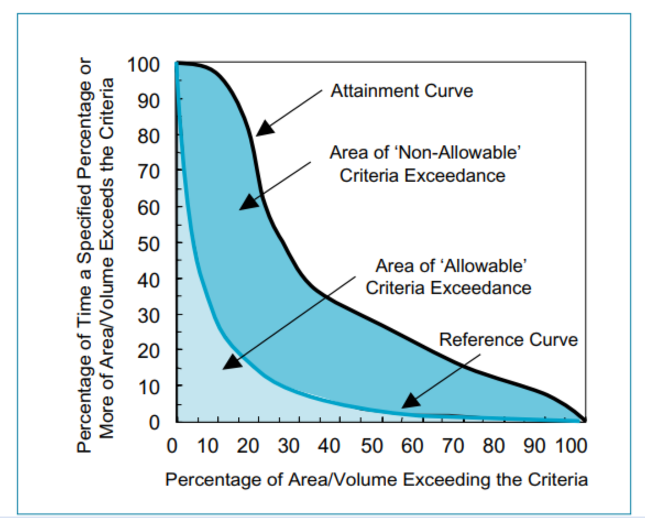



Figure VI-7. The horizontal axis is the spatial extent of criteria exceedance based on monitoring data extrapolated using spatial interpolation. The vertical axis is the cumulative frequency of criteria exceedance for the monitoring events conducted during the assessment period.

CFD



# Why do interpolation with all this new data available?

- USEPA 2003, p155 – “For the Chesapeake Bay and its tidal tributaries, using a grid-based spatial interpolation software **provides a common spatial framework and spatial extrapolation**”.
- (PT note, this is the Bahner 2001 Bay interpolator, aka “the 3D interpolator”)

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**Figure VI-2.** Chesapeake Bay Program segment boundaries, fixed monitoring station locations and summer chlorophyll *a* concentration (µg liter⁻¹) distribution in the Tangier Sound area of the Eastern Shore of Maryland and Virginia. Summer chlorophyll *a* concentration distribution is defined by spatial interpolation.

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- Spatial interpolation provides estimates of water quality measures for all locations within a spatial assessment unit.

  - **Step 1 of the recommended assessment method: Interpolation of water quality monitoring data**. (p154, USEPA 2003)


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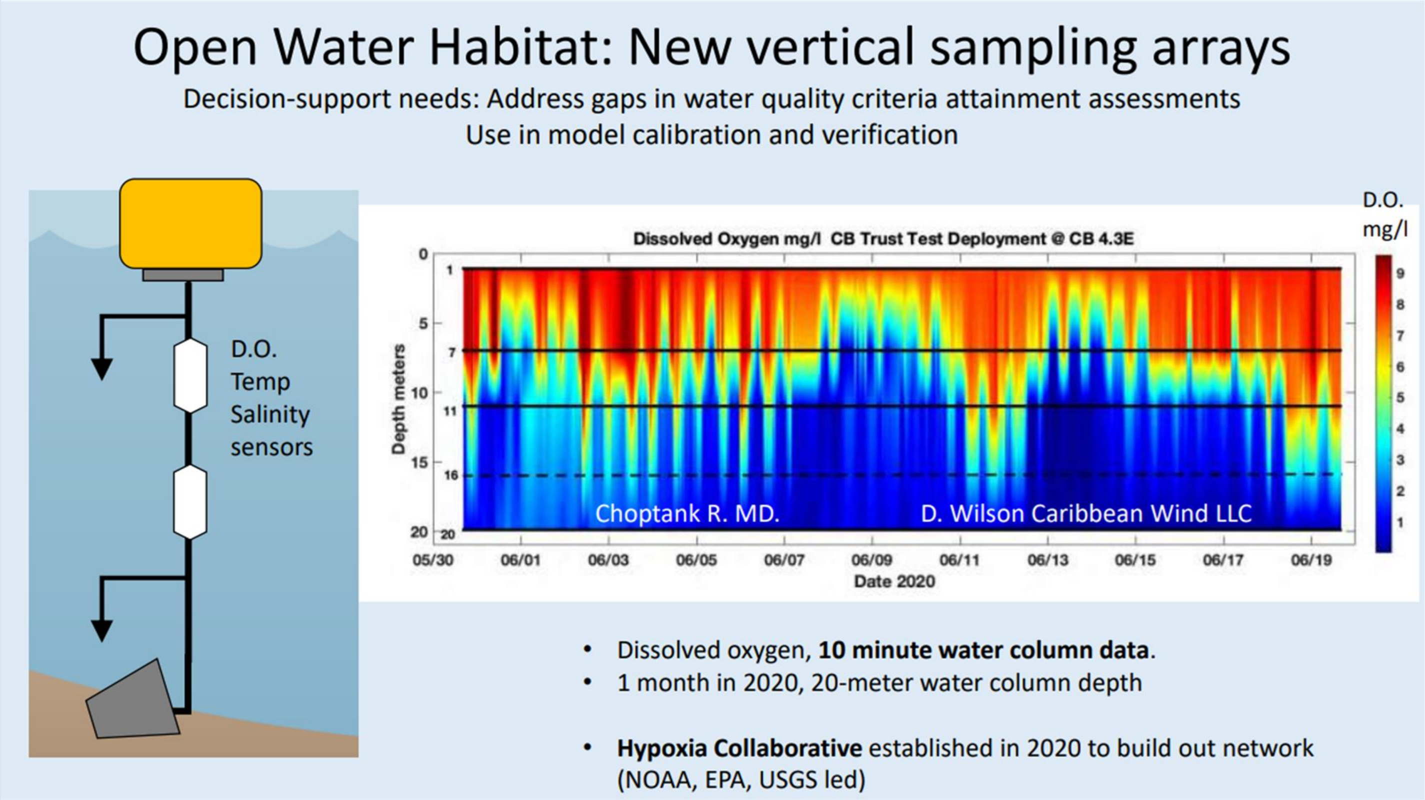
# Insights from the 2022 Vertical Array transect deployments regarding spatial variation in D.O. – Mainstem Bay

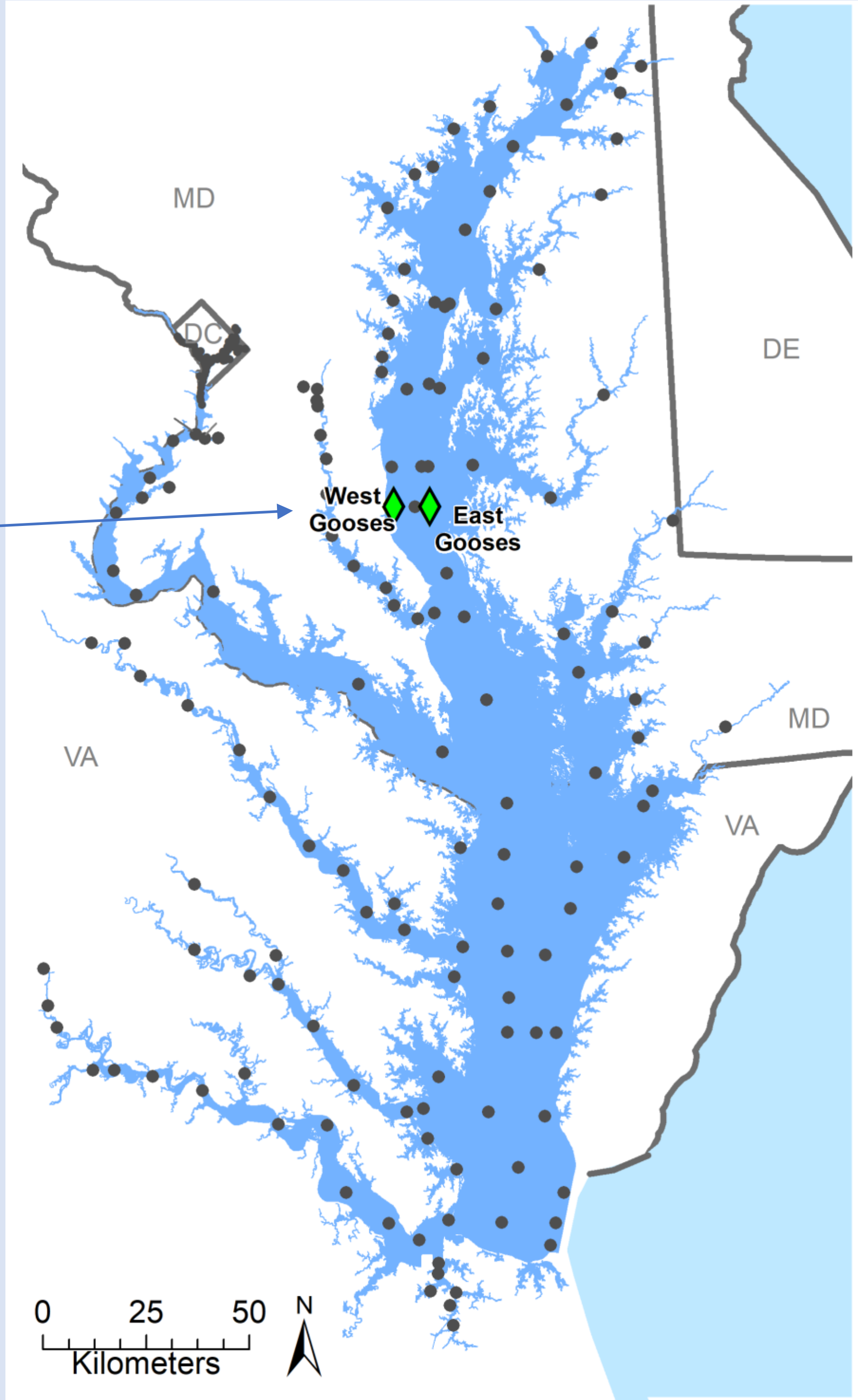


# Spatial: Vertical array insights

- The mainstem vertical arrays in 2022 at East and West Goose Reef (near CB4.3E and CB4.3W) are a good case to see how high frequency data compares

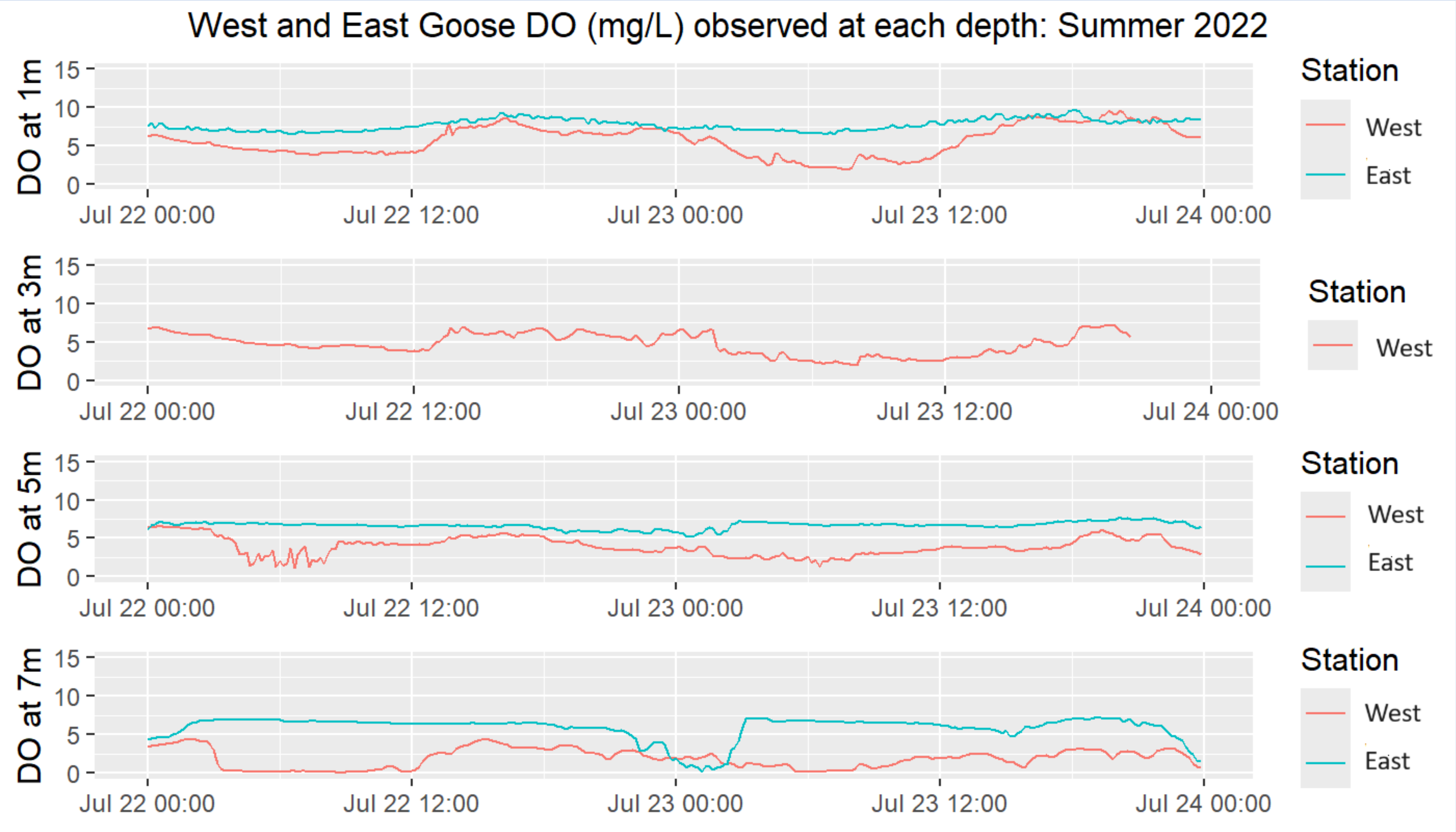
  → And if using just one to represent DO conditions (without interpolation) is accurate

- Station differences:
  - West is 10m deep
  - East is 23m deep



# Spatial: Vertical array insights

- 2 days, 48 hours in 2022: 10 minute data. Comparisons frequently show significant difference in magnitude of DO at the 2 locations, at the same depth

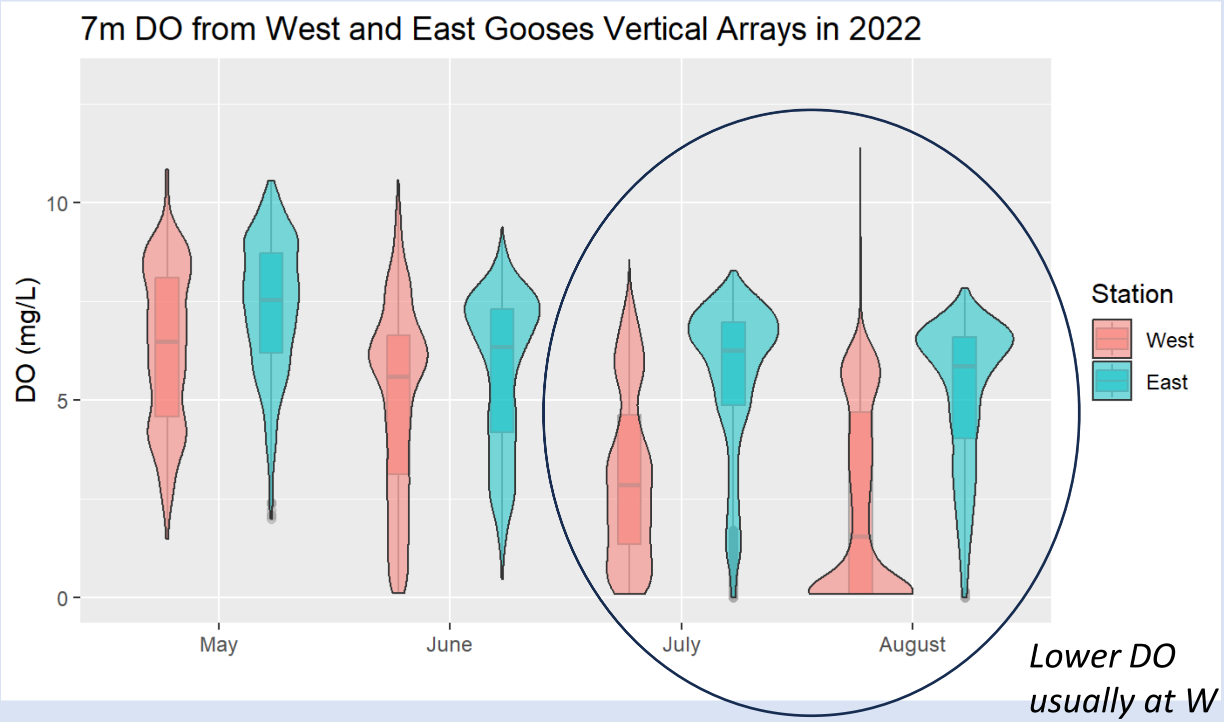



R. Murphy

# Spatial considerations: Vertical array insights 7m depth only depicted in the image

- Across the entire summer, the distribution of DO at the same depth at these 2 stations differ

- At every depth in common, the W station usually has lower DO concentrations than the E station.




*Lower DO usually at W at same depth*

# Spatial: Vertical array insights

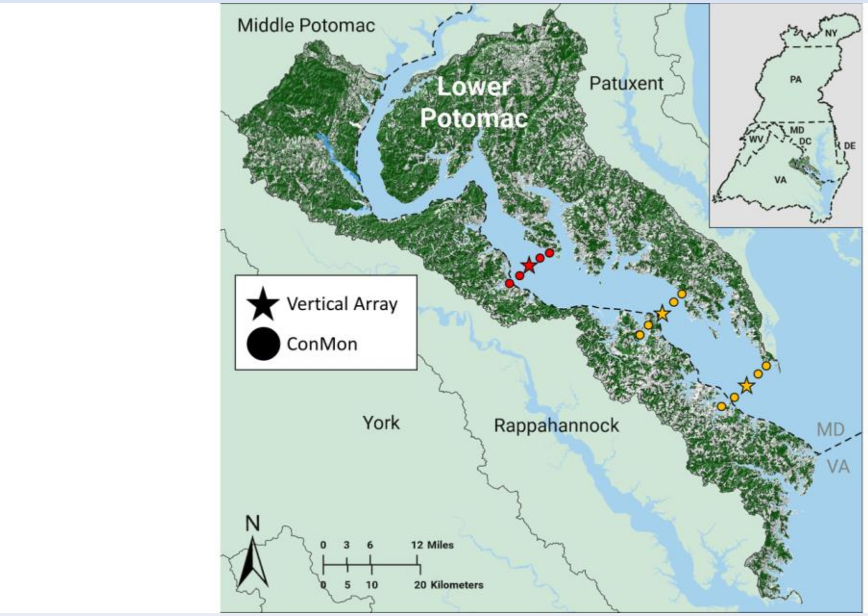
- This could lead to very different insights if only one of these stations was considered in a criteria evaluation

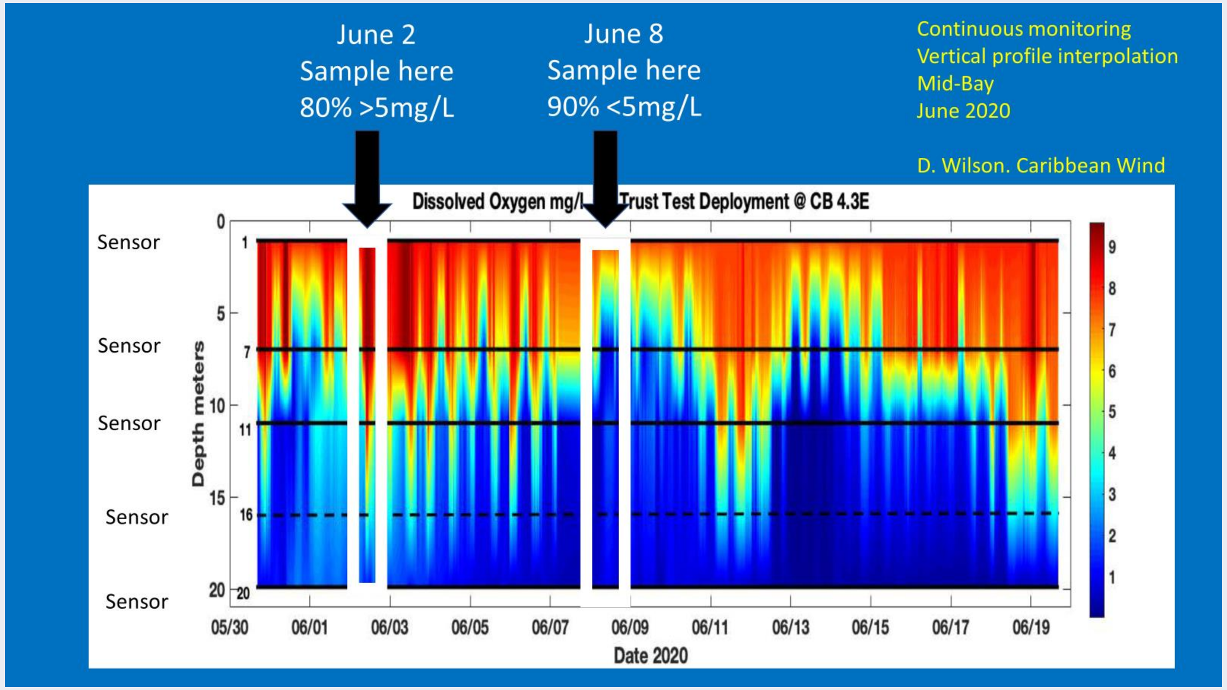
**Summary from summer 2022: 7m only**

| | May | | June | | July | | August | |
|---|---|---|---|---|---|---|---|---|
| | West | East | West | East | West | East | West | East |
| Sample count | 2191 | 1923 | 4299 | 4238 | 4450 | 2959 | 4420 | 4195 |
| percent <3.2 mg/L | 6.0% | 1.5% | **26%** | **15%** | **56%** | **14%** | **62%** | **18%** |
| percent <1.7 mg/L | 0.3% | 0% | **13%** | 2.2% | **30%** | 7.4% | **51%** | 6.1% |

- <u>Solution:</u> Our 4d interpolation will fit a statistical relationship between **DO, bottom depth, and distance E&W of the main channel** that easily explains these DO differences we see in the data.
- Ultimately, this information from the data + statistical relationship will help make good DO estimates non-monitored places using bathymetry and spatial coordinates.

# Going forward, strategic consideration of improved spatial and temporal habitat conditions in our evolving monitoring strategies and designs to capture habitat conditions influencing attainment assessments




High frequency for temporal habitat resolution

Transect considerations for spatial habitat resolution

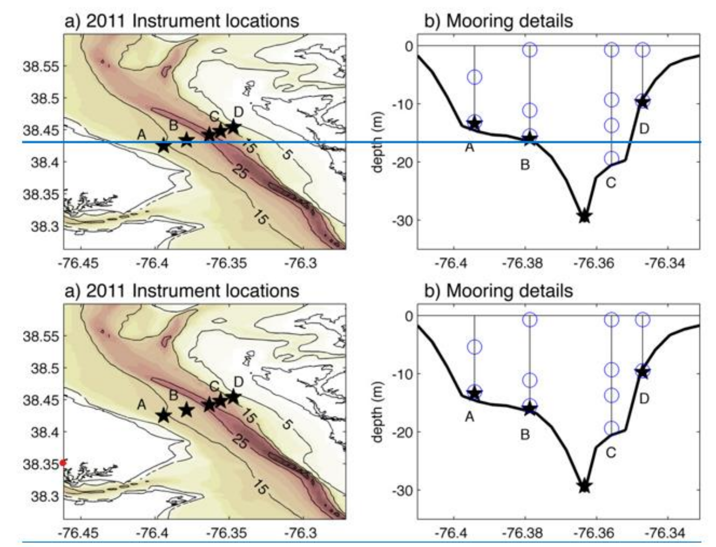



Figure 3. Scully (2016) used a transect of monitoring sensors across the mainstem Chesapeake Bay to track bay habitat positions and conditions.

# The evolving path to the new interpolator

# Just for comparison – the evolution of load estimation for Chesapeake Bay continues for RIM and NTN: 1990s-present

1. 1990s - 2010 - **ESTIMATOR/LOADEST** - Mike Langland/Joel Blomquist/Doug Moyer and others
2. 2006 - trend evaluation and documentation - Langland/Raffensperger/Moyer/Landwehr/Schwarz - https://pubs.usgs.gov/sir/2006/5178/pdf/sir2006-5178.pdf
3. 2010-2012 - **Combined ESTIMATOR/WRTDS** analysis for comparison - Moyer/Hirsch/Hyer/Blomquist -
4. Pub documententing the transition from **ESTIMATOR to WRTDS for the RIM stations** – Moyer/Hirsch/Hyer – https://pubs.usgs.gov/sir/2012/5244/pdf/sir2012-5244.pdf
5. 2012-2015 - Comparison and Documentation of **ESTIMATOR and WRTDS analyses across the NTN** -- Chanat/Moyer
6. Pub Documenting the transitions from ESTIMATOR to WRTDS for the NTN Stations - Chanat/Moyer/Blomquist/Hyer/Langland - https://pubs.usgs.gov/sir/2015/5133/pdf/sir20155133.pdf
7. 2015-2020 - Use WRTDS to compute loads and trends across the entire NTN
8. ~2018 - **Elgin Perry compares WRDTS and GAMS for estimating concentration trends at all MD core network** locations
9. 2020 - WRTDS-K - **WRTDS-K is being used to determine loads** (Mason) – WRTDS still is being used to determine trends in loads. (Mason).

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*For a beautiful historical summary, see PPT:*


**Water-Quality Trends in Virginia Waters:**
**An Evaluation and Review of Methods**

Jimmy Webber[1], Chris Mason[1], and Elgin Perry[2]
*jwebber@usgs.gov* *camason@usgs.gov* *eperry@chesapeake.net*
[1]U.S. Geological Survey (USGS), Virginia and West Virginia Water Science Center
[2]Independent consultant

# Partnership interest in moving from 3D to 4-dimensional (4D) water quality interpolation: 2008 STAC Panel and report

Assessing the feasibility of developing a four-dimensional (4-D) interpolator for use in impaired waters listing assessment December 2008 STAC Publication 08-008

Recommendations from the STAC Expert Panel

- Frank Curriero (Johns Hopkins University)
- Eileen Hofmann (Old Dominion University)
- Ragu Murtugudde (University of Maryland)
- Jian Shen (Virginia Institute of Marine Science)
- J. Andrew Royle (U.S. Geological Survey)

Microsoft Word - 4D report final.doc (chesapeake.org)

***"Why is the Chesapeake Bay Program interested in 4D interpolation?"***

- "The numerical water quality criteria established by Chesapeake Bay Program partners for the 303d listing process require assessment at space and time scales that are at higher resolution than is feasible with currently available data."
- "The development of an approach(es) that allows 4-D interpolation of the monitoring data sets…would allow combining and integrating measurements from numerous disparate datasets to generate a more complete interpolation of available data in space and time."
- **"This would improve the ability to evaluate water quality for the 303d listing process."**

# Historical interest in moving from 3D to 4-dimensional (4D) water quality interpolation: 2008 STAC Panel and report

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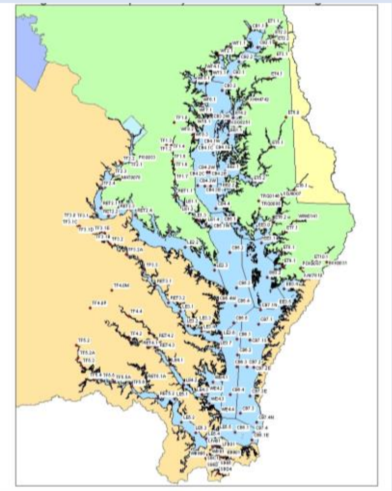
2008 Panel Findings

- Insufficient information available to evaluate the feasibility of a 4-D interpolator
- The panel recommended a study to evaluate the different approaches available for developing a 4-D interpolator
- Data analysis studies should be initiated to develop the statistical basis for a 4-D interpolator.

Microsoft Word - 4D report final.doc (chesapeake.org)

# 2008 STAC Workshop findings:



- A consensus opinion from the expert panel was that **the sampling frequency and spatial resolution of the existing Chesapeake Bay datasets are insufficient for successful extrapolation to four dimensions**.

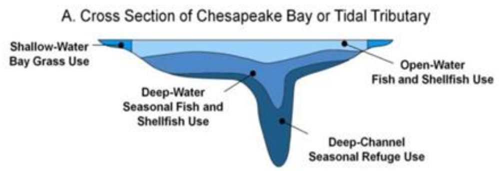
On the Monitoring front, it took over a decade – solving the data needs issue expressed in USEPA 2003

# Innovation Grants

2019: Two Chesapeake Bay Program working groups co-created a proposal for and innovation grant opportunity

Chesapeake Bay Program
*Science. Restoration. Partnership.*

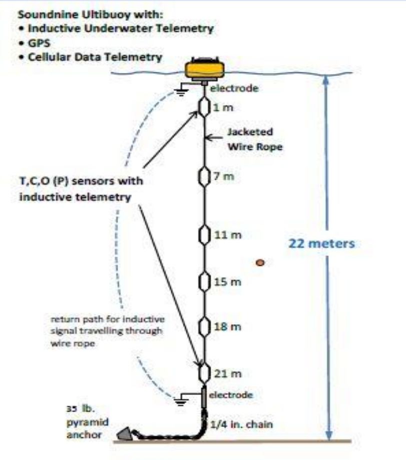
- $50,000, 18 months
- Develop a robust, efficient, effective water quality monitoring tool
- Collect realtime, full water column water quality data in the challenging conditions of the open waters of Chesapeake Bay

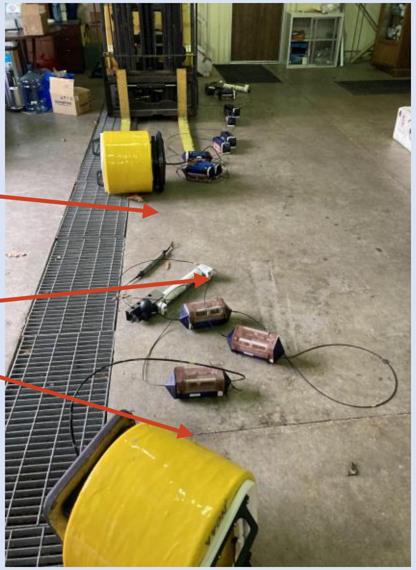


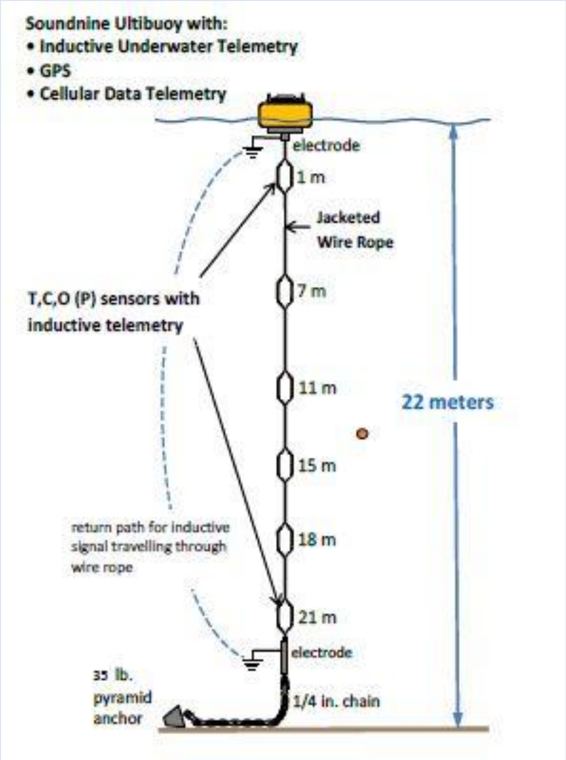
# Winner! Monitoring infrastructure: Portable vertical water quality monitoring array

- A station consists of
  - buoy/controller/cellular modem
  - some number of sensors on an inductive wire
  - mooring

- XIM-CTD-DO Sensor
  - conductivity cell
  - temperature sensor
  - pressure sensor
  - dissolved oxygen sensor
  - barnacles not included






Chesapeake Bay Program
40 years of science, restoration and partnership.

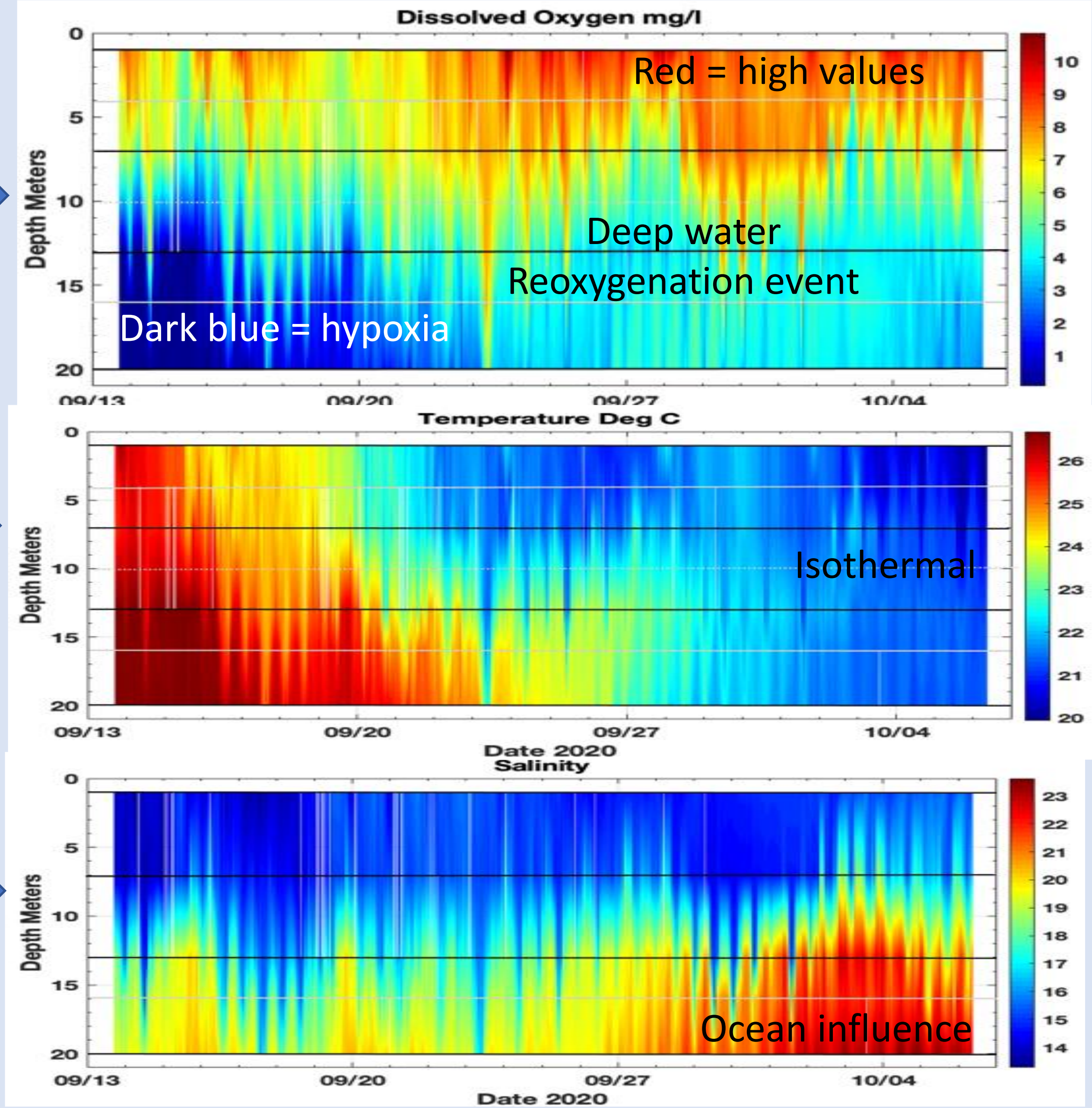
NOAA FISHERIES

# 2020 One location pilot study of new arrays in 20m of water, open Bay

- **Dissolved oxygen**
  water at this station becomes oxygenated with fall turnover

- **Temperature**
  stratification is lost and becomes isothermal

- **Salinity**
  stratification declines before oxygen rich high salinity water moves into the bottom waters




**~ $50K Instrument with high data return on investment**

**$4-5K per sensor**

Dates:9/13/20-10/7/20

D. Wilson 2020. CBT GIT-funded pilot project data

- In parallel, on the analytical science side, methods for 4-D interpolation to derive patterns in dissolved oxygen conditions were developed, and applications demonstrated

# 2019-20 publications

*Ecological Applications*, 30(2), 2020, e02032
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Bayesian mechanistic modeling characterizes Gulf of Mexico hypoxia: 1968–2016 and future scenarios

Dario Del Giudice[1,3] V. R. R. Matli,[2] and Daniel R. Obenour[1,2]

*Environmental Science & Technology* > Vol 54/Issue 20 > Article

Cite Share Jump to

CONTAMINANTS IN AQUATIC AND TERRESTRIAL ENVIRONMENTS | September 3, 2020

**Fusion-Based Hypoxia Estimates: Combining Geostatistical and Mechanistic Models of Dissolved Oxygen Variability**

Venkata Rohith Reddy Matli*, Arnaud Laurent, Katja Fennel, Kevin Craig, Jacob Krause, and Daniel R. Obenour

"The fusion-based approach also **reduces hypoxic area uncertainties by 11% on average** and **up to 40% in months with sparse sampling**."

"Moreover, our **new estimates of mean summer hypoxic area changed by >10% in a majority of years, relative to previous geostatistical estimates**."

"These fusion-based estimates can be a valuable resource when assessing the influence of hypoxia on the coastal ecosystem."

# Summer 2021

Chesapeake Bay Program
Science. Restoration. Partnership.

- Working under CBP-STAR guidance, a small team of analysts of the Chesapeake Bay Program's monitoring and modeling teams, with consultation and collaboration from independent statisticians and academicians, re-evaluated the state of the science on 4-D interpolation during spring and summer of 2021.

- **The team agreed 4-D interpolation of Chesapeake Bay water quality was now feasible**, and multiple options for approaches were available to address the issue.

# Organizationally, under COVID days: 2 new workgroups formed under STAR to address infrastructure and analysis developments needed to support habitat assessment and 4-D interpolator development



- Hypoxia monitoring network design, operation, and maintenance

Co-Leads: Peter Tango, Bruce Vogt, Jay Lazar, Kevin Shabow
CRC Staff: Justin Shapiro

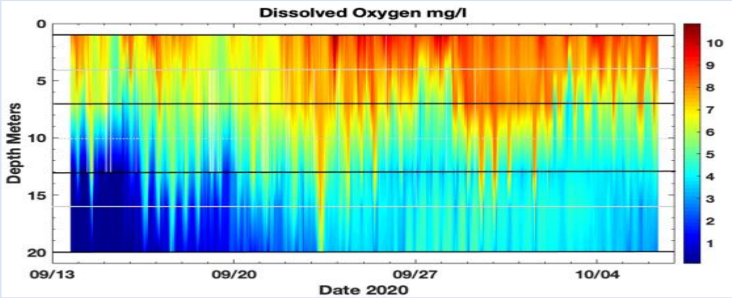
- 4-dimensional interpolator development, data needs, data ingestion and interpretation

Co-chairs: Rebecca Murphy and Peter Tango
CRC Staff: August Goldfischer

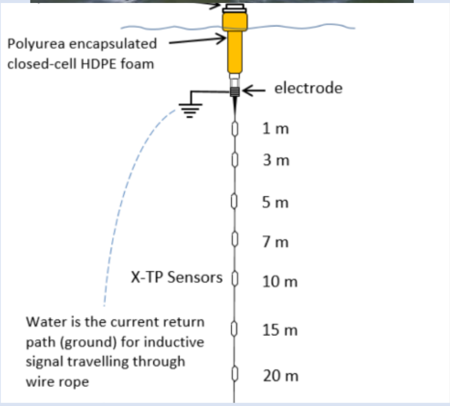
2021-2022 PSC requested Monitoring Program review:
The final report contained science-based recommendations including needs to address nearly 2 decades of data limitations of the monitoring program for addressing criteria assessment.

- Investment in a 10-array system equated to boosting program support to meet "adequate monitoring" described in USEPA 2003.


- 2023: Approximately $1M in new monitoring investments to deploy continuous monitoring buoys, which are equipped with vertical arrays of sensors to profile deep water areas of the Chesapeake Bay and tidal tributaries.




*"If these efforts succeed, then the shortcomings of existing datasets will be greatly alleviated."* Curriero et al. 2008 STAC Panel.



Where are we a decade or so later addressing the 4-D workshop recommendations towards supporting assessment of unassessed criteria?

# Data usage in 4-dimensional (4-D) interpolator development and application

Rebecca Murphy (UMCES/CBP)
Bay Oxygen Research Large Group
May 20, 2024

Key input on presentation from:
Elgin Perry (statistics consultant) and Jon Harcum (Tetra Tech)

# 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.

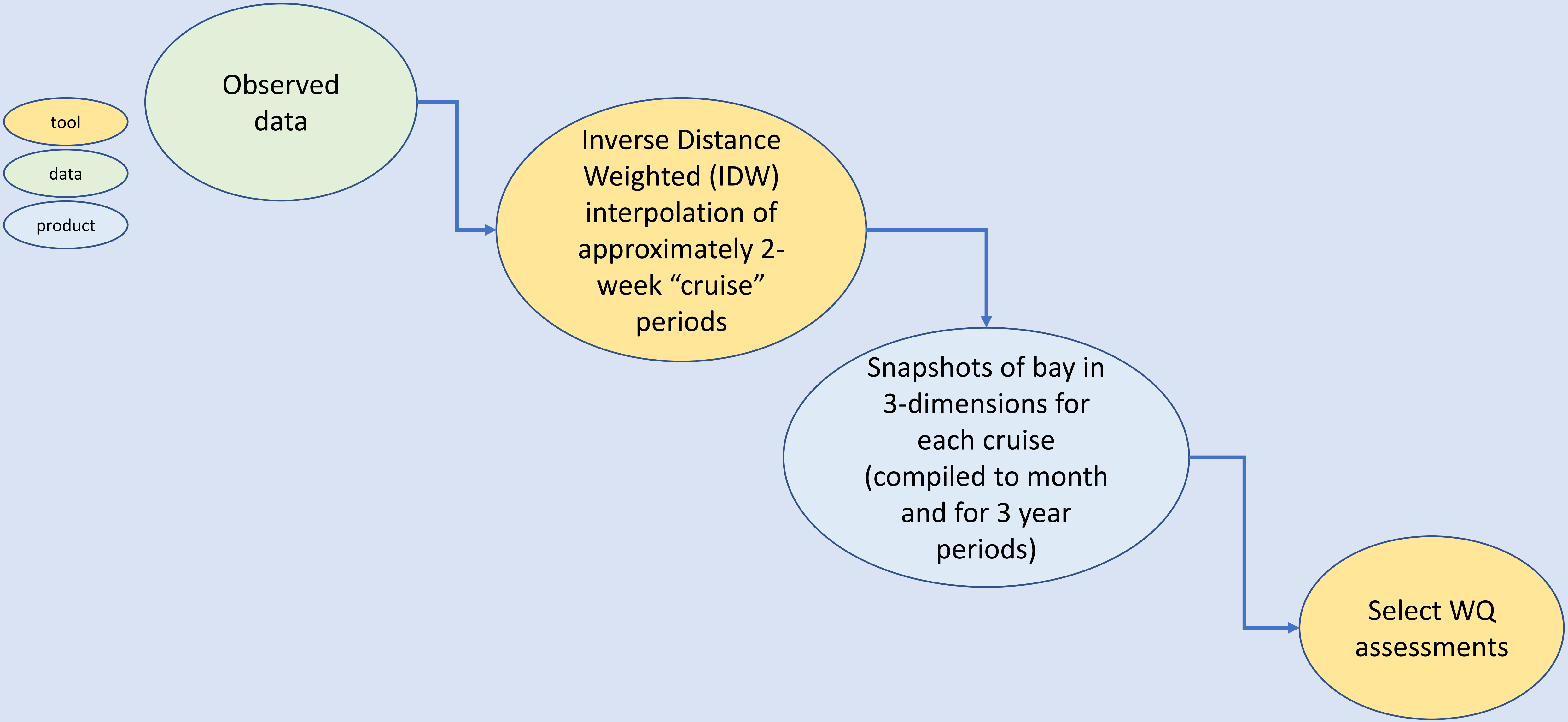
| Designated Use | Criteria Concentration/Duration | Protection Provided | Temporal Application |
|---|---|---|---|
| Migratory fish spawning and nursery use * | 7-day mean ≥ 6 mg $liter^{-1}$ (tidal habitats with 0-0.5 ppt salinity) | Survival/growth of larval/juvenile tidal-fresh resident fish; protective 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

# Current process (simplified)



# Current process (simplified)

Observed data

Tidal DO in CBP DataHub for “cruise” period =

- Long-term fixed stations +
- Calibration from ConMon and Dataflow +
- Citizen/riverkeeper monitoring that meets requirements.

*https://datahub.chesapeakebay.net/; data from MDDNR, VADEQ, VECOS, DOEE, and more*

Inv
We
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each cruise (compiled to month and for 3 year periods)

Select WQ assessments

# Goal for BORG team & 4-D tool

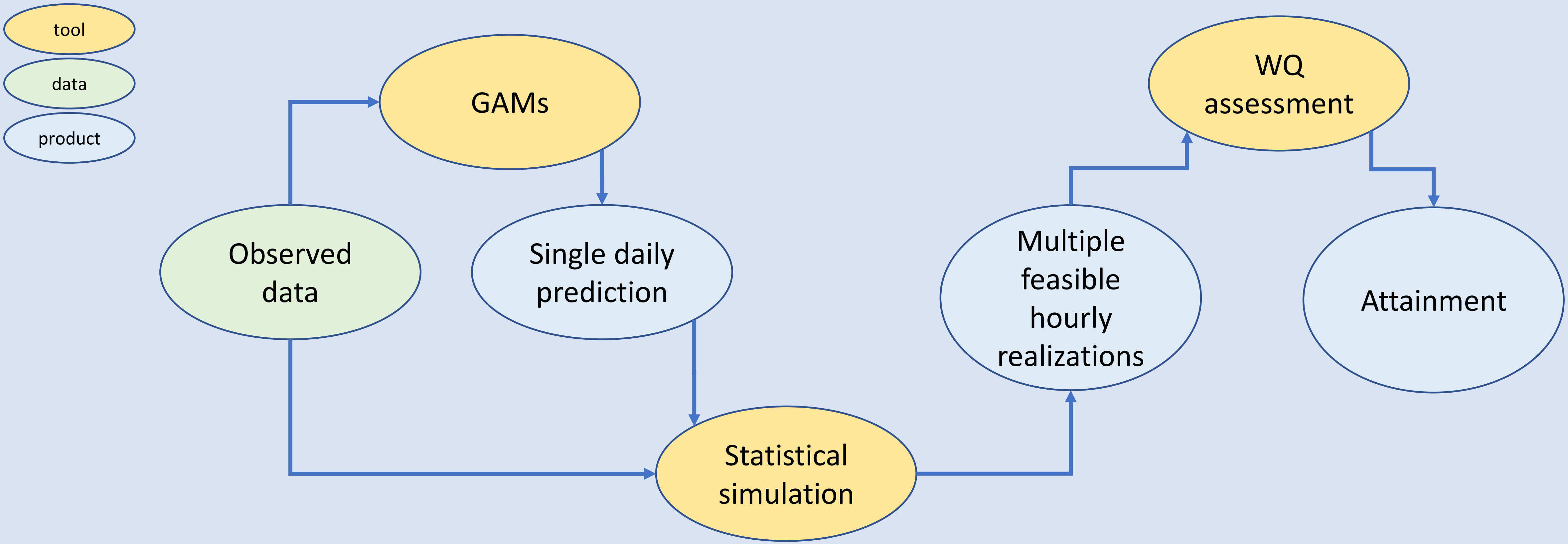
To develop a spatial-and-temporal interpolation tool for water quality monitoring data collected in the tidal waters of the Chesapeake Bay, thus enabling the evaluation of both long- and short-duration water quality criteria.

Specifically, the tool should be able to:

- Interpolate observed dissolved oxygen in space and time (“4D”),*
- Provide statistical estimates of uncertainty,
- Reproduce daily and hourly variability of the data, and
- Allow for post-processing of the interpolation output into designated uses (DU).

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

# WQ Assessment with new (aka "4D") interpolator



# 2022: New 4-D water quality interpolation is under development (Bay Oxygen Research Group):

Space-time interpolation with GAMs

*Simulator components*

## Long term temporal patterns

*Smoothly varying change from observations aided by deterministic relationships with continuously available information (flow, wind, temperature, dynamic model output, etc)*

Key data example: Long-term fixed network

+

## Spatial structure

*Spatial autocorrelation; anisotropy in depth direction; deterministic relationships to other spatial data (bathymetry, satellite images, etc)*

Key data example: Dataflow

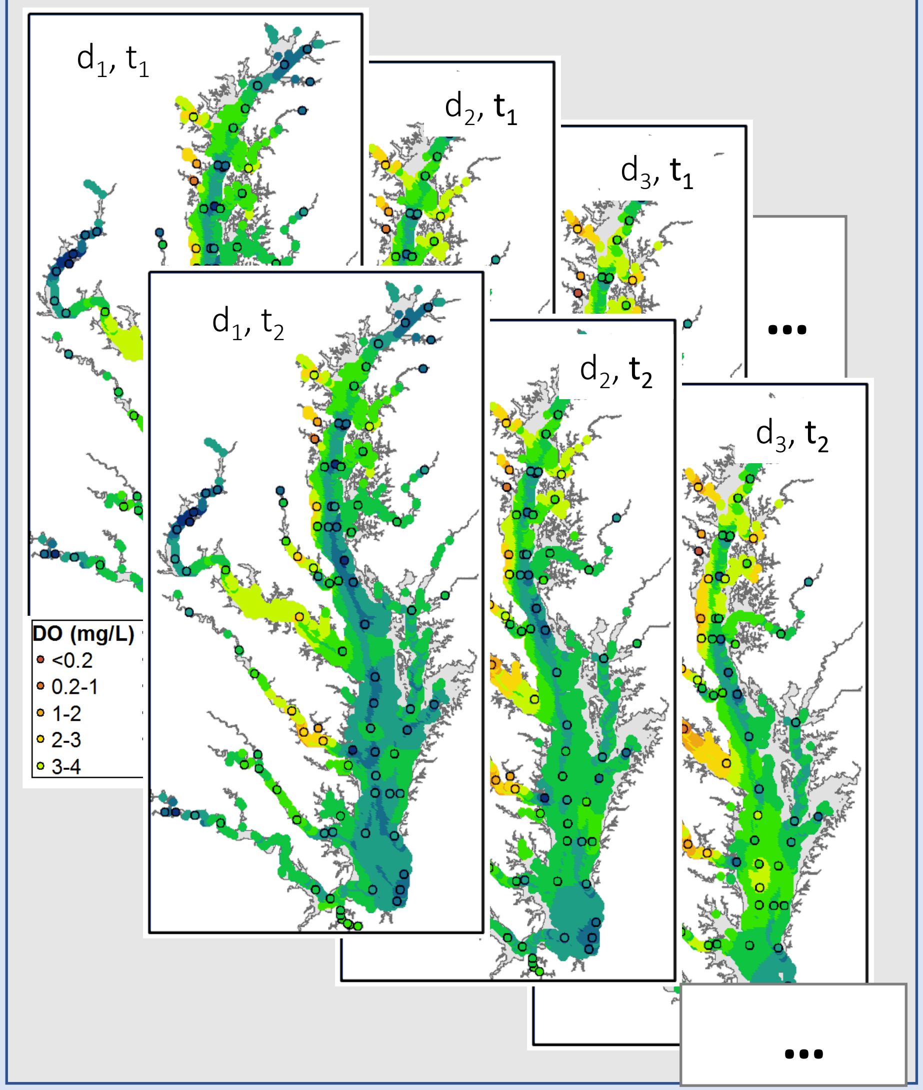
+

## Short term temporal variability

*Daily & tidal cycling, temporal autocorrelation, etc*

Key data example: Conmon

*"4d" Spatial & temporal estimates of DO*




Source: R. Murphy

# 2022: New 4-D water quality interpolation is under development (Bay Oxygen Research Group):

Space-time interpolation with GAMs

# Generalized Additive Models

*Simulator components*

## Long term temporal patterns

*Smoothly varying change from ob...*
*deterministic rel...*
*... model*

...mple: Long-term fixed network

✚

## Spatial structure

*Spatial autocorrelation; anisotropy in depth direction; deterministic relationships to other spatial data (bathymetry, satellite images, etc)*

Key data example: Dataflow

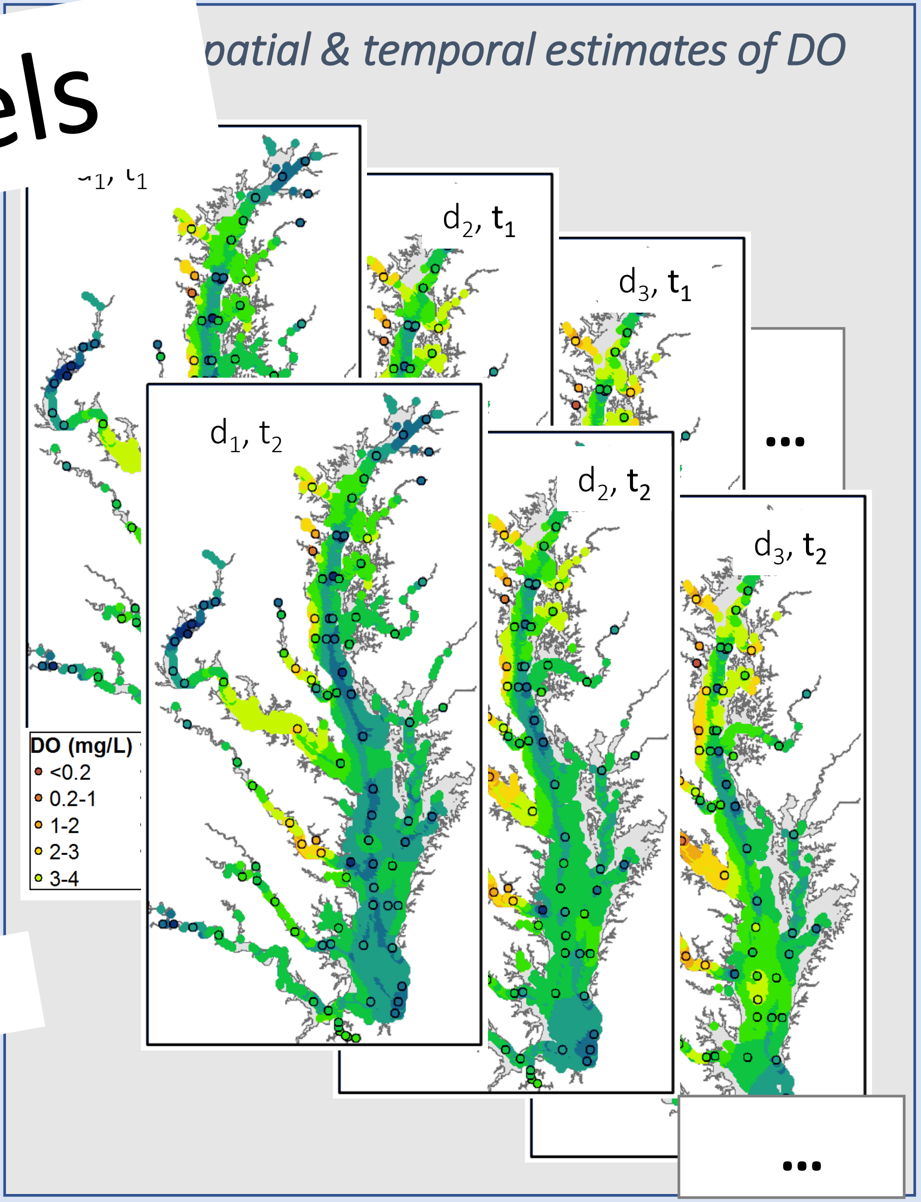
✚

## Short term temporal variability

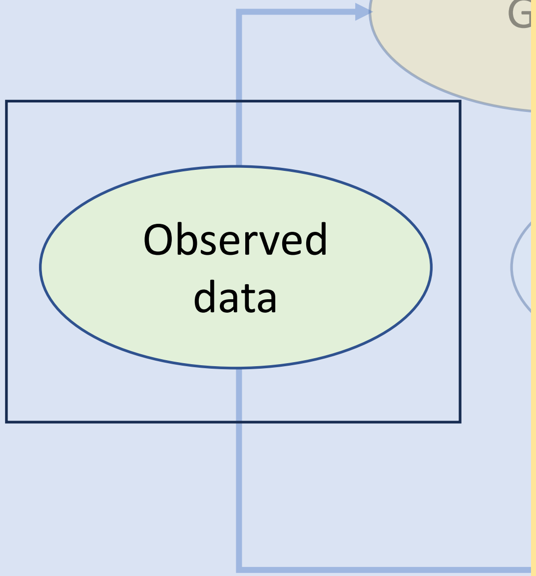
*Daily & tidal cycling, temporal a...*

Key data examp...

Exploring Wavelet Analysis and more

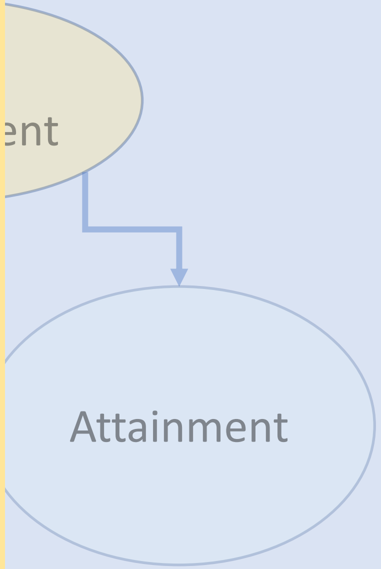



Source: R. Murphy




# Some general notes on data use

- The data used for the current interpolator will still be used.
- This *will not be a process-based model* but is based on **observed data.**
- The "modeling" is building **statistical relationships** between DO data and: 1) location, 2) time, 3) other DO observations (i.e., autocorrelation).
- These relationships will enable us to estimate (with uncertainty) what the DO was in a place and time when there was no data collected.



# Uses of data, as envisioned to-date*

1. Explore patterns to inform development

2. Development & testing

3. Validation

4. Application

**Note:** *Changes are very possible as we move forward in development and learn about additional data sets and how the models work.*

# Uses of data

1. Explore patterns to inform development

- Identify high frequency cycles (e.g., tidal & daily)
- Parameterize temporal autocorrelation
- Parameterize spatial autocorrelation

2. Development & testing

- Fit and estimate daily DO
- Fit and estimate hourly DO deviation
- Fit and estimate pycnocline depths

3. Validation

- Conduct hold-out tests
- Conduct future validation tests using additional data sets

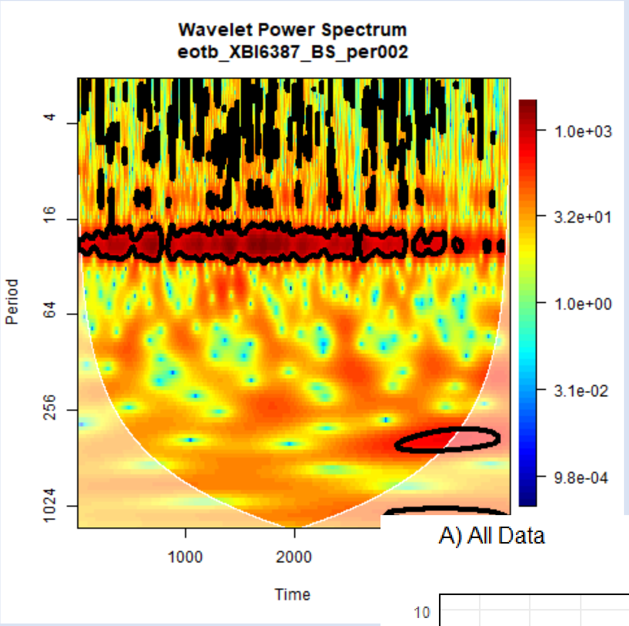
4. Application

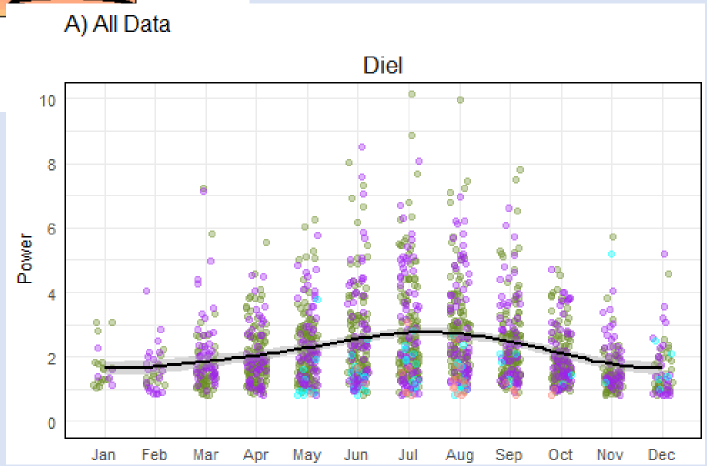
- Fit and estimate DO and pycnocline for specific 3 years

1. Explore patterns to inform development

# Identify High Frequency Cycles

*When and where are there sub-daily cycles in DO?*




From Jon Harcum and Erik Leppo, Tetra Tech

- **EOTB: Eyes on the Bay (MDDNR)**
  - *2001-2022*
  - *126 ConMon stations*
- **VECOS: Virginia Estuarine and Coastal Observing System (VIMS)**
  - *2003-2022*
  - *52 ConMon stations + 2 profilers*
- **NOAA vertical arrays**
  - *2022-2023*
  - *5 stations*
- **Additional data used in Umbrella Criteria Analysis**
  - *1987-1995*
  - *23 stations with sufficient record length (EMAP, plus some others)*

➢ NOTE: data >4 days duration needed for this analysis; and we can add additional data in other steps.

1. Explore patterns to inform development

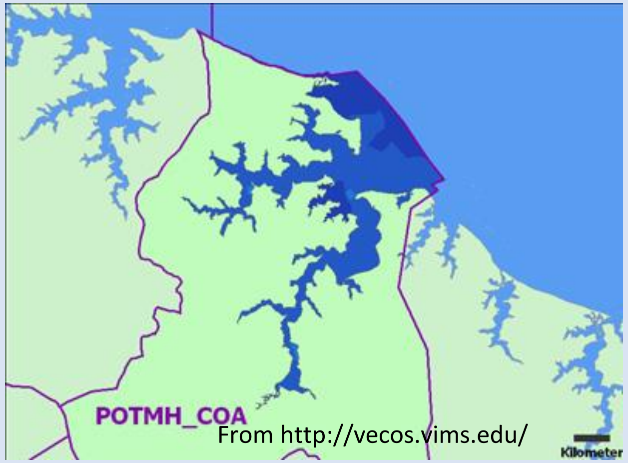
*Fill in the correlation matrix to represent similarity of data points close to each other*

# Parameterize Autocorrelation

From http://vecos.vims.edu/

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

10/13/2009 VECOS




From http://vecos.vims.edu/

## Temporal autocorrelation

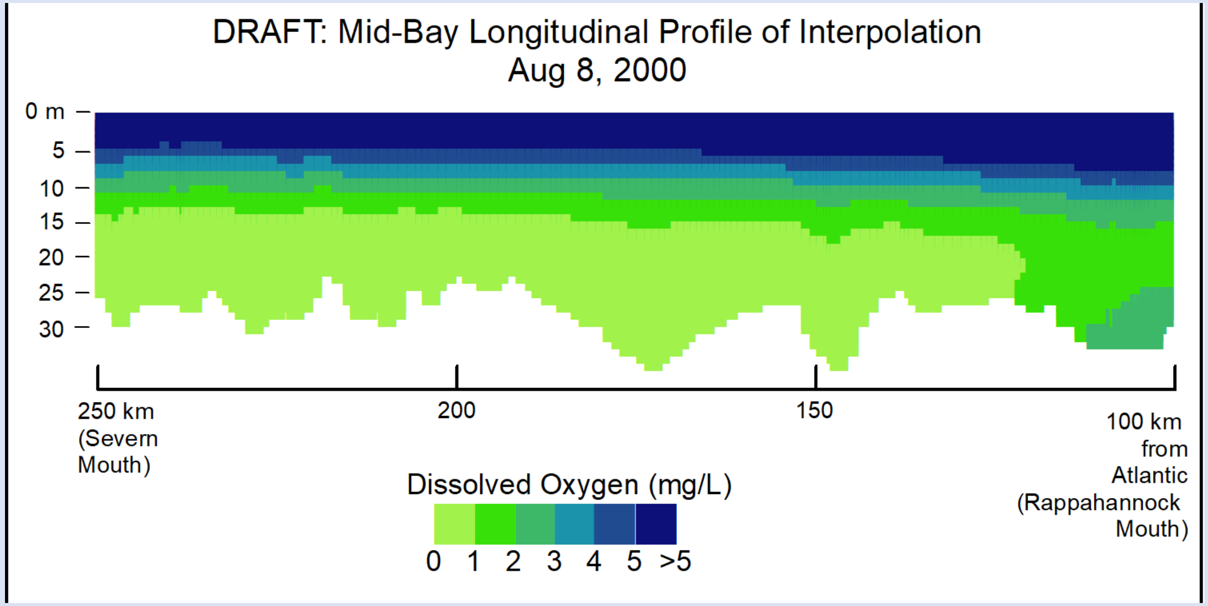
- **All ConMon and vertical array data (previous slide)**
  - *Used in Arima analysis to get autocorrelation parameters (Elgin Perry, Jon Harcum)*

## Spatial autocorrelation

- **Dataflow – all years of data from MDDNR and VECOS**
  - *Focus on horizontal dimension*
  - *Initial work is starting in Potomac fitting variograms (Wes Slaughter, UMd)*
  - *Future work: test and compare elsewhere*
- **High frequency vertical arrays & fixed stations with multiple depths**
  - *To identify spatial correlation in the vertical*
  - *Not started*

*Uses a Generalized Additive Model (GAM) for mid-day estimates, everywhere*

# Estimate Daily DO (and pycnocline)




- **DataHub DO, salinity and temperature data**
  - *This is MD, VA, and DC fixed station data; ConMon & dataflow calibration data; and additional approved data*
- **EOTB, VECOS, and NOAA high frequency ConMon and Vertical array data, <u>daily subset</u>**
  - *Subset to a single daily value from each station to be consistent with sampling time of fixed station data*

2. Development & testing

*Uses Fourier analysis to estimate the expected deviation from the mid-day DO at each hour of the day*

# Estimate the Hourly DO Deviations

**Example:** Fourier analysis with just daily cycle to fit hourly DO ($DO_h$)

$$DO_h = lc * h + sc * \sin\left(\frac{2\pi * h}{24}\right) + cc * \cos\left(\frac{2\pi * h}{24}\right) + \tau$$

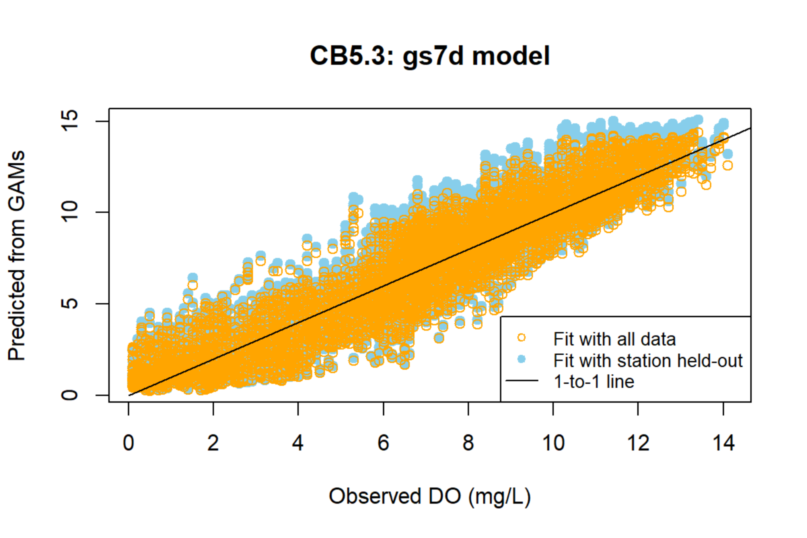
*coefficients*

***h = hour 1:24***

- **EOTB, VECOS, and NOAA high frequency ConMon and Vertical array data, <u>hourly subset</u>**
  - *Subset to hourly only if collected at higher frequency*

# Evaluating the Tool

Validation tests




## Hold out tests

- **All same data as daily GAM fitting**

## Additional validation tests

*Not started.  The extent of this work to be determined by time, funding, and other evaluations of performance*

- **Water quality collected along with fisheries data**
- **Other citizen science data**
- **Location-specific:** Perhaps hold-out tests in some high-density sampling program segments (e.g., MD's work in Fishing Bay)

# Interpolation for 3-year Assessment Periods

- **DataHub data**: for the same time period, as done currently
- **EOTB, VECOS, and NOAA high frequency ConMon and vertical array data,** used in 2 ways:
  - *Subset to daily for daily component, and*
  - *Used at hourly level for hourly deviation estimates*.*

- *We may use some high frequency data outside the 3 years for predicting hourly deviations.
- Decisions on when & where to model tidal and daily cycles and autocorrelation parameters will be built from more than just 3 years of data.

# Other possible data sets & uses

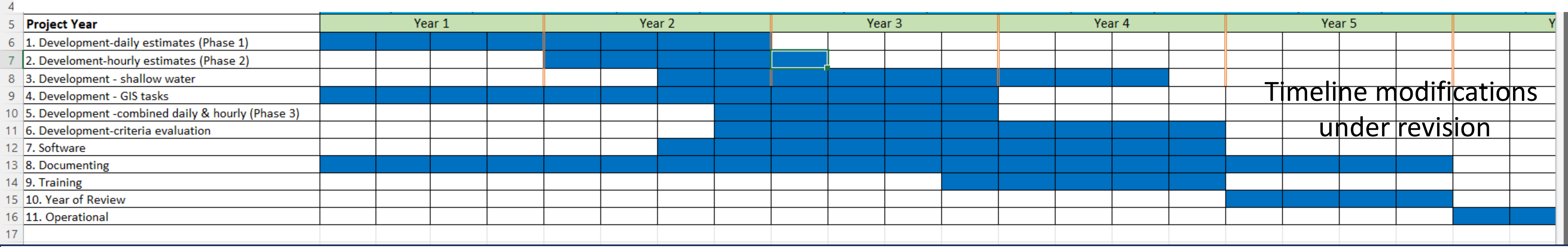
- Shallow water explorations
  - *NOAA daily products for salinity and temperature based on satellite data (Wes Slaughter's work)*
- Pycnocline:
  - *Possibly use freshwater flow measured at USGS gages*
  - *Maybe meteorological data as well*
- Bathymetry:
  - *We need to know the bottom depth everywhere, and want to use any updated information if possible.*

2024: We are in still in the first half of the development phase

2024-5: Documentation phase

2026: Review year

2027: Phase 1 Operational



# Documentation phase – CAP WG work and decisions ahead.

- Document details of new interpolator framework

- Document assessment decision structure
  - Updates on state boundaries
  - Updates on DU
  - Updates on precision and rounding
  - Updates on process for 30-day, 7-day, 1-day, IM
  - Updates on seasonal assessments
  - Updates applying to D.O., SAV, CHLA as developed and agreed upon.

# Sources and thank you!

Chesapeake Bay Program
Science. Restoration. Partnership.

- Data compilation thanks: Mike Mallonee (ICPRB); Mark Trice and Rebecca Burrell (MDDNR); David Parrish (VIMS) and Carl Friedrichs (VIMS); Jay Lazar and CJ Pellerin (NOAA); Erik Leppo (Tetra Tech).
- MDDNR EOTB: https://eyesonthebay.dnr.maryland.gov/
- VECOS: http://vecos.vims.edu/
- CBP DataHub: https://datahub.chesapeakebay.net/
- Umbrella Criteria Analysis data citations:
  - Tidal Monitoring and Assessment Workgroup. (2011). Retrieved from https://d18lev1ok5leia.cloudfront.net/chesapeakebay/documents/2011_umbrcrit_wrkshp_rprt_dec2011pt.pdf
  - Tidal Monitoring and Analysis Workgroup (TMAW). (2012). STAC Publication 12-02. Retrieved from https://www.chesapeake.org/pubs/289_UmbrellaCriterionActionTeamTidalMonitoringandAnalysisWorkgroup2012.pdf

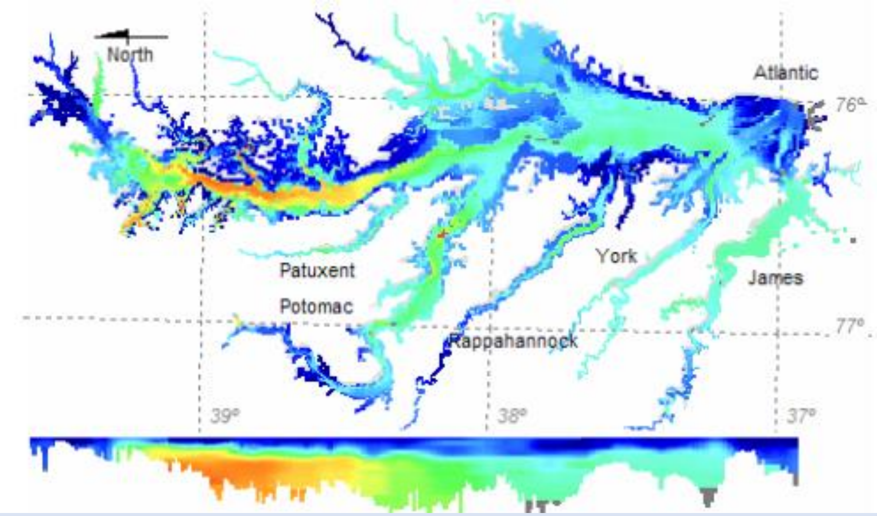
# BORG leadership

- Rebecca Murphy Co-coordinator
- Peter Tango Co-coordinator
- Elgin Perry
- Gary Shenk
- Breck Sullivan
- Isabella Bertani
- Richard Tian
- Jim Hagy
- Angie Wei
- John Harcum
- Eric Leppo

Hypoxia Leadership: Bruce Vogt, Jay Lazaar, Kevin Shabow, Bailey Roberty, Justin Shapiro

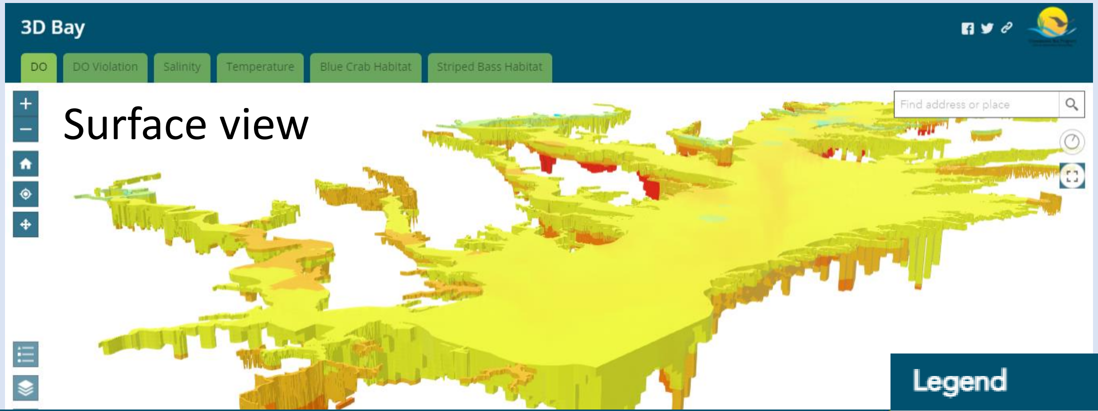
EPA support and our newest addition, Kaylyn Gootman!

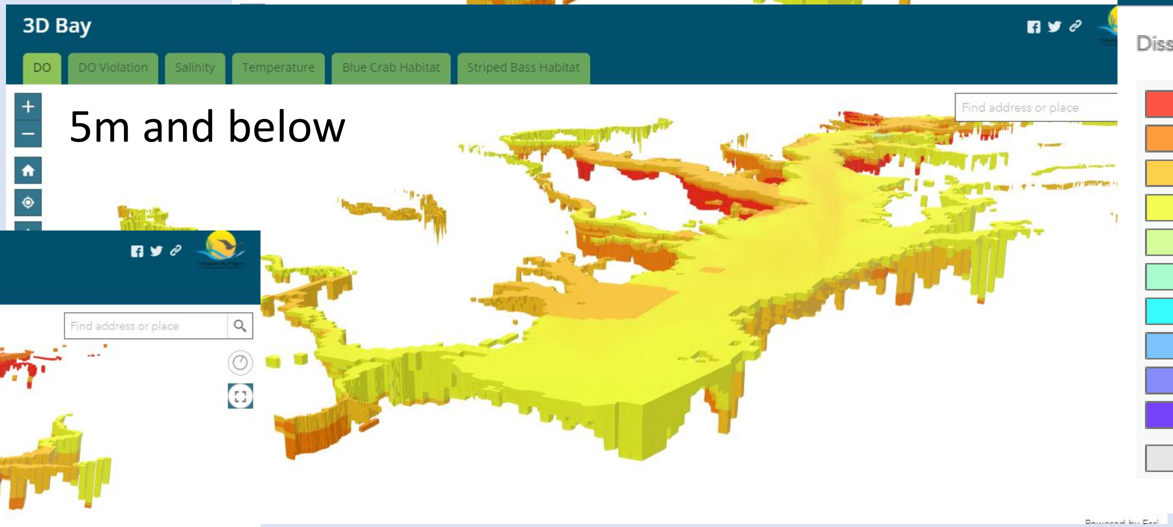
# Interpolation tools: Currently, we are still in 2008 interpolation world getting water quality snapshots in time (inverse distance weighting algorithm)




*VOL3d program output*

**July 2017 interpolation of DO**






*Zhaoying (Angie) Wei: beta tool*
*https://bit.ly/2IoRqbm and*
*https://chesbay.maps.arcgis.com/apps/MapSeries/index.html?appid=9ece32c58926433a99e066c4fe6edd78*

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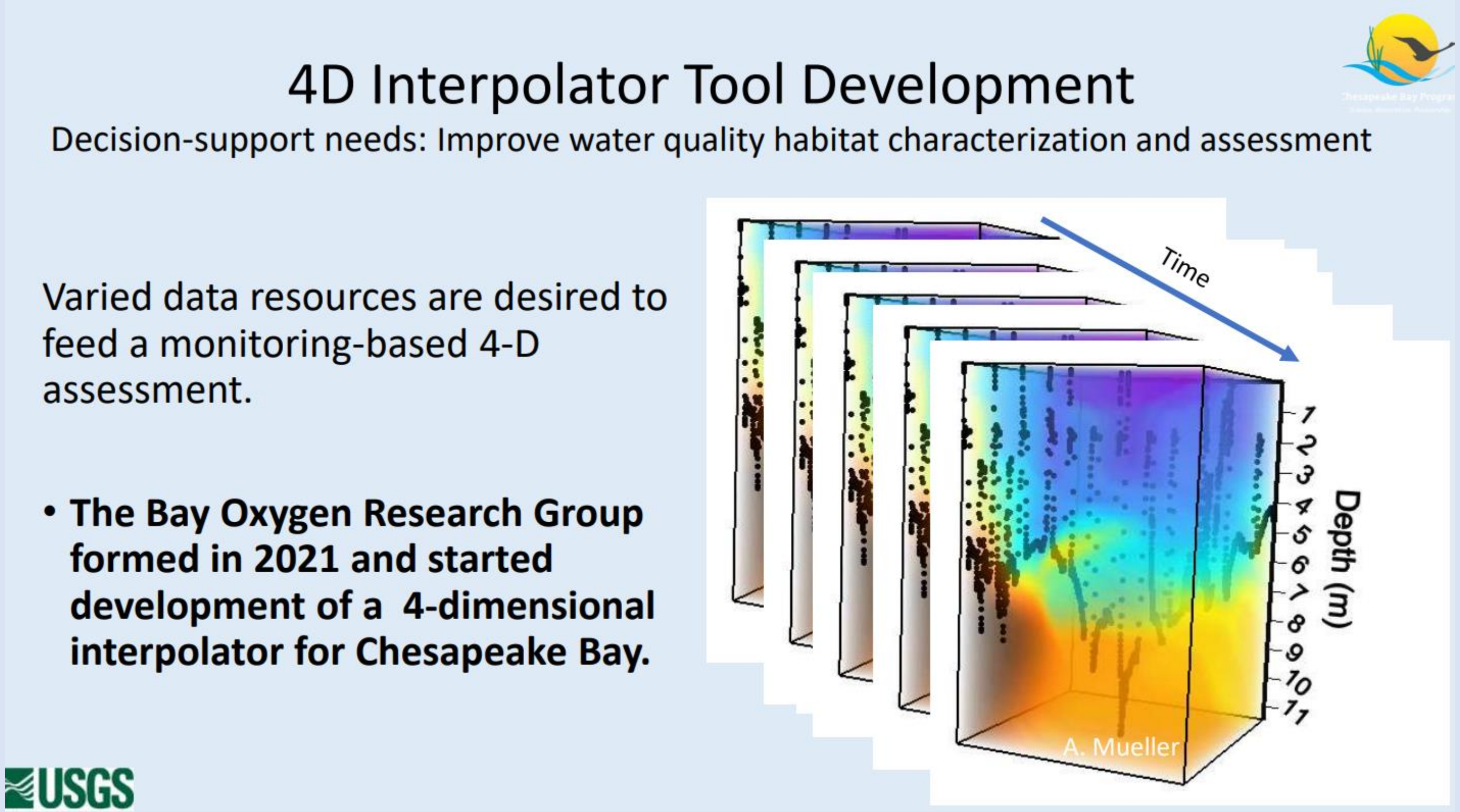
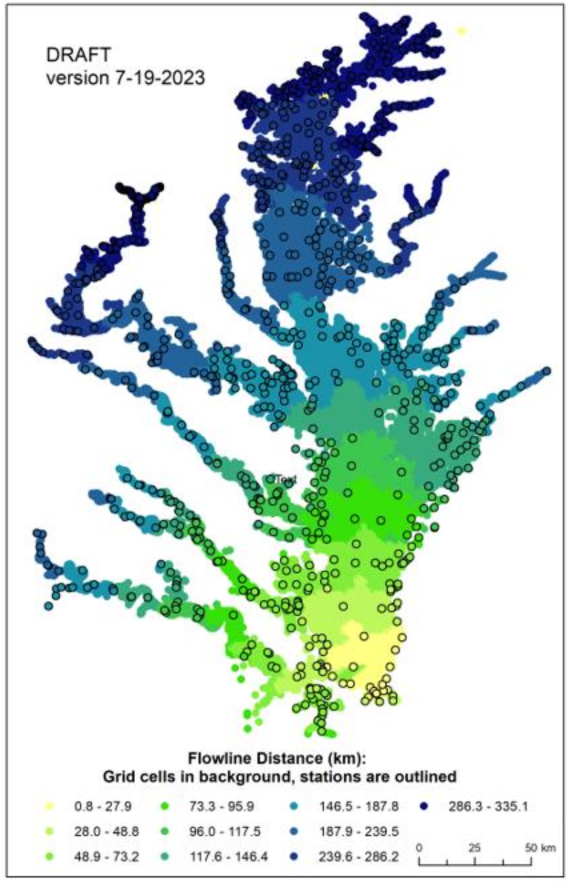
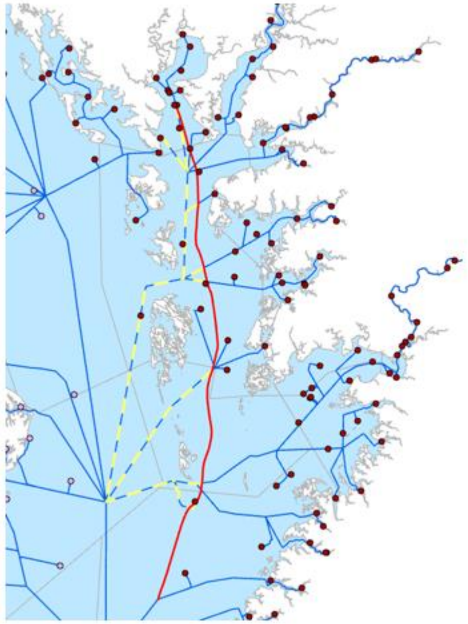


# Coordinate system design based on flowline distances underpinning the interpolator tool



Working draft example of some flowline-based pathways between stations, as well as work we are doing to adjust paths to follow bathymetry in certain regions.

Angie Wei UMCES
Geospatial analyst