Bay Oxygen Research Group

Monday, September 16th, 2024
12:00 PM – 1:30 PM

Meeting Materials Link

This meeting was recorded for internal use to assure the accuracy of meeting notes.

Action Items:

- ✓ Let Rebecca Murphy (rmurphy@chesapeakebay.net), Peter Tango (ptango@chesapeakebay.net) and August Goldfischer (agoldfischer@chesapeakebay.net) know if you would like to attend the monthly development team meetings.
- ✓ If anyone has questions for Wes Slaughter on his research or wants to follow up about the DataFlow analysis, reach out to him at wslaught@umd.edu and/or Slaughter.Weston@epa.gov

Attendance

August Goldfischer (CRC), David Kintgen (Arlluk), Breck Sullivan (USGS), Peter Tango (USGS), Jon Harcum (TetraTech), Andrew Keppel (MD DNR), Mark Trice (MD DNR), Elgin Perry, Isabella Bertani (UMCES), Guido Yactayo (MDE), Leah Ettema (EPA), Wes Slaughter (ORISE/UMD), Rebecca Murphy (UMCES), Marjy Friedrichs (VIMS), Becky Monahan (MDE), Matt Stover (MDE), Richard Tian (UMCES), Cindy Johnson (VA DEQ), Tish Robertson (VA DEQ), Amanda Shaver (VA DEQ), Lee McDonnell (EPA), Gabriel Duran (CRC), Colin Hawes (VIMS), Gary Shenk (USGS), Anthony Johnson II (NOAA), Anna Lisa Mudahy (EPA), Jay Lazar (NOAA), Angie Wei (UMCES), Joseph Morina (VA DEQ), Jim Hagy (EPA), Aaron Bever (VIMS), Lew Linker (EPA), Carl Friedrichs (VIMS)

Minutes

12:00 PM Introductions/announcements – *Peter Tango (USGS)*

Rebecca Murphy invited anyone who would like to attend the development team meetings to let her and Peter Tango know.

Jay Lazar introduced himself and Anthony Johnson II, both from NOAA's Chesapeake Bay Office. Jay oversees the hypoxia stations field work, data collection, quality control and delivery. Anthony works on the hypoxia stations team as well.

Aaron Bever introduced himself. Aaron works with Marjy Friedrichs at VIMS on real time forecasting.

Peter Tango introduced Gabriel Duran, the newest STAR staffer.

Marjy Friedrichs announced in the chat:

If anyone is interested, feel free to check out the data from the real-time hypoxia sensor array, along with Chesapeake Bay Environmental Forecast System (CBEFS) output for greater context, here. I just emailed out some example figures as well. Let me know if anyone has any feedback/questions/etc. Just click on "Vertical Profile Comparisons" on this site.

12:10 PM **Update from Criteria Assessment Protocol Workgroup –** *Peter Tango (USGS)*

Summary:

The CAP WG met in person and virtually on August 13, 2024 at Colonial Beach, VA/online. Meeting objectives were: Continue building common understanding on evolving and improving our monitoring and regulatory assessment frameworks; take stock of Dissolved Oxygen (D.O.) criteria assessment options; continue building community understanding of the new tidal Chesapeake Bay water quality interpolator. The meeting was divided into 3 sessions: Monitoring and Assessment Framework; Interpolator 101; Short duration criteria attainment considerations. Presentations were given by EPA on regulatory expectations of 303(d) listing, MDE on their enhanced monitoring case study in Fishing Bay, and their regulatory needs and perspectives, and VA DEQ on their proposal for assessing all Bay DO criteria with existing datasets and assessment tools. VA DEQ also shared updated CB6/CB7 boundary conditions. Clifton Bell (Brown & Caldwell) also spoke on the binomial decision structure. Peter Tango gave an overview of the 4-D interpolator and concepts around interpolation.

Needs going forward include:

- ✓ Computational definitions for our DO criteria – with 15 minute data, what is our procedure for computing instantaneous minimums, 1 day mean, 7 day mean, 30 day mean?
- ✓ Any minimum data requirements
- ✓ How to address data gaps in time series
- ✓ Using data from multiple sources (e.g., nearshore continuous monitoring/con-mon and offshore vertical arrays)
- ✓ Allowable criteria exceedance levels when high temporal frequency data assessments are available?
- ✓ Consider interim assessment rules for making standards assessments while the new interpolator is under development
- ✓ Support from CBP to the states for operating the 4-D interpolator

Follow-up from the meeting include: small meetings with state partners (currently being planned); bi-monthly CAP WG meetings scheduled to address growing list of topics; monitoring strategy support being developed through GIT funding; and continued cooperation and collaboration with our partners on new interpolator development. The CAP WG will continue to discuss what data is being used, in what ways for the development of the 4-D interpolator and running an assessment with the interpolator. The CAP WG will also continue to work on the criteria definitions (instantaneous minimum, means and data needs) along with assessment details necessary to integrate with the BORG Team interpolator development. BORG Team will continue to show how data are being used to inform development, and Hypoxia Collaborative and CAP WG will continue to address monitoring strategy support.

Discussion:

Richard Tian: The 4-D interpolator will not be applied to modeling scenarios, am I understanding that correctly?

Peter Tango: My understanding is that as scenarios are developed and data are modified, those are the modeling results that can be put through the interpolator to look at change in expectation relative to the TMDL scenarios.

Gary Shenk: In terms of the way we'd use the water quality model and interpolator together, there wouldn't be any change in the relationship between those two. We'd still look to modify the input dataset which would be processed through the interpolator.

Elgin Perry: It's possible we'd use output from the Bay Model as a benchmark dataset to test the interpolator against. But it wouldn't be used as an input. We'd take the output from the water quality model, sample that and interpolate that. We'd have the advantage of comparing the interpolated results to the Bay model results to see how well the interpolator does. The water quality model won't serve as an input database to the interpolator.

Marjy Friedrichs in the chat: Excellent point, Elgin! I hope that is indeed part of this process. That will be really useful.

Tish Robertson: Will the 4-D interpolator be ready in time for the newest planning targets?

Gary and Peter: That's the plan. That would be in 2028.

12:25 PM 4-Dimensional Interpolator Development Updates

12:30-12:45 Development overview: Rebecca Murphy (UMCES)

Summary:

We are working on a new interpolation method within the context of criteria assessment. It goes back to the 2003 ambient water quality criteria document where the Cumulative Frequency Distribution approach is laid out with notes about how spatial interpolation is needed as part of this process. There is discussion about how other criteria assessments are done only on temporal variation; but the reason for an approach with interpolation and the CFD is the size of the Chesapeake Bay.

The current approach for the criteria assessment is mostly focused on using the biweekly monitoring data at fixed stations in the Bay, spatially interpolating it cruise by cruise, and aggregating those interpolations over a 3-year period. Each interpolation result for each cruise is compared to criterion values in each grid cell. Those comparisons are aggregated and compiled in a Cumulative Frequency diagram. That's how we determine whether a segment is or isn't meeting a specific Designated Use over a 3-year period.

We know that we need estimates of interpolation of oxygen at high frequency throughout the Bay. For the current interpolator, it does not use the high frequency data at high frequency. It uses the calibration data at the con-mon stations but not the 15 minute or hourly high frequency data. The way the current interpolation is implemented is that horizontal layers are interpolated and stacked on top of each other. It's also implemented one cruise at a time, which is usually a 2-week period. Results assume the 2-week period of oxygen is static, which is not the case.

The new interpolator will address the challenges of the old interpolator. All the high frequency data will be used at high frequency. We will interpolate all the data together, not in vertical layers. We will interpolate in time, so we don't have the 2-week snapshots. 3 dimensions in space + 1 in time = 4 dimensional interpolator. It will be statistical. Advances in approaches and computing power have allowed for getting uncertainty bounds if deemed necessary for criteria assessments.

Summary of the new method: We intend to use all the DO data collected in the Bay, including fixed station data, Tier 3 citizen science data, high frequency con-mon data at high frequency, high frequency vertical array data. We'll make full use of DataFlow data in the future, and any emerging data sets. All that data is used in different parts of interpolation. We have split it up into 4 pieces. Mid-day space and time interpolation will give an overall picture of oxygen every day throughout space in the Bay. Large-scale correlation component will capture variability spatially and temporally. Within-day cyclic interpolation will use the high frequency data to see the daily and tidal cycles of oxygen in places where we have that data and interpolate it where we don't have that data to provide an hourly picture of oxygen in the Chesapeake Bay. That comes with a small-scale correlation component to capture uncertainty bounds and variability.

These pieces were designed to represent different spatial and temporal features of the DO data; ultimately, it will be the sum of these 4 components that will be used as our interpolation results, not any incremental results. All 4 pieces go together, all the time.

Rebecca then stepped through an example of using all 4 components of the interpolation, and explained that Elgin has an example of how he applied the techniques at East Gooses' Vertical Array in 2022 to see if we could piece together all these parts and if it matches the data; and it does. Jon is taking all the high frequency data and pulling out the different parameters for the different parts of interpolation, and aggregating it all plus the correlation components to apply that information where the data is and interpolate where we don't have data in order to generate reasonable hourly DO interpolations in the tidal waters. Ultimately, all of these pieces go together. We're in the middle of development in 2024; documenting, review, and training will occur through 2026.

Discussion:

Tish Robertson commented in the chat: It was my understanding that there is a vertical interpolation step to "fill in" missing depth intervals. But Rebecca is correct that it isn't a 3D interpolation. The above applies to the 3D Interpolator.

Rebecca Murphy responded in the chat: Tish - that is right, there is a vertical interpolation to get an estimate every meter before IDW is applied to the horizontal layers. That vertical interpolation is a linear one. I anticipate it would be an improvement to consider all the data together as opposed to one step at a time.

Lew Linker: Using all the observed info for DO is smart. But if we look at June 8 DO is approaching 9 mg/L. The only way to get that is to have enough chlorophyll to make that oxygen. Do you see ancillary datasets like the amount of chlorophyll that would be able to be used? When we get into the deeper waters, wind is a big thing and operates in a predictable way. If you have enough velocity you can overturn the water column. Or if you have a constant Westerly wind you'd have Westerly hypoxia. Will you be looking at other datasets like wind and chlorophyll to augment interpolation of DO?

Rebecca Murphy: We've considered both of those things, but don't have enough chlorophyll data (we don't have it everywhere we have oxygen data). Wind is more likely.

Lew Linker: Shallow water and chlorophyll is where you find this phenomenon. Would satellite sweeps of chlorophyll help to add enough data?

Rebecca Murphy: I agree.

Aaron Bever: What's the timeframe of the training data going to be? Does it go back to 1985?

Rebecca Murphy: In development, we're starting at 1990. For applying it for the assessment, we're focusing on the 3 most recent years.

Carl Friedrichs: We don't have wind sensors everywhere. Wouldn't that be a model product? With that logic couldn't you use other products from models? Like modeled chlorophyll?

Rebecca Murphy: I was more thinking we'd use the wind stations. We will be staying away from using dynamic model output in the interpolation at least for now.

Mark Trice commented in the chat: Accurate wind over water is complicated to assess where you are not measuring it directly. If further consultation is needed, Jay Titlow of WeatherFlow, Inc. was/has been involved in these products via MARACOOS.

12:45-1:00 Example Goose Reef simulation case study results: Elgin Perry

Summary:

The goal of this case study was to see if the ideas for having the interpolator mimic the diel cycle and other short term cycles worked. Elgin also is working on a stochastic model that tries to model the temporal and spatial correlation at the same time. Ultimately, we want to see how well multiple simulations will cover the observed data.

The first thing Elgin worked on is getting a mid-day interpolation estimate. With our fixed station data those are all based on day-time cruises which is why we call that part of the interpolation a mid-day estimate. We've gone back and forth about where to put depth in this model, and in this exercise Elgin put depth in the small scale variability part of the process since it's on a scale of meters vs longitude and latitude being on a scale of kilometers.

The data was at East Gooses profiler site from May to September 2022; during this time period there weren't many missing data points. The data was collected from 1m to 19m in 2m increments, but will be interpolated in 1m increments. Jon Harcum worked out a procedure for reducing the data to hourly data as opposed to the 10-15 minute data that was collected.

For estimating the mid-day interpolation point, Elgin used a beta logit transformation which improves the normality of the DO observations, in particular at the lower end of DO. The data was smoothed with a function of depth and day of year. Depth was the most important variable for determining DO. Residuals from the smoothed data were used to estimate autocorrelations. It started with autocorrelation of 0.5-0.7, and got less as it went down through the water column, then got stronger towards the bottom. Next Elgin created a grid with days of year and depth. It is not expected that the simulations will exactly line up with the observed data, but that they will have the same variability.

For the small scale variability, Elgin fit a harmonic or cyclic model to each day and depth. In that model there is a term for linear trend, and diel cycles and tidal cycles about the linear trend which is done by adding a sin cosin term. For the process of modeling space time

dependence, he used a single correlation number for the hour to hour correlation. Within each day he took the residuals, estimated the hour to hour correlation for every depth and day, and used RA Fisher's method for averaging correlations to get an average hour to hour and depth to depth correlation. Because data were collected at 2m intervals, would have to take the square root of the correlation to get it down to 1m intervals. Elgin set up a prediction grid with hours by depth.

For time of day, mid-day prediction of one day is subtracted off from the mid-day prediction at the day before and divide by 24. The tidal and diel cycles are added to that. For the space-time correlation, it is a synthesis of an autoregressive 1 process over time. Over space it's an exponential variogram type model.

Smooth of depth and day of year, plus error, plus within day diel and tidal cycles to give the deterministic part of within day variability, plus error term that's a function of correlation over hour and correlation over depth → gets you time series plots. Simulated variability covers the observed data pretty well. Getting back to Lew's question, in Rebecca's graph the cycles didn't reach the high points because those cycles were the deterministic parts of the interpolator. These random parts will try to capture some of that noise when there are high levels of DO for example caused by high levels of chlorophyll. Elgin then showed additional examples of time series plots. He also shared some Cumulative Distribution Function examples.

Next steps are to work on the mid-day prediction model and include estuary latitude and longitude and develop a space-time error model for that.

Discussion:

Jim Hagy: At 7m, it was falling off – why is that? Is the model struggling at the pycnocline?

Elgin Perry: No, my thinking is depth 7 is a rare event. We didn't see it at depth 5 or depth 9. I don't know why the data showed this quirk at depth 7. I consider that the interpolator smoothed over it and did what you expect an interpolator to do. Depth 3 is also looking unusual in the observed data, but the interpolator does not reflect that. The CFDs are looking smooth.

Jay Lazar: We had some problems at the 3m and 5m for a period. Early in the process we didn't have a lot of the QA protocols in place to clean through that after, so some of the observed data could not be correct.

Peter Tango commented in the chat: Elgin - the array data collections are set up at 2m intervals now. Did anything you showed suggest we should invest, if and when possible, in 1m sensor intervals? Is 2m separation in the vertical good to continue to work on as a spacing we continue to use?

1:00-1:15 Overview of analyzing high frequency data: Jon Harcum (TetraTech)

Summary:

Three uses of the high frequency data we're focusing on are daily cycles (within day interpolation and small-scale variability); large scale correlation (patterns in DO from day to day); and spatial correlation using DataFlow data (Wes is working on developing this). We've compiled data from the CBP Data Hub, Eyes on the Bay, VECOS, NOAA vertical arrays and DataFlow. We screened the data based on data qualifiers and looked at variable naming conventions. The actual assessments will not use 1985 (for example) data, with the exception of maybe helping parameterize some coefficients. The work that Wes is doing focuses on data around the Potomac.

Looking at daily cycles, high frequency data are pulled out at an hourly frequency (to be consistent across data sources). Diel and tidal harmonic coefficients are computed for each station/layer/day of data. Small-scale (hourly) correlation coefficient is computed using residuals; they tend to be close to 0.

For large-scale correlation (day-to-day), high frequency data are subsampled to one value per day. Seasonal DO cycles are estimated by fitting a mid-day model. A sliding 21-day window of data is selected. Large-scale correlation coefficient is computed using residuals; they tend to be mid-range values (0.2-0.7).

Wes is doing pilot work using DataFlow data on the Potomac to look at spatial correlation in DO. This data was chosen because it has corresponding con-mon stations in the same geographic space. Surface measurements are taken every 4 seconds. Wes is making a geostatistical analysis, creating a variogram, which is a representation of if we have a high DO in location 1, is it also high in location 2, where as the DO is less correlated the further away it gets.

Discussion:

Mark Trice: With the spatial correlation, there's a temporal component where these cruises are 4-6 hours. There are 4-6 cruises representing the Potomac on one day or across multiple days. If the cruise started at 6am and went to noon, you're going to see a temporal change in the DataFlow data that may throw off your spatial correlation.

Jon Harcum: Great question. We are aware of that. We're considering a mid-day model to account for that.

Elgin Perry: We are looking at the Geo R variogram program which has the option to detrend data before you estimate the variogram. I've only tested that option on simulated data. The trend I asked that function to remove was exactly the same as the trend that I put in the data with my simulation - it worked great. I'm guessing when we start trying this with real

data it probably won't work as well. We're trying to estimate what the spatial correlation is at the scale of about a kilometer because that's the grid we'll be interpolating in on the latitude/longitude scale. It doesn't take too long to cover a kilometer. Hoping at that scale we get a fairly accurate estimate of what the covariance is. We're not worried about getting interpolations from the DataFlow data. If we make some effort to remove it and what we can't, won't be too much of a contamination of a covariance variable at the scale of a kilometer.

Mark Trice: Got it. You shouldn't have much problem then. If you have a narrower tributary though, it could be a problem.

Wes Slaughter commented in the chat: Thanks so much everyone! I have to leave for a different meeting, but I wanted to say that if anyone has questions or wants to follow up about the DATAFLOW analysis, please feel free to reach out to me at wslaught@umd.edu and/or Slaughter.Weston@epa.gov - thank you!

1:30 PM **Adjourn**