Chesapeake Bay Program
Science. Restoration. Partnership.

Integrated Trends Analysis Team (ITAT) Meeting

Wednesday, September 25th, 2024

10:00 AM – 11:00 AM

Meeting Materials: Link

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

Meeting Minutes

10:00 – 10:05 Welcome – Breck Sullivan (US Geological Survey, USGS) and Kaylyn Gootman (Environmental Protection Agency, EPA)

Announcements:

- Scientific and Technical Advisory Committee (STAC) Synthesis Request for Proposal ***Due December 2nd***.
    - *Description:* STAC is seeking proposals to conduct a science synthesis product related to effectively managing climate change at the intersection of impacts of water quality, people, and living resources within the Chesapeake Bay Watershed. Great opportunity for supporting climate adaptation while also addressing further diversity, equity, inclusion and justice within the Bay Program. If you are interested, please reach out to Breck (bsullivan@chesapeakebay.net) for connection with Meg Cole and STAC Leaders.
- University of Michigan School for Environment and Sustainability (SEAS) Program - ***Deadline September 29th***.
    - *Description:* UM-SEAS Master's Projects are applied research projects for client organizations addressing a sustainability research need or related problem, over a one-and-a-half year timeframe, with teams of approximately five graduate students spanning multiple disciplines of study within the SEAS Master's degree program. This might be a good fit for Chesapeake Bay Program (CBP) Science Needs identified in the Strategic Science and Research Framework.

Upcoming Conferences, Meetings, Workshops and Webinars

- Restore America's Estuaries (RAE) 2024 Coastal & Estuarine Summit – October 6-10, 2024, Washington, D.C.
    - Panel on Beyond 2025.
- American Planning Association (APA) Maryland 2024 Conference – October 22-24, 2024, Ellicott City, Maryland.

- American Geophysical Union (AGU) 2024 Fall Meeting – December 9-13, 2024, Washington, D.C.
- 14th National Monitoring Conference – March 10-12, 2025, Green Bay, Wisconsin.
- The 35th Annual Environment Virginia Symposium – April 8-10, 2025, Lexington, VA. Call for presentations is now open.

10:05 – 10:50 Chesapeake Bay hypoxia projections are sensitive to model methodology

Presenter(s): *Kyle Hinson, Virginia Institute of Marine Science (VIMS)*

Description: *Recent research comparing commonly applied techniques for modeling climate change impacts has shown that choices made during the experimental design stage can substantially alter future estimates of Chesapeake Bay water quality. This presentation will discuss how these different approaches affect estuarine hypoxia projections and potential implications for future nutrient reduction efforts in the Bay watershed.*

This work was part of Kyle's dissertation that was published in *Scientific Reports*. To start, we want to ask what are the current state of projections of hypoxia in Chesapeake Bay? We gathered data from published material that projected hypoxia in the future, whether it was the effect of watershed changes, temperature changes (both in the water and air), sea level rise, and combined factors and their individual effects on hypoxia on the Chesapeake Bay. Generally, it was expected that climate change will worsen hypoxia in the future.

However, there remains some disagreement on things like whether it affects oxygenation or stratification, the inundation of wetlands and the release of carbon. There are much more consistent results showing that estimates of temperature will worsen hypoxia and that watershed changes will have a large impact. It was also recommended in this report that there should be a consistent metric to allow for better comparing.

The question remains: what does it take to get a realistic climate projection in the Chesapeake Bay to estimate future hypoxia? Determining the correct climate model for the research question is trivial since there are so many models to choose from and they all have their own pros and cons. The climate model is then read into a watershed model which gives you estimates of changes to things like discharge, nutrient loadings, sediment runoff and consequently effecting the estuarine model and hypoxia. Finally, you get a combined set of estimates for changes to hypoxia, and this can become convoluted quickly.

Some uncertainties include wetter models giving more hypoxia, or dryer models giving less hypoxia - all of which change year to year. One of the biggest unknowns is how well we address climate change and whether these nutrient loadings are actually implemented. These sources of uncertainty can equally contribute to final estimates of change in annual hypoxic volume – a target for the Total Maximum Daily Load (TMDL) goals in reducing hypoxia in the future.

In considering all of this, we must ask how our methodology employed actually affects hypoxia, if at all? For our work, we're using this three-dimensional hydrodynamic biochemical model. The methods include; continuous simulation, delta simulation, and time slice.

- *Continuous Simulation:* simulate multiple decades in a row to get from current base state to a future state (1980–2065). For instance, if there's an acceleration of increase in hypoxia at the tail end of the 2040s, this might be important for a lot of living resources.
- *Delta simulation:* this is the most commonly used method, used in almost all other climate change hypoxia literature. Essentially, you take a set of future conditions and subtract it from the past conditions, a climate delta, that is then added onto a baseline scenario. By doing this, you isolate the impact of climate change while maintaining the intensity of the past. For instance, a dry year in 1991 will be a dry year in 2046. So, this limits the accessibility of the models to simulate extreme events of what looks like if the hydrology is different in the future.
- *Time Slice simulation:* simulates a single decade for the same baseline forcings of the continuous and delta experiment (1991-2000) and employs the same future forcings as the other two methods for the period between 2046-2055. It looks to be the exact same as the Delta Experiment, but the future condition doesn't retain watershed or coastal model memory.

This leads to the central question of the research being conducted here: how do climate scenario approaches affect future uncertainty? If we just simulate a future effect, what are some of the big extremes that we could be missing? How does the ecosystem respond to those over time? What do we lose in terms of better understanding the nature of the Bay in the future?

The model here is called ChesROMS-ECB which is just the regional ocean modeling system with the combined atmospheric inputs, coastal fluxes, and riverine inputs (collected from the Bay Program's website that is extensively validated against monitoring stations). Climate impacts are taken into consideration here as well, including climatological data at the ocean boundary. It has 20 vertical levels that are stretched to get more wide space in the central channel and daily outputs of things like changes to hydrodynamics, biogeochemistry and the simulation of oxygen levels and hypoxia. We're evaluating watershed changes, air temperature, and sea level rise together to see how they interact.

Experimental Design:

The Continuous Experiment was run from 1980 to 2065 and in analyzing the results, we compared two-30-year periods for baseline forcing (1980-2010) and future forcing (2036-2065). This experiment took about 40 days of continuous supercomputer run time to complete.

The Delta Experiment took the same baseline conditions over the years 1991-2000 because running 10-years is much less computationally expensive (5-day run time). Then, we added climate data calculated from the same baseline and future periods that we use for the analysis and the continuous experiment, and this provides the future setting conditions.

The Time Slice Experiment simulates a single decade for the same baseline forcings of the continuous and delta experiment (1991-200) and employs the same future forcings as the other two methods for the period between 2046-2055. It looks to be the exact same as the Delta Experiment, but the future condition doesn't retain watershed or coastal model memory. You don't capture the evolution of changes over time to things like soil nitrogen and any kind of sediment dynamics in the Bay that could persist over many years and affect things from one year to another.

Results:

Bottom temperature: for the continuous run, the baseline around 16°C on average and 2° warmer at the end of the simulation period (85-year simulation). For the Delta and Time slice experiments, they have the exact same temperature. The baseline conditions would again be the same as the continuous simulation but for the future, we found the delta and time slice methods to be the same. However, it is still around a 2°C increase in the future.

Annual Hypoxic Volume (km^3 d^{-1}) is basically the amount of volume that's affected by low oxygen levels over a year in the Chesapeake Bay. Nearly equivalent results for all methods for the baseline conditions (1990), however in the future, this changes. The continuous and time slice experiments were very similar, indicating a 10% increase in hypoxia. On the other hand, there was a 20% increase in hypoxia in the Delta experiment hypoxia, ~2x greater than continuous and time slice methods. What could be driving this change?

In trying to answer this, we explored other parameters that might be indicators to this change like watershed change and things like discharge, rate loadings, and nitrate concentrations that are coming into the estuary. We found that there was a bit less decrease in discharge and greater nitrate loadings in comparison to the continuous experiments. The continuous experiment actually demonstrated a decrease as opposed to Delta and time slice methods. Lastly, in comparing the nitrate concentrations, they are all increasing, albeit at different amounts. The delta and time slice methods demonstrate large increases to nitrate concentrations in the future than the continuous method, demonstrating the impact of model memory to the different methods.

Discussion:

To help conceptualize what is occurring, here is a schematic on slide 13. Under normal conditions, a watershed with nitrate loadings that enter through the rivers of the estuary kills phytoplankton plumes that sink and die at certain times of the year and causing hypoxia. But, with Climate Change, you might expect warmer temperatures, both in the land and water, leading to decrease in solubility in the estuary, change in the timing of some of the runoff, probable increase in nitrification, and greater alpha growth and respiration.

In the climate change experiments, we also expect lower precipitation levels where precipitation increases across the watershed will come from high precipitation events – modifying sediment wash off and the associated Phosphorus loadings, and possibly affecting soil moisture levels. In comparing the delta and continuous experiment, you are either increasing or decreasing precipitation that is being added to the inputs so that you affect all events in the watershed equally. For instance, if you have a low rainfall day, it will be a little bit wetter, as did the high rainfall days. This means that soil moisture is generally greater for all rain events, and this can help in increasing nitrate loadings. This will eventually get to the Bay and fuel even greater hypoxia in the summer. Consequently, increasing hypoxia in both the time slice and continuous experiments. However, this will run out earlier in the summer because there won't be enough nitrate to sustain it.

This is not what is seen in the delta experiment. What is observed is a continuous increase in hypoxia over the summer, but this is not nutrient limited as the continuous and time-slice experiments.

To provide another conceptual schematic on slide 15, imagine we have a garden in the 1990s, and we skip to 60 years later (2050s) and the garden has changed substantially, and things are a bit warmer. To try and fix it, we add just a bit of water. This isn't exactly how things work as biogeochemical cycling both in the vegetation and the soils have been modified and just adding water won't make much of a difference. The whole ecosystem has changed fundamentally and capturing the evolution through a continuous experiment is computationally intensive, but potentially important to understand how nutrients flow down to the Bay. As we know, the continuous experiment retains model memory and captures these important components.

Summary:

Overall, hypoxia is greatly affected by chemical changes in the Bay and its watershed, and the choice of method can strongly affect oxygen projections. The delta experiment is the most commonly utilized method and can potentially project hypoxia levels that are twice as large as the continuous and time slice experiments. As well, the role of ecosystem memory should also be explored further. For instance, what do key events look like under these methods and how could missing these events modify how the ecosystem responds in the future?

Future Directions:

Consideration of possible feedback with larger-scale climate modeling. Previous efforts in the Baltic Sea show a multinational effort to run dozens of climate scenarios and mining them for research results. Lastly, evaluating future trends with possible ecosystem shocks, like hurricanes.

Questions:

Q: *Olivia:* It seems to me that we have a handle on what happens in the Bay, taking into account the watersheds. I just haven't seen presented the decisions that change, like energy usage, crops, irrigation, etc. that are used throughout the watershed. Is there something that combines the decisions that are made on the landscape with the work being done here? ***A:*** *Kyle:* We kept the land use constant from the 1980s levels, and this of course has an impact on the modeled simulations. What you highlight will of course modify the timing distribution of these loads and therefore affect hypoxia. There needs to be a bigger effort to fix this. For instance, how many land use scenarios can you run through 2 continuous experiments, which requires 80 days of computer time? Maybe having some simplified representation or basic sensitivity tests to understand things like more urban, more energy use, more emissions, etc. can be more useful.

- ***Comment:*** *Olivia:* I have been trying to integrate these things into my own previous work, considering irrigation, crops and more extreme events, and it certainly has been a challenge to incorporate landscape decisions into these climate change modeling efforts.
- ***Response:*** *Kyle:* If you can turn that into change in discharge, nutrient, sediment and put that into an estuarine model that could work, but that would also be challenging.
- ***Q:*** *Marjy:* You did mention something like this in your earlier work? ***A:*** *Kyle:* That was all TMDL effects, and those scenarios assume total implementation of the TMDL in the future and they show big decreases in hypoxia even with climate change. So, if these changes are what you're talking about Olivia, they will also help reduce nutrient loads and we would expect it to move in a similar direction. But in the presence of irrigation, I am not sure how much that would affect discharge or even the timing of it, and I don't think that would change much as just the decrease in nitrogen loadings.
- ***Comment:*** *Kaylyn:* Thinking of the big picture, we know land use/land cover has not been the same since the 1980s and it won't be the same in the next 20-50 years. So, being able to translate land use changes into things mentioned here would be great input for the estuarine model.

Q: *Breck:* You are with the Northwestern Lab. Are you changing your work from Chesapeake Bay? ***A:*** *Kyle:* I am now doing wind energy. For instance, we are working on a model coupling project with the idea of dropping a regional and coastal (or whatever you want) with more resolution and to capture things that are important for coastal fluxes and returning circulation. Also, I am working on another project on marine carbon dioxide removal by adding alkalinity to coastal waters to see if it can help sequester CO^2.

Q: *Kaylyn:* Digging more into the role of ecosystem memory, are you aware of folks that are looking into this concept? ***A:*** *Kyle:* No one that I am aware of that has simulated this on the estuarine model for such a long period for hypoxia. There have been others that ran scenarios looking at temperature and salinity but those are pretty responsive to air temperature and freshwater fluxes. Maybe some people in the SAV community. Chesapeake Bay wide, no one comes to mind. It is likely happening but with probably very simplified representation of changes. A great paper to look at is Carlos Duarte – Return to Neverland.

Q: *Gary:* The modeling team and the Bay program uses the Delta Method. And we have been impressed with this work and how we can possibly overestimate hypoxic conditions. It is difficult for us to use the continuous method because the base of these continuous experiments is different for every climate run, and we have a base that we need to be constant in the TMDL. We always need to use the Delta Method for this reason. However, we want to incorporate some components of this work into our modeling efforts. We want to incorporate this the next time as a partnership makes their decisions in 2027/2028.

Q: *Joseph:* Were your nitrification rates a hypothesis to explain potentially the increase in nitrate that you were seeing? ***A:*** *Kyle:* The watershed model that we used was the dynamic land ecosystem model (DLM) from our collaborators at Boston College. The functions they have in their model equations show that with greater soil moisture, you get increased nitrification. This might not be exactly what's happening and USGS may have investigated this with greater detail and maybe Phase-6 (P6) has a different representation too. However, we were unable to create a nitrogen budget to definitively prove that.

- ***Q:*** *Joseph:* Were there other biogeochemical transformations of nitrogen considered in the model? ***A:*** *Kyle:* Yes! For example, there was long-term mineralization of organic nitrogen; one of the key findings of the continuous experiment where you can't get in the delta method and time slice because there is no time for it to actually mineralize.

11:00 Adjourn

Next Meeting: Wednesday October 23rd, 2024, from 10am – 12pm

Attendance:

Kyle Hinson (VIMS), Breck Sullivan (USGS), Jon Harcum (Tetratech), Claire Buchanan (ICPRB), Elgin Perry (Consultant-CBPO), Anthony Timpano (VA DEQ), Qian Zhang (UMCES), Gregory Noe (USGS), Joseph Morina (VA DEQ), Olivia Szot (VIMS), Roger Stewart (VA DEQ), Ibrahim Mukhtar (MWCOG), Alexa Labossiere (VIMS), Andrew Keppel (MD DNR), Kaylyn Gootman (EPA), Gabriel Duran (CRC), Marjy Friedrichs (WM), Olivia Devereux (Devereux Consulting), Helen Golimowski (Devereux Consulting), Gary Shenk (USGS), James Webber (USGS), Carl Friedrichs, Tish Robertson (VA DEQ), Cynthia Johnson (VA DEQ), Tom Parham (MD DNR), Stephanie Nummer (ICPRB), George Onyullo (DC DOEE), Carol Cain (MD DNR), Rebecca Murphy (UMCES).