Original email from James P (June 7, 2021)
Hi Mark, Wilson, Lisa and Tom,
As we are getting close to having a running version of the FVCOM model with simple phosphorus kinetics, I am working on the scope and objective of a paper that I want to write as part of my EPA deliverable. The deliverable is due September 2022 – thus a paper has to be submitted before then. (I hope this work and paper is the start of a greater collaboration with Mark and others at NOAA, Dale Robertson and others at USGS and beyond. The ultimately goal is working towards an open source community-based model for the Great Lakes).

For the paper I want to, as much as possible, take advantage of the work that Mark did for his 2017 modeling paper (which he made available to us). I hope to combine this with a number of other interesting research ideas and turn it into a (hopefully) cohesive paper. Here are my ideas, please let me know what you think. Too much for one paper? Mark, I made assumptions as to what you already have available and what "relatively easily" can be done – please comment.

- Develop a simple (transparent) phosphorus model similar to Chapra and Dolan 2012 and our recent work in Lake Ontario (paper in review). We might add a bit of complexity by using e.g. variable "apparent" settling velocities, us some correlation between TP and chl-a (perhaps a bit more complex that this, but still likely some empirical correlation).
- Compare this model with the Rowe et al. 2017 model for the same years as their paper – 2000, 2005 and 2010.
  - Investigate how the two models compare (in terms of TP and maybe chl-a)
  - Compare the models with chl-a data (similar to what Mark did)
  - Compare the models with phosphorus data from GLNPO, NOAA etc.
  - Perform the above analysis in both the nearshore and offshore. Probably the emphasis will be southeastern Lake Michigan (close to the Muskegon, Grand, Kalamazoo and St Joseph rivers).
  - Discuss the limitation and possible advantage of a simple vs a more complex approach, where the simple model compares well and where it does not (and where both models do well and have challenges). My early hypothesis is that the simple model will perform pretty well in the very nearshore and perhaps the offshore. In-between it might not do so well because the lack of biology including mussels.
  - Address nearshore vs offshore phosphorus concentrations in Lake Michigan as it relates to the GLWQA target of 7 ug/L – do the models have the predictive power to do it (good enough hydrodynamics? Are accurate daily/weekly phosphorus loads necessary and available? Do we have a good enough understanding of the kinetic process and sufficient data?)
  - (I hope to involve Dale Robertson in some capacity – this paper or later). Using other loading estimates such as SPARROW (USGS), SWAT or a more conventional LOADEST or LOADEST-like approach, does it impact the model results and predictions significantly?
- Compare both models to 2015 data as an independent dataset (we collected additional data during that CSMI). See how both models perform, especially in the nearshore. Of, course this is under the assumption that we have the forcing functions to run the FVCOM model for then.
- It seems 2013 was an interesting year with record high flows for the Grand and other Michigan Rivers. We might have Robertson "LOADEST" type loads, perhaps SPARROW and SWAT loads to compare. Once again, I am not sure if we will be able to run the FVCOM model for this year, but it will be interesting to see if our models can deal with extreme events (or to what extent can and can the model do any credible predictions). If this is possible, we can perhaps address this as a "climate change" issue which is of high priority and importance for this administration and USEPA.

So, questions to the group:

- Would you like to (and do you have time to) participate as co-authors in this study (we can later figure out the order of the authorship)? We might also add an author or two depending on who else is involve and help with the paper. We have approximately a year to get the work done and write the paper. This sounds a long time from now, but it is probably not – lots must get done.
- Should be invite specific other people to be co-authors? Of course we will acknowledge people as well.
- Do you generally agree with the aim of the paper? Do you think it is too much for one paper? Suggestion what else to include, exclude, tweaks etc.?

Questions specifically to Mark:
Mark, we want to respect your time, so we need to know what is feasible with your available time on this project. Depending on your time, we might somewhat change the emphasis of the paper.
- Do you have your 2000 and 2005 model output saved and can you share it with us at some stage (we do not need it right away)?
- Do you have the forcing functions for 2000 and 2005 saved and can you share it with us?
- Since we are considering also 2013 and 2015 can you work with us to get the forcing functions for these years so we can run both models for these years.
- Of course, then we also need initial conditions and loadings 2013 and 2015. We will work on this, but hope you can provide your insight gained from your previous work. Perhaps Peter A. can also help with the loadings?

Note: I am still hoping we can work towards a collaborative community-based model and involve several people and agencies. Also, I am working with Wilson and Lisa to get the Lake Erie model running and will be talking to GLNPO (Santina W) about future work on this front. I also want to talk to Kristina Heinemann (EPA Region 2) who is the Lake Ontario LaMP manager about possible additional modeling work in Lake Ontario.

Once we have a general plan, I will also approach Dale Robertson to see if and to want extent does he wants to be involved with the paper (I have no problem making him a co-author – do any of you?), and hopefully a longer term collaboration.
James

Tom H response with my comments in red and Mark comments in blue.
This all sounds really interesting and useful. I look forward to seeing how this develops. When thinking about extreme events, we might consider both extreme precip and extreme wind events that can have both different effects and/or compounding effects (resuspension, upwellings, versus high flows with sediment or both). Here's an example of modeling the extreme wind events in Lake Superior.
https://aslopubs.onlinelibrary.wiley.com/doi/abs/10.1002/lno.11117
[We probably have to see how extreme events have been handles in other lake models. I think it is rather difficult addressing extreme events with conventional models. If we can just move the lake modeling science a bit forward, we are making progress. I guess every event is a bit different – we know the Grand River flows went crazy (and probably other Michigan rivers too). We might want to check with Dale R (USGS) and Yongping Yuan (EPA/ORD) to get their opinion how these high flows impact loads using SPARROW and SWAT.

Also I wonder if there might be an agent-based element for some of this, particularly phosphorus/sediment fate and transport? Terry Brown used agent based particle tracking for Bromide

movement from coal fired power plants to drinking water intakes in the Great Lakes. It provided a way to track the relative contribution of tributaries to a particular area of the lake over time.
[Agent based modeling sounds interesting and it will be good to get Terry involved. I/we need to work more on the modeling objective to see how and where these models can fit in?]
[Mark's comment: Tracking the relative contributions of specific tributaries to nearshore water quality is something that could be done with a TP or similar model. This could be done with an Eulerian grid model or Lagrangian particle tracking model; we have both types linked to FVCOM]

Mark R response with my comments in red
A relatively simple TP model sounds like an interesting concept. I'll be happy to support the effort and participate in a paper. I'll insert some comments and questions into your email below.

- Develop a simple (transparent) phosphorus model similar to Chapra and Dolan 2012 and our recent work in Lake Ontario (paper in review). We might add a bit of complexity by using e.g. variable "apparent" settling velocities, us some correlation between TP and chl-a (perhaps a bit more complex that this, but still likely some empirical correlation).

It might help to further discuss the structure of the model, and what will be used for input, calibration, and assessment data.
[As I think more and with additional discussions, I will refine the model structure and provide more details. For 2000, 2005 and 2010, I will likely use the Rowe et al 2017 model input. I do not plan to calibrate the simple model, but instead perform sensitivity analysis using different settling velocities, and P:chl-a rations (if I use such approach to estimate chl-a in the lake).]

I assume the goal is to predict TP concentrations in the lake, nearshore and offshore, as a function of TP loads and meteorology?
[Yes, I think that will be the main goal, but other interesting things might appear once we start running model scenarios.]

I think that the Chapra model has one state variable (TP), and an apparent settling velocity, which was calibrated. That model was run over many years to calibrate the settling velocity. My FVCOM-GEM simulations were only 12-month simulations, so they would be less well suited to calibrate the settling velocity.
[I will likely be using the post mussel apparent settling rate (as described in Chapra & Dolan, 2012) for Lake Michigan and do sensitivity analysis. From the Lake Ontario paper, it seems the settling rate have little impact in the nearshore (<20 m) – we will see how sensitive it is for Lake Michigan]

Availability of TP data nearshore and offshore will also be a limitation. There is EPA GLNPO, and the GLERL data at Muskegon. The Muskegon data are at 15, 45 and 110 m stations, so represent a nearshore-offshore transect, although only at one location. Harvey Bootsma might have TP monitoring data from near Milwaukee, although I'm not sure of availability. Are you aware of other data? What will we calibrate/validate, and what TP data will we use?
[We have already collected/processes all the GLNPO data. Steve Pothoven graciously send us a good record of the extended Muskegon area data (similar to his 2020 paper). We (ORD) collected nearshore data during the 2015 CSMI. There is also 2015 NCCA data out there – might be a bit tricky to get. Finally, I might reach out to Harvey B (as you suggested) for Milwaukee area data. Mark, I would like to get your opinion on calibrating the models for 2013 and 2015 (if we also look at these years).]

Will the TP model also simulate chlorophyll? How will that be structured?
[The plan is to use some correlation between TP and chl-a. In addition, we might also look at season and offshore vs nearshore – we have Aubree, an EPA ORISE student looking into this].

- Address nearshore vs offshore phosphorus concentrations in Lake Michigan as it relates to the GLWQA target of 7 ug/L – do the models have the predictive power to do it (good enough hydrodynamics? Are accurate daily/weekly phosphorus loads necessary and available? Do we have a good enough understanding of the kinetic process and sufficient data?)
- (I hope to involve Dale Robertson in some capacity – this paper or later). Using other loading estimates such as SPARROW (USGS), SWAT or a more conventional LOADEST or LOADEST-like approach, does it impact the model results and predictions significantly?

It could be interesting to simulate TP at GLERL Muskegon transect stations, and look at sensitivity to different sources of loading estimates. It might also be interesting to look at including water discharge at the rivers or not.
[Yes. It will take a bit more work, but will be very interesting. I need to contact Dale and see what he can provide, and perhaps Yongping Yuan. Not sure how much more work more work will adding water discharged to the model.]

- It seems 2013 was an interesting year with record high flows for the Grand and other Michigan Rivers. We might have Robertson "LOADEST" type loads, perhaps SPARROW and SWAT loads to compare. Once again, I am not sure if we will be able to run the FVCOM model for this year, but it will be interesting to see if our models can deal with extreme events (or to what extent can and can the model do any credible predictions). **If this is possible, we can perhaps address this as a "climate change" issue which is of high priority and importance for this administration and USEPA.**

Yes, 2013 would be interesting. Ed Rutherford was asking me to simulate 2013 back when I was a postdoc. They did a cruise with the Laurentian and plankton survey system and saw effects of the big discharge event in the area. I have not simulated that year yet, but it should be relatively easy to generate the atmospheric forcing files and discharge. Loading estimates are always more challenging. If we involve Peter Alsip, we should include him as a coauthor.
[Let us talk about this. There might be all sorts of loading of this. It will be great if we can include Peter as a collaborator and co-author. Would you reach out to him, or should I?]

Mark, we want to respect your time, so we need to know what is feasible with your available time on this project. Depending on your time, we might somewhat change the emphasis of the paper.

- Do you have your 2000 and 2005 model output saved and can you share it with us at some stage (we do not need it right away)?
- Do you have the forcing functions for 2000 and 2005 saved and can you share it with us?

Yes, I can share that

- Since we are considering also 2013 and 2015 can you work with us to get the forcing functions for these years so we can run both models for these years.
- Of course, then we also need initial conditions and loadings 2013 and 2015. We will work on this, but hope you can provide your insight gained from your previous work. Perhaps Peter A. can also help with the loadings?

I have already run the model for 2015, so that is available.

Peter has been generating forcing, loading, and initial condition files for the model for additional years. We included some funding for him in a USGS climate program project with Michigan Tech and Purdue. In that project, we are linking the Lake Michigan FVCOM-GEM model with a Lagrangian particle model to simulate dispersion of larval fish from nearshore areas, and Purdue will apply larval fish bioenergetic models. The goal is to predict recruitment potential for alewife and yellow perch as a function of meteorological conditions. We will also run some future climate scenarios using Pengfei Xue's regional climate model.
[I am not familiar with Pengfei Xue's climate model – is there a paper? What is he simulating? I am interested in learning more.]

For that project, Peter is generating forcing files for the years below. I could also ask Peter to include 2013. I can check with my collaborators to make sure they are OK with us using the files for another purpose, but I think that the focus of the two projects is complementary, so it shouldn't be a problem. As we go further back in time, there are more problems with meteorological data. 1996 had some gaps in cloud cover data that we had to fill.

Strong Recruitment: 1998, 2005, 2010, 2016
Weak Recruitment: 1996, 2001, 2014, 2015
[There might be enough work here for more than a paper – we should think a bit about it. Once we refine the objectives a and perhaps run a few simulations we should have a better idea. And, of course some things are a bigger effort and will take longer than others.]