Biogeosciences Discussions

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Comment on bg-2021-156

Anonymous Referee #1

Referee comment on "Modeling cyanobacteria life cycle dynamics and historical nitrogen fixation in the Baltic Proper" by Jenny Hieronymus et al., Biogeosciences Discuss., https://doi.org/10.5194/bg-2021-156-RC1, 2021

The Hieronymus et al., have done through approach toward modeling phytoplankton and N2 fixation in Baltic Sea. The model seems to be well constructed developed upon the accumulated bodies of modeling and certainly provides new aspects of the regional modeling targeting this area. One challenge I had was to see how the cyanobacterial life cycle is simulated. A schematic and narrative would be useful. That said, I like how explicitly the filamentous bacteria is simulated, which is the unique feature of Baltic Sea. The manuscript is suitable Biogeosciences. The following are my comments hoping to improve the manuscript.

Main text:

L20: in timing of -> in the timing of

L21: runs we -> runs, we

L28: of its -> of their

L30: nitrogen fixing -> nitrogen-fixing (there are other cases below, which I would not mention)

L46: in bloom formation -> in the bloom formation

L46: e.g. -> e.g., (there are other cases below, which I would not mention)

L54: In the model growing -> in the model, growing (for clarity)

L66: in abundance -> in the abundance

L73: gain understanding -> gain an understanding

L81: which has -> that has

L83: three dimensional -> three-dimensional

L88: the northern -> northern

L101: tense should be consistent

L112: remove ‘a’ or make it to ‘the’

L144: for the entire period -> for the entire period of (or put 1850 – 2008 in parenthesis)

L150: by very large burial -> by a very large burial (or ‘the’ very ...)

L175: For this work -> For this work,

L176: post processed -> post-processed

L186: includes also -> also includes

L189: true also -> also true

L193: A -> The (or remove ‘A’)

L197-210: There are different modeling experiment. I wonder which one is considered as default. Is there a model run that includes all the factors, which could be considered as default? I think it was done in the previous study? In any case, it would be useful to compare these sensitivity analysis to be compared with the default, so I suggest putting the results from the default along with these simulations.

L220: which -> ,which

L225: in this case -> in this case,

L227: generating -> , generating

L228: faster growing -> faster-growing

L240: we -> , we (for clarity and improving readability)

L245: I am having a hard time understanding what is meant by the life cycle model. Is that the diurnal cycle or is that longer cycle? A schematic (in addition to figure 2) and additional explanation (model summary with a few sentences) would be useful. I am suspecting it is a seasonal cycle, so it would be nice if it is clearly defined here.

L268: release -> the release

L301: we -> , we (for clarity and readability)

L301: seasonality of -> the seasonality of

L314: bloom forming -> bloom-forming

L320: however -> however,

Figure 2: Many different shapes are used. I wish to have a list of explanations for different shapes. Also, It is less clear where and how phytoplankton are represented. There seem to be multiple functional types of phytolankton but it is hard to see from the figure. I suggest another figure or panel to focus on phytoplankton functional types, as well as the life cycle of them since they seem to be key in the paper.

Figure 3: Model seem to show much higher values than observations. I wonder what are the reasons.

Figure 4: I am personally curious about how the population of N2 fixers change.

Figure 5: The rate of nitrogen fixation seems to match despite the difference in biomass shown in

Figure 3. I wonder what explains this. Also, I wish to see discussion on how Heterotrophic N2 fixation may alter the result.

Figure 6: How do these compare to the model simulation?

Figure 8: Could this be compared with observation?

Supplementary material:

I wish to get the explanations behind (8). Why is it power of 4? Is that based on some previous studies?

I wish to get the reasoning behind (9). What is it formed with the addition of square termed in square root instead of the simple additions? Is that based on some previous studies?

I wish to get some explanations behind equation (10) and (11), especially the reasoning of the mathematical formulas and qualitative interpretation of them.

Other points for discussion:

There are studies suggesting that heterotrophic bacteria may contribute to N2 fixation. I suggest considering discussing their effect on the overall N2 fixation in the Baltic Sea. The following papers may be useful: (Bentzon-tilia *et al.*, 2015; Farnelid *et al.*, 2013; Bentzon-Tilia *et al.*, 2014; Chakraborty *et al.*; Pedersen *et al.*, 2018).

N2 fixers (or nitrogenase) are known to be sensitive to O2. However, heterocysts have glycolipid layer which may protect them from O2. I think the hidden assumption in the model is that O2 does not matter to heterocysts. To support the assumption, the authors may consider citing (Inomura *et al.*, 2017), as it shows that respiratory protection is not required for heterocysts; otherwise the rate of N2 fixation would be O2 dependent.

References:

Bentzon-Tilia M, Farnelid H, Jürgens K, Riemann L. (2014). Cultivation and isolation of N2-fixing bacteria from suboxic waters in the Baltic Sea. *FEMS Microbiology Ecology* **88**: 358–371.

Bentzon-tilia M, Severin I, Hansen LH, Riemann L. (2015). Bacteria Isolated from Estuarine Surface Water. *Mbio* **6**: 1–11.

Chakraborty S, Andersen K, Visser A, Inomura K, Follows MJ, Riemann L. Quantifying nitrogen fixation by heterotrophic bacteria in sinking marine particles. *Nature Communications* Accepted.

Farnelid H, Bentzon-Tilia M, Andersson AF, Bertilsson S, Jost G, Labrenz M, *et al.* (2013). Active nitrogen-fixing heterotrophic bacteria at and below the chemocline of the central Baltic Sea. *The ISME Journal* **7**: 1413–1423.

Inomura K, Bragg J, Follows MJ. (2017). A quantitative analysis of the direct and indirect costs of nitrogen fixation: a model based on *Azotobacter vinelandii*. *The ISME Journal* **11**: 166–175.

Pedersen JN, Bombar D, Paerl RW, Riemann L. (2018). Diazotrophs and N2-Fixation associated with particles in coastal estuarine waters. *Frontiers in Microbiology* **9**: 1–11.