

Interactive comment on “Ocean Phosphorus Inventory and Ocean Deoxygenation: Large Uncertainties in Future Projections on Millennial Timescales” by Tronje P. Kemena et al.

Anonymous Referee #2

Received and published: 21 December 2018

Kemena et al. present 12 long-term global warming simulations of the UVic Earth System Model of Intermediate Complexity to assess how projected P and O₂ inventories depend on implemented weathering and sedimentary fluxes. The focus is on biogeochemical feedbacks, as the physical response is almost identical across the simulations. They suggest weathering fluxes contribute most to projected increased P inventories. I consider this to be a welcome contribution to the field of long-term Earth system projections. I have several questions regarding the methodological approach and conclusions which should be considered to improve the readability and focus of the manuscript.

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-Bur simulations: I find it hard to judge the “meaningfulness” of the Bur simulations given that they release P from an unlimited reservoir. The Bur_Res simulation seems to indicate an upper limit on the potential P release, which all other Bur simulations appear to surpass. So all other simulations release more P than can be assumed to be in the sediments, correct? Should the reservoir constraint not apply to all simulations? You might want to consider disqualifying those simulations a bit faster in the text and highlight the importance of this constraint a bit clearer, including the abstract and method/results section.

-Weathering simulations: Why do these simulations not have a burial formulation? Of course, addition of P to an otherwise “closed” ocean just increase its P inventory. Would it not be important to assess the feedbacks associated with deposition and redissolution in this context, as increased P supply to the upper ocean stimulates NPP, export and deposition? I could not find a discussion on this matter in the manuscript.

-It is not clear to me which simulation corresponds to the best estimate reported in the abstract and conclusion. Do you just add the result of the Weath0.15, Bur_Res and Anthr simulations? You may want to guide the reader a bit better here, and explain why these simulations are simply additive? That seems strange to me, as for instance, the Bur_Res simulation would suggest a $W_0=0.41 \text{ TmolPa}^{-1}$, much higher than the 0.15 TmolPa^{-1} considered in Weath0.15.

-Language: I find the language at times ambiguous. Most importantly, the usage of benthic fluxes, burial and sediment release appear confusing, and it’s not clear whether gross or net exchange is meant. Please consider explicitly introducing these terms and using them consistently.

-Balance between presentation of P and O₂ response: Even though deoxygenation is mentioned in the title, there is very limited mentioning of deoxygenation in the abstract and discussion. The most important driver of ocean deoxygenation appear to still be circulation changes, and the assessed biogeochemical feedbacks should be presented

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in this context. There are several papers worth citing/discussing in the introduction and discussion on the matter of long-term projections of ocean deoxygenation, e.g.: Battaglia & Joss 2018, ESD, Yamamoto et al. 2015, GBC, Schmittner et al. 2008, GBC As such, the modeled circulation response may be compared to other long-term projections.

Specific comments:

Line 27: “this is in contrast to paleo reconstructions”: not clear what is meant from the text

Line 29: “more reliable projections of ocean deoxygenation”: context of ocean deoxygenation does not emerge from the abstract. How do the biogeochemical feedbacks assessed compare to uncertainties in circulation changes?

Introduction: centers round CO₂-driven ocean deoxygenation. Please include recent literature on ocean deoxygenation, and the fact that circulation changes are crucial for ocean deoxygenation associated with global warming, not CO₂ per se.

Line 57: “could”: will?

2.3/2.4: Please consider presenting weathering first, consistent with presentation of results/Table 1

Line 126: “every grid box”: every bottom grid box?

Line 137: “all organic C is remineralized in the deepest ocean layer”: statement must be wrong?

Eq. 3a-c: potentially include $z < 1000\text{m}$ and $z > 1000\text{m}$ on the respective lines for clarity.

Eq. 4: Is there only a O₂-feedback on P fluxes? Should the C burial/redissolution not also be O₂-dependent? Potentially worthy of discussion.

Line 170: Please add numbers in parenthesis.

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Line 183-200: Hard to understand. Examples below:

Line 187/188: “for the continental shelf and slope”: how was this done for all other grid cells?

Line 194: “local inventory”: what do you mean with this? Do all cells have this inventory? Or is this an upper limit for inventories globally?

Line 195/196: reservoir can be replenished, but excess P is permanently buried? Is the ΔRESp the replenished P or excess P?

Eq. 6: are the $>$ and $<$ correct?

Line 197: “depending on environmental conditions”: what do you mean with this statement? Depending how? Earlier you mentioned local inventories of 113 umol/cm^2 ?

Line 277: “the way sediment P reservoirs are represented”: if represented at all or not.

3.2: Preferably start section with PI RR (lines 295-299) and PI burial rates (lines 279-283). Then, would strongly suggest changing the tone of this section, in that Bur simulations without a reservoir constraint are not realistic. Potentially exclude those runs from Figs.5-8, Figures are very busy anyway and lines are hard to tell apart. Or explain why those are considered for assessment of ocean deoxygenation, still.

Line 308/309: Please add more citations of long-term O₂ projections.

Line 374: “recovered”: strange language. O₂ inventory is still increasing and simulation has not reached steady state yet.

Line 377: How is AOU/O₂sat calculated? Potentially discuss/mention Ito et al., 2004, GRL?

Line 390: Are preformed nutrients carried as explicit tracers? Please introduce how signal is separated.

Line 397: “are likely”: how come you are not sure about this?

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Line 398: “global N inventory constant”: does not appear to be the case in Fig. 9a?

Line 399: Physical response: potentially summarize physical response earlier, perhaps right after 4., as this is the baseline response of the scenario which applies to all variables?

Line 400: is this the max of the global meridional overturning?

Line 402: “consistent with reduction of export”: in section 4.1 you appear to conclude that warmer temperatures enhance remineralization in the shallower ocean which reduces export?

Line 404-407: “speculate”? This reasoning, also in line 415, I do not understand. I would speculate that these changes are associated with older water masses. AOU and ideal age probably are highly correlated, indicating that more O₂ is consumed in older waters. See literature.

Table 1: Bur_low and Bur_high: reference to equation (4) rather than (3)? Bur: potentially also add coefficients here for consistency with Bur_low, Bur_high

Figure 2a: net flux? What are the step-like increases in the Bur simulations associated with? Those are also present in subsequent figures?

Figure S2/S3: might benefit from an improved aspect ratio.

Interactive comment on Earth Syst. Dynam. Discuss., <https://doi.org/10.5194/esd-2018-58>, 2018.

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