

Interactive comment on “A model study of warming-induced phosphorus-oxygen feedbacks in open-ocean oxygen minimum zones on millennial timescales” by Daniela Niemeier et al.

Anonymous Referee #1

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General comments

This is an interesting paper on coupled phosphorus and oxygen dynamics in the modern ocean essentially showing that both weathering and, to a lesser extent, a phosphorus-oxygen feedback, can contribute to expanding anoxia on a time scale of 1000 kyrs. While the results are important and definitely deserve publication, there are a number of issues that I recommend the authors consider in a revision, as detailed below.

Major issues:

1. The context could be more clearly presented. The point is that you wouldn't really

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expect a major impact of P recycling on global ocean biogeochemistry (apart from the coastal zone) on time scales of 1000 kyrs given the relatively long residence time of P in the ocean. In this paper, changes in the modern day ocean under climate change on time scales of 1000 years are repeatedly even compared directly to changes in the Cretaceous Ocean that acted on time scales of 100,000 years and more in an ocean with a very different configuration (other paleogeography, higher sealevel, larger coastal zone). This direct comparison is not recommended: the temporal and spatial scales were just too different. More careful phrasing is thus needed. Furthermore, various recent studies of Cretaceous biogeochemistry suggest that both weathering and recycling of P were needed to sustain the oceanic anoxia (e.g. see the work of Ruvalcaba et al. published in BG in 2014 and the work of Monteiro in GBC).

2. The referencing needs more attention. There are three issues: results of quite some key papers are missing (e.g. relevant to river P fluxes, modeling for the Cretaceous, etc., see below), not all references in the text are in the reference list (see below) and it's strange to cite a thesis when the same work has already been published in the peer-reviewed literature. (work of Tsandev).

3. The writing style can be improved. There are words missing and there are several awkward and/or unclear formulations.

4. Many key issues, such as the role of the coastal zone (in what detail is it included in this model), the bathymetry, the role of anthropogenic fluxes of nutrients (are they considered?) etc. are discussed only at the end of the paper in a section "uncertainties". It would be much better to address these issues up front in the introduction and/or as assumptions in the model description sections.

5. The river fluxes assumed in the model are critical to the results but the river fluxes from the literature discussed seem to be selected rather arbitrarily. I miss references to the work of Ruttenberg (2004; Treatise of Geochemistry), for example. Further details are provided below.

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Detailed comments

Page 1. Line 9: replace “reduced solubility” by “reduced oxygen solubility” Page 1. Line 13: replace “Higher availability in phosphorus” by “A higher availability of phosphorus” Page 1. Line 16: the last part of the sentence is repetitive and can be removed, i.e. “which in turn, got there through weathering”. Page 1. Lines 19-21. The use of “although” in this sentence suggests that the finding here for the OMZ somehow contrasts with the findings described for the Cretaceous. However, the direct comparison of the impact of the benthic phosphorus release feedback on the size of the OMZ over the coming 1000 years to the feedback on anoxia in the Cretaceous ocean is not appropriate. This is because the relevant processes in the Cretaceous ocean acted on time scales of more than 100,000 years, i.e. there is a 3-order of magnitude difference in time scale. Page 1. Line 21. Previous studies do not “assume” that the P feedback “was the main factor for anoxic conditions during Cretaceous period”. They show that both increased river inputs and enhanced regeneration of P likely played a role.

Page 2 Lines 3-4. Sentence is too long. Please break up into two sentences. Line 4. Stramma et al. (2012) and Cabre et al. (2015) are not in the reference list. Line 11. A reference to Tyrell (1999; Nature) would be appropriate here. Line 13. Change to “is river input” Line 18. Specify that you are using the pre-anthropogenic flux of P from rivers. Lines 18-20. Why are the data of Ruttenger (2004; Treatise of Geochemistry) not used here? That is the most comprehensive summary of reactive and total P fluxes in the marine environment, including river input. Importantly, she reports higher fluxes of P to the marine environment.

Page 3 Lines 8-10. Add references for these statements. Line 11. Change “in previous studies” by “in a previous study”. Lines 17-19. Rephrase. It is not correct to refer to Cretaceous studies as “Other studies on OMZs” since in many cases there was not an OMZ but the water column was anoxic to the seafloor also in the deep sea. Line 23. The Cretaceous work by Tsandev et al. was published in EPSL in 2009 – that paper should be referenced, not the PhD-thesis. Line 23. I miss a reference to the modeling

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paper of Ruvalcaba et al. (2014; Biogeosciences) here.

Page 4. Section 2.1. I miss details on the bathymetry and how the model deals with coastal processes here. Line 17. Change to “the following equations”

Page 5. How do P burial fluxes calculated in this manner compare to actual P burial fluxes in the ocean per m² and per time?

Page 6. Line 4. So is burial of P also excluded in this simulation? If so, this should be mentioned specifically (“benthic fluxes” is not generally assumed to refer to burial). Page 6. Line 5. And burial of P? (see previous point). Page 6. Line 5. Change to “was performed” Page 6. Line 6. What about anthropogenic inputs of P? Page 6. Line 19 and further. Here, it is important to distinguish between burial rates for the open ocean and coastal zone. Palastanga et al. used a coarse resolution model that did not resolve the coastal zone and the burial flux thus refers to the open ocean.

Page 6. Note total fluxes of P to the ocean in the published have also been summarized by Ruttenger (2004; Treatise of Geochemistry) and Slomp (2011; Treatise on Coastal and Estuarine Science) with estimates ranging from 0.258 to 0.92 Tmol yr⁻¹. Part of this total P can indeed be mobilized (i.e. become soluble) in the coastal zone and it is well-known that river fluxes of dissolved P fluxes to the ocean thus underestimate P inputs. Thus there are significantly more data available than suggested here.

Page 7. Lines 1-4: where is the P buried in the current model, i.e. how much is buried in the coastal zone and how much is buried in the open ocean? Again, comparisons should be done carefully: the Palastanga et al. estimates refer to the open ocean because the coastal zone is not well-resolved.

Page 7. Lines 16-17. I would remove this here; because you are pointing forward and are not explaining this fully, it doesn't really fit.

Page 7. Lines 23-24. Where can I see that benthic burial acts as a P sink? Page 8. Lines 11-13. Please show the results for P burial (if you don't want them in the main

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paper, add them in a supplement). Page 8. Line 17. Please show these results (see above). Page 8 Line 18: I would suggest to remove “also” Page 8. Line 27: explain :“unlimited” Page 8. Lines 28-30: what about the coastal regions? Page 8: Lines 29-30. Show the result for the 10000 year simulation (e.g. in a supplement) Page 9. Lines 16-17: Based on the residence time of P in the ocean, I wouldn’t expect run-away anoxia on a time scale of 1000 years to start with. Page 9. Lines 18-19. Adding “as has been suggested during the Cretaceous” is inappropriate because the processes at the time occurred at a different time scale, thus, a direct comparison should not be made. Note also that we know for certain that parts of the ocean (the proto-North Atlantic) were anoxic in the Cretaceous. Page 9. Line 19. Tsandev et al. 2009; EPSL is the right reference. It would also be logical to discuss the Monteiro et al. and Ruvalcaba-Baroni et al. results here, if you want to discuss modeling results for the Cretaceous. See earlier comment. Page 9: 21-23. I would also add: “present-day paleogeography” because the latter factor also played a role in Cretaceous nutrient cycling. Page 9. The cause of the “unlimited P reservoir” could be better explained, see earlier comment. Page 10. Lines 1-3: It would be better to describe up front in the model how well the coastal zone is resolved and use that information when discussing results and the parameterization (e.g. burial of P and benthic fluxes, see earlier comment). Page 10. Lines 14-19. The potential role of anthropogenic inputs of P to the ocean is better discussed in the model description section, especially because anthropogenic CO2 inputs are considered. Is there not more recent work on anthropogenic inputs of P to the ocean that is relevant to include here, e.g. from the Global NEWS project? (e.g. Harrison et al., Beusen et al. etc.). Page 10. Lines 29-32. This feedback is not explained well.

Figure 2: Please improve the readability of this figure by adding legends in the panels and/or other markers. It takes a lot of time for the reader to figure out what is what.

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