Review of BPOP-v1 model: exploring the impact of changes in the biological pump on the shelf sea and ocean nutrient and redox state (Lovecchio & Lenton)

The authors present a new box model for the simulation of the marine oxygen and phosphorus cycles on geological time scales. They extend previous box models by introducing two different types of particulate organic matter (small and large) characterized by different sinking speeds. The model results presented by the authors confirm that the depth of the oxycline is to a large degree controlled by the remineralization length (size/settling velocity) of the sinking particles.

My major comments are related to the benthic model employed by the authors

- The model for phosphorus (P) degradation in marine sediments considers aerobic respiration (Eq. 11) but seems to ignore anaerobic degradation. As a result the burial efficiency increases when oxygen is deleted in ambient bottom waters whereas the available observations show that P burial efficiency actually decreases under low-oxygen conditions (Slomp et al., 2002; Van Cappellen and Ingall, 1994; Wallmann, 2010). The authors should try to change their benthic model (i.e. include anaerobic degradation and enhanced P release under anoxia) or explain why they apparently ignore the strong evidence for enhanced benthic P release under low oxygen conditions.
- The shelf model ignores P burial in shallow-water shelf sediments even though observations in the modern ocean indicate that most burial of particulate organic matter (POM) occurs in the inner shelf region at <50 m water depth (Dunne et al., 2007). The authors should try to change their benthic model to include shallow shelf burial or explain why they ignore burial in shallow shelf regions.
- Small (slowly sinking) particles are mostly degraded in the water column whereas a substantial fraction of the large (rapidly sinking) particles is not degraded but deposited at the seafloor. Consequently, large POM particles reaching the seabed are more reactive (fresher) than small (older) particles and the kinetic constant for benthic degradation should increase with increasing particle size (Stolpovsky et al., 2018). Since particle size (sinking speed, mineralization length) is the major parameter varied in the modeling, the authors should try to consider this effect in their benthic model.

Considering these model limitations, I do not know whether the authors' conclusion: "shelf ocean anoxia can coexist with an oxygenated deep ocean" (abstract, line 19) is really valid. Moreover, this conclusion depends on the model assumption that deep water formation takes place in the open ocean. This assumption is questionable since much of the modern deep water formation happens at continental margins. If these margin sites are oxygen depleted the resulting deep water would also be oxygen depleted. The authors should discuss this possibility and critically assess the validity of their model assumption.

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