

## ***Interactive comment on “Resolving ecological feedbacks on the ocean carbon sink in Earth system models” by David I. Armstrong McKay et al.***

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Thank you for a thorough and clear review of our paper. Here we will respond in brief to your comments and describe how we will subsequently revise the paper, prior to a full response to referees after the editor’s decision.

We recognise that we need to provide a fuller description of the model in the revised manuscript, which Reviewer #2 also picked up on. Although the model is described in detail elsewhere (and for simpler studies citing those may be sufficient), given our intended audience is a wider selection of Earth system model users and those more generally interested in climate feedbacks we agree that it would be useful to provide more

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model details. We will focus particularly on physical aspects, hard pump processes, represented ecological interactions between the different plankton size classes, and the limitations these factors introduce. We will also emphasise more the limitations that the low-res physical representation imposes in the Discussion and Conclusions.

You are right to say that the physical climate change response of c/ecoGEnIE is important context to interpreting the response of the biological pump and ocean carbon sink in comparison to other models. We will include details of this at the start of the Results section in the revised manuscript. We will also make clear in the Methods that our experiments are emissions-driven rather than concentration-driven (so as to allow carbon cycle feedbacks to fully emerge). We can also confirm that in this study we quantify the biological pump as the POC export from cGEnIE's surface box (with its base at  $\sim 81\text{m}$  depth), which we indicate in lines 195-197 but can further emphasise (and discuss the limitations of) in our revisions.

Both yourself and Reviewer #2 asked for more context in the way of comparing our results with existing ESM/EMIC projections, which we will include in our revisions. We will also add graphs of the long-term carbon sink results beyond the 21st century cumulative to the supplementary material (along with graphs for the biological pump for RCPs 3PD/2.6 and 6.0 in addition to 4.5 and 8.0 in the main manuscript), which we left out of the initial submission for reasons of brevity. We will also present results directly showing shifts in plankton size distribution during the ECO configuration runs, which Reviewer #2 requested as well.

We recognise that our wording on the importance of the biological pump for climate feedbacks and the implications of our results (as "critical") gave the wrong impression. We of course accept that the solubility pump is the dominant factor in the ocean carbon sink (as stated on line 54) with biological processes are of second order importance, and that our carbon sinks results show relatively minor changes ( $< \sim 1\%$ ) in comparison to the biological pump ( $< \sim 10\%$ ). We believe our results help illustrate that representing ecological dynamics relating to metabolism and size classes is important (even if

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not dominant) for biological pump projections but less so for the overall ocean carbon sink, and we will clarify this in the revised manuscript. However, we do not agree that the example given of a typically bombastic statement (“Additionally, NPZD-type models cannot fully resolve the potential impact of climate change or ocean acidification on ecosystem structure, biodiversity, and plankton size shifts.”) does overstate the situation – given that allometric effects are shown to be important for climate impacts on plankton community structure and function, it seems relatively uncontroversial to state that models that don’t represent allometric effects will be limited in resolving climate impacts on ecosystem structure and function. It was definitely not our intention though to imply that the model we use here is not limited in any way, or that other models are fatally limited in comparison. We will carefully review the manuscript for unclear or missing statements on respective model limitations, and will clarify or rephrase these instances as necessary.

Regarding the minor comments, we will provide clarifications in the revised manuscript where relevant, including exploring rearranging table 2 to improve its clarity, rephrasing the statement on past hard pump model development, and revising the flagged supplementary figures and captions.

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