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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 Jamie for a thoughtful 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 #1 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

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more model details. We will include saturation state-dependent PIC:POC ratio and size-dependent DOC:POC production. We will also provide additional background discussion of the role of POC remineralisation depth and ventilation processes in the operation of the biological pump. Thank you for pointing out that BIOGEM is a parametrised rather than an explicit NPZD-type biogeochemistry module – this was an inadvertent mistake and will be corrected in the revised manuscript, and the implications of resolving biomass explicitly discussed.

You are correct that in order to achieve equivalent POC export in the four configurations, some POC remineralisation parameters were altered, although we did not change the remineralisation depths (and so the potential depth timescale bias described doesn't directly apply). Instead we changed the proportion of recalcitrant POC (increasing it in the ECO configurations) and to a lesser extent the PIC:POC ratio, with the aim of equivalent baseline POC & PIC export across all four configurations and as similar carbonate chemistry as possible. Recalibrating the setups to have as similar a carbon cycle as possible was pursued in order to make the results easily comparable across the configurations, while POC export was chosen as the primary calibration constraint as the main variable being analysed. However, we recognise that we weren't clear as to how and why the model was recalibrated or how the calibration choices may limit the results, and this along with revised supplementary plots of the model-data fit for each calibration will be made clearer in the revised manuscript. Short Comment #1 also brings up a similar issue on whether difference in [CO3] across the setups are affecting our ocean carbon sink results, which will also investigate in our revisions. We can present the results of existing uncalibrated/published configurations for BIO+FPR, BIO+TDR, and ECO+FPR along with a recalibrated ECO+TDR in order to illustrate the impact of the POC export calibration relative to the changed ecological dynamics (which we believe will be relatively small).

We also recognise that as critical elements to the paper our explanations of the mechanisms proposed to drive both the biological pump and ocean carbon sink responses

could be clearer. In the revised manuscript we will expand and clarify these explanations utilising extra figures and simulations where necessary, as well as investigate and explain the potential role of additional mechanisms such as zooplankton grazing. As a brief specific response, on line 218 we do indeed mean that we believe more POC is remineralised in the surface layer and so initially lowers export production, the impacts of which we will clarify and further justify in the revised manuscript. While we do not directly discuss the impacts of representing stoichiometry or ocean acidification on our results they are implicit (for example, the latter in our discussion of the mechanisms behind ocean carbon sink changes, line 268-280). However, in our revisions we will explicitly discuss their role in our results. Both yourself and Reviewer #1 also asked for more in the way of comparing our results with existing ESM/EMIC projections in order to provide additional context along with results directly showing shifts in plankton size distribution, which we will include in our revisions as well.

Regarding the minor comments, we will provide clarifications in the revised manuscript where relevant, including clarifying terminology in the Introduction, rephrasing the statement on past hard pump model development, and exploring a reorganisation of the Figures.

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