

We thank the reviewers for their constructive feedback, which has substantially improved the manuscript. Below, we detail the changes committed to in our initial responses and those finally implemented in the revised version.

General Changes

- Clarified the scope of the work in the Abstract, Introduction, and Conclusions to emphasise analysis of mesopelagic POC turnover processes through PISCES model simulations compared to available observations.
- Expanded the model evaluation section with additional observational datasets, including moving relevant content from Methods to Results where appropriate, accompanied by improved discussion of modelled vs. observed patterns. New Table 2 now gives an overview of the model evaluation datasets.
- Improved the evaluation of vertical POC fluxes. Epipelagic POC export fluxes are now evaluated using both sediment trap data (Mouw et al., 2016) and Th-234 export flux data from Le Moigne et al. (2013), as shown in the new Figure 4. Former Figure S7 appears now in the main text (Fig. 5), showing overall good correspondence between modelled and measured POC fluxes across epi-, meso- and bathypelagic layers.
- Added evaluation of simulated mesozooplankton biomass against recent datasets (e.g., Clerc et al., 2024) and satellite-derived biomass for small phytoplankton and diatoms (Sathyendranath et al., 2019).
- Reorganised Figures 2 and 3 to better convey model evaluation results with the new datasets, including observational estimates and evaluation metrics where feasible.
- Added a summary table comparing our results with budget values from Giering et al. (2014), removing details from the main text.
- Added comparison of simulated POC degradation rates against empirical estimates (e.g., Lemaitre et al., 2018).
- Expanded the study limitations section, linking diagnosed POC budgets to model uncertainties and biases and to missing components (e.g., explicit Rhizaria representation). Thus, section 4.4 now provides a more balanced synthesis and briefly acknowledges uncertainties and unknowns.
- Improved the Abstract, adding model evaluation results, and revised the title to "Dissecting particulate organic carbon budgets in the mesopelagic North Atlantic Ocean: Mechanistic diagnosis using PISCESv2_RC and observations."
- In addition, we revised the whole text to improve clarity and logical flow. The Results and Discussion sections were revised in depth. The new version better conveys the mechanistic insights gained from dissecting POC budgets in PISCESv2_RC, while integrating insights from model evaluation. Such integration is also reinforced by the addition of new summary table (Table 3).

Reviewer 1 Responses

- Revised Figures 2 and 3 into more comprehensive model evaluation figures showing annual maps and seasonal cycles of key variables (NPP, plankton type biomasses, POC stocks) with observational overlays or metrics; added model-observation bias maps.
- Revised the biological carbon pump definition in the Introduction to include the balance between downward organic carbon transport/remineralisation and DIC return to the surface via circulation/outgassing, citing Frenger et al. (2024), plus Marinov et al. (2008) and Volk & Hoffert (1985). We also clarified throughout that our focus is on POC export/transfer efficiencies, using the term biological particulate carbon pump.

Reviewer 2 Responses

- Added satellite phytoplankton biomass comparisons using Sathyendranath et al. (2019) approach, identifying bias compensation between diatoms and nano+picoplankton at mid and high latitudes.
- Incorporated mesozooplankton comparisons, prioritising Clerc et al. (2024) because their gridded dataset provides finer spatial resolution and was specifically produced for evaluating PISCES mesozooplankton against the MAREDAT database. We declined adding comparisons with Liu et al. (2024) and Laget et al. (2024) because the organisms they represent do not correspond well with PISCES zooplankton types (see below).
- Expanded limitations to discuss Rhizaria/flux-feeding gaps, citing Stukel et al. (2019), Lampitt et al. (2023), and Laget et al. (2024). In sections 4.2 and 4.4 we now briefly discuss the limited correspondence between PISCES-modelled flux feeders and the actual zooplankton groups performing flux feeding or other modes of detritivory. Functional and taxonomic correspondence are not always aligned in models, reflecting the necessary simplification of food webs and reduction of tunable parameters. For these reasons, we have not included quantitative comparisons with data from Laget et al. (2024).
- A whole paragraph in Sect. 2.3 is devoted to describing the flux-feeding parameterisation in PISCES. In addition, a thorough description is provided in the SI (S1 Text). In the main text (Sect. 4.4.), we note that sensitivity analyses of this process will be presented elsewhere (Orihuela-García et al., *in prep.*).

All relevant manuscript changes are highlighted in the revised version using track changes