Dear Editor,

We would like to thank both reviewers for their time and constructive evaluation of our manuscript. We are pleased that both reviewers found the work suitable for publication, we have carefully addressed the specific comments raised by Reviewer 3, while Reviewer 4 found the manuscript acceptable as submitted. Our point-by-point responses are provided below.

- RESPONSE TO REVIEWER 3

We sincerely thank Reviewer 3 for their careful reading of the manuscript and their constructive comments, which have helped us improve the clarity and precision of the text. Below, we address each point in turn.

General comments
This manuscript presents a detailed assessment of how PISCES performs in simulating particulate organic carbon (POC) budgets in the North Atlantic and what mechanisms are responsible for the various transformations that small and large pools of POC undergo.
The manuscript first describes the performance of the model with respect to various observational datasets and then describes the POC budgets in three regions of the north Atlantic that represent the three main ecosystem types: the subtropical, transition and subpolar biomes.
The final part of the work is an assessments of the main limitations of PISCES in simulating POC dynamics and suggestions for future improvements.

Having passed already a first round of reviews, I do not think this manuscript needs much more work before publishing. I did find reading it a little hard at times (result section), but I guess this is how a model-validation manuscript is supposed to be. The main issue I have is that the title and abstract seem a little misleading because they suggest that this is an investigation on POC dynamics, rather than a model validation / assessment. I would recommend making this more evident.

We thank the reviewer for this observation. We agree that greater clarity on this point is beneficial. We have revised the abstract to more explicitly reflect the model-validation nature of the study, reporting model evaluation results upfront, while retaining the focus on POC dynamics as the subject of the assessment.

Specific comments:

Abstract: It's not clear to me how small detritus can "sustain" POC decay.
Do you mean that most of the decay of large-detritus flux is converted to small detritus?

We thank the reviewer for pointing out this ambiguity. We have rephrased this sentence to clarify the message, and now reads as follows:
" Small detritus plays a central role in the model, accounting for ~55% of mesopelagic POC decay and driving 33–50% of vertical flux at 1000 m."

Page 8: " the base of the productive layer": was this fixed? If not, then to make it comparable across biomes, you might have to normalise the transfer efficiency by the thickness of the layer.

We thank the reviewer for raising this point, as it allows us to clarify an important methodological choice. The base of the productive layer (Zprod) was fixed per biome and year. Using a biome-specific Zprod, rather than a fixed reference depth, is intentional: it ensures that the epipelagic layer captures the full zone of net photosynthetic production in each region, accounting for the specific biogeochemical transformations of POC that occur within this layer before reaching the mesopelagic zone. Indeed, measuring export at a fixed depth, such as 100 m, can be misleading when comparing regions with different productive layer thicknesses, as extensively discussed in the literature (Palevsky and Doney, 2018, 2021; Buesseler et al., 2020; Wilson et al., 2022; Walker and Palevsky, 2025). For example, in the SPNA, where Zprod is ~87 m, POC dynamics between 87 and 100 m are controlled by removal processes (remineralisation, fragmentation and zooplankton ingestion), so measuring export at 100 m would underestimate true export out of the productive layer. Conversely, in the STNA, where Zprod reaches ~200 m, the model is still producing organic matter between 100 and 200 m, so measuring export at 100 m would overestimate it. What is ultimately evaluated and compared across biomes is the particulate C pump efficiency from 0 to 1000 m, defined as

$$EE\ x\ TE = \frac{F_{Zprod}}{NPP} x \frac{F_{1000m}}{F_{Zprod}} = \frac{F_{1000m}}{NPP} ,$$

where 1000 m serves as a universal lower boundary of the mesopelagic zone. We hope this clarifies our approach, and we have added a new paragraph justifying the choice of biome-specific Zprod in Section 2.3, and a sentence explaining this formulation in Section 2.4.

Line 400: "good agreement": please quantify

We agree that quantification must be shown here, apart from the figure. We have replaced the qualitative statement with the relevant statistical metrics (bias = -21%), making the sentence more rigorous.

Line 501: Fig 8 reports the annual climatology, not the seasonal cycle

The reviewer refers to line 501, but we don't see any reference to the seasonal cycle there. We assume they are referring to line 521, where Figure 8 is mentioned along with Figure 9, S5, and S6 to illustrate the amplitude of the seasonal cycle for the SPNA and STNA regions. The reviewer is right; although Figure 8 shows the results of the district POC's annual budget, the vertical lines in Figure 8 represent the temporal standard deviation of total monthly inputs and outputs after normalisation by the annual mean value. Therefore, we have added a reference to these lines to clarify the sentence, avoiding confusion.

Line 553: Fig 11: if this is the correct reference, then Fig 11 is mentioned in the text before Fig 10
The reviewer is right, in line 553, we should have referenced Fig 10, not Fig 11; we have revised it.

Line 559: " particulate C pump efficiency at 1000 m" in fig 10 you called EExTE "particulate C pump strength": please be consistent.

We thank the reviewer for this suggestion. We have revised the terminology throughout to refer consistently to particulate C pump efficiency

Line 577: " This study provides a comprehensive analysis of POC dynamics". Please specify that these are "modelled POC dynamics"

Thanks for pointing this out. We have clarified the sentence.

- RESPONSE TO REVIEWER 4

We are very grateful to Reviewer 4 for their thorough and positive evaluation of our manuscript. We greatly appreciate the time and effort dedicated to reading the work in detail, and we are glad that the manuscript was found to be ready for publication as submitted.

We hope that the revised manuscript and these responses satisfactorily address the reviewers' comments. We remain available for any further queries.

Best regards,

M. Andrea Orihuela-García, et al.,

References:

Buesseler, K. O., Boyd, P. W., Black, E. E., and Siegel, D. A.: Metrics that matter for assessing the ocean biological carbon pump, Proc. Natl. Acad. Sci., 117, 9679–9687, https://doi.org/10.1073/pnas.1918114117, 2020.

Palevsky, H. I. and Doney, S. C.: How Choice of Depth Horizon Influences the Estimated Spatial Patterns and Global Magnitude of Ocean Carbon Export Flux, Geophys. Res. Lett., 45, 4171–4179, https://doi.org/10.1029/2017GL076498, 2018.

Palevsky, H. I. and Doney, S. C.: Sensitivity of 21st Century Ocean Carbon Export Flux Projections to the Choice of Export Depth Horizon, Glob. Biogeochem. Cycles, 35, e2020GB006790, https://doi.org/10.1029/2020GB006790, 2021.

Walker, S. L. and Palevsky, H. I.: Ocean carbon export flux projections in CMIP6 Earth System Models across multiple export depth horizons, https://doi.org/10.22541/essoar.172434585.50661378/v1, 22 August 2025.

Wilson, J. D., Andrews, O., Katavouta, A., De Melo Viríssimo, F., Death, R. M., Adloff, M., Baker, C. A., Blackledge, B., Goldsworth, F. W., Kennedy-Asser, A. T., Liu, Q., Sieradzan, K. R., Vosper, E., and Ying, R.: The biological carbon pump in CMIP6 models: 21st century trends and uncertainties, Proc. Natl. Acad. Sci., 119, e2204369119, https://doi.org/10.1073/pnas.2204369119, 2022.