Revision Note on the revised manuscript, dynamic upper-ocean processes enhance mesopelagic carbon export of zooplankton fecal pellets in the southern South China Sea, manuscript no. egusphere-2025-2864, submitted for publication in Biogeosciences.

We thank all the reviewers for their valuable comments and suggestions. We have carefully revised the manuscript in response to all the comments, and we sincerely hope the editor and referees will be satisfied with our revision. This Revision Note is written based on the annotated (using track changes) version of the manuscript (uploaded in the system). Appended to this letter is our point-to-point response to the comment raised by the reviewers. The notes (in blue) explain how and where each point of comment has been addressed. The line numbers mentioned are new numbers in the annotated version of the manuscript.

Reviewer#1: 'Comment on egusphere-2025-2864', Anonymous Referee #1, 24 Nov 2025

The authors made great efforts in improving the manuscript. Now the revised manuscript is good in science, logic and other details. It can be accepted after some minor revisions. The detailed comments are below:

Reply: We sincerely appreciate the reviewer's time and effort in evaluating our revised manuscript. We are grateful for your positive comments regarding the scientific quality, logical structure and improvements. We have carefully addressed all minor comments and have incorporated corresponding changes throughout the manuscript. Thank you again for your constructive feedback and valuable guidance which have largely strengthened the quality of our work.

Comment #1:

Line 21: Please change "which converts massive, dissolved CO2.." to "which convert massive CO2 …"

Reply: Thank you for this helpful comment. We agree that our previous expression "dissolved CO2" was not accurate and could lead to misunderstandings of the BCP carbon sources, as surface ocean inorganic carbon pool includes multiple species, not only dissolved CO_2.

Accordingly, we have now corrected this sentence as follows: *"Central to this uptake lies the biological carbon pump (BCP), which converts massive CO_2 in the surface ocean into particulate organic carbon (POC) via phytoplankton photosynthesis (Falkowski, 2012; Boyd and Trull, 2007; Nowicki et al., 2022)."* (Lines 21-23)

Comment #2:

Line 163: Figure 3 should be Fig. 3

Reply: Thank you for this helpful comment. We have now examined all figure citations in our manuscript to ensure consistency, and have corrected this sentence as follows: *"Geometric and flux characteristics are summarized in Table 1 and Fig. 3, with detailed data in Table S1."* (Lines 167-168)

Comment #3:
Please add units for the mean values in lines 168-169.

Reply: Thank you for this helpful comment. We have added units for mean values and checked the unit consistency throughout the manuscript. The revised sentence now reads: *"FPN ranged from 9.4 × 10^2 to 4.61 × 10^5 pellets m^{-2} d^{-1} (mean: 7.39 × 10^4 pellets m^{-2} d^{-1}, Fig. 3a), while FPC spanned from 0.03 mg C m^{-2} d^{-1} to 4.62 mg C m^{-2} d^{-1} (mean: 0.91 mg C m^{-2} d^{-1}, Fig. 3d), both exhibiting pronounced seasonal variations."* (Lines 173-174)

Comment #4:
I still think Figures 3a and b, d and e are overlapped, and Figures 3b and e were not cited in the text. I suggest present the total FPN and three kinds of FPN in one panel, FPC in the same manner.

Reply: Thank you for this helpful comment. Indeed, the datasets of Figures 3a-b, d-e were identical and were often discussed together in the text, which further resulted in data redundancy of different subplots and missing citations of figures in the manuscript.

We have carefully evaluated your suggestion of combining total and component pellet fluxes into a single panel. Across most plotting methods, we think stacked bar charts remain the most effective way of visualizing our data, as they can display both total fluxes and contributions of individual FP types, while preserving the seasonal patterns (as in the original Fig. 3a and d).

In response, we have now removed Fig. 3b and 3e to avoid data overlapping and have reorganized the sequence of subplots according to their reference in the text. The revised Figure 3 now consists of 4 subplots, including (a) FPN flux (stacked bar chart showing total FPN and fluxes of three FP types), (b) FPN percentage (%); (c) FPC flux (stacked bar chart showing total FPC and fluxes of three FP types); and (d) FPC percentage (%). The captions and references of the figure have been updated accordingly. (Lines 200-203).

Comment #5:
The legends are not clear for Figure 4b. There are four lines in this panel, but the authors did not explain the meaning of each line. In addition, Figure 4c was not cited in the text. In line 205, the authors said FPC/POC displayed inverse seasonal variation to POC fluxes based on Figure 4b, but according to Figure 4c, positive correlations between POC flux to FPN and FPC. To some extent, it seems contradictory.

Reply: Thank you for this helpful comment. We sincerely apologize for the unclear legends in Figure 4b and the confusion caused by the incomplete citation in Figure 4c. In response, we have now redrawn and reorganized Figure 4 with clearer legends and descriptions (Lines 218-220). Specifically, Figure 4c now illustrates the correlations among FPN, FPC and POC flux, while a new panel (Fig. 4d) has been added to show the relationship between the FPC/POC ratio and POC flux.

As shown in Figure 4c, FPN, FPC, and POC fluxes are all positively correlated with each other, with all linear relationships being statistically significant ($p < 0.01$). However, though FPC and POC flux are positively correlated, their ratio does not scale with POC flux and can display opposite seasonal patterns (Fig. 4d). For example, between August and November 2022, POC fluxes remained extremely low, whereas the FPC/POC ratio reached its annual maximum (Fig. 4b).

Comment #6:
In figure 6, the points are shown in different colors, please using color bar or other means to explain them. Also the dashed lines are in red and blue, which one denotes EAM and non-EAM?

Reply: Thank you for this helpful advice. We sincerely apologize for the unclear visualization in the previous version of Figure 6. The blue-green-yellow color range previously used in the scatter plot did not correspond to any specific meaning and may have caused confusion. In response, we have now redrawn and reorganized Figure 6 for clearer interpretation. In the revised plot, the two groups of data are distinctly colored, with EAM in blue and non-EAM in red, and the linear regression lines are shown in the same corresponding colors. (Line 273)

Reviewer#2: 'Comment on egusphere-2025-2864', Anonymous Referee #2, 24 Nov 2025

Comment #1:
Line 35: The studies by Estapa et al. (2017) and Terrats et al. (2023) provide estimates of carbon fluxes associated with both large and small particles. However, we do not think that the “large-particle flux” in these studies can be directly interpreted as fecal pellet–driven carbon fluxes.

Reply: Thank you for this helpful comment. We agree that the particle fluxes reported in Estapa et al. (2017) and Terrats et al. (2023) cannot be directly interpreted as fecal pellet carbon fluxes, and therefore these studies are not suitable to support the sentence. In the previous manuscript, they were cited as evidence for the use of Argo in fecal pellet research. However, Argo and Bio-Argo estimates also include both small and large particles, and the contribution of fecal pellets cannot be separated.

In response, we have now removed the two references and revised the sentence as follows: *"In-situ observations from sediment traps and large filtering systems provide high-resolution time-series flux records (Shatova et al., 2012; Turner et al., 2015; Li et al., 2022; Wang et al., 2023; Cao et al., 2024; Darnis et al., 2024), while complementary approaches including satellite observations (Siegel et al., 2014) and numerical modeling (Stamieszkin et al., 2015; Countryman et al., 2022) largely expand the scope of investigation across broader spatial and temporal scales."* (Lines 33-38)

Comment #2:
Line 325: The abbreviation "EAM" has been repeatedly defined throughout the manuscript. It should be introduced only once when it first appears.

Reply: Thank you for this helpful comment. We have now examined all terms, definitions, and abbreviations throughout the manuscript, including EAM, BCP, POC, SCS, WSPs, TCs, and CEs, and ensured that each term is introduced only once at its first occurrence. The specific first appearances are as follows: EAM (Line 62), BCP (Line 21), POC (Line 22), SCS (Line 61), WSPs (Line 227), TCs (Line 228), CEs (Line 329). Thank you again for your careful examination.

Comment #3:
Table 2: It is somewhat unclear how the generalized linear model (GLM) was used to quantify the relative contribution of physical events to carbon export. For each event type, was it treated as a single independent factor or as a composite factor including multiple environmental variables? Please provide more methodological details to clarify this.

Reply: Thank you for this helpful comment. In our GLM model, each physical event (typhoon, monsoon, eddy) was treated as an independent binary factor, coded as 1 when the event occurred and 0 otherwise. Since the aim of this analysis was to evaluate the relative contribution of each event to fecal pellet export, we did not combine multiple environmental variables into composite factors, as doing so could increase the model uncertainty and the risk of overfitting, giving the limited number of observations we have (n = 13).

In response, we have expanded Section 2.4 to include more description of the GLM model. The revised text reads as follows:
"To evaluate the relative contribution of different events to fecal pellet export, we applied a generalized linear model (GLM) with a Gamma distribution and a log link function:

$$FPN \sim Monsoon + Typhoon + Eddy$$

Each physical event was treated as an independent binary factor indicating whether the event occurred during the sampling period." (Lines 157-162)

Comment #4:

Line 530: The typical range of the FPC/POC ratio in oligotrophic oceans should be specified, along with the corresponding references.

Reply: Thank you for this helpful comment. We agree that specifying the range of FPC/POC ratio in oligotrophic oceans is essential and can greatly strengthen our discussion. According to recent studies and earlier reviews, FPC/POC ratio ranges from 0.3 % to 35 % in oligotrophic mesopelagic (200–1000 m) regions. Reported values and related references include: the southern SCS (1.3–30.0 % at 500 m, mean 9.6 %; Li et al., 2022); the northern SCS (0.3–15.7 % at 500 m, mean 3.4 %; Wang et al., 2023); the western SCS (0.7–28.2 % at 500 m, mean 4.4 %; Cao et al., 2024); Shikoku, Japan (0.4–1.7 % at 500 m; Ayukai and Hattori, 1992); the central North Pacific (14–35 % at 500 m; Wilson et al., 2008); the northwestern Mediterranean (3–35 % at 500 m; Carroll et al., 1998), and the Sargasso Sea (0.4–10.0 % at 500 m; Shatova et al., 2012).

In response, we have now revised the sentences as follows:
"In the SCS, zooplankton fecal pellets make the most contribution to POC export in the southern region, with FPC/POC ratio ranging from 10.0 % to 42.6 %, reaching an average of 21.6 %. This range is relatively higher than the typical values reported for oligotrophic mesopelagic regions (0.3–35 %; reviewed in Turner et al., 2015; Li et al., 2022), including Station ALOHA in the central North Pacific (14–35 %; Wilson et al., 2008), the northwestern Mediterranean (3–35 %; Carroll et al., 1998), and the Sargasso Sea (0.4–10.0 % at 500 m; Shatova et al., 2012), highlighting the critical role of zooplankton fecal pellets in shaping the unique carbon export process in the southern SCS." (Lines 401-407)

References cited in this Reply:

Ayukai, T., & Hattori, H.: Production and downward flux of zooplankton fecal pellets in the anticyclonic gyre off Shikoku, Japan, Oceanolog. Acta, 15(2), 163-172, 1992.

Bao, M., Xiao, W., and Huang, B.: Progress on the time lag between marine primary production and export production, J. Xiamen Univ. (Nat. Sci.), 62, 314–324, https://doi.org/10.6043/j.issn.0438-0479.202204044, 2023.

Carroll, M. L., Miquel, J. C., and Fowler, S. W.: Seasonal patterns and depth-specific trends of zooplankton fecal pellet fluxes in the Northwestern Mediterranean Sea, Deep Sea Res. Part I, 45, 1303–1318, https://doi.org/10.1016/s0967-0637(98)00013-2, 1998.

Cao, J., Liu, Z., Lin, B., Zhao, Y., Li, J., Wang, H., Zhang, X., Zhang, J., and Song, H.: Temporal and vertical variations in carbon flux and export of zooplankton fecal pellets in the western South China Sea, Deep Sea Res. Part I, 207, 104283, https://doi.org/10.1016/j.dsr.2024.104283, 2024.

Countryman, C. E., Steinberg, D. K., and Burd, A. B.: Modelling the effects of copepod diel vertical migration and community structure on ocean carbon flux using an agent-based model, Ecol. Modell., 470, 110003, https://doi.org/10.1016/j.ecolmodel.2022.110003, 2022.

Darnis, G., Geoffroy, M., Daase, M., Lalande, C., Søreide, J.E., Leu, E., Renaud, P.E. and Berge, J.: Zooplankton fecal pellet flux drives the biological carbon pump during the

winter–spring transition in a high-Arctic system, Limnol. Oceanogr., 69, 1481–1493, https://doi.org/10.1002/lno.12588, 2024.

Estapa, M., Durkin, C., Buesseler, K., Johnson, R., and Feen, M.: Carbon flux from bio-optical profiling floats: calibrating transmissometers for use as optical sediment traps, Deep Sea Res. Part I., 120, 100–111, https://doi.org/10.1016/j.dsr.2016.12.003, 2017.

Li, J., Liu, Z., Lin, B., Zhao, Y., Cao, J., Zhang, X., Zhang, J., Ling, C., Ma, P., and Wu, J.: Zooplankton fecal pellet characteristics and contribution to the deep-sea carbon export in the southern South China Sea, J. Geophys. Res.: Oceans, 127, e2022JC019412, https://doi.org/10.1029/2022jc019412, 2022.

Siegel, D. A., Buesseler, K. O., Doney, S. C., Sailley, S. F., Behrenfeld, M. J., and Boyd, P. W.: Global assessment of ocean carbon export by combining satellite observations and food-web models, Global Biogeochem. Cycles, 28, 181–196, https://doi.org/10.1002/2013GB004743, 2014.

Stamieszkin, K., Pershing, A. J., Record, N. R., Pilskaln, C. H., Dam, H. G., and Feinberg, L. R.: Size as the master trait in modeled copepod fecal pellet carbon flux, Limnol. Oceanogr., 60: 2090–2107, https://doi.org/10.1002/lno.10156, 2015.

Terrats, L., Claustre, H., Briggs, N., Poteau, A., Briat, B., Lacour, L., Ricour, F., Mangin, A., and Neukermans, G.: BioGeoChemical-Argo floats reveal Stark latitudinal gradient in the Southern Ocean deep carbon flux driven by phytoplankton community composition, Global Biogeochem. Cycles, 37, e2022GB007624, https://doi.org/10.1029/2022GB007624, 2023.

Turner, J. T.: Zooplankton fecal pellets, marine snow, phytodetritus and the ocean's biological pump, Prog. Oceanogr., 130, 205–248, https://doi.org/10.1016/j.pocean.2014.08.005, 2015.

Wang, H., Liu, Z., Li, J., Lin, B., Zhao, Y., Zhang, X., Cao, J., Zhang, J., Song, H., and Wang, W.: Sinking fate and carbon export of zooplankton fecal pellets: insights from time-series sediment trap observations in the northern South China Sea, Biogeosciences, 20, 5109–5123, https://doi.org/10.5194/bg-20-5109-2023, 2023.

Wilson, S. E., Steinberg, D. K., and Buesseler, K. O.: Changes in fecal pellet characteristics with depth as indicators of zooplankton repackaging of particles in the mesopelagic zone of the subtropical and subarctic North Pacific Ocean, Deep Sea Res. Part II, 55(14–15), 1636–1647, https://doi.org/10.1016/j.dsr2.2008.04.019, 2008.

Shatova, O., Koweek, D., Conte, M. H., and Weber, J. C.: Contribution of zooplankton fecal pellets to deep ocean particle flux in the Sargasso Sea assessed using quantitative image analysis, J. Plankton Res., 34, 905–921, https://doi.org/10.1093/plankt/fbs053, 2012.