

Dear Editor

Thanks for forwarding the reviewer reports on our manuscript “A Novel Approach to Estimate Carbon and Nitrogen Flux from In Situ Optics: Application to Cyclonic Eddies off the Cape Verde Islands” by N. Moradi et al. We also thank both reviewers for their thorough evaluation and helpful suggestions, which have significantly enhanced the focus and clarity of our study. We have amended the manuscript according to all of the reviewers’ recommendations.

In particular, to address the reviewers’ comments regarding the clarity and focus of the manuscript and the lack of an uncertainty analysis, we have undertaken the following major revisions:

- The manuscript has been shortened to focus entirely on the methodology.
- The methodological framework has been substantially refined: we implemented a vertically discretized water column model, in which the domain was divided into layers of increasing thickness with depth, to more accurately represent the effects of variations in water temperature and oxygen concentration on carbon degradation rates. Both zero-order and first-order degradation models were implemented and compared to estimate POC flux. The formulation of the dynamic PON model was improved to better match observational data showing variation in the C:N ratio with increasing water depth.
- A comprehensive uncertainty analysis has been incorporated.

In line with these revisions, the title has been changed to more accurately reflect the primary contributions of our study: “Estimating Particulate Organic Matter Flux from In-Situ Optics: A Framework for Correcting for Suspended Particles and Incorporating Depth-Dependent Degradation.” The body of the manuscript has been updated accordingly.

Below, we provide a detailed, point-by-point response to each of the reviewers' comments.

Response to Reviewer #1

The authors describe field observations of sinking particle fluxes and its modeling from particle imagery using data from the Cape Verde Islands both inside and outside of cyclonic eddies. They introduce two methods for modeling sinking particle fluxes from in situ particle imagery to model POC and PON fluxes and their characteristics. They show a two-fold increase in flux inside cyclonic eddy compared with sites outside. Several issues preclude the publication of this paper at this time.

Point 1: *There seems to be a significant error in the formulation of the model used in their second method for assessing sinking POC/PON fluxes. This issue must be reconciled before this paper can be considered for publication.... Equations 4 & 5 (and the text before that) all state that the carbon content at depth should decrease linearly in time due to remineralization processes, implying that at some time the Carbon Mass would be negative. This is incorrect.*

Response: We thank the reviewer for highlighting this important point, which was not sufficiently clear in the original manuscript. To clarify, our zero-order degradation model was already constrained to prevent negative POC mass (see lines 284–287 in the preprint). This non-negativity constraint reflects the natural scenario where, once a settling marine particle’s organic carbon is entirely consumed, no further carbon degradation of that particle can occur. Nevertheless, our results show that, in practice, due to the relatively low microbial respiration (measured on in situ collected aggregates) and the suppressing impact of a temperature decrease, it is unlikely that POC mass would become negative even at great depths, as illustrated in Fig. A4 of the revised version for depths up to 3500 m.

However, we recognize that the model formulation and its mechanistic basis were not clearly presented. We have now completely rewritten this section (see Sect. 2.2.2 of the revised manuscript) to explicitly detail the model's mechanistic basis. The choice of a zero-order degradation model is mechanistically grounded in our experimental approach, which derives carbon degradation rates from microbial-driven oxygen fluxes measured at the particle-

water interface (see Eqs. 14–16 in the revised version). This formulation treats remineralization as a surface-area-limited process and assumes that the microbial enzymes responsible for degradation are saturated with substrate. This results in a constant carbon degradation rate under constant ambient conditions, an observation supported by direct measurements on settling marine aggregates (e.g., Ploug et al., 1997; Ploug et al., 2002; Ploug and Bergkvist 2015).

Point 2: *Typically, the loss of mass due to a first order decay process is modeled as $CarbonMass = InitialCarbonMass * exp(-DecayRate * Time)$. This is fundamental and the analysis presented needs to be entirely reworked.*

Response: Following the reviewer's recommendation, we also implemented and evaluated a first-order degradation model for comparison (see Sect. 2.2.3 and 3.3.2 of the revised manuscript). As shown in the revised manuscript (Fig. 7), the results of the two degradation models are nearly identical, providing further support for the zero-order degradation model as an adequate representation of carbon degradation for this dataset.

Point 3: *The paper ignores uncertainty in the modeling performed, making it impossible to tell how robust any of the methods are. The model parameters are developed using least squares fits and it is straight forward to estimate their confidence levels. All through the paper, the model fit parameters are reported to the 5th or some 6th digit, which is way more precision than Any revision of this paper needs uncertainties properly calculated and reported AND their propagation to final calculations.*

Response: We agree that a robust quantification of uncertainty is essential. We have now incorporated a comprehensive uncertainty analysis using a sequential Monte Carlo (nested bootstrapping) procedure (see Sect. 2.3 in the revised manuscript). This approach allows us to propagate uncertainties from all input sources through the entire modeling chain. We now report all optimized parameters and derived fluxes with their median and associated 95% confidence intervals. All parameter estimates and their uncertainties have been reported to an appropriate level of precision. Specifically, each uncertainty was first rounded to one or two significant figures, and the corresponding parameter estimate was then rounded to the same decimal place.

Point 4: *I was unclear of the paper's intent. Is it a methods paper or is it about the roles of eddies on sinking particle fluxes? This needed to made clear from the onset (title, abstract and intro) and this was not accomplished. Last, the paper needed a good deal of editorial help before it was submitted. There were many writing and presentation issues that made this paper very hard to review. I do wish I could be more positive in this recommendation as I think there are several interesting analyses presented.*

Response: We thank the reviewer for this important feedback and apologize that the initial submission did not meet the expected standards of clarity and presentation. We have revised the manuscript to focus entirely on the development and validation of our methodological framework. The analysis and discussion related to the role of mesoscale eddies have been removed and will be the subject of a subsequent paper. Consequently, the title, abstract, and introduction have been rewritten to clearly state the paper's methodological focus. The manuscript has been substantially restructured and rewritten to enhance its overall narrative flow and logical progression.

Point 5: *The comparison of the UVP and gel trap spectra could be very interesting. However, all what is presented are the one-to-one coefficients from the fits (Figure 7), and it is unclear what this represents. More analysis is needed here and it would be easy. For example, it would be good to know if the concentration of sinking particles seen by the gel traps is always less than the suspended seen by the UVP (taking into account uncertainties in the method too!). Also, what is the fraction of sinking to suspended particles, what its dependence on size would be, etc. These obvious results are missing and should be included in a revised manuscript.*

Response: We have added a new figure and accompanying text in the Results section (see Fig. 3e-j in the revised manuscript), which directly compares the size distribution of particle fluxes from the UVP and the gel traps, clearly illustrating the bias from non-sinking particles before the correction is applied. We have also added new figure panels (Fig. 4b-d in the revised manuscript) that explicitly show the UVP-derived particle flux is systematically higher across all size classes than that measured with the gel traps, even when accounting for uncertainties in the measured size-specific sinking velocities.

Point 8: *The paper was very difficult to read and review. Part of it was overall construction. The paper does not lead the reviewer through the story effectively. Not sure what the point was. The introduction should lay that path and that was a mess. Some of that was in the discussion. I found myself guessing what the point of the paper was. At the next level down, paragraphs need to focus on a single topic with a useful topic sentence that describe the goal of the paragraph. What was the hardest was the lack of polish on the paper. Many things were hard to figure out. For example, the acronym "SDPF" is used multiple times starting on page 7 before it is defined on page 11. There are many other examples that made this tough to review. Again, I wish I could be more positive in this recommendation, but the paper needs some serious attention to details that I know the authors are capable of.*

Response: We thank the reviewer for his/her careful reading and for pointing out issues with the manuscript's writing and presentation. The manuscript has been substantially restructured and rewritten to improve its narrative flow and logical progression. Paragraphs now focus on single topics, and the paper tells a coherent story, moving from identifying limitations in conventional methods to the development, validation, and comparison of our novel, multi-step framework.

Response to Reviewer #2

This is an interesting study of cyclonic eddies off the coast of the Cape Verde Islands, where the authors show an increase in particulate flux within the core of the eddy compared with outside. This has implications for the flux of particles (and by inference Carbon and Nitrogen) within the global ocean where hotspots of particle sinking may be remaining unobserved (certainly) or unaccounted for (possibly) in our estimations of key elements within the Earth System. These type of "funnel" features have been observed before, on a seasonal basis (e.g. Dall'Olmo and Mork, 2014). The use of this type of approach allows the flux of particles to be captured in real-time (i.e. as it is happening) rather than being an integral over several days / weeks / months / years as is the case for sediment traps. The methods themselves involve several steps and assumptions. This includes assumptions about the sinking velocity of particles (as a function of size) which, as the authors show, in Figure 5 only explain 11% of the variance. This isn't necessarily unusual in this field, as is shown by the intercomparison with other works (Cael et al.). The other assumptions regard the conversion of particle diameter to carbon content (which they start off using a power law relationship, which then gets modulated through the water column by physics and chemistry (temperature and oxygen)). The authors use an optimisation step for A_{car} and B_{car} . The PON content is then related to the POC content through another factor γ .

Point 1: *It is here that the authors need to be clear. They are estimating the POC and PON flux based on particle size spectra without any recourse to measuring POC or PON. Anywhere that it is stated that these are observations, I think requires re-writing.*

Response: Our mechanistic models are rigorously calibrated and validated against direct POC and PON flux measurements from spatiotemporally aligned drifting sediment traps. We acknowledge that this crucial information was not stated with sufficient clarity in the original manuscript. This validation procedure is now explicitly clarified and illustrated in the revised version (see Eqs. 18 and 26, the accompanying text, and Fig. 6).

Point 2: *Also, there needs to be a thorough analysis done to determine uncertainties at every step. This should be relatively straightforward - given they draw on the work of Guidi et al. (2008), and build on it, the use of the standard deviations (errors) should be invoked here to cascade down through the calculation chain.*

Response: We agree that a robust quantification of uncertainty is essential. We have now incorporated a comprehensive uncertainty analysis using a sequential Monte Carlo (nested bootstrapping) procedure, as detailed in Section 2.3 of the revised manuscript. This approach allows us to propagate uncertainties from all input sources through the entire calculation chain. We now report all optimized parameters and derived fluxes with their median and associated 95% confidence intervals.

Point 3: *Overall some of the reasoning was difficult to follow, and using non-standard nomenclature for things like number (#) should be changed. At times the authors used in-paragraph equations and other times they were separated out of the text.*

Response: We thank the reviewer for this valuable feedback. We have thoroughly revised the entire manuscript to improve the narrative flow and the clarity of our reasoning. By restructuring the paper to focus exclusively on the methodology, we have made the logical progression of our arguments more direct and easier to follow. Furthermore, we have addressed the specific inconsistencies the reviewer identified and have carefully reviewed and standardized all notation throughout the manuscript to adhere to standard conventions. Additionally, all equations now have a consistent format to enhance readability.

Sincerely,

We hope and trust that the substantially revised manuscript now meets the standards for publication in Biogeosciences (BG).

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