

Geosci. Model Dev. Discuss., author comment AC2
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Reply on RC1

Gwenaëlle Gremion et al.

Author comment on "A discrete interaction numerical model for coagulation and fragmentation of marine detritic particulate matter (Coagfrag v.1)" by Gwenaëlle Gremion et al., Geosci. Model Dev. Discuss., <https://doi.org/10.5194/gmd-2020-423-AC2>, 2021

We would like to thank the first anonymous referee for the time he/she spent to review our manuscript with very helpful comments that will certainly improve the quality of our work. We include the comments from the referee and our responses below. We hope that this version, alongside the improvement related to the second reviewer will meet your expectations for publication.

Sincerely yours,

Gwenaëlle Gremion, on behalf of all co-authors.

- **Firstly, I was surprised to see links to the cloud microphysics field had not been made. These spectral bin models are used frequently e.g. Khain et al 2004 and a discussion is warranted.**

We do agree that some concepts used in our study come from aerosol physics. We recognize this when we refer to the seminal work of Gelbard et al. (1980) on aerosol coagulation, but we agree that a short discussion on more contemporary work in this field is relevant and will be added. We thank the reviewer for its suggestion.

- **Line 375 states "But, the sensitivity of our model outcomes to many arbitrary constant parameters needs to be profoundly investigated". This is an extremely pertinent point and I think at least a basic sensitivity analysis should be conducted.**

We fully agree with the reviewer that a thorough sensitivity analysis must be conducted. However, the main objective of our manuscript is to present a numerical framework representing coagulation and fragmentation based on discrete interaction and to test its consistency and robustness with respect to the spectral resolution and discretization. This is specified at p. 3 lines 73-76: "*a formulation is sought that will attenuate the dependence of the results to the size discretization resolution. Numerical experiments are designed to study the dependence of the results on i) the number of size bins used to discretize a given size range (i.e. the resolution) and ii) the type of discretization (i.e. linear vs nonlinear)*". Although we are considering applications in biogeochemical modeling, what is presented remains general in scope. Carrying sensitivity analyses was also purposely left out because it is lengthy when properly done and that we currently have 31 pages already. Again, we agree that it is important and it is currently being done

in a working manuscript.

- **Regarding the penalty function: while I appreciate the simplicity used to reconcile the errors arising from nonlinearity, more tests should be carried out to confirm the applicability of the parameter choices used in the function.**

The penalty function was empirically set up to demonstrate that it is required to correct for the asymmetry between the reactions. Following this idea, parameters were chosen by trial-and-error to achieve an arbitrary satisfactory reduction of the asymmetry. However, as mentioned in p. 22, lines 347-350, a more systematic inquiry of the resolution and non-linearity dependence is needed (which is ongoing and will be the subject of a subsequent paper) to find either an exact or empirical formulation of the penalty function.

- **The work aims to replace the simplified coagulation parameterizations currently used in OGCMs, which use several detritus compartments. While I completely agree that the approach used here is a positive step, it would be useful to demonstrate exactly why the model developed here is preferable beyond the current discussion given in the introduction. Is there evidence showing that carbon fluxes are estimated more accurately using this type of method? Can a simple experiment be carried out to show the shortfalls of the other approaches? There is going to be a computational penalty for including more tracers, so it should be shown that the sacrifice is worth it.**

OGCMs that use many detritus compartments do not necessarily take into account coagulation. This requires that the detritus variables react together, which is not the case to our knowledge. Our ultimate objective is to explicitly implement the coagulation and fragmentation reactions in NPZD models coupled to OGCMs, with a number of detritus variables that is as low as possible.

In some OGCM-BGC models, a depth-dependent function is prescribed to account for the degradation of organic matter as it sinks to the ocean floor and transformed into dissolved organic carbon p. 2 line 52: "*Gloege et al. (2017), e.g. exponential decay, Martin's curve, ballast hypothesis*". However, this cannot be viewed as an explicit parameterization of coagulation-fragmentation reactions. Other OGCM-BGC models consider numerous detritic variables, but they do not use the coagulation-fragmentation reaction results as a determinant of the size representation of their detritus variables. For example in Butenschön et al. (2016), detritus are only split up in size classes, related to size-specific primary or secondary producers variables, for which they are the terminal variable (where they end up when dead). In this example, once the material ends up in those detritic variables it is not able to move from one size class to another. They can however move from a particulate variable to a dissolved one. Thereafter, this matter is exported to the seafloor according to the size-dependent settling velocity. In our work, the particulate matter when placed in a size-specific detritic variable is able to move from one size bin to another following coagulation and fragmentation reactions. Once coupled to a BGC model, this will vary as a function of depth and time. To sum up, size-detritic variables will not be considered as terminal variables of the particulate matter, and matter dynamics and export rates will be fluctuating depending on the biological and physical environment.

Therefore, we then think that our approach will provide new carbon export patterns in NPZD models that ultimately will be compared with the depth-dependent degradation functions of the organic matter as reference. Indeed those functions are representative of what is observed in the ocean, as they are based on field results. Although this is a really stimulating and important question, we are however unable, in the current state of our research, to carry out any experiment of comparison. This requires additional work, such as the implementation of parameters known to be varying with size (coagulation and fragmentation), and a parameterization with a physical and biological environment. This is

precisely stated in the manuscript (p.24 line 385): “Ultimately, when reliably parameterized, this model will be coupled to an upper trophic level ecological model and OGCMs that will enable addressing further questions related to the fate of particle evolution with depth.”

- **Takeuchi et al. 2019 finds aggregates are bounded in size by the Kolmogorov length scale. Rather than using an arbitrary upper bound, this characteristic could be used to inform the choice of upper bound.**

This is true that the Kolmogorov length scale constrains the upper bound of particle sizes and we thank the reviewer for pointing out a recent study about this. However, there are also evidences that some phytoplankton species (e.g. *Melosira Arctica*) can form ~20 cm-long strands that reach the seafloor thousands of meters below the surface (Boetius et al, 2013). Despite its importance, prescribing an upper bound is beyond the scope of our paper which is to develop a numerical framework that is robust and that can be adapted to practical applications. There are multiple ways to represent the effects of turbulence in and those will be discussed in a subsequent study.

References

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