Submission to EGU—Biogeosciences: Answer to reviewers (round 1)

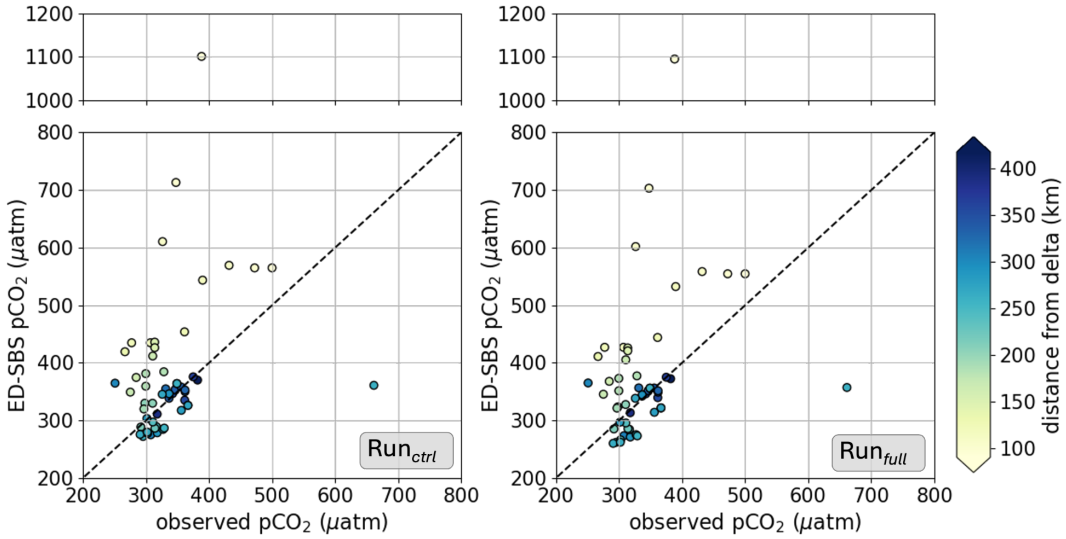
In their manuscript, Bertin et al. investigate the implications of including colored dissolved organic matter (CDOM), which can be photodegraded to dissolved inorganic carbon and thereby absorbs heat, for the heat budget and carbon cycle in the Southeastern Beaufort Sea. The methodologies are sound, with a model is established and validated for the investigated region, and a novel parametrization for CDOM and its main effects introduced (e.g. for light attenuation parametrization). The results show a significant effect on surface ocean temperature seasonally (+1.7°C), which in turn then has a significant effect for the regional carbon budget, with the CDOM warming effect causing a switch from a sink to a source for the region. The manuscript is well structured and streamlined, and I would recommend the article for publication with a few clarifications and minor revisions.

1. The validation of including CDOM and arguments for explicitly representing CDOM (in the context of actually improving the model) can be strengthened. Figure D1 shows that biological productivity timings seem worse in the early season with CDOM effects (although the peak timing is then improved). It would also be interesting to see if including CDOM generally improves model SST, and the biological productivity variables spatially. Would pCO2 data also be available? I think Figure D1 should be integrated and discussed in the main manuscript (or the observational timeseries integrated in the main figures).

We thank the reviewer for his comment and strengthened our discussion to better emphasize how CDOM improves the model ability to simulate physical and biogeochemical seasonality with regard to the sea-ice mel. Below are the following aspects of the paper we changed to strengthen the discussion:

- We moved Figure D1 in the main text (Now Figure 9). Note that changes in time-series appear due to the adjustment of a bug observed in the Lewis et al. (2020) product. This point is now further explained in Appendix D (L507–513) and new Figure S3.
- We added a paragraph (L380–396) discussing the model-observation comparison with regard to SST, phytoplankton and sea-ice phenology and further discussed model improvements needed to enhance bloom phenology (L397–414).
- We modified Appendix D to further detail the comparison method and analyze SST comparison and added a new Figure D1 showing the model-observation spatial comparison for SST and surface Chl.

Regarding pCO_2, we compared simulated pCO_2 with observed pCO_2 during the Malina campaign of 2009, as done in Bertin et al. (2025, PPP). CDOM appears to have a very small impact on pCO_2 (see comparison figure below). This confirms our statement that changes in air-sea CO_2 fluxes are rather related to a change in flux efficiency through SST rather than change in the carbon constitution. We therefore decided to not add this comparison as the changes compared to no CDOM are small and since the model-observation comparison for pCO_2 (Run_{ctrl}) has already been published in Bertin et al. (2025).



2. The study refers to colored dissolved organic matter, but what is actually represented in the model is only carbon. What are typical stoichiometries of CDOM and would representing the additional nutrient input have an effect on presented results?

CDOM is expressed in the model as a carbon mass concentration, but the product of its degradation generates DON and DOP following the canonical Redfield ratio. We clarified this point with the following sentence (L97-98): "When *degraded into DOC_{sl}, CDOM products DON and DOP following the Redfield ratio of 120:16:1, allowing to represent the additional nutrient input generated by organic matter consumption.*"

3. The study focuses solely on impacts of CDOM for heat budget and carbon dynamics, but I think it would be fitting to further discuss in more detail potential implications of POC and other particle effects. Would these feedbacks go in the same direction? I assume both of the fluxes of these compounds would also correlate with increased terrestrial DOM fluxes since the processes leading to increases would be similar (coastal erosion, increased runoff, permafrost t aw etc.)

According to the reviewer comments, we further discussed the potential implication of particulate matter in coastal Arctic CO_2 flux (L432–437): "*Similarly to CDOM, terrestrial POC fluxes are likely to increase in the future with increased runoff, permafrost thaw, and coastal erosion (Nielsen et al., 2024; Sauerland et al., 2025). The additional amount of carbon exported to the coastal water by erosion alone could decrease the Arctic Ocean CO_2 uptake by 7–14% by 2100 (Nielsen et al., 2024). Although not producing heat, particulate matter backscattering decreases the light available for primary production (Stramski et al., 2004). Contrary to what is shown in this article with CDOM, the decrease in coastal CO_2 uptake would then mainly be driven by lower phytoplankton production rather than increased heat.*"

We also added the following text(L442-443): "*Combined with the new Plankton, Aerosol, Cloud, ocean Ecosystem (PACE) satellite mission, which includes a hyperspectral imaging radiometer, the next generation of ED-SBS will be able to disentangle signature of Chl, CDOM, and particulate matter to better estimate coastal Arctic CO_2 fluxes.*"

4. I don't think the title really reflects the study that well, since the study only focuses on a specific region, and even then, I am not really convinced the phenology is actually improved (see above point). Maybe a more general title that represents the CDOM effects on regional heat budget and carbon dynamics would be more suitable.

We agree and have changed the title to: "*COLORED DISSOLVED ORGANIC MATTER (CDOM) ALTERS THE SEASONAL PHYSICS AND BIOGEOCHEMISTRY OF THE ARCTIC MACKENZIE RIVER PLUME*".

Specific Comments:

Abstract

L1 "*Arctic warming affects land-to-ocean fluxes of organic matter, with significant impacts on coastal ecosystems and air-sea CO_2 fluxes*."
I would already specify the specific processes (mobilization through permafrost thaw & coastal erosion?). I don't think terrestrial browning is really the correct statement here? Just state from terrestrial organic matter dynamics (?).

TO DO

Methods

L93 "*degradation rate as DOCsr (τ = 10 years)*" This would be a degradation time scale, no?

We changed "*degradation rate*" by "*turnover time*".

L105 "*After a sensitivity analysis (detailed in Appendix B), we set the ratio to 2% — re-partitioning Mackenzie River tDOC mass flux into 50%, 48%, and 2% DOCsl, DOCsr, and CDOM, respectively*." Are there CDOM contribution estimates from observations to compare to (Aarnos et al., 2018?)

According to the reviewer comments, we added the following sentence L108–110: "*Our ratio of total tDOC exported as CDOM falls in the lower range of estimates for the top 10 DOC exporting rivers (4–38% of tDOC; Aarnos et al., 2018).*"

Discussion
L347 "*However, ocean circulation and physics often shape the biogeochemical state without possible bio-geochemical feedbacks*." Unclear what is meant here.

We rephrase the sentence as follows (L358-359): "*..., however, ocean circulation and physics often drive the biogeochemical state without the potential feedback of biogeochemistry on physics*."

L367 "*These results highlight that the coupling between CDOM and sea-ice have an important role in shaping phytoplankton phenology*" -> play the dominant role in shaping phytoplankton phenology?

Changed as suggested.

L376 "This work is presently underway." I am not sure I would state this (and the statement will soon not be up to date soon, I guess).

We removed the statement.

Edits

L21 "*resulting in*" -> resulting from

Done

L57 that govern the air-sea CO_2 flux

Done

References

Bertin, C., Carroll, D., Menemenlis, D., Dutkiewicz, S., Zhang, H., Schwab, M., ... & Le Fouest, V. (2025). Paving the way for improved representation of coupled Physical and biogeochemical processes in Arctic River Plumes—A case study of the Mackenzie shelf. *Permafrost and Periglacial Processes*, 0, 1–15.