Submission to EGU—Biogeosciences: Answer to Editor decision

Thank you very much for your responses to the reviewers' comments. I have carefully examined your responses and am now inviting you to submit a revised manuscript. Please modify the manuscript according to the plan you described in the response letters. In addition, please pay attention to the following points when revising the manuscript.

Your response to reviewer#1's major comment#4
The responses do not directly address the three aspects which the reviewer requested to clarify. Please clarify them when revising the manuscript.

We hereby clarify comment #4's comment by pointing out the sentences in the added model-observation comparison paragraph (L384–400) where we improve the aspects requested by reviewer #1:

- Which simulation is being evaluated when claiming agreement with observations:

In the paragraph (L384–400) we compare into more detail regarding which aspects Run_{ctrl} and Run_{full} match observations and state L389-390: "*However, with respect to the initiation of the bloom Run_{ctrl} better matches observations (surface Chl and NPP), where Run_{full} bloom initiate with 2 to 3 weeks delay*". We later add L392–394: "*We therefore acknowledge that the combination of sea-ice and CDOM light attenuation (Run_{full}) triggers the correct phenology in phytoplankton bloom initiation with respect to sea ice melting, but the incorrect timing as the bloom initiates 3 weeks later due to delayed DofO.*"

- Whether CDOM improves or delays bloom timing relative to the data:

In the first part of the paragraph (L384–391), we describe how Run_{ctrl} and Run_{full} match observations and acknowledge that Run_{ctrl} better simulates the bloom initiation (see above). In the second part of the paragraph (L392-400), we further discuss how Run_{full} "*triggers the correct phenology in phytoplankton bloom initiation with respect to sea ice melting*".

- How this affects the interpretation of CDOM's role in modulating bloom phenology:

We state in L402–403: "*We argue that including CDOM does not necessarily improve the phytoplankton phenology in the Mackenzie River plume compared to observations but does enhance its behavior regarding to sea ice melting.*" and further discuss (L403–419) the importance of adding CDOM regarding to SST (improved SST compared to observations) and how we can improve the relationship between the phytoplankton bloom and sea-ice melting.

Your response to reviewer#2's comment#2.

Please provide references to your statement that the degradation of CDOM produces DON and DOP according to the canonical Redfield ratio. To my knowledge, CDOM is enriched with high-molecular-weight DOM, which is relatively richer in carbon but poorer in N and P compared to fresh DOM or POM. Moreover, the end products of degradation of CDOM (either microbial or photochemical) are inorganic compounds (e.g., CO2, DIN, and DIP), although the refractory fractions remain as organic forms. I think what you intend to mean is that the stoichiometry of CDOM follows the canonical Redfield ratio (but this may not be true as I mentioned above).

The Redfield ratio applied for CDOM photodegradation was taken from the parameterization previously published by Dutkiewicz et al. (2015) and documented in the ECCO-darwin documentation (section 8.7.3.10). We didn't find any literature providing the C:N:P ratio for the specific photodegradation of refractory DOC into a more labile DOC fraction and thus use the canonical Redfield ratio. However, we independently estimated the tDOC, tDON and tDOP fraction coming from the Mackenzie River, then providing an estimate of the DOM pool exported without having to constrain the C:N:P ratio. We further precise this as follows (L88-89): "As each export of dissolved organic constituents (DOC, DON & DOP) are estimated independently, the terrestrial dissolved organic matter pool is not constrained by a constant C:N:P ratio."

Your response to reviewer#2's comment#3.
Particulate matter contains organic matter, part of which comprises chromophores (i.e., colored particulate organic matter or CPOM). Like CDOM, CPOM also absorbs light and produces heat. Even some particulate minerals, such as Fe, Mn, etc., also absorb light throughout the UV-visible spectrum. Although the effect of particle light backscattering may overtake the effect of CPOM and mineral light absorption, it's probably premature to say particulate matter does not produce heat.

We corrected this mistake in the discussion as follows (L441–443): "*Particulate organic matter also decreases the light available for primary production through absorption and backscattering (Stramski et al., 2004; Wozniak and Dera, 2007), potentially having an even stronger effect on the phenology. The effect of particle light backscattering may however overtake the effect of absorption, likely driving a decrease in coastal CO_2 uptake mainly by lower phytoplankton production rather than increased heat as shown with CDOM in this study*".

Associate Editor's comments

L27: What do you mean by "complex aromatic cycles"?

We precise as follows (L27): "*Due to complex molecular composition including aromatic cycles…*"

L38: I would remove “drastically”. This is an exaggeration.

Done.

L38: Belanger et al. (2006) did not directly study the effect of CDOM on primary production. This is not an appropriate reference.

We removed Belanger et al. (2006) reference from this sentence and replaced it by the Berezovski et al. (2025) reference which explicitly studies this effect (L38).

Figure 1: This figure uses “tDOC” in two instances without spelling it out. However, the definition of tDOC in the main text (L100) occurs after the citation of Figure 1 (L91).

We thank the reviewer for noticing this issue and clarified this by spelling out tDOC in the Figure 1 caption.

L95: “bleaching rate of 1/6 days”. The units are days not a rate unit. Is this the turnover time? (I doubt it. I do not think CDOM photobleaching is so fast). Or is it 1/6 (i.e. 0.17) per day? If so, it is the first-order bleaching rate constant (corresponding to a turnover time of 6 days). Please clarify.

We thank the reviewer for pointing out this statement leading to confusion. We indeed meant a rate of 1/(6 days), i.e., 0.167 $days^{-1}$. We clarified the statement (L96) as follows: “*CDOM was photodegraded into* DOC_{sl} *with a maximum bleaching turnover time of 6 days…*”

L95: Does this rate apply to the euphotic zone, surface mixed layer, or the exact surface (depth~0 m)?

CDOM maximum bleaching turnover time (6 days) parameter is constant throughout the water column everywhere in the domain. However, photobleaching turnover time is modulated linearly by the light intensity, with a maximum set to 13 W m^{-2} and the CDOM photodegradation turnover time is further modulated by a temperature function. We clarified this L96–99: “*CDOM was photodegraded into* DOC_{sl} *with a maximum bleaching turnover time of 6 days (Dutkiewicz et al., 2015), which was modulated by light intensity. Bleaching rate linearly increased from 0 when light intensity is 0 W* m^{-2} *to a maximum value (0.167* $days^{-1}$*) when light is above 13 W* m^{-2} *(Dutkiewicz et al., 2015). CDOM photodegradation rate corresponds to the bleaching rate modulated by a temperature function.*”

L96-97: Why CDOM photobleaching rate does not further increase when light intensity is >13W m^{-2}?

Using a maximum photobleaching for 13 W m^{-2}, we consider that photobleaching is maximum for 13 W m^{-2} and avoid photobleaching from increasing linearly with light intensity, potentially leading to unrealistic values of photobleaching. This value is the reference value for ECCO-Darwin CDOM parameterization from Dutkiewicz et al. (2015). This value was determined in this study at the global scale with sensitivity experiments.

L117-118: The MKR delivers a large load of particles. Scattering is potentially an important contribution to light attenuation in the water column.

We are aware that the Mackenzie River is the Arctic greatest contributor for particulate matter, but stress here that we focus on dissolved organic matter for reasons discussed L445-447: "*However, we aim here to focus on the effect of the dissolved fraction and do not explore further assumptions regarding the particulate fraction effect, since our model does not account for solid sedimentation parameterization and bottom-sediment/seawater interactions. Future work will focus on the addition of a sediment model to fill this gap (Sulpis et al., 2022)*".

However, we further emphasize that particulate organic matter could plays an important role as follows (L124–126): "*We acknowledge that the backscattering effect could play an important role in the SBS as the Mackenzie River is the Arctic's greatest exporter of particulate matter, but we aim here to build a foundation for determining the contribution of each component of terrestrial organic matter.*"

Figure 2a: No explanation why "$a_{CDOM}(440)$" is in the graph.

The $a_{CDOM}(440)$ statement was initially here to point out the values used in the CDOM estimate relationship (Equation 2). However, we removed this statement from Figure 2a as this doesn't add crucial information to the text.

Equation 1: The calculation of K_{CDOM} is confusing. First, the contribution of CDOM absorption to light attenuation is far more important than the contribution of CDOM scattering. So, what's the point of calculating K_{CDOM} (i.e., a_{CDOM} ~=K_{CDOM}). Second, the Mackenzie River delivers a large load of particles. Particle scattering is potentially an important contribution to light attenuation in the water column. Please justify neglecting the particle scattering. Third, according to equation 1, K_{CDOM} is dimensionless, while in fact K_{CDOM} is in m^{-1} (L122). Please clarify.

We acknowledge that the Mackenzie River is the Arctic greatest contributor for particulate matter and that particulate matter may play an important role in light attenuation, potentially greater than CDOM. With this study, we aim to estimate only the contribution of dissolved organic matter on the physical and biogeochemical characteristics of the SBS and

build a steppingstone toward a full representation of terrestrial organic matter effect in future modeling efforts. As mentioned in discussion L446-448, "*... our model does not account for solid sedimentation parameterization and bottom-sediment/seawater interactions*" and "*Future work will focus on the addition of a sediment model to fill this gap*".

We acknowledge that K_{CDOM} dimension was confusing because all of the steps for computing Equation 1 were not fully detailed in the text. To clarify, we have added text (see L132) and additional details in the Figure 2 caption describing this extra step to better explain the units for Equation 1. This now better walks the reader through our computation and should remove any confusion regarding the units.

L257: *KCDOM*. CDOM should be in subscript.

Done.