Responses to Reviewers' Comments for Manuscript egusphere-2025-4190

Assessment of transparent exopolymer particles in the Arctic Ocean implemented into the coupled ocean–sea ice–biogeochemistry model FESOM2.1–REcoM3

Addressed Comments for Publication to

Geoscientific Model Development

by

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Authors' Response to Reviewer 2

General Comments. The article "Assessment of transparent exopolymer particles in the Arctic Ocean implemented Into the coupled ocean–sea ice–biogeochemistry model FESOM2.1–REcoM3" by Zeising and colleagues presents new developments within the coupled physics-biogeochemistry model FESOM–REcoM allowing the simulation of PCHO and TEP, which are essential molecules produced by phytoplankton that have an increasingly recognized role in ocean particle dynamics and aerosol formation. This model is currently parametrized for Arctic ecosystems, but the authors provide a short global picture of TEP and PCHO.
This article is overall well written and the model evaluation is quite comprehensive and complete. The topic of the study is timely and the model developments presented here represent a promising avenue of research.
I have one major comment regarding the presentation of model results and more minor comments regarding model evaluation and the presentation of results.

Response: Thank you for your review of our manuscript. We appreciate all the constructive comments and suggestions, which we have carefully addressed in revising the manuscript. In the following, we provide detailed answers to the reviewer's comments and list the changes in the manuscript. We have carefully addressed all the issues item by item as follows.

Comment 1

The lack of a control simulation without PCHO and TEP production makes it difficult to assess the impacts of these tracers on ocean biogeochemistry.
If I understand correctly, the modeled PCHO is produced from phytoplankton exudation. Phytplankton exudation gives both DOC and PCHO. Is the total exudation (DOC+PCHO) different in this version of the model than in previous versions without PCHO? If yes: then I think the current model should be compared to a control simulation without PCHO exudation. If not, then maybe the model has already been evaluated previously and Chla should be the same as in previous versions? Then, I think model evaluation could be limited to PCHO and TEP data.

Response: Thank you for the comment. We agree that the manuscript can profit from a comparison to a control run. Therefore, we added the comparison to a control run without the implemented features conducted by us to several sections of the manuscript (see below). We also added a conceptual figure following your suggestion in Comment 6 to clarify the carbon cycle implemented in REcoM3.

Regarding your specific question on the exudation of DOC and PCHO: The total phytoplankton exudation is specified for small phytoplankton in Eq. 1. The exudation rate as such is determined by the phytoplankton carbon concentration, the exudation rate constant and the nutrient limitation. At this point, the phytoplankton exudation does not differ between DOC and PCHO. The organic carbon is just exuded by the phytoplankton. The equation is the same in both control without PCHO/TEP and model run containing PCHO/TEP. Only the next step, a difference between control and model run is introduced: In the control run, all of the exuded organic carbon is attributed to the DOC pool, whereas in the model run, the exuded organic carbon is split between the DOC and PCHO pool. In the model run, PCHO is described as a constant fraction of exuded organic carbon by the parameter f_{PCHO} in Eq. 3.

Comment 2

When evaluating model performances based on Chla concentrations (in sections 3.1 and 4.1), the model should be compared to satellite and to a control version.

Response: Thank you for the comment. We integrated a control run in our manuscript and enriched the evaluation as suggested in several parts of the manuscript. In the Methods, the control run is formally introduced (L. 117):

> Additionally, a FESOM2.1–REcoM3 control run was conducted using the same setup as described above but without the additional organic carbon process descriptions for PCHO and TEP.

For the general model assessment in terms of primary production, we added a comparison of the Total Chlorophyll *a* (TChla) concentrations of the simulation with the control run and the Copernicus remote-sensing data product to Fig. 3 (Fig. 3 in this document). In the Results Section, we added a figure description in Section 3.1 (L. 275–292):

The phytoplankton biomass in the surface Arctic Ocean in terms of TChla is depicted in Fig. 3, where the FESOM2.1–REcoM3 simulation is compared to the CMEMS Arctic satellite re-analysis product and a control run without TEP. The data is averaged over the years 2000 to 2019 (as a mean model state) for the months May to September when satellite data are available. The CMEMS TChla product shows no coverage of the central Arctic Ocean due to the satellite sensors configuration not enabling observations at these high latitudes (Fig. 3 panel a). In the Barents, Kara, and Laptev Seas, TChla ranges from 0.5 to 5 $\mathrm{mg\,m^{-3}}$, with peaks of up to 15 $\mathrm{mg\,m^{-3}}$ close to the coastline. In the East Siberian, Chukchi, and Beaufort Seas, the concentration of TChla is lower, ranging from 0.1 to 1 $\mathrm{mg\,m^{-3}}$, also with very high concentration close to the coast. The standard deviation of TChla from the CMEMS TChla product is mostly lower than 0.5 $\mathrm{mg\,m^{-3}}$. However, it increases to more than 2 $\mathrm{mg\,m^{-3}}$ along the coastline (Fig. 3 panel d). In the control simulation of FESOM2.1–REcoM3 without TEP, TChla concentration range from below 0.2 $\mathrm{mg\,m^{-3}}$ in the central Arctic Ocean to approximately 2 $\mathrm{mg\,m^{-3}}$ in the Fram Strait and Chukchi Sea, reaching even values of 3 $\mathrm{mg\,TChla\,m^{-3}}$ close to the coast of the Russian shelves. The FESOM2.1–REcoM3 including TEP simulates highest TChla concentrations of up to 6 $\mathrm{mg\,m^{-3}}$ along the Russian coast and in other shelf seas between 0.5 and 3 $\mathrm{mg\,m^{-3}}$ (Fig. 3 panel c). In the Fram Strait, TChla range from 1 to 3 $\mathrm{mg\,m^{-3}}$ with highest concentration in its central part, while in the central basins of the Arctic Ocean, TChla is generally low, with concentrations of up to 0.8 $\mathrm{mg\,m^{-3}}$. Compared to the control run without the TEP implementation, TChla concentrations are slightly elevated by 0.2 to 1 $\mathrm{mg\,m^{-3}}$ in the Fram Strait, in the Beaufort Gyre, and in the Chukchi Sea (Fig. 3 panel f). In the coastal areas of the Russian shelves, the simulated TChla is predominantly lower compared to the remote sensing product.

In the Discussion Section 4.1, we added more details on the TChla of the model run compared to the control run, to the CMEMS remote-sensing product, and to observations. We restructured and enriched the whole first part of the section (L. 404–453):

In terms of Arctic-wide TChla, the FESOM2.1–REcoM3 output is evaluated with the remote-sensing product provided by CMEMS and with various in situ datasets. Generally, FESOM2.1–REcoM3 aligns with the compiled remote-sensing data

of CMEMS TChla (Fig 3). The control run without the TEP implementation underestimates the TChla concentration in large parts of the Barents Sea and on the Arctic shelves, which was reported in Gürses et al. (2023) as well. Overall, the model run including TEP performs in better agreement with CMEMS. Still in the Chukchi Sea and the Beaufort Gyre, as well as in the Fram Strait, the model run overestimates the TChla compared to both the control run and CMEMS. Climatological monthly maps of TChla are included as Supplementary Fig. A2.
As such, this pattern of the FESOM2.1–REcoM3 model run compares well to the results from Nöthig et al. (2020) and also to other observations. The generally higher TChla concentrations in the model run compared to the control might reflect the higher turnover of phytoplankton biomass: TEP increases the aggregation of phytoplankton to detritus, which partly gets remineralized, replenishes nutrients to the seawater, and enables new build-up of phytoplankton biomass. In accordance with this hypothesis, we observe higher nutrient concentrations in the central Arctic Ocean, in the Beaufort Sea, and in the Chukchi Sea compared to the control run (Supplementary Fig. A3). However, we have not yet investigated the influence of TEP on the nutrient dynamics in the Arctic Ocean any further.
Evaluating the TChla patterns in more regional detail, we start with the eastern Fram Strait. Both CMEMS and the model run present the beginning of the phytoplankton bloom in May which prevails with TChla of approximately 1–3 $\mathrm{mgm^{-3}}$ through the summer months (Supplementary Fig. A4 and A2 panel a). In the eastern Fram Strait, in situ measurements of Nöthig et al. (2020) result in a median vertically integrated concentration of 44 $\mathrm{mg\,m^{-2}}$ (0–100 m depth), and in the Barents Sea of 42 $\mathrm{mg\,m^{-2}}$ which agree with simulated median concentrations of 40.4 and 33.8 $\mathrm{mg\,m^{-2}}$, respectively (Fig. 4 panel a). The results are also in line with the two-year round mooring observations at the long-term ecological research observatory HAUSGARTEN in the eastern Fram Strait with simulated TChla concentration reaching up to 5 $\mathrm{mg\,m^{-2}}$ in the upper 30 m compared to 7 $\mathrm{mg\,m^{-2}}$ in measurements (von Appen et al., 2021). In the MIZ, especially in the area of Fram Strait, phytoplankton growth is expected to be highest, as the sea-ice breaks up, light availability is increased and the water column is stratified (Cherkasheva et al., 2014; Nöthig et al., 2020). Likewise in the western part of Fram Strait and in the Siberian seas, the lower amount of simulated TChla matches in situ data for these regions spanning 13 to 26 $\mathrm{mg\,m^{-2}}$ (Nöthig et al., 2020; Piontek et al., 2021).

In the Chukchi and Beaufort Seas, the simulated TChla concentration itself (and the difference between FESOM2.1–REcoM3 and CMEMS) is generally low (less than 1.5 mg m^{-3}, Fig. 3 panel c and f). However, the timing of the phytoplankton bloom differs from May in CMEMS to June–July in the model run (Supplementary Fig. A4 and A2 panel a). Other observations from in situ data and satellite-derived products draw a diverse picture in these seas with massive under-ice blooms in the Chukchi Sea with high TChla concentration of up to 30 mg m^{-3} (Arrigo et al., 2014), and low (0.02–0.25 mg m^{-3}) TChla concentration in the northern Chukchi and Beaufort Seas (Jung et al., 2022; Park et al., 2019). In the central Arctic Ocean, vertically integrated TChla is low in both simulation (integrated over 0–100 m water depth, median 0.01 mg m^{-2}) and measurements (7–8 mg m^{-2}). No coverage by the remote-sensing product by CMEMS is available.

As such, the higher TChla concentration of the FESOM2.1–REcoM3 model run might be a better fit to observation data than CMEMS. One explanation for the observed difference may be that CMEMS sampled far less days than are simulated by FESOM2.1–REcoM3. Schourup-Kristensen et al. (2018) explain lower TChla in the simulation by full spatial and temporal coverage whereas only open-water productive regions are accessible from remote-sensing measurements. However, Assmy et al. (2017) suggest that remote-sensing products don't capture the phytoplankton bloom forming under thin ice or melt ponds, therefore often result in too low TChla estimates. A likely explanation for the higher simulated median TChla concentration in several regions and higher variability in comparison to Nöthig et al. (2020) might be the consideration of up to 62k data points in the regional subsets (Fig. 4 panel a) compared to only a few hundred in Nöthig et al. (2020), where the in situ sampling is mostly limited to one campaign each spring-summer season. Additionally, the evaluated regions of the model run contain the whole continental shelve grid points, whereas the in situ measurements are located mostly in the northern parts of the shelf seas (Nöthig et al., 2020).

However, in the coastal areas of the shelf areas (the Barents, Kara, and Laptev Seas and close to the Canadian coast) FESOM2.1–REcoM3 model run highly underestimates TChla concentrations provided by CMEMS (Fig. 3 panel c). There, CMEMS is error-prone (high standard deviation, Fig. 3 panel d), most likely due to the very high colored dissolved organic matter and total suspended matter concentrations, which have not been sufficiently accounted for in the retrieval

process. This results in a significant overestimation of TChla (Copernicus Marine Service, 2023; Heim et al., 2014; Schourup-Kristensen et al., 2018). Also other remote-sensing products overestimate TChla on the Arctic shelves (Mustapha et al., 2012).

Comment 3

In the results and discussion, the climatology of Chla is mentioned several times, I think that comparison of the climatology of Chla with satellite climatology would be strengthen your arguments.

Response: Thank you for the comment. We included the CMEMS climatology as monthly maps in the Supplement of the manuscript (Fig. A4/ Fig. 6 in this document) and used it for a comparison of TChla in the Discussion Section 4.1, which we restructured and cited in the reply to your comment above. However, the climatology of this remote-sensing product may as well exhibit the same uncertainties and overestimates of TChla especially on the shelves as discussed already in the manuscript. That's why we included also in situ datasets available for the assessment of TChla in the model run.

Minor comments

Comment 4

Intro lines 32-40: I am missing a little bit of numbers.
Maybe give some average concentrations of TEP measured? E.g. "remote marine regions, particularly the Arctic, organic compounds emitted from the upper ocean can serve as an important source of particles, thereby influencing the cloud feedback mechanisms and the overall radiation budget (Hamacher-Barth et al., 2016; Goosse et al., 2018; Hartmann et al., 2020; Ickes et al., 2020)." Is there an estimate of the flux or the proportion of organic compounds in the Arctic aerosols?

Response: Thank you for the comment. Because of the continuum of dissolved to particulate organic carbon, it is difficult to state the amount of PHCO and TEP present in the water column. Arnosti et al. (2021) estimate that approximately half of the amount of DOC calculated by Hansell et al. (2009) could be dissolved combined carbohydrates. In our introduction, we referenced these reviews among others. For TEP concentrations in the Arctic Ocean, there are measurements available which we had put into context in the Discussion section of our manuscript. Nevertheless, we added a sentence to the introduction following your recommendation (L. 36):

> For the Arctic Ocean, TEP concentrations of up to 405 µg C L^{-1} have been reported for the Canadian coast, and 7–139 µg C L^{-1} in the Fram Strait and on the shelves (Zamanillo et al., 2019).

Regarding the ocean-atmosphere interaction, we can refer to an accompanying research project. Leon-Marcos et al. (2025) present an approach to simulate the transfer of marine biogenic aerosol precursors derived from our model output to the atmosphere based on the OCEANFILMS (Organic Compounds from Ecosystems to Aerosols: Natural Films and Interfaces via Langmuir Molecular Surfactants) parameterization by Burrows et al. (2016). As such, OCEANFILMS serves as an interface between the organic carbon simulated in FESOM2.1-REcoM3 and the primary marine organic aerosols simulated in the aerosol-climate model.

As such, the organic mass fractions of the three molecular groups are set as ocean boundary conditions for the aerosol-climate model in a test run spanning ten years at a resolution of 1.9°×1.9°. As a result, global primary marine organic aerosol emissions are also dominated by polar lipids (87.2%), with PCHO contributing 2.3% and dissolved combined amino acids 10.5%. Overall, the primary marine organic aerosol emission adds up to 13.6 Tg $year^{-1}$. Regarding the Arctic, Leon-Marcos et al. (2025) find that the primary marine organic aerosol emissions are low compared to other regions. Still, the share of these emissions is especially high during phytoplankton blooms compared to the total aerosol emissions (Leon-Marcos et al., 2025).

Comment 5

You mention the PASCAL campaign several times, I think adding the location of the measurements on one of your maps would be good (e.g. On figure 1 or 4).

Response: Thank you for the comment. We understand your concern when trying to locate the campaign. However, the PASCAL measurements were compiled in categories for the open water, marginal ice zone, and pack ice. That's why there is no specific spot to mark on the maps in the figures suggested.

Comment 6

Paragraph lines 125-131: maybe add a simple schematics of the PCHO and TEP model?

Response: Thank you for the comment. We added a conceptional figure to the manuscript (Fig. 1/ Fig. 1 in this document) and linked the processes described in the lines 125-133 to it. The paragraph now reads (L. 129–137):

> In a first step, organic carbon is built up by photosynthesis in small phytoplankton and diatoms (Fig. 1, process A) and exuded in form of two different dissolved, labile pools: PCHO (B) and residual DOC (C, considered as consisting of labile organic compounds, but the chemical composition is not specified in greater detail). In a second step, multiple PCHO molecules may form aggregates or react with already existing TEP (D). Both DOC and TEP are remineralized to dissolved inorganic carbon (DIC, processes E and F). These processes are detailed out further below with respect to the simulated state equations. Following the organic carbon further, the phytoplankton classes are diminished by aggregation losses to detritus (G) and by grazing by the two zooplankton classes (H), where also the small zooplankton is grazed upon by macrozooplankton (I). Additionally, both zooplankton classes contribute to the detritus through sloppy feeding and mortality (J), but graze on these detritus particles as well (K). A surplus of organic carbon is excreted by zooplankton to DOC (L). Detritus particles can either degraded to DOC (M) or sink down into the water column (N), finally reaching the benthic layer.

Comment 7

Line 345 : you show the results of your simulations only for 0-30m, what do TEP and PCHO concentrations look like below ? Do they fall at 0 ?

Response: Thank you for the comment. We focused on the upper ocean because the implementation of TEP does not account for ballasting the sinking of ballasted TEP particles themselves. This model short-come was discussed in Section 4.3 (Lines 531-553). For clarification, we added a depth profile for TEP as Supplementary Fig. A7 (Fig. 7 in this document) and inserted a reference to it into the discussion in Section 4.3 (L. 594–598).

> Regarding TEP, no explicit sinking of TEP themselves has been implemented in the model because of its positive buoyancy. Still, the FESOM2.1–REcoM3 simulation contains a substantial decrease of TEP concentration with depth alongside the phytoplankton biomass decrease with depth (Supplementary Fig. A7). In the Arctic Ocean, the TEP concentration rapidly decrease to zero in the upper 40 m, whereas the averaged TEP concentration in the Northern and Southern Hemisphere decrease more slowly to zero over the upper 100 m.

Comment 8

Line 355 : you remind in this sentence that the model is optimized for the Arctic region, but also show global results. What are the implication of the Arctic parametrization on your global results ?

Response: Thank you for the comment. Our study builds on the tuning for the Arctic Ocean by Schourup-Kristensen et al. (2018) and Oziel et al. (2022), who focused on TChla and primary production in the tuning process. The Arctic-specific tuning involves parameterizations for aeolian and riverine nitrogen input, and benthic denitrification, which are not included in the global (standard) parametrization of REcoM3 by Gürses et al. (2023). Furthermore, we switched off the photo-damage parametrization implemented by Álvarez et al. (2019). This might lead to an increase of TChla concentrations in the global oceans compared to the standard parametrization. Additionally, we used the model grid

fARC providing a high resolution in the Arctic and a lower resolution elsewhere, which might result in weak upwelling or neglecting small-scale processes (Gürses et al., 2023).

There is no specific tuning for the implementation of PCHO and TEP for the Arctic Ocean. However, transferring the thoughts on TChla to the production of PCHO and TEP in the global ocean, we would expect that the tuning might as well result in higher PCHO and TEP concentrations (corresponding to the TChla concentration) compared to the standard setup.

Comment 9

Line 515 : "TEP aids in the aggregation of other particles (the TEP dependency of the aggregation rate, Eq. 7), but is not itself transferred in the process" even though TEP itself is not sinking, does it have an effect on particles sinking and subsequent C export in your model ? Since this is a potential strong implication of this work, I would like to see it discussed. Again, a comparison with a simulation without TEP would strengthen the demonstration.

Response: Thank you for the comment. The stickiness of PCHO and TEP may contribute to an aggregation of other particles/phytoplankton cells and increase the POC formation in this way (Passow, 2002). The buoyancy of TEP depends on the ballasting material which is incorporated in these aggregates, and as such, determines the rising or sinking speed in the water column (Engel et al., 2020). In our study, we implemented the parametrization of Engel et al. (2004) into a global ocean biogeochemistry model for a first assessment of the implementation in the context of the surface Arctic Ocean. We limited our analysis to the upper ocean because an assessment of the carbon export would require the addition of a TEP sinking parametrization, which would involve ballasting, microbial/zooplankton grazing, and degradation processes, which are not thoroughly investigated and quantified by observational data. We acknowledged these short-comes in the Discussion Section 4.3 and highlighted where observations and lab experiments could contribute to a more detailed parametrization in our model regarding carbon export.

So far, we included a first assessment on particulate organic carbon in our model run, which shapes the export of organic carbon. We presented the total concentration of POC integrated over the upper 100 m water column similar to the measurement compilation

of Nöthig et al. (2020) in our model run (Fig. 4) and compared it to this compilation region by region in the Discussion Section 4.1.

Following your suggestion, we added a figure displaying the impact of our implementation on the DOC and POC pools, which we included as maps for the whole Arctic Ocean as Fig. 5 (Fig. 5 in this document). We added a description of the control and model run regarding POC and DOC to the Results Section 3.1 (L. 299–304) and 3.2 (L. 323–326):

> Broadening the perspective from phytoplankton biomass to POC, the sum of the two phytoplankton, detritus and TEP (in the model run) pools is shown in Fig. 5. The simulated concentration reaches up to 400 µg C L^{-1} in the eastern Fram Strait and along the coastline of the shelves averaged over May to September of the upper 30 m (Fig. 5 panel b). In the central Arctic Ocean, the POC is mostly simulated with concentrations below 100 µg C L^{-1}. Thus, the model run results in POC concentrations of 100–200 µg C L^{-1} higher compared to the control, except for the central Arctic Ocean, where no large differences are found (Fig. 5 panel c).

> Comparing the dissolved part of organic carbon in FESOM2.1–REcoM3 between control run (without PCHO) and model run (with PCHO), both simulations result in highest DOC concentrations in the eastern Fram Strait and Barents Sea, with peaks along the coastline of the Russian shelves (Fig. 5 panel d and e). The DOC concentration in the control run spans approximately 100–150 µg C L^{-1}, where the DOC concentration in the model run ranges from 75 to 200 µg C L^{-1}.

The differences between the control and model run containing the PCHO and TEP implementation are now discussed in the Sections 4.2 for POC (L. 463–465, 476–480) and Section 4.3 for DOC (L. 517–528):

> The implementation of the additional processes for carbon exudation and aggregation impacts the amount and distribution of POC (Fig. 5). As such, the general agreement of simulated POC concentrations to observations confirms the improvement made in the model run.
> [...]
> Additionally, Engel et al. (2019) report 240 µg C L^{-1} POC in upper 30 m of the eastern Fram Strait in summer, which are comparable to the FESOM2.1–REcoM3

simulation of 200-350 µg C L^{-1} POC in the same area (Fig. 5 panel b). Further to the north of the Fram Strait, Gao et al. (2012) measured subsurface POC concentrations between 72 and 204 µg C L^{-1}, where the simulated POC concentration spans 50–100 µg C L^{-1}. The control run without the TEP implementation underestimates the POC concentration in all cases.

PCHO is considered a dissolved pool of organic carbon in FESOM2.1–REcoM3, which is generally part of the DOC pool when it comes to in situ methodology. However, we introduce a distinction between the DOC and the PCHO pool in the model setup, as the exuded phytoplankton organic carbon is split between DOC and PCHO. Furthermore, FESOM2.1–REcoM3 simulates only the (semi-)labile (fresh) DOC pool, which is considered as consisting of labile organic compounds and not refractory (old) ones. As such, a direct comparison of simulated DOC to observations results per se in the underestimation of DOC in the model. As such, in the Fram Strait, DOC concentrations of 720–2040 µg C L^{-1} have been reported for the upper 200 m of the water column (Engel et al., 2019, 2020; von Jackowski et al., 2020, 2022). von Jackowski et al. (2020) estimate the fraction of semi-labile DOC to 3.5–8.4 ±4.7% in their campaign, resulting in a concentration of 30–74 µg C L^{-1} semi-labile DOC. In the East Siberian Sea, DOC concentration reached 648 ±96 µg C L^{-1} during a bloom phytoplankton bloom (Jung et al., 2022). The FESOM2.1–REcoM3 model run yields higher DOC concentrations (sum of DOC and PCHO) compared to the control run (DOC, Fig. 5 panel f), with values still falling at the lower end of the in situ measurements cited above. Thus, we assume that the implementation of PCHO and TEP might result in a better fit to in situ measurements.

Modified/added figures

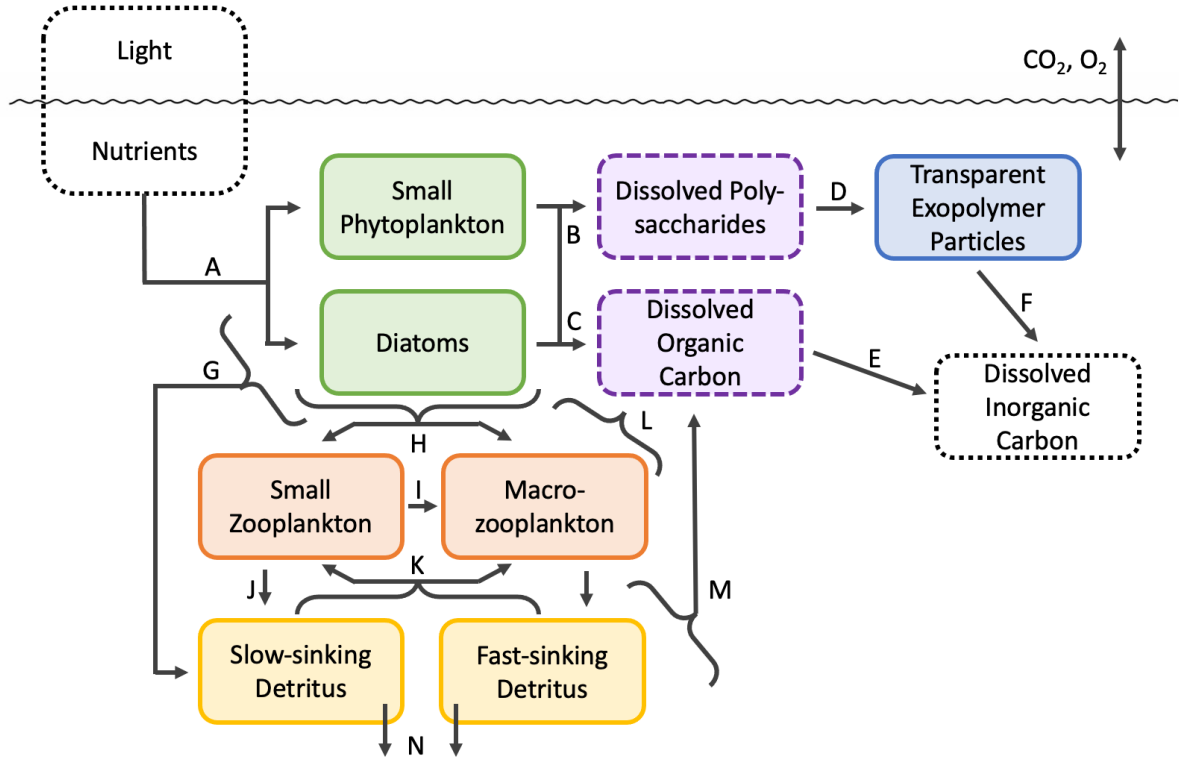

Figure 1: Concept of biogeochemistry processes included in the version of REcoM3 presented in this study. The labels refer to the processes described in Section 2.2.

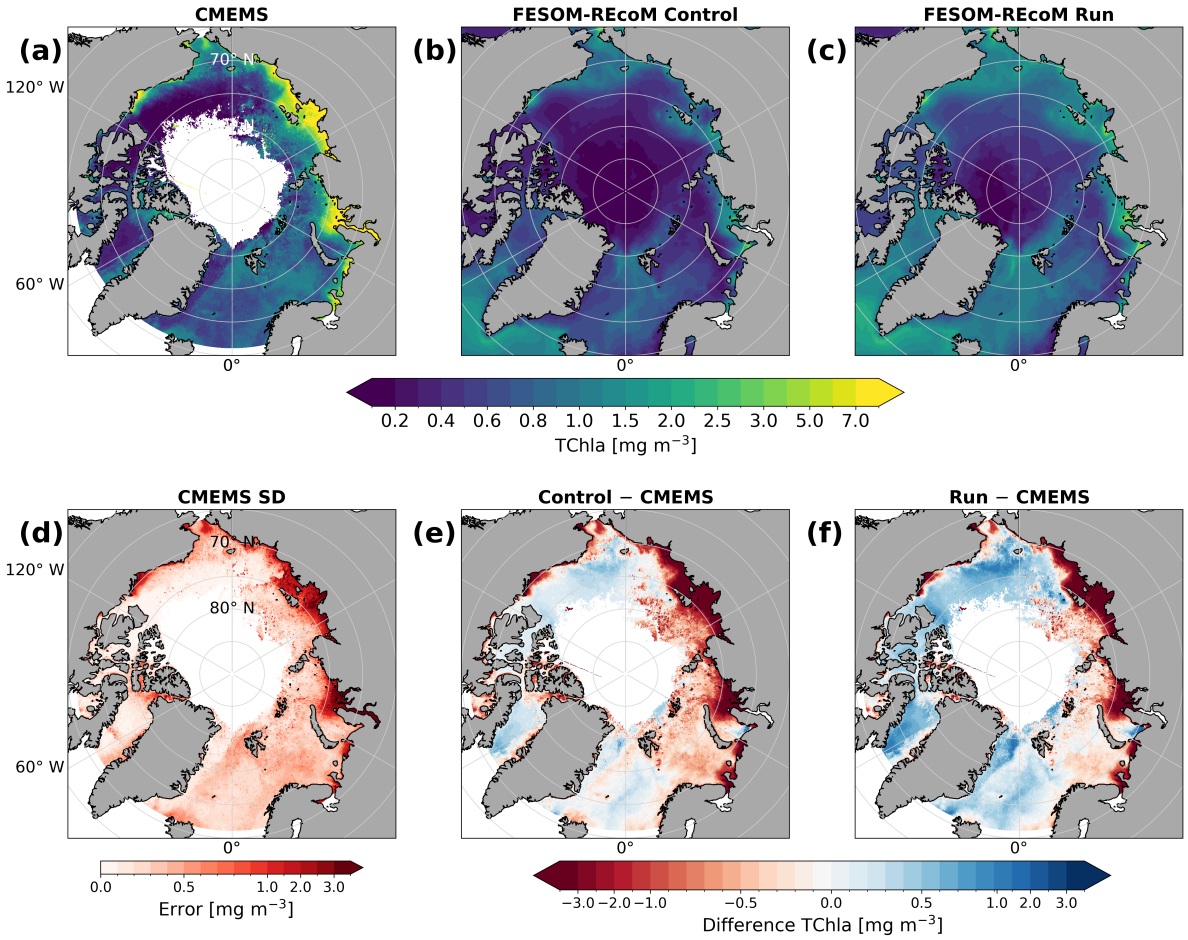

Figure 3: Maps of surface total Chlorophyll *a* (TChla) of Copernicus Marine Environment Monitoring Service level 4 monthly reprocessed Arctic Ocean Color product (CMEMS, panel a), of the FESOM2.1–REcoM3 control run without TEP (Control, panel b), of the FESOM2.1–REcoM3 run including transparent exopolymer particles (panel c), the standard deviation of TChla stated by CMEMS (SD, panel d), the difference of the control run compared to CMEMS (panel e), and the difference of the run including transparent exopolymer particles compared to CMEMS (panel f) as average of May to September of the years 2000 to 2019. CMEMS data does not cover the central Arctic Ocean.

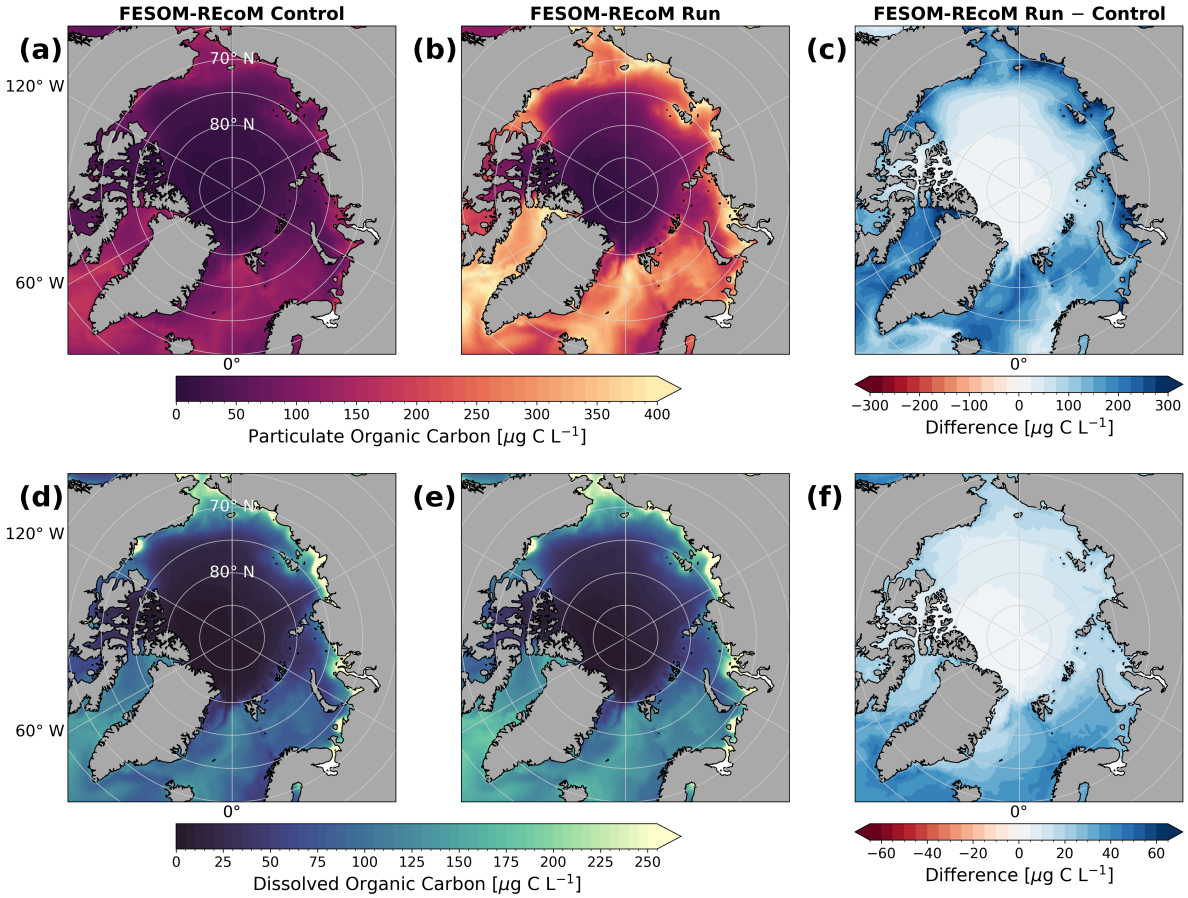

Figure 5: Maps of volume-weighted organic carbon concentrations of the upper 30 m of the FESOM2.1–REcoM3 control run (first column) compared to the model run (second column), and their differences (third column). The panels depict particulate organic carbon concentration as sum of diatoms, small phytoplankton, TEP and detritus (first row, panel a-c), and dissolved organic carbon (second row, panel d-f) as average of May to September of the years 2000 to 2019.

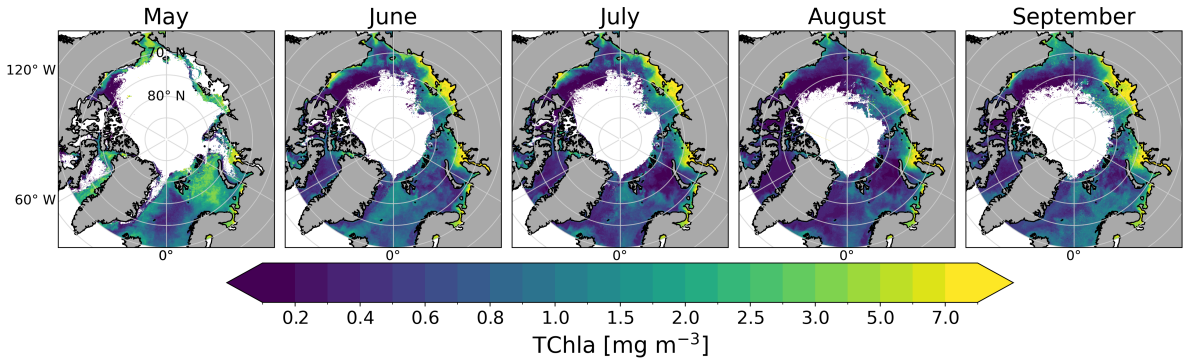

Figure 6: (Supplementary Fig. A4) Climatological maps of Copernicus Marine Environment Monitoring Service level 4 monthly reprocessed Arctic Ocean Color product (CMEMS) Total Chlorophyll *a* concentration of 2000 to 2019. CMEMS does not cover the central Arctic Ocean.

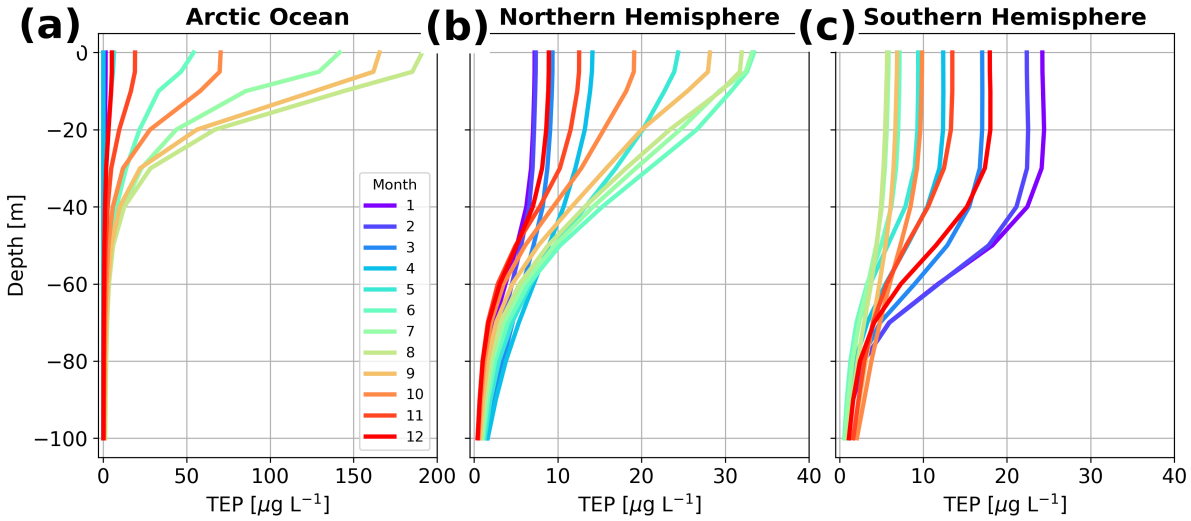

Figure 7: (Supplementary Fig. A7) Depth profiles of transparent exopolymer particle (TEP) concentration in the upper 100 m) as monthly mean of the years 2000 to 2019 for the Arctic Ocean (panel a), the northern hemisphere (panel b), and the southern hemisphere (panel c).

References

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