Respond to RC2

RC2: 'ReviewerComment-2025-5385', Anonymous Referee #2, 22 Jan 2026

1) General assessment

The manuscript presents a detailed investigation of biochemical characteristics of the sea surface microlayer in the central Baltic Sea, with a particular focus on potential links to cyanobacterial blooms. The study addresses an important and understudied interface in marine biogeochemistry, and the authors do a good job of placing their results within the context of existing literature. However, aspects of the manuscript would benefit from improved clarity and clearer framing. Additionally, some conclusions appear to be stated more strongly than is supported by the presented data, and certain interpretations would benefit from additional clarification. In several sections, especially in the Discussion, more explicit references to figures, supplemental material, and the specific datasets being discussed would substantially improve readability and help guide the reader through the results. These issues appear readily addressable through focused revisions of the text and its organization.

We are particularly grateful for the detailed feedback regarding clarity, framing, and interpretation. The reviewer's comments have helped us to critically reassess several sections of the manuscript. In response, we have carefully revised the text to improve clarity and structure, especially in the discussion and we have modified several statements where conclusions were previously phrased too strongly relative to the supporting data.

Overall, we believe that the reviewer's constructive comments have significantly improved the clarity and readability of the manuscript, and we are grateful for the opportunity to revise it accordingly.

2) Comments on the Abstract

The abstract generally reads well. However, unlike other acronyms, POC is not defined and should be introduced explicitly.

We defined acronyms at it first appearance.

Changes in text:

Line 25: […] mirroring particulate organic carbon >20µm (POC>20µm) […]

Regarding the sentence in the abstract: "While SML enrichment patterns and carbohydrate concentrations were comparable to those previously reported for the Western Baltic Sea, concentrations of total amino acids (TAA) and surfactants were substantially higher, suggesting enhanced production by cyanobacteria." The sentence reads well stylistically, but the concluding phrase "suggesting enhanced production by cyanobacteria" appears too early in the abstract. At this point, the abstract has not yet established the mechanistic/observational links between surfactants and cyanobacterial presence. The following sentences provide information that would support this inference, but as currently written this conclusion seems insufficiently justified at this stage. Consider either softening this statement or restructuring the abstract so that the supporting context precedes this statement.

We thank the reviewer for this comment and agree that this statement appears too early in the abstract. We decided to change this phrase.

Changes in text:

Line 18: […] under cyanobacteria-dominated phytoplankton conditions […]

3) Comments on the Body of the Manuscript (substantive)

General comment: When trends or results from this study are discussed in the Discussion section, it would be very helpful to consistently reference the corresponding figures or supplemental material. The discussion frequently refers to data generated here, but it is not always clear where the reader can quickly locate those results. Aside from this, the manuscript does an excellent job of engaging with and referencing related literature.

We will refer systematically to figures or supplementary material so that statement in which we discuss the results are easier to follow and that the reader can go directly to the Figure and knows which data we are referring to.

Lines 84–86: "Biochemical studies in the Baltic Sea have shown that the SML is enriched in amino compounds and carbohydrates relative to the underlying water (Van Pinxteren et al., 2012). In mesocosm experiments, proteinaceous gels (CSP) abundance was five times higher than that of carbohydrate-rich gels in the SML (Galgani and Engel, 2013)."

- The first sentence compares enrichment between the SML and the underlying water, whereas the second sentence compares proteinaceous versus carbohydrate-rich material within the SML. Since the first sentence already establishes that both compound classes are enriched in the SML, it would be helpful if the second sentence either (i) explicitly stated how CSP abundance compared between the SML and underlying water (if available), or (ii) provided clearer justification for why the relative abundance of proteins versus carbohydrates is important in this context. For example, how does this comparison advance understanding of phytoplankton bloom dynamics or surfactant production?

Thanks for this comment. We will explain how the higher abundance of proteinaceous gels compared to carbohydrate-rich gels in the SML is important here.

- More broadly, the paragraph spanning lines 84–98 contains interesting and relevant material, but the narrative does not clearly guide the reader toward a central takeaway. The key point appears to be articulated later in line 100 ("cyanobacteria represent major producers of extracellular organic matter"). If this is indeed the main message, consider introducing this idea earlier in the paragraph to better frame the supporting evidence.

Thanks for pointing this out. We agree that the guidance provided through this paragraph is lacking. Lines 100-101 were supposed to summarize lines 84-98, but we agree that this comes a bit late. We will add key messages throughout the paragraph to guide the reader and clarify why the information in this paragraph is important, in order to then introduce our central message.

Lines 97 – 98: "Seasonal records further indicate that surfactant concentrations peak during summer months following the spring bloom and reflecting intensified solar radiation (Laß et al., 2013)."

- A slightly weak statement to have as the final sentence of a paragraph. Also, is not entirely clear what the implication of intensified solar radiation is here. For example, is this meant to link to climate warming, enhanced biological activity, or altered near-surface physical processes as mentioned in the previous sentence ("The release of such compounds can result in visible surface slicks, which locally warm the upper sub-millimeter ocean skin and modify nearsurface physical processes")? Clarifying this connection and providing a stronger closing sentence would improve the paragraph's coherence.

We will clarify the connection to the solar radiation and end the paragraph with a stronger statement, as suggested by the reviewer.

Lines 266–268: "Accordingly, phytoplankton >20µm abundance was grouped into high (HPA>20µm) and low (LPA<20µm) categories (Fig. 2b), and phytoplankton <20µm abundance into high (HPA<20µm) and low (LPA<20µm) categories (Fig. 2c). A summary of this classification is provided in Table A2."

- There may be an inconsistency here: should the first low category be LPA>20µm rather than LPA<20µm?

Thanks for pointing that out! Of course, it should say >20µm.

Both reviewers found the abbreviations difficult to understand and has caused confusion throughout the manuscript. We have decided to change the abbreviations to enable clearer classification and a clearer structure in the manuscript.

New abbreviations:

- **H-Micro/L-Micro**
  - Micro: includes microphytoplankton (larger 20µm) and refers to the net samples.
- **H-Nano /L-Nano**
  - Nano: includes pico- and nanophytoplankton (smaller and equal 20µm) and refers to the flow cytometry samples.

HPA>20µm and LPA>20µm will be changed to H-Micro and L-Micro. HPA<20µm and LPA<20µm will be changed to H-Nano and L-Nano in the whole manuscript (text and figures). We expect that these changes will substantially improve the clarity and interpretability of the results and discussion.

- More generally, I found the rationale for distinguishing between HPA and LPA categories difficult to follow. If stations with ULW concentrations above the median are classified as "high" and those below as "low," it seems that each station would belong to only one category (either HPA or LPA). The purpose of this classification, and how it captures variability across stations, would benefit from clearer explanation.

We agree here with the reviewer that this classification is rather confusing and that a clearer explanation will improve the manuscript. We will therefore describe in more detail that, as shown in Table A2, at 10 out of 15 stations we observe an inverse pattern: high abundances of microphytoplankton (>20 µm) is associated with low abundances of nanophytoplankton (<20 µm), and vice versa. However, this pattern is not observed at three stations (12-11, 14-01, and 21-02), and at two stations no >20 µm phytoplankton (Micro) were sampled, preventing classification into high or low >20 µm (Micro) abundance. We believe that a clearer explanation of the relationship we observe between the Micro- (>20 µm) and Nano- (<20 µm) phytoplankton fractions will help reduce confusion.

Line 345: "Despite the increase, EFs were close to 1 across stations (1.1 ± 0.1)."

- This sentence refers to enrichment in TOC levels. It would be helpful to try and explain why TOC concentrations differ significantly while enrichment factors do not.

We will explain why EF of TOC were close to 1, while concentrations differ between depth: It results from overall elevated TOC concentrations, which reduce the relative enrichment, while absolute differences between the SML and ULW still remain statistically significant.

Lines 354–357: "During HPA<20µm conditions, surfactant concentrations (Fig. 5c) were elevated in the SML (0.56 ± 0.09 mg L^{-1} TX-100 equiv.) relative to the ULW (0.52 ± 0.14 mg L^{-1} TX-100 equiv.), corresponding to an EF of 1.1 ± 0.2 (median = 1.1). In contrast, surfactant EFs were lower under LPA<20µm conditions (1.1 ± 0.2; median = 1.0)."

- This comparison is somewhat confusing, as the mean EF values are identical and the median EFs are very similar. The concentrations are also not statistically different between the two groups, making the use of terms like "elevated" and "lower" a bit of an overstatement.

We will formulate these statements more cautiously and point out that, although the surfactant concentration tends to be higher in the SML than in the ULW, this difference is not significant and EF during HPA<20µm and LPA<20µm are similar.

Line 505: "Our data showed that Chl a concentration increased over time"

- This statement seems potentially inaccurate. As I understand it, concentrations were measured at different stations, with each station sampled only once during the cruise (with two stations sampled daily). If I am understanding the sample collection methodology correctly, then these concentrations of ~1.63 µg L⁻¹ and ~2.47 µg L⁻¹ would represent different sampling locations, correct? Because the current statement reads as though Chl-a levels at a set location/ station were increasing over time during the duration of the cruise.
- If I am misinterpreting the sample collection methodology, please add some clarifying information on how many times the stations were visited and at what time.

this seems inaccurate since you were measuring concentrations in different stations, correct? Each station was only measured once, with two stations measured every day? If not, then where is the temporal data shown, since this statement does not contain that information. And if it is temporal data then during what time period did the concentrations measure 1.63 ug/L and when did they measure ~2.47 ug/L?

Thanks for this thoroughly comment! You did not misinterpret the sample collection. We will change this in the manuscript. This change refers to the change in Chl a concentration from station 12-02 to station 22-07 (Fig. 2a) and is therefore not a temporal Chl a increase at a specific station! We will change this properly.

Lines 538–539: "TAA concentrations in the SML peaked in autumn with a maximum EF of 2.4 (Dreshchinskii and Engel, 2017), which is comparable to the highest EF reported in this study"

- This highest EF appears to be shown in the supplemental material (likely Fig. S7 based on line 362). Please clarify where and when this highest EF was observed in the present study and provide the corresponding value.

 We agree with the reviewer and will refer to the supplement material and provide the highest TAA EF.

Lines 547–548: "The enrichment of surfactants in the SML differed in dependence of phytoplankton abundance, as the EF during HPA<20µm (1.1 ± 0.2; median = 1.1) exceeded the EF during LPA<20µm (1.1 ± 0.2; median = 1.0)."

- This statement is awkward given how similar the EF values are. It is unclear whether these differences are statistically or mechanistically meaningful, and this should be addressed explicitly.

We agree with the reviewers on this point and will adjust our statement accordingly.

E.g. "The enrichment of surfactants in the SML showed only minor differences with phytoplankton abundance. Although the median EF during H-Nano (median = 1.1) was slightly higher than during L-Nano (median = 1.0), this difference was small and not statistically significant (H-Nano: 1.1 ± 0.2; L-Nano: 1.1 ± 0.2)."

We will also add another decimal place to show minor differences in the EFs.

Lines 629–630: "Data separated only into the defined categories of HPA and LPA<20µm along PC2, which explained considerably less variance of the TAA data"

- It is not clear to me what new information this sentence is intended to convey. Additionally, while the amino acids associated with PC1 are listed (line 625), a similar description is not provided for PC2. Clarifying this would improve interpretability.

We understand that it is not clear what this sentence intends to convey. We will provide a more detailed explanation here of what this statement was intended to imply.

What we wanted to convey: the PCA shows a more pronounced separation of TAA between SML and ULW (Fig. S8) than a separation between the categories HPA<20μm and LPA<20μm (Figure 9b).

4) Other Minor / Editorial Comments that were noticed

Line 53: "A large-scale oceanic in the Atlantic demonstrated…" This sentence appears to be missing a word (e.g., "study" or similar), which disrupts readability.

We thank the reviewer for this comment. The sentence will be revised by adding the missing noun "study" to complete the phrase.

Lines 352–354: "When samples were pooled across categories (i.e., not distinguished by HPA/LPA), TAA concentrations differed significantly between depths….resulting in an average EF of 1.2 ± 0.4 (median = 1.1)."

It is unclear whether this statement refers to >20μm or <20μm conditions. Based on the preceding sentence, it appears to refer to <20μm, but clarification would be helpful.

Thanks for this comment. With this sentence we wanted to say, that if we pool our data in SML vs ULW and do not group further into >20μm or <20μm conditions, we observed significant differences between SML and ULW. We will describe this more explicitly.

Line 406: GABA could be redefined here or in the Figure 7 caption/legend, as it was last mentioned much earlier in the introduction.

We will redefine GABA to improve understanding of this abbreviation.

Line 470: Instead of stating that correlations "appeared," a more definitive term such as "were observed" may be more appropriate.

We will replace "appeared" with the more appropriate "were observed".

Line 573: "summerly" does not appear to be a standard usage word.

Thanks for pointing this out. We will change the sentence appropriately.

Changes in text:

Line 573: […] The observed summer TOC variability can likely be attributed to phytoplankton production. […]

Line 590: "Central Baltic Sea and in spite the absence of a bloom." This sentence appears to have an extra "and" which is causing some confusing grammar.

Indeed, it sounds confusing. We will change that so that the meaning of the sentence is clear.

Change in text:

Line 590: […] Central Baltic Sea, even in the absence of a bloom. […]

Figures:

Figure 5 caption: Regarding the statement "surfactants (c) and total combined carbohydrates (TCCHO) (d) were differentiated for high and low phytoplankton <20μm abundance (HPA<20μm and LPA<20μm)."

On initial reading this caption was confusing because the lowercase "s" made it appear to continue the previous sentence. This also led to confusion because the x-axis (at least on the left side of the figure) refers to >20μm categories. Consider leading with a clearer framing, for example: "High and low

phytoplankton <20µm abundance groups (HPA<20µm and LPA<20µm) were compared for differences in surfactant concentrations (c) and total combined carbohydrates (TCCHO) (d)."

We thank the reviewer for this constructive comment. The "s" in "Surfactants" should indeed be capitalized, as it begins a new sentence. In addition, the classification in Figure 5c and d are correct subdivided into L-Nano and H-Nano. We understand that the lowercase "s" may have caused confusion and will correct this accordingly. Furthermore, we will improve the clarity of the figure structure to prevent similar misunderstandings.

Changes in text:

Line 341: […] High and low nanophytoplankton abundance groups (H-Nano and L-Nano) were compared for differences in surfactant concentrations (c) and total combined carbohydrates (TCCHO) (d)." […]