EGUSPHERE-2025-5902
Point-by-point response to reviewers' comments

New insights into the primary production and the structure of the phytoplankton community in the South Indian Ocean using size fractionation experiments

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EGUSPHERE-2025-5902 Research article

Reviewer #1 – Andres Gutiérrez Rodríguez

We would like first to thank the reviewers for their relevant comments and suggestions which helped us to improve our manuscript. Reviewer comments are in black font, and responses are in blue font. Figures that have been modified in the revised manuscript were added to this document. Below are the authors' point-by-point responses to Andres Gutiérrez Rodríguez's comments and questions.

General comments:

Deteix et al preprint´s investigates spatial variability of phytoplankton community structure and net primary productivity across different zones and regions of the Indian Ocean using size fractionated net primary production and size-fractionated pigment-based community composition. This is a powerful approach rarely used, in general and specifically in the Indian Ocean, which together with the adopted vertically-resolved strategy generates a novel dataset with potential to shed light on the relationship between phytoplankton community composition and net primary production. Yet, I find at times that the preprint does not fully exploit the potential of the data and lacks discussion of certain aspects, such as growth rates and C:Chla and reported size and taxonomic dependent differences, that are critical for the interpretation of the data and conclusions about the linkage between Chla biomass and NPP. While similar data from the Indian Ocean are scarce or absent (see Landry et al. 2022), studies containing bulk community, size- and taxon-specific data on Chla biomass, NPP and growth rates conducted in analogous oceanographic zones and biogeochemical conditions in other ocean basins are missing and improve the discussion.

The authors would like to thank Andres Gutiérrez Rodríguez for his insightful feedback, relevant suggestions and time spent reviewing this manuscript. All comments were carefully considered, and the issues raised have been addressed We believe that these revisions have significantly improved the clarity of the manuscript.

Specific comments:

1. The preprint builds on the analysis of the relationship between size-fractionated and taxon-specific Chla partition to assess the influence of phytoplankton size structure and composition on NPP. Yet, C:Chla and growth rates, and their size and taxonomic dependence can alter this relationship and

the conclusions inferred. The influence of differences in C:Chla and intrinsic growth rates between phytoplankton size and taxonomic groups needs to be discussed with regards to the links between primary production and phytoplankton (Chla) biomass structure. Some studies investigating this bulk and group-specific variability that could help improve the discussion in this regard are listed below Strom et al. 1991; Landry et al. 1993; Arin et al. 2002; Beherenfeld et al. 2005; Sathyendranath et al. 2009; Latasa et al. 2014; Jakobsen and Markager 2016; Liefer et al. 2018; Marañón et al. 2021; Landry et al 2022; Gutierrez-Rodríguez et al. 2023; Yingling et al., 2025.

Thank you for this comment and your relevant insight. We have modified the paragraph, in section 4.3, by adding several references and by emphasizing the importance of considering C:TChl*a* ratios and growth rates in future studies when investigating the relationships between NPP and phytoplankton size structure and composition. The following additions and modifications (in bold) have now been included in the manuscript:

"Therefore, our findings contribute to a better understanding of the role of phytoplankton community size structure in modulating primary production in the **South Indian Ocean**, highlighting that NPP was influenced by the phytoplankton size structure and was not necessarily driven by a single dominant phytoplankton group within a given zone. **Nevertheless, the relationship between NPP and phytoplankton TChla biomass size structure should be interpreted with caution, as it is influenced by ecological and physiological factors such as the carbon to TChl*a* ratio (C:TChl*a*) and the growth rates. For instance, C:TChl*a* ratio in phytoplankton varies with temperature, irradiance and the degree of nutrient limitation, being the lowest under high temperature, low irradiance and nutrient-replete conditions (Geider, 1987; Geider et al., 1997; Jakobsen and Markager, 2016; Landry et al., 2022). Moreover, the C:TChl*a* ratio depends on cell size and taxonomy, with larger cells having higher C:TChl*a* ratio than smaller cells (*e.g.* Geider, 1987; Yingling et al., 2025). Consequently, observed correlations between size-fractionated TChl*a* biomass and NPP may be partly influenced by differences in the C:TChl*a* ratio among size classes and taxa. Similarly, growth rate displays taxonomic dependence, with diatoms, cryptophytes and chlorophytes exhibiting higher rates than dinoflagellates, haptophytes and pelagophytes in the Southern Ocean (*e.g.* Latasa et al., 2014; Gutiérrez-Rodríguez et al., 2023). As a result, high growth rates can lead to elevated NPP even when TChl*a* is low, while slow-growing taxa may accumulate TChl*a* without contributing proportionally to NPP (Behrenfeld et al., 2005). Consequently,** additional field studies using the size fractionation approach **combined with measurements of C:TChl*a* ratios and growth rates across size classes and phytoplankton groups** are needed to improve our understanding on the influence of phytoplankton biomass size structure on NPP, especially in the SAZ and STZ where NPP and phytoplankton data remain sparse."

2. Results presented in figures and tables refer to stations, regions and zones (Figure 3 and 5) or zones (Tables 2 and 3) but results described throughout the text mostly refer to specific stations instead. Figure 2, for instance, presents size-fractionated Chla biomass and NPP profiles for individual stations representative of different zones while the rest of stations are included as supplementary material. It is not obvious for the reader how representative these are or how marked the differences between zones are. I think showing the mean +/- error profiles estimated for stations of each zone would be useful to investigate the differences in the biomass and productivity structure in each zone, while leaving the individual stations profiles for supplementary material. Similarly, the starting sentence of the discussion "At several offshore stations in the STZ (O16), SAZ (O14), PFZ (O6, O7, O9) and AZ (O11), NPPTChlaMICRO peaked below the SML while NPPTChlaNANO and NPPTChla PICO were minimal

(Fig. 2k-o; Fig. A3)". It is not clear how representative this feature is of the region/zone. I think the message would be more clearly conveyed if the focus is placed on zones, pointing then to specific stations to describe intra-zone or intra-region variability. This would also facilitate comparison with other studies and identification of shared patterns or differences with analogous zones and biogeochemical conditions in other basins.

Thank you for this comment. We have revised figure 2 following your recommendations, by plotting the mean +/- standard deviation profiles estimated for stations within each hydrological zone. We have also modified the associated result text (section 3.2.1) and in discussion (section 4.1.1) as well as the starting sentence of the discussion cited above, to better reflect the description for each zone. The profiles for individual stations are provided in the appendix.

Section 3.2.1:

"The **mean** TChl*a* profiles of the total fraction (TChla_{TOTAL}) and the size classes (TChla_{PICO}, TChla_{NANO}, TChla_{MICRO}) are presented in Fig. 2a-e **for each hydrological zone**, and in Fig. A1 (Appendix A) for all stations. **Across** all **zones**, the **depth of** SCM **(**Z_{SCM}**)** of TChla_{TOTAL} occurred between 60 and 100 m and was usually below the Z_{SML}, except in **the KER region** where the SCM was located above the Z_{SML}. **For all zones**, the Z_{SCM} was similar for the total fraction and the size classes**, except in the KER region where the** Z_{SCM} **for TChl**a_{MICRO} **peaked around 40 m while the** Z_{SCM} **of TChl**a_{NANO} **was deeper (between 60 and 80 m)**. Despite vertical variations in TChl*a*, the TChla size structure – *i.e.* the relative contributions of each size class to TChla_{TOTAL} – remained unchanged with depth for all **zones (not shown).**

As for TChl*a*, the **mean** NPP profiles of the total fraction ($\text{NPP}_{\text{TOTAL}}$) and the size classes ($\text{NPP}_{\text{PICO}}$, NPP_{NANO}, $\text{NPP}_{\text{MICRO}}$) are presented in Fig. 2f-j **for each zone** and displayed in Fig. A2 **(**Appendix A**)** for all stations. Here, the subsurface NPP maximums were not as marked as the SCM. Moreover, the subsurface NPP maximums coincided with SCM in the STZ **and PFZ**. Contrary to TChl*a*, the NPP size structure – *i.e.* the relative contributions of each size class to $\text{NPP}_{\text{TOTAL}}$ – was heterogeneous with depth **(not shown)**. In the STZ, surface NPP was evenly distributed in each size class, while subsurface NPP maximum was dominated by one size class. It is noteworthy that **in the STZ,** subsurface NPP maximums at O2 and O3 were mainly dominated by nanophytoplankton while that **at** O16 was surprisingly dominated by microphytoplankton **(Fig. A2)**. In the SAZ, PFZ and AZ, surface NPP was mainly supported by nano- and microphytoplankton, while subsurface NPP maximum was dominated by microphytoplankton. In the KER region, NPP was mainly dominated by microphytoplankton. By normalizing NPP to TChl*a*, **we calculated** ~~(~~**$\text{NPP}^{\text{TChl}a}$**~~,~~ **(in** mgC mgTChla^{-1} d^{-1}) which can reflect photosynthesis efficiency under given environmental conditions (*e.g.* light/nutrient availability; Cermeño et al., 2005). $\text{NPP}^{\text{TChl}a}_{\text{TOTAL}}$ was maximal **in the first 50 m** at all **zones –** except at O3 and O6 where it peaked below the SML – and decreased with depth (Fig. 2k-o; Fig. A3). Interestingly when considering the size classes, $\text{NPP}^{\text{TChl}a}_{\text{MICRO}}$ often peaked **at depth across all zones and coincided with minima in** $\text{NPP}^{\text{TChl}a}_{\text{NANO}}$ **and** $\text{NPP}^{\text{TChl}a}_{\text{PICO}}$**, except in the STZ**."

Section 4.1.1: "**In all zones within the study area, except in the STZ,** $\text{NPP}^{\text{TChl}a}_{\text{MICRO}}$ peaked **at depth and coincided with minima in** $\text{NPP}^{\text{TChl}a}_{\text{NANO}}$ **and** $\text{NPP}^{\text{TChl}a}_{\text{PICO}}$ (Fig. 2k-o)."

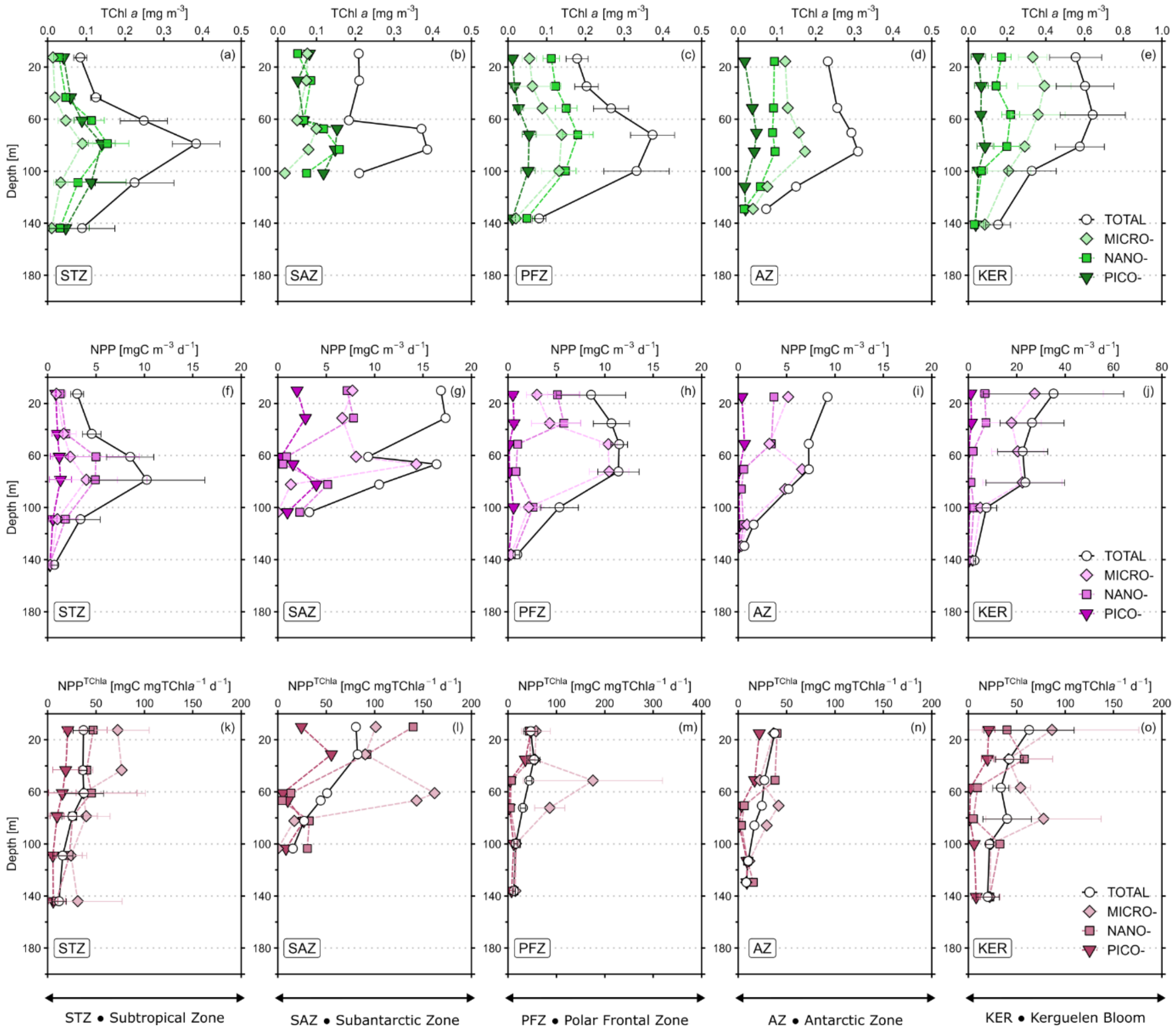

Figure 2: **Mean** vertical profiles of (a-e) total chlorophyll *a* (TChl*a*), (f-j) net primary production, (k-o) TChl*a*-normalised primary production (NPP^{TChla}) **for the five hydrographic zones in the study area: Subtropical zone (STZ: a, f, k, n=3), Subantarctic zone (SAZ: b, g, l, n=1), Polar Frontal zone (PFZ: c, h, m n=3), Antarctic zone (AZ: d, i, n, n=2) and Kerguelen bloom (KER: e, j, o, n=3). Values are mean ± SD (or mean value only when n < 3). Note the differences in scale for KER** for TChl*a* and NPP**, and in PFZ for NPP^{TChla}.** All the profiles for every station are presented in Appendix A: Fig. A1 for TChl*a*, Fig. A2 for NPP and Fig. A3 for PP^{TChla}.

3. In the discussion section 4.1.2. Global feature of phytoplankton biomass and productivity size structure across the study area – The authors indicate that their results of microphytoplankton being the dominant contributor to NPP while nano and micro dominated the TChla biomass are in agreement with previous studies. But they only refer to Froneman et al. 2001. Relevant studies investigating phytoplankton structure, growth and productivity across contrasting zones and regions are not mentioned. Examples of such studies include Boyd et al. 1999 JGR; Bradford and Grieve et al. 1999; and Mckay et al. 2005 conducted in ST, SA and AZ of the SW Pacific. I would also refer to studies conducted around islands, plateaux and bathymetric features such as the Kerguelen, Crozet, Campbell plateaux (e.g. Irion et al. 2020 or Gutierrez-Rodriguez et al. 2020) with relevant data obtained in analogous productive and oligotrophic (HNLC and HNLC-LSi) conditions that could be useful to broaden the discussion.

Thank you for this comment. Our goal of section 4.1.2 is to discuss the size structures features of phytoplankton biomass and productivity across the study area, by averaging our values to provide a synoptic view. At the time of the writing, we had identified only the study by Froneman et al. (2001) which also investigated during the austral summer, size-fractioned phytoplankton biomass and productivity across similar zones in the Atlantic sector, allowing a comparison in a synoptic view. To strengthen our comparison with additional studies, we have now included the study by Mishra et al. (2020), who found similar results in TChl*a* size structure in the South Indian Ocean, during the austral summer, using phytoplankton functional pigments tools to the bulk fraction. The studies cited by Andres Gutiérrez Rodríguez focused on specific zones or regions, which would fit better in section 4.1.3, where we compare our results at the scale of individual zones and regions with the literature. Note that we do not cite Bradford-Grieve et al. 1999 or Irion et al. 2020 in the following additions, because Irion et al. 2020 do not provide size fractionated data, and Bradford-Grieve et al. 1999 conducted their study during austral winter and spring, which is not directly comparable to our austral summer observations.

The following additions and modifications (in bold) are now included in the manuscript:

Section 4.1.2: "Across the study area, microphytoplankton was the main contributor of $\mathrm{NPP_{TOTAL}}$ (56 ± 12%) while the main contributors to $\mathrm{TChl}a_{\mathrm{TOTAL}}$ were nano- (40 ± 11%) and micro- (37 ± 18%). **At the scale of the study area,** our results in TChl*a* size structure are **similar** with previous studies conducted during austral summer **in the South Indian Ocean using phytoplankton functional pigments approaches to the bulk fraction (Mishra et al., 2020) and** in the South Atlantic and **the** Atlantic sector of the Southern Ocean **from size-fractionation approaches** (Froneman et al., 2001).

Section 4.1.3: "In our study, the TChl*a* and NPP size structures in the PFZ, AZ and KER were mainly sustained by nano- (TChl*a*: 40 ± 12%; NPP: 30 ± 12%) and microphytoplankton (TChl*a*: 47 ± 14%; NPP: 66 ± 13%), which were consistent with previous studies conducted in the Atlantic and Indian sectors of the Southern Ocean**, encompassing both HNLC and HN-LSi-LC low-productivity waters as well as high-productivity waters near the Crozet and Kerguelen Islands (Froneman et al., 2001, 2004; Seeyave et al., 2007; Uitz et al., 2009).** By contrast, **the TChl*a* size structure in the SAZ was mainly dominated by pico- (41%) and nanophytoplankton (36%), consistent with observations from other sectors of the SAZ in the Atlantic (Froneman et al., 2001) and western Pacific sectors (Boyd et al., 1999; McKay et al., 2005; Gutiérrez-Rodríguez et al., 2020). Similarly,** the TChl*a* size structure in the STZ was mainly driven by the pico- (43 ± 10%) and nanophytoplankton (40 ± 10%)."

4. I am concerned with the Spearman rank correlation approach adopted to explore the role of each size fraction and phytoplankton group in driving the NPP variability, particularly with regards to potential spurious correlation and covariation in phytoplankton groups's Chla biomass. I wonder whether multiple regression (e.g. (NPP_SF ~ group1 + group2,… + environmental variables or the use of partial least squares could help handle these respective issues.

Thank you for pointing that observation. As indicated in Materials and Methods section, not all volumetric datasets met the assumptions of normality and homoscedasticity, consequently the choice of statistical tools available to explore the role of each size fraction and phytoplankton chemotaxonomic group in driving NPP variability was limited. Moreover, we wanted to explore this aspect for each zone in our study, which further limits the possible options for statistical analyses.

Multiple regression proposed by Andres Gutiérrez Rodríguez may also fall in some limitations in this context:

- It requires normality and homoscedasticity assumptions to be met, which is not the case for our dataset;
- It requires a sample size of n > 20 which is not compatible with our approach when exploring for each zone with 6 < n < 18;
- It requires to avoid multicollinearity: this might be the case when computing the size-fractioned phytoplankton group biomass as multiple predictors – although phytoplankton biomass data could be transformed to improve the test.

Nevertheless, we consider that the PCA used in our manuscript remains an appropriate and relevant tool for our dataset and enables to provide a different perspective on the issue, with results complementary to Spearman's correlation analysis.

5. Pigment size-fractionated results. I found interesting and striking the significant contribution of picoplanktonic groups such as Syn, Prochl or green algae to the micro-size Chl a biomass as well as the dominant contribution of haptophytes in the picophytoplankton fraction, which yielded almost 3-fold higher contribution than Chlorophytes, which tend to co-dominate in similar open ocean waters (see SAWS region in Figure 7 of Nunes et al. 2019 mentioned in the preprint. Given the importance of these results, I recommend the authors to expand the discussion around these points and potential methodological bias. Given the scarcity of this type of data the study by Rodríguez et al., 2006, although from a different region and conditions, could add to this discussion.

Thank you for this comment. We have expanded the discussion to incorporate the points raised by Andres Gutiérrez Rodríguez, including potential methodological biases, that were not sufficiently addressed in the initial manuscript. The following additions and modifications (in bold) are now included in section 4.1.2 of the revised manuscript. Please note that the additions also include one from the second reviewer's comments.

"To our knowledge, **Rodríguez et al. (2006) and** Nunes et al. (2019) **are the only two studies that have applied** these approaches – with CHEMTAX algorithm and two size classes (< 3 µm and > 3 µm) – to investigate phytoplankton communities in the **northwestern Iberian basin and in the** surface Atlantic Ocean**, respectively**. **Consistent with these studies, our results highlight** that each phytoplankton chemotaxonomic group was not strictly associated **with** one specific size class (Fig. 4). These results underline the **limitations** of phytoplankton functional type approaches used to estimate phytoplankton size structure from bulk measurements (e.g. Uitz et al., 2006; Hirata et al., 2011). For instance, diatoms and dinoflagellates, which are commonly associated with the microphytoplankton in **such** approaches, were also distributed in the pico- and nanophytoplankton **size classes** (Fig. 4). **This likely reflects the presence of nanoplanktonic dinoflagellate genera such as *Amphidinium*, *Gymnodinium*, *Protoperidinium* and *Prorocentrum* which have been reported in the Indian sector of the Southern Ocean (Georges et al., 2014; Hörstmann et al., 2021; Sreerag et al., 2023). Additionally, pico- and nanoplanktonic diatom genera such as *Minidiscus* and *Fragilariopsis*, as well as bolidophytes, a eukaryotic picophytoplankton group genetically very close to diatoms and sharing a similar pigments composition (Guillou et al., 1999), have previously been observed in the South Indian and South Atlantic Oceans (Hinz et al., 2012; Leblanc et al., 2018; Nunes et al., 2019; Deteix et al., 2024). Also, the presence of haptophytes in the picophytoplankton could be attributed to some coccolithophore genera such as small *Emiliana*, and to other genera such as *Chrysochromulina* and *Phaeocystis* (Poulton et al., 2007; Hinz et al., 2012; Patil et al., 2017; Hörstmann et al., 2021). Notably**, Nunes et al. (2019) **have shown** that phytoplankton functional types approaches **based on** bulk measurements predicted a high **contribution** of nano- and microphytoplankton in the Atlantic sector of the Southern Ocean, while the size fractionation approach indicated the dominance of picophytoplankton."

Furthermore, **our findings revealed that** *Prochlorococcus*, *Synechococcus* **and chlorophytes** were mainly distributed in the picophytoplankton, but were also detected in the nano- and microphytoplankton (Fig. 4a-b). This result, also reported in previous studies **(Rodríguez et al., 2006; Nunes et al., 2019)**, can be explained by the size fractionation methodology, as the 3 µm and 20 µm pore sizes may retain a part of these organisms **due to aggregation or adhesion**. In addition, **the attribution of pigments like zeaxanthin – associated with *Synechococcus* in this study – to larger size classes may be influenced by the presence of this pigment in nanophytoplankton (*e.g.* UCYN-B; UCYN-A in symbiosis within nanophytoplankton haptophytes) and microphytoplankton (*e.g.* *Trichodesmium spp.*; diatom diazotroph associations) previously detected in the STZ of the South Indian Ocean (Metzl et al., 2022; Chowdhury et al., 2024) or** in some **diatoms** under high irradiance (Lohr and Wilhelm, 1999)**.-Thus, our result underline the importance of interpreting phytoplankton size structure data in the context of methodological constraints. The presence of picophytoplankton groups in larger size classes and the dominance of haptophytes in the picophytoplankton underscore the need for complementary validation using microscopy, flow cytometry or molecular techniques.**"

6. It is unclear why in the 4.2 intrazonal variability Discussion section subsections include the Subtropical Zone and the Polar Frontal Zone but the Kerguelen bloom region instead of the Antarctic Zone, comprising both the KER and HNLC and HNLC-LSi regions as in Table 1.

Thank you for this comment. We have updated the section 4.2.3, by adding a paragraph on the intrazonal variability of phytoplankton biomass and productivity in the Antarctic Zone and the Kerguelen Bloom area. The following addition has now been included in section 4.2.3 of the revised manuscript:

4.2.3 The **Antarctic Zone and the** Kerguelen bloom area

The HN-LSi-LC station O10, located southwest of the Kerguelen plateau, and the KER stations (A3, E and O12), exhibited similar NPP size structure, with a dominance of the microphytoplankton (75% ± 10%), although $\mathrm{NPP_{TOTAL}}$ was approximately 2.5 times higher at the KER stations (Fig. 3b, Table S3). Similarly, the TChl*a* size structure at O10 and the KER stations was similar, with a dominance of microphytoplankton (59% ± 2%) dominated by diatoms, although $\mathrm{TChl}a_{\mathrm{TOTAL}}$ was approximately 1.6 times higher at the KER stations (Fig. 3a and 5d, Table S3). No major differences were observed in the chemotaxonomic biomass structure – except a slightly higher contribution of pelagophytes in the $\mathrm{TChl}a_{\mathrm{MICRO}}$ at O10 compared to the KER stations (Fig. 5d). In contrast, the offshore HNLC station O11 displayed distinct size structures relative to the other stations. Both $\mathrm{NPP_{TOTAL}}$ and $\mathrm{TChl}a_{\mathrm{TOTAL}}$ were dominated by nanophytoplankton (mainly haptophytes and diatoms) with respective contributions of 50% and 57%. In addition, both $\mathrm{NPP_{TOTAL}}$ and $\mathrm{TChl}a_{\mathrm{TOTAL}}$ at O11 were lower than those measured at station O10. Our results are consistent with the study by Uitz et al. (2009), conducted during the austral summer, which reported a dominance of microphytoplankton (mainly diatoms) in the Fe-fertilized waters of the Kerguelen Plateau and an increasing contribution of nanophytoplankton at offshore HNLC stations.

We now compare**the southeastern and northeastern blooms in KER, at stations A3 and O12, respectively.** The highest integrated TChl*a* and NPP at A3 and O12 reflected the well-documented natural Fe fertilization. Despite sharing similar TChl*a* and NPP size structures, integrated NPP displayed variability, as integrated NPP$_{\text{TOTAL}}$ at A3 was 70% lower compared to O12 (Fig. 3)."

7. Lines 449 – 455. If I understand correctly the authors here cite Schluter et al 2011 to point that opportunistic taxa belonging to nano and microphytoplankton are adapted to exploit excess nutrients in a way consistent with size-fractionated trends observed in richer AZ and KER regions. There have been recent studies pointing in this direction (e.g. Leblanc et al. 2018) or even that certain picophytoplankton specific groups such as prasinophytes (Barber and Hiscock 2006; Irion et al. 2020; Gutierrez-Rodriguez et al. 2023) often respond also to improved nutrient conditions in HNLC open ocean waters.

Thank you for this comment and insight. The following addition (in bold) is now included in the manuscript in section 4.1.3. Please note that the additions also include one from the second reviewer's comments.

"Phytoplankton chemotaxonomic groups biomass also varied in association with changes in TChl*a* size structure. Cyanobacteria, pelagophytes and chlorophytes mainly sustained picophytoplankton in the STZ – typical for **LNLC** areas with low mixing – while diatoms, haptophytes and dinoflagellates mostly sustained nano- and microphytoplankton in the PFZ, AZ and KER region – typical in areas where these opportunistic taxa are particularly well suited to take advantage of excess nutrient (Fig. 5 and 6) (Schlüter et al., 2011**; Leblanc et al., 2018**). **Possible species that may account for much of the biomass of these phytoplankton chemotaxonomic groups include: *Synechococcus* and *Prochlorococcus* for cyanobacteria; *Pelagomonas, Micromonas* for pelagophytes; *Chloroparvula*, *Chloropicon* for chlorophytes;, *Chaetoceros, Corethron, Coscinodiscus, Eucampia, Fragilariopsis, Thalassiosira* for diatoms; *Gephyrocapsa, Chrysochromulina*, *Phaeocystis* for haptophytes; and, *Amphidinium*, *Gymnodinium, Protoperidinium, Prorocentrum* for dinoflagellates (Armand et al., 2008; Lasbleiz et al., 2016; Patil et al., 2017; Hörstmann et al., 2021; Irion et al., 2020; Sreerag et al., 2023, 2025; Thyssen et al. 2024). Recent studies have nevertheless underlined that some eukaryotic picophytoplankton groups, such as prasinophytes – belonging to the green algae lineage within ?as chlorophytes – can also benefit from enhanced nutrient conditions (*e.g.* ammonium; Irion et al., 2020) or deep-mixing and low-light regimes in HNLC open ocean waters (Gutiérrez-Rodríguez et al., 2023).**"

8. Section 4.2.1. Here the authors invoke the passage of a cyclonic eddy to explain increased productivity observed in ST O3 compared to O2 without concomitant shift in community composition. Similar results have been reported in the NPSG (Landry et al. 2008; Beatty et al. 2025) in more recent and complementary studies that I find relevant for this discussion point.

Thank you for this comment and additional references. The following additions and modifications (in bold) are now included in section 4.2.1 of the manuscript:

"Our NPP fluxes are **similar to** previous studies, reporting a 20–100% increase in integrated NPP$_{\text{TOTAL}}$ in cyclonic eddies compared to non-eddy areas in the Bay of Bengal (Prasanna Kumar et al., 2007; Sarma et al., 2020)**,** in the South Indian Ocean (Dalabehara and Sarma, 2021) **and in the subtropical North Pacific Ocean (Landry et al., 2008)**. Moreover, Sarma et al. (2020) reported no significant differences in the NPP size structure between cyclonic eddy and non-eddy areas, which supports our findings. About TChl*a*, there is a lack of previous studies focusing on eddies in the Indian Ocean to compare with our dataset. Nevertheless, Vaillancourt et al. (2003) reported a similar 28% increase of integrated TChl*a* in cyclonic eddy compared to non-eddy areas in the subtropical North Pacific Ocean. **In addition, Beatty et al., (2025) reported, in the latter region, based on amplicon sequencing data, that protistan community composition showed no response to eddy forcing in the water column, which is consistent with our results from phytoplankton chemotaxonomic group biomass.**"

9. I found the discussion point developed in the paragraph starting in line 402 of particular relevance and suggest including it as part of the abstract.

Thank you for this comment. The following addition (in bold) is now included in the abstract:

"In the Subtropical and Subantarctic zones, NPP and TChl*a* were sustained by pico- and nanophytoplankton with a diversified community (cyanobacteria, haptophytes, chlorophytes, pelagophytes). Conversely in the Polar Frontal and Antarctic zones, NPP and TChl*a* were dominated by nano- and microphytoplankton with a less diversified community (diatoms, haptophytes). **The coupling of pigment-based chemotaxonomy with size fractionation reveals new insights into the size-specific distribution of phytoplankton chemotaxonomic groups, challenging traditional functional type approaches on the bulk fraction and highlighting the presence of key groups such as diatoms and haptophytes across all three size classes.** Our results also underline the intra-zonal variability of NPP and TChl*a* through bottom-up processes, such as cyclonic eddy in the Subtropical zone or Si-depleted water mass intrusion in the Polar Frontal zone."

Minor comments:

Line 114 – Please clarify what "shaken vigorously" means as it may affect protistan grazers to a greater extent than their phytoplankton prey and bias the NPP estimates.

After the addition of the ^{13}C tracer to each bottle, we ensured that the seawater was thoroughly homogenized with ^{13}C by flipping the bottle upside down, shaking it and repeating this operation twice. We agree that the term "shaken vigorously" can appear rough according to your comment; in this way, we have replaced it with "thoroughly homogenized".

Line 378 – Please indicate these stations belong to different zones.

The three stations cited were associated with their respective zone in brackets as follow (addition in bold): "However, haptophytes were the main contributor to TChla_{MICRO} at O14 **(SAZ)** and O7 **(PFZ)**, where $\mathrm{NPP}^{\mathrm{TChl}a}_{\mathrm{MICRO}}$ peaked."

Line 401 – Please indicate "bulk Chla biomass" here and throughout the document when referring to Chla-based phytoplankton biomass.

This has been taken into account.

Line 406 – See Rodríguez et al. 2006 as another example of the size-fractionated pigment analysis approach.

Thank you, this reference was added to the discussion.

Other minor changes in addition to those made by the reviewers

Section 2.3: Typo error in pigment listing: prasinoxanthin has been replaced by lutein. The following modification (in bold) in now added to the manuscript: "In this study, the following eleven accessory pigments were further used to study the TChl*a* biomass of the phytoplankton chemotaxonomic groups: fucoxanthin (Fuco), peridinin (Peri), 19'-hexanoyloxyfucoxanthin (Hex-fuco), 19'-butanoyloxyfucoxanthin (But-fuco), alloxanthin (Allo), chlorophyll *b* (Chl*b*), zeaxanthin (Zea), neoxanthin (Neo), **lutein (Lut)**, violaxanthin (Viola), and DVChl*a*."

Table 1:

- Surface TChl*a* at O2: ~~**0.07 mg m^{-3}**~~ → **0.08 mg m^{-3}**
- Surface TChl*a* at O12: ~~**0.71 mg m^{-3}**~~**-**→ **0.59 mg m^{-3}**

Table S2 (in supplement): NPP values reordered correctly according to their respective station.

Figure S5 (in supplement): ~~**mg.m^{-2}**~~ → **mg m^{-3}**

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