Response to Reviews for the manuscript #egusphere-2025-156

We sincerely thank Referee #1 and the editor for reviewing and evaluating our manuscript entitled “Extreme carbon fluxes may result from autochthonous particulate organic carbon regulated by the interactions between picophytoplankton and heterotrophic bacteria in river-reservoir systems” (ID: egusphere-2025-156), and for providing valuable and constructive comments. These comments help us to improve the quality of the manuscript. We have revised the manuscript according to Referee #1’s comments and provided detailed point-by-point responses to the comments. In the following, Referee #1’s comments are shown in blue, and our responses are presented in black. The corresponding revisions have been highlighted in yellow in the revised manuscript.

The Referee #1’s general and specific comments and our responses are as follows:

General comments included 3 points.

1) Lack of study context : The Abstract lacks context to what is studied. Extreme fluxes are not described until Line 67 — well into the introduction. One could assume this means a one time event rather than over the course of an algal bloom. Adding a brief description would provide valuable context for the reader. Similarly, it is awkward to say river-reservoir without providing this detail earlier in the abstract. It would be useful to specifically state earlier what your study system is.

We thank you for pointing this out. We have provided study context about extreme fluxes in the *Abstract* in Lines 23-25 of the clean version of the revised manuscript. We have also added that the system we studied was the river-reservoir system in the section *Abstract* in Lines 29-31 of the clean version of the revised manuscript. Specific revisions are below.

Revised manuscript
Reservoir ecosystems are significant natural sources of atmospheric CH_4 and CO_2, while also receiving large amounts of nutrients and particulate organic carbon (POC) from various sources. Ecosystem-level events, particularly algal blooms due to eutrophication, significantly contribute to the occurrence of extremes in CH_4 and CO_2 concentrations and fluxes, likely linked to ecological factors and processes. The trophic interaction between picophytoplankton (PP) and heterotrophic bacteria (HB) plays a vital role in the carbon cycle within aquatic systems. However, it remains unclear which source of POC primarily drives carbon extremes in reservoirs and how PP-HB interactions influence extreme carbon emissions. Here, we investigated contributions of POC from different sources to extreme carbon emissions, along with the interaction between PP and HB in river-reservoir ecosystems. The evidence from isotope analysis further proved that the extreme carbon fluxes were strongly influenced by autochthonous POC rather than allochthonous POC. Network analysis showed that the positive interaction strength between phytoplankton and bacterioplankton in extreme carbon groups was higher than in normal carbon groups. The results of the structure equation modeling analysis also highlighted that the PP-HB interaction strongly drove the extreme carbon values. This study first introduced the probability statistics method to

identify and classify high or low extreme carbon values. These findings also highlight the importance of PP and HB in carbon extreme emissions, and we hope our study can provide an important implication for integrating PP-HB interaction into predicting extreme carbon emissions in river-reservoir ecosystems.

2) Over-speculation and lack of data comparison in discussion: The CO_2 and CH_4 concentration and flux data are not presented in light of previous studies. As such, the reader has no context for these values unless they are familiar with specific studies themselves. There are loads of studies on CO_2 and CH_4 fluxes, concentrations, etc and the authors could shorten the current Discussion which is overly speculative in some areas (particularly the amplicon data which is only DNA, not related to function or activity, etc) to make room to discuss the actual values here and how they compare to other studies. There is no need to write so much about r- vs. K-strategists or correlation networks when the data only support correlations and not in situ activity that can be directly linked to fluxes or concentrations.

We sincerely appreciate the reviewer's constructive suggestions. CH_4 and CO_2 concentrations and fluxes in warm and cold seasons across reservoirs with different trophic states from this and previous studies were presented in Table 5. The CO_2 and CH_4 concentration and flux data comparisons with other studies have been added in the third paragraph of section 4.3 *Extreme and normal patterns of carbon emissions driven by picophytoplankton and heterotrophic bacteria*. The discussion of actual values in our study has been added in the last two paragraphs of section 4.3. We have also shortened the speculative discussion on the results related to r- vs. K-strategists and correlation networks in section 4.3. Hence, we revised section 4.3 in Lines 577-648 of the clean version of the revised manuscript according to these suggestions. Specific revisions are below.

Revised manuscript
4.3. Extreme and normal patterns of carbon emissions driven by picophytoplankton and heterotrophic bacteria Although some extreme CO_2 and CH_4 air-water fluxes could be induced by short-term physical processes, the short-term physical processes were not the focus of our study. We found that water temperature showed no difference between normal and extreme groups of CO_2 fluxes (Fig. 2B). Yet, the picophytoplankton abundance in the extremely low group of CO_2 concentration was significantly higher than that in the normal group of CO_2 concentration (Fig. 4C). These results suggested that the extreme and normal values of CH_4 and CO_2 were probably influenced by ecosystem response (such as microbial community composition or abundance variation), rather than physical factors (such as temperature and wind). The dramatic fluctuations in the abundance of PP and HB are important ecological factors driving extreme values of carbon concentrations and fluxes. This can be primarily attributed to two key characteristics of PP and HB. First, their rapid response to environmental changes. When exposed to elevated temperatures and increased nutrient inputs, PP and HB respond quickly, often exhibiting explosive growth (Flombaum et al., 2013; Azam and Malfatti et al., 2007). In contrast, larger phytoplankton respond more slowly, and their abundance tends to remain relatively stable under changing environmental conditions (Litchman et al., 2007). Second, their strong capacity to decompose easily degradable OC, including autochthonous OC and labile fractions of allochthonous inputs. Based on their

growth rate and carbon utilization efficiency, microbial communities can be classified into two ecological functional groups, r- and K-selected species (Li et al., 2021). As r-strategists, picophytoplankton and heterotrophic bacteria exhibit a fast growth rate and a rapid response to labile C, whereas K-selected species are slow-growing, decompose recalcitrant OC more efficiently, and respond slowly to OC inputs (Li et al., 2021). This may explain the positive associations between picophytoplankton abundance and extreme CH_4 and CO_2 concentrations (Fig. 7). Hence, picophytoplankton and heterotrophic bacteria play essential roles in maintaining short-term extreme carbon emissions.

Seasonal comparisons of CH_4 and CO_2 concentrations and fluxes across reservoirs (Table 5) revealed that in eutrophic reservoirs, CH_4 concentrations and fluxes in the warm season were higher than those in the cold season, whereas CO_2 exhibited the opposite trend. These results were consistent with findings reported for lakes (Zhang et al., 2022; Sun et al., 2021; Wang et al., 2022), where frequent algal blooms significantly increase CH_4 emissions and enhance CO_2 uptake from the atmosphere in warm seasons. Together, these observations suggest that dramatic fluctuations in PP and HB abundance, induced by high nutrient levels and elevated water temperatures, may have contributed to extremely high CH_4 values and extremely low CO_2 values in eutrophic reservoirs.

Extremely high CH_4 concentrations and fluxes mainly occurred in July (Fig. 2A), and extremely high values of CH_4 concentration were positively influenced by PP abundance (p<0.001; Fig. 7A). During the algal blooming period, high nutrient inputs and elevated temperatures facilitated the explosive growth of PP and HB in the warm season (Tang et al., 2017). The increased cell density of PP (Fig. S7) likely enhanced the possibility of interactions between PP and HB (Christie-Oleza et al., 2017). Increased PP-HB interactions facilitate cell aggregation, which increases carbon flux export to the bottom water column, thereby providing sufficient substrate for CH_4 production in the bottom layer (Gärdes et al., 2011). Additionally, eutrophication promotes positive interactions (i.e. cooperation) between PP and HB (Fig. S11), strengthening positive feedback between PP and HB (Coyte et al., 2015). These findings help explain why strong positive interaction strength (number of links) between phytoplankton and bacterioplankton was found in extreme carbon groups (eutrophic state) compared with normal groups (mesotrophic state) (Fig. 6). In eutrophic reservoirs, the efficient production and rapid decomposition of easily degradable autochthonous POC by PP and HB, respectively, accelerate CH_4 production in the short term (West et al., 2012; Gärdes et al., 2011), resulting in extremely high CH_4 concentrations and fluxes in the warm season (Fig. 2A). Indeed, a significant positive correlation between network degree (interaction strength) and CH_4 concentrations and fluxes was found under eutrophic conditions (Fig. S12). Such a positive correlation may support our third hypothesis; however, further validation through laboratory incubation experiments and functional gene analysis is still required.

The abundance of PP and HB had a significantly positive impact on extremely low CO_2 concentration (*p*<0.001; Fig. 7E), and extremely low CO_2 concentrations and fluxes were predominantly observed during warm seasons (Fig. 2A). Increased PP-HB interactions enhance cell aggregation of PP, which increases downward carbon fluxes and thereby reduces CO_2 production in the upper water column (Hopkinson and Vallino, 2005). Moreover, the impact of algal blooms on CO_2 dynamics is co-determined by both CO_2 production (including external DIC input and the decomposition of OC) and consumption via primary production (Zhang et al., 2022). In winter, lower water temperature would inhibit PP reproduction, weaken photosynthesis of PP, and thus reduce CO_2 uptake (Ren et al., 2022). In contrast, during warm seasons, the explosive growth of PP in eutrophic reservoirs greatly enhances CO_2 uptake, and massive CO_2 consumption by primary production can offset or even exceed CO_2 production from external DIC input and microbial decomposition of autochthonous OC by HB (Zhang et al., 2022). Additionally, high CO_2 uptake is supported by high DO, Chl-a, and water temperature (Yang et al., 2021), consistent with the higher DO, Chl-a, and water temperature observed in the extremely low CO_2 groups (Fig. 2B). This helps explain why the eutrophic Shizitan Reservoir acted as a CO_2 sink in the warm season, but as a source of atmospheric CO_2 in the cold season (Table 5). Hence, autochthonous OC critically influenced the fate of extreme carbon values through the interaction between PP and HB.

Table 5

Concentrations and air-water fluxes of CH_4 and CO_2 in the investigated reservoirs compared with those in other reservoirs of different trophic states.

Reservoir name	Trophic state	Climate zone	Chl-a (Warm/Cold)	CCH_4 (Warm/Cold)	FCH_4 (Warm/Cold)	CCO_2 (Warm/Cold)	FCO_2 (Warm/Cold)	Reference
Reservoir Xiaoba II	Oligotrophic	Subtropical	2.90±0.08/ 1.76±0.22	0.12±0.01/ 0.20±0.05	0.11±0.01/ 0.15±0.07	29.68±0.13/ 38.33±0.20	14.90±0.62/ 1.96±1.27	This study
Reservoir Chapéu d'Uvas	Oligotrophic	Tropical	11.5a	-	2.50/1.60	-	11.00/1.60	Linkhorst et al., 2021; Paranaíba et al., 2021
Reservoir Panjiakou	Mesotrophic	Temperate	3.96/0.21	0.152/0.146	0.01/0.03	187.52/195.07	17.91/32.00	Yang et al., 2021
Reservoir Daheiting	Mesotrophic	Temperate	-	0.19±0.12/ 0.41±0.26	0.07±0.05/ 0.12±0.08	72.75±67.49/ 394.64±104.13	19.45±18.98/ 115.75±30.00	Gong et al., 2019
Reservoir Xiluodu	Mesotrophic	Subtropical	2.75±0.92/ 1.03±0.12	0.04±0.00/ 0.02±0.00	0.03±0.00/ 0.01±0.00	43.14±3.34/ 37.85±0.43	21.68±5.25/ 17.61±2.78	This study
Reservoir Qianxiahu	Mesotrophic	Subtropical	5.26±3.12/ 4.68±2.54	0.25±0.10/ 0.11±0.07	0.17±0.09/ 0.02±0.04	3.05±1.51/ 6.54±1.94	-47.4±29.4/ -8.69 ± 8.30	Zhang et al., 2024
Reservoir Shizitan	Eutrophic	Subtropical	65.45±4.83/ 2.67±0.55	0.07±0.03/ 0.02±0.01	0.08±0.03/ 0.01±0.00	9.18±0.63/ 80.04±4.36	-2.68±1.21/ 42.07±7.74	This study
Reservoir Andean	Eutrophic	Subtropical	-	1.44±0.41/ 0.50±0.39	2.19±0.47/ 0.75±0.04	148.4±50.57/ 500.57±41.26	-6.54±50.72/ -18.48±5.34	Eliana et al., 2024
Reservoir Yuqiao	Eutrophic	Temperate	46.82±19.17[a]	0.16±0.02a	1.44/0.12	-	-	Zhong et al., 2023
Reservoir Funil	Eutrophic	Tropical	29.5[b]	-	0.06±0.00	-	0.04±0.00	Paranaíba et al., 2021

Note: a The average value over study period. CCH_4 and CCO_2 denote the concentrations of CO_2 and CH_4 in the surface water ($\mu mol \cdot L^{-1}$), respectively. FCH_4 and FCO_2 denote the fluxes of CH_4 and CO_2 across the water-air interface ($mmol \cdot m^{-2} \cdot d^{-1}$), respectively. Warm denotes the warm season, i.e. spring, summer, or autumn; Cold denotes winter. Chl-a denotes the concentrations of chlorophyll a ($\mu g \cdot L^{-1}$). -: not exist.

3) Inconsistent terminology: Sometimes the paper uses acronyms for samples, other times it does not. This adds confusion to the writing. I would choose one and stick with that style throughout.

We thank you for pointing this out. To maintain consistency throughout the text, all sample names in the article are not abbreviated. All acronyms for sample names in the text, such as Ext_h, Ext_l, and Nor, have been deleted from the revised manuscript. We have replaced the "CCH_4_Ext_h" with "extremely high group for CH_4" and "CCO_2_Ext_l" with "extremely low group for CO_2" in Lines 525-526 of the clean version of the revised manuscript. Specific revisions are below.

Revised manuscript
In this study, we found that the abundances of both picophytoplankton and heterotrophic bacteria were slightly higher in the extremely high group of CH_4 concentration and the extremely low group of CO_2 concentration (eutrophic state) than those in the corresponding normal groups (mesotrophic state) (Fig. 4; Table 2; Fig. S7).

Specific comments included 19 points.

1) Line 80: Providing significant.

We thank you for pointing this out. We added the significance of picophytoplankton in the carbon cycle in Lines 89-91 of the clean version of the revised manuscript. Specific revisions are below.

Revised manuscript
The minor component of the planktonic communities (Stockner and Antiam,

1986), the picoplankton (defined by a cell size of 0.2-2 μm) (Sieburth et al., 1978), mainly includes autotrophic picophytoplankton and heterotrophic bacteria (Stockner, 1988). Picophytoplankton are active and critical primary producers in aquatic ecosystems due to their wide distribution, rapid growth rates, and metabolic capabilities (Stockner, 1988). Picophytoplankton play a crucial role in primary production and carbon fixation in global aquatic ecosystems (Platt et al., 1983; Stockner, 1988).

2) Line 81: This is an awkward statement that could be re-phrased. Also is there any specific quantitative information you can provide other than"more CO2"? Related —the next statement is about picophytoplankton generally and not blooms specifically so you might consider reorganizing here for clarity.

We thank you for pointing this out. We have deleted "during an algal bloom" and provided the specific contribution proportion of picophytoplankton to CO_2 fixation in oligotrophic oceans. The description can be found in Lines 93-96 of the clean version of the revised manuscript. Specific revisions are below.

Revised manuscript
In the ocean, picophytoplankton can contribute 50-90% of primary productivity (Poulton et al., 2006), significantly providing autochthonous organic carbon to heterotrophic bacteria. In addition, picophytoplankton contribute substantially to CO_2 fixation in aquatic ecosystems. Especially in oligotrophic oceans, CO_2 fixation by picophytoplankton, such as *Prochlorococcus and Synechococcus*, can account for up to 60% of the total CO_2 fixation (Flombaum et

al., 2013). This is because picophytoplankton have higher growth rates and are more effective in nutrient and light acquisition than larger phytoplankton (Irion et al., 2021).

3) Line 86: Why is tiny here? Are these smaller than "defined by a cell size of 0.2-2 μm"?

We thank you for pointing this out. We understand that the use of "tiny" is ambiguous here, therefore we have removed "tiny" in the revised manuscript.

4) Line 89: In water? Or in all environments?

We thank you for pointing this out. The research findings here are focused on the marine ecosystem. The phrase "In the ocean" has been added in Line 103 of the clean version of the revised manuscript. Specific revisions are below.

Revised manuscript
On the other hand, heterotrophic bacteria decompose organic carbon, transferring different sources of OC into CH_4 or CO_2 (Guillemette et al., 2013). It was reported that heterotrophic bacteria can consume 20-60% of the total primary production (Williams, 1981) in the ocean.

5) Line 108: autotrophic

We thank you for pointing this out. We have corrected "autrophic" to "autotrophic" in Line 108 of the clean version of the revised manuscript.

6) Line 115: Why the quotes for "physical interactions"? Do you need to define this? Does it mean something other than what is stated?

We thank you for pointing this out. In our study, we indeed don't need to define “physical interactions”. We have corrected it in Line 129 of the clean version of the revised manuscript. Specific revisions are below.

Revised manuscript
First, the cooperative relationship between picophytoplankton and heterotrophic bacteria produces strong coupling and positive feedback between these two organisms, increasing microbial metabolic efficiency and full utilization of OC (Coyte et al., 2015). Second, the interactions between picophytoplankton and heterotrophic bacteria mediate the level of aggregation of picophytoplankton biomass, which manipulates downward C flux (Seymour et al., 2017).

7) Line 128: Why the quotes again?

We thank you for pointing this out. We understand the confusion and have replaced “specific participants” with “PP and HB” in Line 141 of the clean version of the revised manuscript. Specific revisions are below.

Revised manuscript
Little is known about the dynamics of CH_4 and CO_2 production and emissions driven by the interactions between PP and HB in freshwaters.

8) Line 137: Reference needed?

We thank you for pointing this out. We have added relevant references regarding the research on excessive carbon emissions from reservoirs in Line 151 of the clean version of the revised manuscript. Specific revisions are below.

Revised manuscript
Over the past two decades, there has been increasing concern about the

excessive carbon emissions from reservoirs (Beaulieu et al., 2019; Wei et al., 2025).

9) Line 139, Line 142, Line 154: As I mentioned above, a definition of extremes is needed.

We thank you for pointing this out. We have added a definition of extreme values in the second paragraph of the *Introduction* in Lines 68-75 of the clean version of the revised manuscript. Specific revisions are below.

Revised manuscript
The term "extreme values" is commonly used in meteorology and hydrology (Sun and Qin, 1989; Ding and Jiang, 2009). Extreme values refer to values that fall within the 5% or 10% range at the tails of both ends of the probability distribution curve—that is, values corresponding to the low frequency, such as extremely high or low wind speeds and air temperatures (Ding and Jiang, 2009). Although extremes of CH_4 and CO_2 concentrations or fluxes are not frequently detected, their extreme values may reflect ecosystem-level states and processes. The air-water CH_4 flux was expected to exhibit extremely high values during algal blooms, concurrently with low levels of surface water CO_2 concentrations, leading to an apparent CO_2 sink during the blooming period (Sun et al., 2021).

10) Line 142: Can you provide specific numbers for what is high or low?

We thank you for pointing this out. We employed the Pearson Type III probability distribution to determine the extreme and normal values of CH_4 and CO_2 concentrations and fluxes. Values corresponding to the 10% probability range at both tails of the theoretical curve were selected as extreme values, while those within the

10–90% probability range were defined as normal values. The empirical frequencies of the samples were calculated based on CH_4 and CO_2 concentrations and fluxes. Meanwhile, the sample data points and the theoretical Pearson Type III curve representing the population were plotted on Hessian probability grid paper (Fig. S1).

For CH_4 concentrations, the threshold values for the extremely high and extremely low CH_4 concentrations were set at 0.131 and 0.004, respectively. The number of samples corresponding to the extremely high, normal, and extremely low groups of CH_4 concentrations was 9, 69, and 0, respectively. For CH_4 fluxes, the threshold values for the extremely high and extremely low CH_4 fluxes were set at 0.309 and 0.023. The numbers of samples in the extremely high, normal, and extremely low CH_4 flux groups were 6, 55, and 17, respectively.

For CO_2 concentrations, the threshold values for extremely high and extremely low CO_2 concentrations were set at 66.985 and 22.868, respectively. The numbers of samples in the extremely high, normal, and extremely low CO_2 concentration groups were 7, 64, and 7, respectively. For CO_2 flues, the threshold values for extremely high and extremely low CO_2 fluxes were set at 46.586 and 7.109, respectively. The corresponding number of samples was 5, 64, and 9, respectively.

The supplementary material Text S3 *Determination of extreme and normal values of greenhouse gases* provides the threshold values and sample numbers for the above three groups of CH_4 and CO_2 concentrations and fluxes.

11) Line 148: The hypotheses — is this about concentration and flux?

We thank you for pointing this out. We have added "fluxes" in Lines 164-168 of the clean version of the revised manuscript. Specific revisions are below.

Revised manuscript
Therefore, we hypothesized that (1) autochthonous organic carbon (OC) in river-reservoir systems greatly contributes to the occurrences of extreme values of CH_4 and CO_2 concentrations and fluxes; (2) terrigenous OC contributes to the normal values of CH_4 and CO_2 concentrations and fluxes; and (3) The interaction of autotrophic picophytoplankton (PP) and heterotrophic bacteria (HB) could be intensified with an increase in trophic state, thus promoting the production of extreme values of CH_4 and CO_2 concentrations and fluxes.

12) Line 154: these hypotheses

We thank you for pointing this out. We have corrected “the hypothesis” to “these hypotheses” in Line 169 of the clean version of the revised manuscript.

13) Line 216, Line 243: Acidification has been show to impact 15N signals.

We thank you for pointing this out. After acidification, we repeatedly rinsed membranes containing particulate matter with deionized water until the pH reached 7, and then dried them prior to stable isotope analysis. The description of HCl removal and particulate matter drying after acidification has been added to the last paragraph of section 2.2 *Physicochemical parameters* in Lines 227-233 of the clean version of the revised manuscript. Specific revisions are below.

Revised manuscript
The membranes containing particulate matter were dried at 65 ℃ for 48 h. Subsequently, the dried membranes were fumigated with HCl (12 M) for 12 h to

remove particulate inorganic carbon, rinsed with deionized water until the pH reached 7, and then dried again at 65 °C (Xie et al., 2020) prior to stable isotope analysis. The concentrations and stable isotope values of POC and PON were measured using an elemental analyzer coupled with a stable isotope mass spectrometer (Thermo Fisher Scientific® Flash HT-Delta V Advantage, USA).

14) Line 230: Do you mean from duplicate samples or what was duplicated here?

We thank you for pointing this out. Here, the purpose of this sentence was to describe the DNA extraction in duplicate, but the expression was incorrect. We understand that it may cause confusion, and we have made the correction in the second paragraph of section 2.3 *Analysis of microbial communities* in Lines 246-247 of the clean version of the revised manuscript. Specific revisions are below.

Revised manuscript
Genomic DNA was extracted in duplicate from the filters using the FastDNA SPIN kit (Mo Bio laboratories®, USA), following the manufacturer's instructions. The duplicate DNA extracts were mixed for the following PCR amplification.

15) Line 329: Doesn't the previous statement imply the opposite — low, July, high, November. This is very confusing as presented.

We felt sorry for the confusion that was caused. We have made the correction in Lines 343-346 of the clean version of the revised manuscript. Specific revisions are below.

Revised manuscript
These results exhibited that extremely high CH_4 and extremely low CO_2

values mostly appeared in July, supporting the inference that cell aggregation mediated by the PP-HB interactions drives these extremes, especially during the summer algal bloom period.

16) Line 277: Why introduce Ext_h, Nor here but not use it before?

We thank you for pointing this out. To maintain consistency throughout the text, all sample names in the article are not abbreviated. All acronyms for sample names in the text, such as Ext_h, Ext_l, and Nor, have been deleted from the revised manuscript. We have replaced the "CCH_4_Ext_h" with "extremely high group for CH_4" and "CCO_2_Ext_l" with "extremely low group for CO_2" in Lines 525-526 of the clean version of the revised manuscript. Specific revisions are below.

Revised manuscript
In this study, we found that the abundances of both picophytoplankton and heterotrophic bacteria were slightly higher in the extremely high group of CH_4 concentration and the extremely low group of CO_2 concentration (eutrophic state) than those in the corresponding normal groups (mesotrophic state) (Fig. 4; Table 2; Fig. S7).

17) Line 391: What do you mean by certain influence?

We thank you for pointing this out. The sentence is intended to describe the influence of some environmental factors, such as DOC, POC, and WT, on the abundance of HB to some extent, but the expression was incorrect. We understand that it may cause confusion, and we have made the correction in the last paragraph of section 3.3 *Picophytoplankton and heterotrophic bacteria abundance across extreme* *and normal groups* in Lines 403-405 of the clean version of the revised manuscript. Specific revisions are below.

Revised manuscript
The main environmental predictors influencing PP abundance were TP, SRP, DIN, NO_3^--N, Chl-a, DO, WT, pH, POC, and DOC (p < 0.05; Fig. 5A). The main environmental variables, such as DOC, POC, WT, DO, Chl-a, and SRP, were found to significantly influence HB abundance (p < 0.05; Fig. 5B). The variance explanation of environmental factors for the abundance of PP (R^2=0.82) was higher than that of HB (R^2=0.39).

18) Line 484: accounts for a large proportion of the POC

We thank you for pointing this out. We have made the correction in the third paragraph of section 4.1 *Contributions of POC from different sources to CH_4 and CO_2* in Lines 498-499 of the clean version of the revised manuscript. Specific revisions are below.

Revised manuscript
Nevertheless, because allochthonous POC accounts for a large proportion of POC in aquatic ecosystems, it may support long-term CH_4 accumulation and emissions (Berberich et al., 2020).

19) Line 580: Correlation is not the same thing as causation. Especially from 16S rRNA (DNA) data. These statements should reflect that this is only a correlation in the network analyses.

We sincerely appreciate the reviewer's insightful comments. Such a positive correlation may support the third hypothesis that increased interactions between picophytoplankton and heterotrophic bacteria promote the extreme values of carbon. However, the correlation results only indicate that PP-HB interactions were associated with GHG emissions and do not allow us to infer causality. In future work, more evidence from laboratory incubation experiments and functional gene analysis will be needed to fully validate this hypothesis. The description has been added to the fourth paragraph of revised section 4.3 *Extreme and normal patterns of carbon emissions driven by picophytoplankton and heterotrophic bacteria* in Lines 624-628 of the clean version of the revised manuscript. Specific revisions are below.

Revised manuscript
Extremely high CH_4 concentrations and fluxes mainly occurred in July (Fig. 2A), and extremely high values of CH_4 concentration were positively influenced by PP abundance (p<0.001; Fig. 7A). During the algal blooming period, high nutrient inputs and elevated temperatures facilitated the explosive growth of PP and HB in the warm season (Tang et al., 2017). The increased cell density of PP (Fig. S7) likely enhanced the possibility of interactions between PP and HB (Christie-Oleza et al., 2017). Increased PP-HB interactions facilitate cell aggregation, which increases carbon flux export to the bottom water column, thereby providing sufficient substrate for CH_4 production in the bottom layer (Gärdes et al., 2011). Additionally, eutrophication promotes positive interactions (i.e. cooperation) between PP and HB (Fig. S11), strengthening positive feedback between PP and HB (Coyte et al., 2015). These findings help explain why strong positive interaction strength (number of links) between phytoplankton and bacterioplankton was found

in extreme carbon groups (eutrophic state) compared with normal groups (mesotrophic state) (Fig. 6). In eutrophic reservoirs, the efficient production and rapid decomposition of easily degradable autochthonous POC by PP and HB, respectively, accelerate CH_4 production in the short term (West et al., 2012; Gärdes et al., 2011), resulting in extremely high CH_4 concentrations and fluxes in the warm season (Fig. 2A). Indeed, a significant positive correlation between network degree (interaction strength) and CH_4 concentrations and fluxes was found under eutrophic conditions (Fig. S12). Such a positive correlation may support our third hypothesis; however, further validation through laboratory incubation experiments and functional gene analysis is still required.