Response to reviewer #2 comments on ms no: egusphere-2024-3273 "Marine carbon dynamics in a coral reef ecosystem of Southern Taiwan" (Meng, Chang, Chou, Fan, Hsieh, Mayfield, and Chen)

Anonymous Referee #2

This study entitled "Marine carbon dynamics in a coral reef ecosystem of Southern Taiwan" took water to analyze its total alkalinity (TA) and pH to calculate dissolved inorganic carbon (DIC) and pCO_2. The authors further estimate air-sea CO_2 fluxes. The authors suggest that this region is dominated by Kuroshio and they find a good relationship between temperature and pCO_2. The authors should add uncertainties for air-sea CO_2 flux calculations. Quantitative discussions are insufficient. The role of Chla in this study may be misleading. My major comments are as follows:

Thank you for your thoughtful and constructive feedback on our study. We appreciate your detailed review and valuable suggestions. Below, we address your major comments:

- **We agree that including uncertainties in the air-sea CO_2 flux calculations is crucial for transparency and accuracy. In the revised manuscript, we have provided a detailed explanation of the uncertainties associated with these calculations, addressing the potential sources of error and their estimated magnitudes. For further details on this issue, please refer to our response to your subsequent comment.**
- **Quantitative discussions: We acknowledge the need for more in-depth quantitative discussions. In the revised manuscript, we have expanded the discussion section to include a more detailed analysis of the data, including additional quantitative comparisons and interpretations.**
- **Role of Chl *a* in this study: We recognize that the role of Chl *a* may require clarification to avoid potential misinterpretation. We have revised the relevant sections to provide a clearer explanation of the relationship between Chl *a* and the observed carbon dynamics, ensuring that its role is accurately represented. For further details, please refer to our response to your comment on this matter.**

We hope that these revisions address your concerns. Thank you again for your valuable feedback, which has helped us improve the quality of our manuscript.

***Uncertainties**:*

***Uncertainty in pCO_2 and CO_2 Flux Calculation**: Though Figure 5 shows +-SD. It is still unclear if this is a measuring error and how the uncertainties are calculated for*

Figure 5d. The Wanninkhof formula was used to calculate CO_2 flux, which is a model based on wind speed. While flux is highly correlated with wind speed, this correlation largely stems from the formula's design. Vertical mixing effects should be considered to improve the accuracy of the results.

Thank you for your valuable comments and suggestions.

The standard deviations (SD) shown in Figure 5d represent the seasonal variability of the data, rather than measurement errors. To estimate the uncertainty in the calculated pCO_2 arising from measurement errors and equilibrium constants, we performed uncertainty propagation using the R package "Seacarb" (Orr et al., 2018). Specifically, we considered measurement errors of 0.01 for pH and 2.7 µmol kg^{-1} for total alkalinity (TA). This approach yielded an estimated uncertainty of approximately 4.7 (±0.2) to 5.6 (±0.2) µatm for the calculated pCO_2 (lines 197–199, 308–310, 450–451).

For the uncertainty in CO_2 flux calculations, we evaluated errors in the calculated pCO_2 based on TA and pH measurements (as described above), as well as the gas transfer coefficient (k). The error in the gas transfer coefficient was assessed by comparing the applied formulation (Wanninkhof, 1992) with an alternative proposed by Ho et al. (2006). Our analysis revealed that the errors in the calculated pCO_2 from TA and pH measurements ranged from 0.03 (±0.03) to 1.5 (±0.2) mmol m^{-2} day^{-1}. Additionally, flux values calculated using the Wanninkhof (1992) formulation were found to be, on average, 17% higher than those derived using the Ho et al. (2006) formulation. (lines 237–241, 478–486)

What is the air CO_2 value?

Thank you for your valuable comments and suggestions.

Since we did not directly measure pCO_2^{air}, we used xCO_2 data provided by the United States National Oceanic and Atmospheric Administration (NOAA) from Dongsha Island (https://gml.noaa.gov/aftp/data/trace_gases/co2/flask/surface/txt/co2_dsi_surface-flask_1_ccgg_event.txt). Dongsha Island, located at approximately 20.70°N, is a coral atoll with a latitude similar to that of Nanwan Bay and shares the characteristic of being part of a coral reef ecosystem. To correct the dry air xCO2 values to 100% humidity, we applied the temperature and salinity data recorded at the time of sampling, assuming an atmospheric pressure of 1 atm. The resulting pCO_2^{air} values were 386, 377, 378, and 383 µatm for March 31, July 5, and October 18, 2011, and January 22, 2013, respectively. (lines 227–237)

Error Discussion: *This includes errors in the gas transfer coefficient (k) and the calculations for TA and pH. Considering these errors, the discussion becomes less definitive, and a more comprehensive error analysis is needed. The uncertainty should be applied to Figure 10 to convince the readers whether this study region acted as an atmospheric CO_2 source or sink. The authors should indicate the limitations of this uncertainty and note the caution raised by this uncertainty when necessary.*

Thank you for your valuable comments and suggestions.

To evaluate whether the study region acts as a source or sink of atmospheric CO_2, we applied uncertainty propagation to Figure 10. Our analysis shows that errors in flux calculation, primarily arising from the estimated pCO_2 values, are generally smaller than the calculated CO_2 flux. Additionally, errors associated with variations in the applied gas transfer coefficient (*k*) result in only minor proportional changes. Crucially, neither source of error alters the direction of the CO_2 flux, thus confirming the original assessment of the region's carbon status (lines 478–492). For further details, please also refer to our response to your comment on "Uncertainty in pCO_2 and CO_2 Flux Calculation."

Insufficient quantitative analysis: *Apart from the quantitative analysis of the temperature effect, other non-temperature effects are only supported by references, lacking corroborating data. Although TA and DIC data are available, nTA and nDIC values have not been calculated, preventing further exploration of the impacts of mixing or biological processes. This results in conclusions being more inferential and lacking sufficient support.*

We appreciate your insightful feedback. To address the concern regarding insufficient quantitative analysis, we have recalculated and included the normalized TA (nTA) and normalized DIC (nDIC) values in the revised manuscript. By normalizing these parameters to a consistent salinity (35.6), we aim to reduce the effects of evaporation and precipitation, allowing for a more precise exploration of mixing and biological processes.

The revised results section now includes a quantitative analysis of nTA and nDIC trends, along with their potential implications for mixing and biological activities. For instance, during summer, nDIC was significantly correlated with Chl *a* concentration and salinity when using pooled data (all $p < 0.01$). This additional analysis strengthens the evidence supporting our conclusions while reducing reliance on external references for non-temperature effects. The updated results have been incorporated into the manuscript.

We believe that incorporating these recalculated values and their analysis has

substantially improved the robustness and clarity of our findings. Thank you for highlighting this important point.

The role of mixing and upwelling is still unclear*. Nanwan is significantly influenced by the Kuroshio Current and South China Sea waters. The concentration of carbon dioxide is affected by these physical factors. However, quantitative analysis is currently not feasible, making it difficult to conclude their specific contributions.*

Thank you for your valuable comment. We agree that the influence of the Kuroshio Current and South China Sea waters on the carbon dynamic was not quantitatively analyzed in this study, making it difficult to determine their specific contributions. Additionally, while their influence is an important and complex issue, it falls outside the scope of this study. To avoid potential confusion, we have slightly modified the related statement in the conclusion. We hope this revision is understandable.

Regarding mixing and upwelling, we have provided additional evidence to clarify and support their roles in this study. For further details, please refer to our response to Reviewer #1 on the Main Comments.

What is the role of coral reefs in this study? The authors mentioned coral reefs in the Introduction. But they did not discuss the impact of calcification or $CaCO_3$ dissolution.

Thank you for your valuable comment. The role of coral reefs in this study lies in their context as part of the ecosystem where the research was conducted, which is why they were briefly introduced in the manuscript's Introduction. While the carbonate system in the water column may interact with processes such as calcification or calcium carbonate dissolution within the coral reef ecosystem, the primary focus of this study is on CO_2 dynamics in the water column itself. To maintain clarity and avoid diverting from the study's main objective, we did not include a detailed discussion on the impact of calcification or $CaCO_3$ dissolution. We believe this approach aligns with the scope of our study and hope this explanation addresses your concern.

The relationship between Chla and pCO_2 is misleading. Biological Effects*: Chlorophyll and nutrient data were used to analyze the impact of biological processes on carbon dioxide. However, the discussion only examines the regression relationship between the partial pressure of carbon dioxide. There have been a few studies displayed that Chl-a is not fully related to pCO_2 though CO_2 should decrease during photosynthesis. Figure 9b,d demonstrated that pCO_2 increases with increasing Chla* *concentration. The authors can focus on the temperature dominated this study region and discuss the possible sources for those high Chla. The authors should explain why pCO_2 decreases with decreasing Chl-a. Otherwise, they should reconsider the application of Chla. What is the role of mixing?*

Thank you for your valuable feedback. Your comments prompted us to reassess the role of phytoplankton and refine our interpretation of the relationship between Chl *a* and pCO_2 in this coral reef ecosystem. Specifically, we recognize the need to clarify the biological effects and the influence of environmental factors such as temperature and mixing processes.

To address your concerns, we conducted additional analyses examining the interactions among Chl *a*, pCO_2, temperature, and nutrient dynamics. Our results revealed that Chl *a* concentration was significantly correlated with nitrate concentration in surface waters, suggesting a nutrient-driven biological response. However, we acknowledge that the observed positive relationship between Chl *a* and pCO_2, as shown in Figures 9b and 9d, contradicts the expected decrease in pCO_2 during photosynthesis.

This discrepancy led us to consider the temperature-dominated dynamics of the study region. Elevated pCO_2 levels were closely associated with higher water temperatures, likely reflecting enhanced stratification and reduced gas exchange, which may limit CO_2 uptake despite increased Chl *a*. Our analysis also confirmed that phytoplankton growth was closely linked to nutrient availability, as indicated by a significant linear correlation between nitrate concentration and Chl *a* in pooled surface water data ($r^2 = 0.23$; $p < 0.001$). Additionally, nitrate concentration exhibited a significant positive correlation with water temperature in surface waters ($r^2 = 0.18$; $p < 0.001$). These findings suggest that elevated pCO_2 levels in surface waters are associated with high water temperature and Chl *a* concentrations, implying that temperature may be the primary driver of surface water pCO_2 variation.

Based on your suggestions, we have expanded the discussion to explore potential mechanisms underlying the positive correlation between Chl *a* and pCO_2, emphasizing the temperature-dominated dynamics. These revisions have been incorporated into the manuscript to enhance clarity and accuracy (lines 400–410).

***Figure and Table References**: The referencing and annotation of figures and tables should be clearer to enhance reader comprehension.*

Thank you for the valuable feedback on the referencing and annotation of figures and tables. We have carefully reviewed and enhanced these aspects to

improve reader comprehension. Specifically, we have provided more precise references to figures and tables within the main text, accompanied by descriptive context to guide readers. Additionally, we have added clearer and more detailed annotations to the figure and table captions to better highlight their relevance to the content. We are confident that these revisions will significantly enhance the clarity and effectiveness of the figures and tables in supporting the manuscript's content and overall readability.

The Abstract is redundant*. The writing style is not precise.*

Thank you for your feedback on the abstract. We acknowledge that the original version may contain redundancy and that the writing style could be more precise. To address this, we have revised the abstract for conciseness and clarity, eliminating repetitive phrases and ensuring that the key points are presented in a more direct and focused manner. We hope the revised abstract improves the overall precision and readability.

We appreciate your constructive comment, which has helped us enhance the quality of the manuscript.