

Response to reviewers' 2 comments on ms no: egosphere-2023-1097 "The impact of coral reef ecosystems and upwelling events on the marine carbon dynamics of Southern Taiwan" (Meng, Chang, Hsieh, Mayfield, and Chen)

1. This is a study about the carbonate system in a bay of Taiwan. It shows data from four seasons enabling conclusions on the seasonal cycle. Air-sea fluxes of CO₂ are estimated and it is concluded that the Nanwan Bay is a CO₂ sink, opposite to many other coral reef regions.

The authors present fluxes of CO₂ of the Bay and conclude that the Bay is a sink.

However, the uncertainty is large. The uncertainty of the calculated $p\text{CO}_2$ was not given and it is likely to be large. Another uncertainty is the atmospheric $p\text{CO}_2$, which is from a region far from the Bay.

Response: We greatly appreciate your thorough review of our manuscript. We have made substantial revisions in response to your insightful recommendations and those of the other reviewers. Your valuable and constructive comments have not only enhanced the quality of our manuscript but have also inspired us to reconsider how we present and interpret our results.

For your convenience, please find our detailed responses to your comments below, with particular attention to your concerns regarding the uncertainty of the $p\text{CO}_2$ calculation. We have addressed these concerns in our responses to your comments numbered 2, 12, and 19, as well as in our responses to Reviewer 1's comments 1-7, which were also centered around this topic. We believe that our revisions adequately address your concerns and have significantly improved the manuscript.

We are now confident that this manuscript meets the standards for publication in *Ocean Science*.

2. There is a lot of background missing on the calculations, for example, how were the $p\text{CO}_2$ values used to produce a number for the area.

Response: Thank you for pointing this out. In this revised version, we have made an effort to offer comprehensive background information about our methodology, particularly focusing on the utilization of the $p\text{CO}_2$ value to generate or calculate subsequent values. Please refer to our detailed response to your comments numbered 35-37. We trust that our response and revisions adequately address your inquiry.

3. In the title and in the manuscript upwelling is mentioned. There is no clear method to show or calculate upwelling, which makes all contentions about upwelling vague.

Response: Thank you for your valuable comment. We agree with your observation

that the discussion of upwelling in the manuscript was not sufficiently detailed. In this revised version, we have expanded the discussion of upwelling and its associated impacts. Additionally, we have slightly adjusted the title to better align with the content of this manuscript.

Below is a listing of mostly minor comments:

4. L59 the coasts of Galicia and Oregon: Why exactly are those mentioned here? Are they representative for other regions?

Response: Thank you! We aim to highlight that even within similar systems, such as those experiencing intensive upwelling, their behavior as CO₂ sinks or sources can vary. To elaborate further, we have slightly modified the sentence as follows: "Furthermore, upwelling areas along the coast of California and Oman act as CO₂ sinks, whereas those along the coasts of Galicia and Oregon serve as CO₂ sources (Borges and Frankignoulle, 2002; Friederich et al., 2002; Goyet et al., 1998; Hales et al., 2005)."

5. L64 delete: can.

Response: It has been deleted as suggested.

6. 72 of the ocean area (add: area).

Response: Thank you; "area" has been added as suggested.

7. L80 will differ (not: may differ).

Response: Thanks. We agree with you, and "may" has been deleted in this sentence.

8. L85-88 I think this is a strange sentence. The second part about oceanographic anomalies does not seem to fit with the previous factors.

Response: In this revised version, we've incorporated an example that demonstrates how alterations in the physiology of resident organisms, prompted by environmental changes, can subsequently influence seawater pCO₂.

9. L98 delete: but.

Response: Thank you once more. We have followed the suggestion and deleted the content. Notably, this paragraph has been relocated to the "2.1 Study Site" subsection within the Methods section.

10. L109 What is basic productivity? Is it the same as primary productivity?

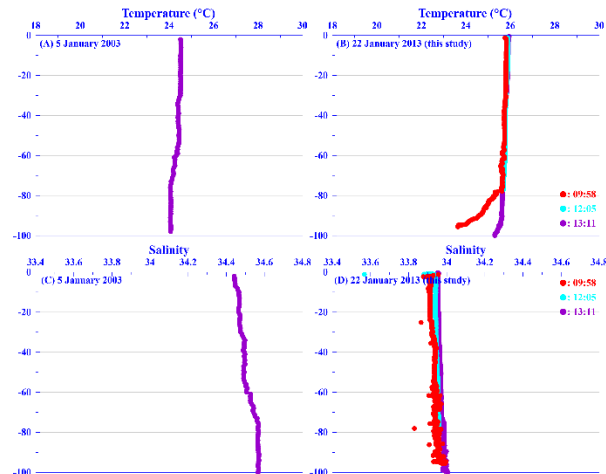
Response: We apologize for any confusion. Yes, we simply meant "primary productivity" here, and have made the corresponding update.

11. L122, 123 Please use format like 31 March 2011.

Response: The suggested format has been implemented.

12. L123 Is the winter cruise in 2013 indeed, i.e., more than one year after the autumn cruise? In that case the data do not show a genuine seasonal cycle; also interannual variability would play a role.

Response: You are correct. The winter cruise occurred in 2013. We recognize that the data may not depict a genuine seasonal cycle. Nonetheless, the data collected during the winter cruise can still serve as a representation of the winter period, drawing from our multi-year study of this coral reef ecosystem. For illustration, we provide temperature and salinity profiles at S10 from this study and data from our earlier study on January 5, 2003, for your reference, as shown below. It is evident that the variables may exhibit slight interannual variation, but the patterns remain similar during the winter period in different years.



13. L125 Is it correct that station S10 is close to the nuclear power outlet? Or are these stations S31 and S33 (also mentioned later in the manuscript).

Response: We apologize for any confusion. Stations S31 and S33, rather than station S10, are situated near the Nuclear Power Plant outlet, as stated later in the manuscript. It's possible that you have an earlier version of our submitted manuscript, and this typo has been rectified in our subsequent submission.

14. L133 and 155 Please also give the precision and/or the accuracy of the oxygen data. In the figures the oxygen concentrations are given in mg/L, which is not usual in oceanography anymore. Usually concentrations are given in (u)mol/kg.

Response: The accuracy of dissolved oxygen (DO) has been addressed as suggested. Regarding the DO unit, we currently prefer using mg L⁻¹, as it is a unit familiar to most biological oceanographers. However, we are open to changing it to

$\mu\text{mol kg}^{-1}$ if you believe that is more appropriate.

15. L158 K1 and K2 (capitals).

Response: Thank you for the reminder. They have now been capitalized.

16. L166 please use superscript for exponents.

Response: Thank you for bringing these typos to our attention. They have been corrected in this revision.

17. L170 please use superscript for exponents.

Response: We apologize for the typos once more. They have been corrected in this revision.

18. L171 mol L⁻¹ atm⁻¹ (no moles and use different format).

Response: Thanks. It has been changed as suggested.

19. L174 The beginning of the Intro says that the atmospheric CO₂ varies significantly based on region. Please justify why you use atmospheric CO₂ values that far from the bay.

Response: Thank you for this comment. We did indeed address the significant variability in atmospheric carbon dioxide concentration based on region and season in the Introduction. Originally, our focus was on understanding the variation in seawater CO₂ concentration with respect to both region and season. Consequently, we have slightly modified the sentence to read as follows: "Carbon dioxide (CO₂) concentrations in marine systems exhibit notable variation according to both region and season (Fay et al., 2021; Sitch et al., 2015)"

You are correct in pointing out that atmospheric CO₂ levels can also vary significantly by region, particularly in forested and industrial areas. Although Dongsha Island is a remote location far from our study site, we opted to feature data from there versus those from the Taiwanese mainland (from NOAA) because of the similar latitudes (approximately 21.90°N) and the fact that Dongsha Island is a coral atoll (i.e., dominated by local coral ecosystems). For more details on this matter, please also refer to our response to comment 5 from Reviewer 1.

20. L178-179 when accessed.

Response: The data were accessed on 21 November 2022.

21. L183 ... circulation patterns as follows:

Response: Thanks! The suggested change has been made.

22. L189 and further: As the explanations are interesting, they are certainly easier to understand when a larger chart with currents etc. would be available. I encourage the authors to provide it.

Response: Thank you for the valuable suggestion. We concur that a chart depicting currents would enhance comprehension. However, we want to highlight that the regions mentioned are already included as an inset in Fig. 1, and we believe that this should suffice in allowing readers to follow our description. Therefore, to maintain consistency with our current presentation and to simplify the content of this manuscript, we plan to retain it as is.

23. L195-200 This is mostly about external influence on the Nanwan Bay. What about local processes?

Response: Thank you for noting this. In the introduction, we have already discussed that the most significant local process is the periodic upwelling, which has the potential to influence the hydrographic patterns in Nanwan Bay. Thus, we aim to avoid repeating this statement here.

24. L203-205 Please explain why this hints at vertical mixing and upwelling.

Response: Thank you for your insightful feedback. We recognize that the initial statement may have oversimplified the explanation of why these findings suggest vertical mixing and upwelling. In this updated version, we have enhanced our explanation by offering a more comprehensive and detailed account of the underlying factors. To gain a deeper understanding, we encourage you to consult the corresponding section in this revised document.

25. L211 Surface $p\text{CO}_2$ levels ...

Response: Thanks. It has been changed as suggested.

26. L213 I think a mean value cannot be a range.

Response: We apologize for the error. The means ($\pm\text{SD}$) for these levels have been provided in this revised article.

27. L214 Are these sea surface temperatures? If yes, that should be mentioned.

Response: Yes! This part has been modified slightly to read as “The mean surface seawater temperatures during ...”

28. L219 It is not clear to me why the authors choose especially station S10 as monitoring station. This is exactly the station where the outlet of the nuclear power plant is. Or isn't that the case (see my earlier comment about this at L125).

Response: Thank you for your comment. We selected station S10 as the monitoring

station due to its significant depth, 105 meters, making it the deepest among all the sampling stations. Our initial intent was to leverage the hydrographic dynamics at this deep station to assess the origins of water masses, whether they originated from the South China Sea, the Kuroshio, or a mixture of the two, as well as to study factors like upwelling intensity and the carbonate parameters of deeper waters. We have elaborated on this intent within the manuscript itself and hope that this explanation addresses your query.

29. L218 What do you mean with gradient changes? Which gradients?

Response: Thank you for highlighting the ambiguity in our statement. We were referring to the changes in temperature and salinity gradients, as evidenced by the depth profiles at Station S10. To provide a clearer explanation, we have made a slight modification to the sentence, which now reads as follows: "Due to the mixing of different water masses by monsoons, tides, eddies, upwelling, and other ocean currents, significant variations in temperature and salinity of the water column were observed at different times at station S10 (Fig. 3) and in the carbonate parameter data (Fig. 5d, S1-S4)." This revision aims to improve clarity.

30. L220-222 The authors state that in summer and autumn more mixing occurs because of vertical variations in the profiles, while in spring and winter this is less, because the profiles are straight. My interpretation would be the opposite. When the profiles are straight, there has been much mixing. When the profiles are not, mixing is not strong enough.

Response: Thank you for highlighting this potentially misleading statement. The sentence has been revised to read as follows: "During spring and winter, pronounced mixing was evident, as demonstrated by the straight vertical profiles in temperature and salinity (Fig. 3a, d, e, and h). Conversely, in summer and autumn, mixing was less apparent."

31. L224-226 Why is Figure 9 done with station S1 and not with S10, like all previous data? It would be important to show and mention whether such figures can also be made for the other stations, or whether this station is special.

Response: Thank you for your valuable comment. Periodic upwelling events have been observed in Nanwan Bay. In the accompanying figure, we have presented data illustrating the relationships between various variables, including temperature, salinity, dissolved oxygen (DO), and pH, throughout a complete upwelling cycle in Nanwan Bay. These data were obtained from a real-time water quality monitoring system at station S1 in our previous study.

It is important to note that in our study, water sampling at each station was conducted discretely and was not synchronized within a complete upwelling cycle during the sampling periods. Therefore, the relationships observed in this figure may not be replicated at each station in our study due to the differences in sampling times and locations. Nonetheless, we have included this figure as an example to illustrate the hydrography and its patterns during an upwelling event.

32. L227 Why are low values evidence for upwelling? Which low values do you mean? Which $p\text{CO}_2$ increases do you mean. Please explain better.

Response: Thank you for your comment. In response to your previous feedback, we plan to leverage the relationships between various variables observed during the entire upwelling event at S1 from our prior study to help explain the potential presence of upwelling-related bottom water observed in this study. The shared characteristics of the bottom water resulting from upwelling were similarly identified during the spring of this study, and we have clearly presented the associated values in this revised article. To provide further clarification, the sentence has been amended as follows: "Seawater quality profiles of S10 provide additional supporting evidence of upwelling, as indicated by the presence of low temperatures ($23.3\pm 0.6^\circ\text{C}$), low pH (8.16 ± 0.01), high salinity (34.32 ± 0.03), and relatively low $p\text{CO}_2$ ($385.4\pm 5.4 \mu\text{atm}$) across the well-mixed water column in the spring (Figs. 3 and 5)". We hope this addresses your inquiry.

33. L278-279 Please provide a reference for this contention.

Response: Thanks for the reminder. A reference has been cited as suggested.

34. L280-281 ditto.

Response: Thanks again. A reference has been inserted as suggested.

35. L304-305 More info is needed how the $\text{del-}p\text{CO}_2$ for the Bay was calculated. Is it just a mean of all stations?

Response: Thank you for your comment. We calculated the $\Delta p\text{CO}_2$ for Nanwan Bay by averaging data from all 17 sampling stations, despite some uneven distribution. Remarkably, excluding certain stations from the analysis did not significantly affect the overall mean value for the bay. Thus, we are confident that these sampling stations are sufficient for providing an accurate representation of the bay's status. For more details on this matter, please also review our responses to your comment 37 and Reviewer 1's comment 3.

36. L314-315 What is the exact unit of the absorption? Tonne C or tonne CO₂? It may be better to use exponents of 10.

Response: Thank you for highlighting this previously unclear statement. The unit in question is tC, and we have made sure to reflect this clearly in the revision. Regarding the value expression, we prefer to maintain its current format as it is more convenient for comparing values across different seasons. However, we are open to using exponents of 10 for the values if you believe that would be a better way to express them.

37. L314-315 Again, how exactly was the result obtained?

Response: Thank you for addressing this important methodological concern. In this revision, we have included a description of how we estimated the bay's area and calculated the seasonal CO₂ fluxes in the Methods section. For your reference, this information is presented as follows: "The bay stretches between Cape Moubitou and Cape Oluanpi, covering an approximate area of 30 km², as estimated using Google Earth Pro." Additionally, "The seasonal fluxes over the Bay were calculated by multiplying the mean CO₂ exchange flux at all stations for each season by the bay's area of ~30 km²." We trust that this clarification addresses your inquiry. For more details on this matter, please also review our responses to Reviewer 1's comments 53 and 54.

38. Figure 1 The inset is not very clear. Also, it is not explained in the caption what all the lines and different arrows mean. I think a simpler map would be better.

Response: We appreciate your comment. To enhance the clarity of the sampling station, we have simplified this figure, and all symbols have now been clearly explained in the caption.