RC1: 'Comment on egusphere-2026-1488', Anonymous Referee #1, 13 May 2026

General comments:

The manuscript presents methane fluxes at the sediment-water and water-air interfaces from field campaigns conducted in Taiwan's seagrass ecosystem. The study shows that methane production is primarily associated with benthic processes at the meadow and provides observations from a tropical seagrass environment for which relatively limited data are available.

The manuscript is generally well structured, and the comparison with previous studies is particularly valuable. However, several parts of the discussion and conclusions currently overinterpret the results or use wording that is stronger than supported by the data. In particular, the manuscript would benefit from a clearer distinction between methane concentrations and methane fluxes, more cautious interpretation of the seasonal dataset, and a more explicit discussion of the large variability associated with some benthic flux measurements.

The manuscript would also benefit from clearer information regarding the exact locations and distances between the sites. Without this information, it is difficult to fully evaluate the independence of the "seagrass" and "sand" stations, particularly given that methane can be transported laterally in shallow coastal waters and could therefore influence the measurements there.

Overall, the manuscript contains an interesting dataset and has the potential to make a valuable contribution, but needs substantial clarification and rephrasing before publication. The conclusion should also be revised accordingly.

Reply: We thank the reviewer for the thorough evaluation of our manuscript and for the constructive comments. We appreciate the positive assessment of the dataset and the recognition of the value of providing methane flux observations from a tropical seagrass ecosystem, a region for which data remain relatively limited.

We agree that several aspects of the manuscript require clarification and more cautious interpretation. In the revised manuscript, we carefully distinguish between methane concentrations and methane fluxes throughout the text, moderate statements that may overinterpret the available evidence, and revise the discussion and conclusions to ensure that all interpretations are fully supported by the data. We have also expanded the discussion of variability in the benthic flux measurements and explicitly acknowledged the associated uncertainties and limitations.

In addition, we agree that clearer information regarding site locations and spatial relationships is needed. To improve clarity, we have revised the study area figure to clearly identify the locations of the in situ incubation experiments at the seagrass and sand stations and added a conceptual figure illustrating the geographic distribution and spatial arrangement of the sampling sites.

Furthermore, following the reviewer's suggestion, we have reorganized the manuscript by separating the Results and Discussion sections to improve the clarity and readability of the presentation. We believe this revised structure facilitates a clearer distinction between observations and interpretations.

We appreciate these valuable suggestions and believe they have significantly improved the clarity, rigor, and balance of the revised manuscript.

Specific comments:

Abstract:

Due to the lack of winter measurements, the term “annual” should be removed. In addition, almost one full year separates autumn 2022 from summer 2023, making the extrapolation to an annual cycle uncertain. All statements here and in the text need to be rephrased.

Reply: We completely agree with the reviewer’s assessment. Because winter measurements were not captured, extrapolating the data to an annual scale introduces undue uncertainty. To address this, we have systematically revised the abstract and the main text to focus strictly on temporal and seasonal dynamics during the specific sampling periods, removing all "annual" scaling and budgets.

Introduction:

Line 44: The authors should not present methane as having a single GWP value of “27–80 times greater” than CO2. Methane has a GWP of ~27 over a 100-year timescale and ~80 over a 20-year timescale. In addition, these values refer to GWP rather than SGWP (sustained-flux GWP).

Reply: We appreciate the reviewer’s insight. We agree with the reviewer that coastal ecosystems emit methane continuously rather than as a single pulse, using Sustained-Flux Global Warming Potential (SGWP) is scientifically more accurate. We have revised the manuscript, and the text now reads:

‘However, these ecosystems are also recognized as sources of CH_4, a potent GHG with a sustained-flux global warming potential 45 times greater than that of CO_2 over a 100-year timescale, and up to 96-time greater over a 20-year timescale on a mass basis (IPCC, 2021; Neubauer and Megonigal, 2015).’

Line 47: The statement: “More broadly, the coastal ocean is a global hotspot for CH_4 emissions, accounting for 75% of oceanic CH_4 emissions” does not appear to be stated explicitly in Weber et al 2019 and should be rephrased more carefully. In addition, the estimate “with continental shelves alone contributing approximately 13 Tg CH_4 yr^{-1} from Bange et al. 1994 is outdated. The manuscript should instead use the more recent estimates shown in Weber et al. (“Extrapolation of rate measurements from active seafloor seeps across areas of likely seepage suggests that global CH_4 ebullition from continental shelf sediments (0–200 m) likely falls between 18 and 48 Tg yr^{-1}, with a most likely rate of ~35 Tg yr^{-1}).

Reply: We thank the reviewer providing the construct comments and suggestion. We have removed the unsupported percentage statement, updated the recent reference and have modified the manuscript. The text has been rephrased and updated as follows:

"More broadly, the coastal ocean serves as a critical global hotspot for marine CH_4 emissions (Weber et al., 2019). Recent estimates indicate that CH_4 ebullition from continental shelf sediments (0–200 m) alone likely falls between 18 and 48 Tg yr-1, with a most probable rate of ~35 Tg yr-1 (Weber et al., 2019)."

Methods:

Line 89: For transparency, the four sites should be indicated in Figure 1c. Since the study compares "seagrass meadow" and "bare sand" sites, the reader needs to know how far they are located from each other and from the surrounding coastal features. Methane can be transported laterally, meaning that methane measured at the sand site could potentially be influenced by emissions originating from the seagrass meadow.

Reply: We thank the reviewer for this helpful suggestion. We have revised Figure 1 to clearly show the locations of all four sampling sites, including the seagrass meadow and bare sand stations used for the in situ incubation experiments. These revisions provide a clearer representation of the study design and spatial relationships among the sampling sites, allowing readers to better evaluate the potential connectivity between them.

We acknowledge that lateral methane transport cannot be completely excluded in this shallow coastal environment and may influence methane concentrations in the water column. However, we do not expect it to substantially affect the incubation results, as these experiments were specifically designed to quantify benthic methane fluxes originating directly from the underlying sediments. We have clarified this point in the revised manuscript.

Figure 1 is modified as below:

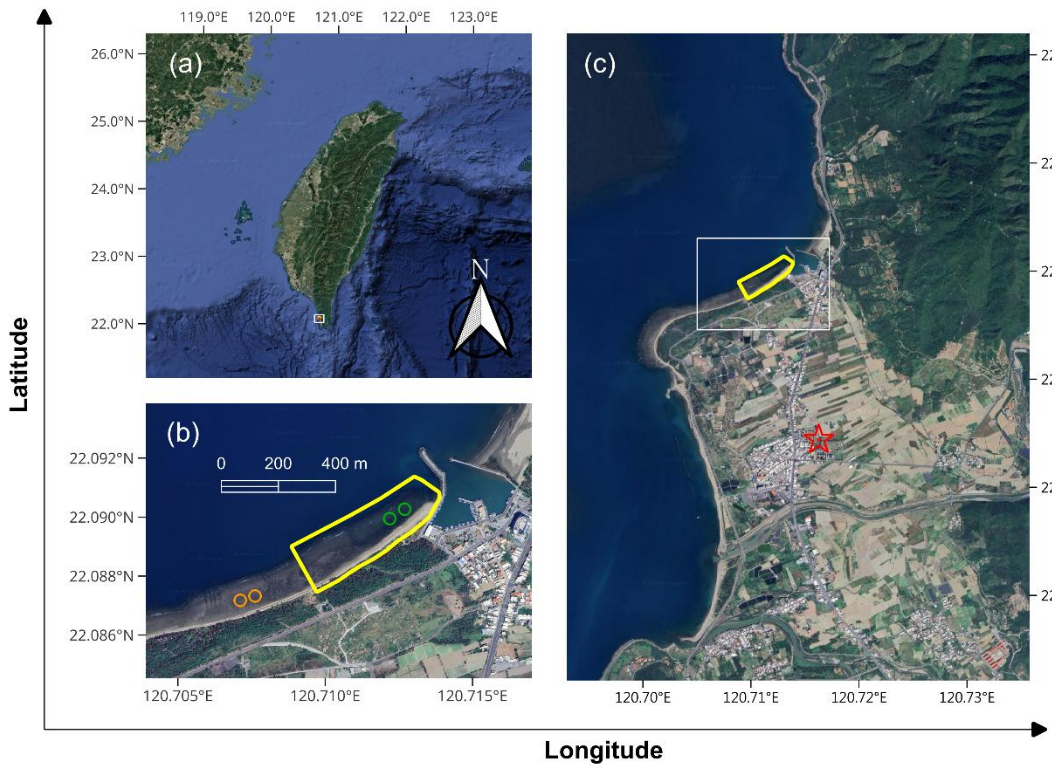

Figure 1. Study area and sampling locations at Haikou, southern Taiwan. (a) Location of the study site in Taiwan. (b) Detailed view of the Haikou seagrass meadow (yellow polygon) and the in situ incubation sites. Green circles indicate the seagrass incubation sites, while orange circles indicate the bare sand incubation sites. (c) Overview of the study area showing the geographic location of the seagrass meadow (yellow polygon) and the Checheng Weather Station (red star). The white rectangle indicates the area enlarged in panel (b).

Sections 2.2 and 2.3: The authors mention that the incubation experiments lasted between 2 and 5 hours “depending on sampling needs”, but these needs are not explained. Please clarify what controlled the duration of the incubations.

Reply: We thank the reviewer for highlighting this important oversight. The variation in incubation duration was not due to shifting experimental goals, but rather to unexpected logistical challenges in the field.

We have removed the phrase "depending on sampling needs" and revised the text to explicitly clarify it. Now the text reads: The in situ benthic cultivation experiments were conducted during both day and night for approximately 2 to 5 hours, depending on wave and weather conditions as well as operational constraints. Specifically, although while a standard 5-hour sampling interval was intended, poor weather conditions occasionally restricted diver deployment, resulting in shorter incubation periods.

It is also unclear why natural water movement needed to be simulated above the chamber if the chamber was fully closed. Please clarify the role of the magnetic agitator and whether it simulated internal circulation within the chamber. Figure 2c is unclear. Zooming on one of the photos to describe the chamber in more detail could help.

Reply: The reviewer is entirely correct: the magnetic agitator was located inside the closed chamber, not outside or above it. Its purpose was to maintain internal water circulation to prevent the development of artificial stagnant boundary layers over the sediment surface during the incubation. The previous sentence didn't make it clear so we have modified this sentence to accurately reflect the setup and clarify the role of the agitator.

Revised Text: "To ensure continuous water circulation, a magnetic agitator was installed inside the chamber near the top and operated continuously throughout the incubation period."

We also modified the Figure 2

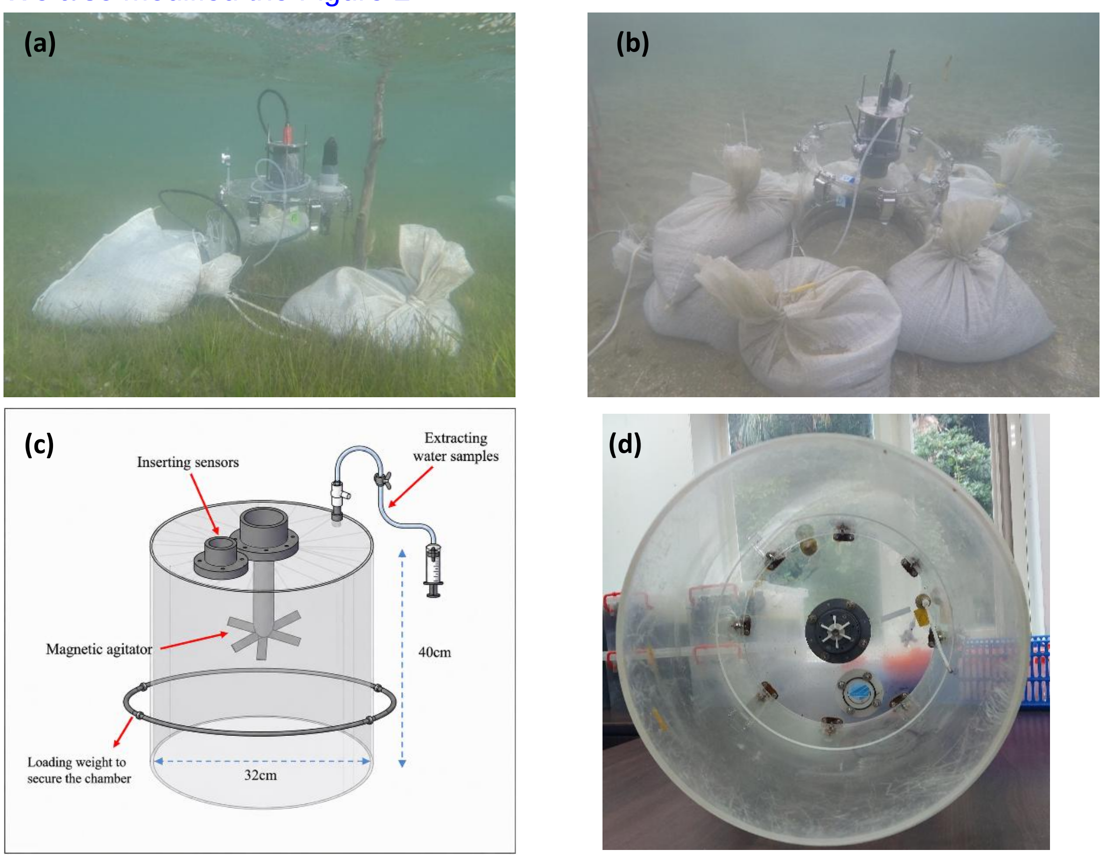

Figure 2. Benthic chamber in situ incubation systems deployed in (a) a seagrass meadow and (b) a bare sediment habitat. (c) Schematic diagram of the chamber design. (d) View from inside the chamber looking upward toward the chamber ceiling.

Sections 2.2 and 2.3 could likely be merged for clarity. After reading section 2.2, the reader is left wondering how the physical and chemical parameters were measured. In addition, the paragraph beginning with “water samples” belongs more naturally in section 2.3.

Reply: We thank the reviewer for this valuable suggestion. Following this excellent suggestion, we have completely merged Sections 2.2 and 2.3 into a single, cohesive section now titled "Section 2.2: In situ chamber incubation system, samples collection and chemical analysis"

It is also unclear how the porewater sampling was conducted relative to the chamber system. Finally, a pH sensor is mentioned but pH is not discussed later in the manuscript.

Reply: We appreciate the opportunity to clarify our sampling design and streamline our parameter reporting.

1. Porewater Sampling Clarification: The porewater sampling was conducted completely separate from the benthic chambers to ensure that the extraction process did not disturb sediment layering or affect the internal flux dynamics of the active chamber deployments. We have clarified this in the text and specified the sampling frequency.

   Revised Text: “Porewater samples were collected once daily from both seagrass beds and sand areas, independently of the chamber systems, to ensure that extraction did not disturb the active chamber deployments.”

2. pH Sensor Mention: While pH was initially measured as part of our baseline monitoring, preliminary analyses indicated that this parameter did not exert a significant statistical influence on methane dynamics in our system. To prevent reader confusion and keep the manuscript tightly focused on the primary drivers of CH_4 fluxes, we have removed the mention of the pH sensor from the Methods section.

Results and discussion:

Section 3.1

The section refers to “surface water conditions”, whereas the methods indicate that temperature, salinity, and dissolved oxygen were measured within the chamber. Please clarify whether the values presented correspond to chamber measurements or ambient surface waters.

Reply: We thank the reviewer for this constructive feedback. The values presented under “surface water conditions” correspond to the ambient surface waters surrounding the incubation setups, not the internal environment of the chambers. We first monitored surface water conditions and calculated sea-to-air methane fluxes, followed by analyses of sediment CH_4 production and benthic fluxes.

Since the values discussed in the text are not always directly consistent with Table 1 or figure 3, please clarify whether the reported values correspond to seasonal averages from all replicates. The source of the freshwater influence responsible for the lower salinity in the seagrass area should also be clarified. Again, the exact locations of the stations would help interpret these observations.

Reply: The reviewer is correct: unless otherwise noted, the values reported throughout the text represent seasonal averages aggregated across all replicates rather than individual raw data points or isolated ranges.

We have revised the phrasing in the text converting instances where concentration ranges were previously discussed into their corresponding average calculations—to ensure perfect alignment with Table 1 and Figure 3.

The updated text now reads as follows:

"Average surface temperatures in spring 2022, autumn 2022 and summer 2023 were 27.2, 29.1 and 28.7 °C, in seagrass water and 27.5, 29.4 and 29.0 °C in coastal water (Table 1). Daytime temperatures were consistently higher than nighttime, particularly in seagrass areas (Fig. 3a). Seasonal average salinity in the seagrass habitat followed a sequence of 32.64, 32.88, and 31.94 (Fig. 3b; Table 1), which was slightly lower than that of coastal water (33.06, 32.97, and 32.12; Fig. 3b), likely due to freshwater input. DO saturation in seagrass water showed strong diurnal variation, increasing from nighttime averages of 87.0%, 94.5%, and 88.5% to daytime peaks of 118.6%, 124.4%, and 109.3% (Fig. 3c) driven by seagrass photosynthesis. In contrast, coastal water DO saturation remained more stable across seasons (averaging 102.8%, 101.3%, and 99.9%), sitting slightly lower than the overall seasonal averages observed in the seagrass meadow (102.8%, 109.4%, and 98.9%; Table 1)."

Please discuss in more detail why autumn 2022 showed lower daytime methane concentration compared to the other seasons. This pattern is likely related to storm-induced wind and enhanced mixing, as suggested by the elevated wind speeds during this period.

Reply: We completely agree with the reviewer's assessment. The lower daytime CH_4 concentrations observed during autumn 2022 were indeed heavily influenced by meteorological forcing. We have expanded the discussion to explicitly incorporate this mechanism, noting the high wind speeds that drove physical degassing.

Revised Text now reads: "During this sampling period, a heavy rainfall event occurred alongside significantly elevated wind speeds. This storm-induced wind enhanced vertical mixing and physical degassing at the water–air interface, driving daytime CH_4 concentrations down to levels notably lower than those observed in other seasons."

In addition, with only three seasonal campaigns available, it seems too strong to state: “Dissolved CH_4 concentrations in seagrass waters exhibited clear seasonal and diurnal variability…”. Please rephrase.

Reply: We agree with the reviewer's point that three campaigns are insufficient to claim a definitive seasonal cycle. We have rephrased this sentence to clarify that the variations occurred among the specific sampling campaigns/periods rather than asserting generalized seasonality.

Revised Text now reads: “Dissolved CH_4 concentrations in seagrass waters varied between the sampling periods and showed diurnal trends, characterized by higher averages at night and lower values during the day, except in autumn 2022 when a severe weather event disrupted this pattern.”

I am also confused by the interpretation in Lines 153-156. If methane production is primarily associated with seagrass sediments, then the lower methane concentration in coastal water is not simply related to water depth and potential oxidation. It may instead reflect the absence of methane production in sandy sediment. Alternatively, methane observed in coastal waters could partly originate from lateral transport from the seagrass area. Again, this is difficult to evaluate without precise site locations.

Section 3.3

I am not convinced that the term “relatively stable” accurately describes methane production and fluxes in seagrass sediment, especially considering the 156% increase observed in autumn. Similarly, the description of “episodic peaks” in sandy sediment may be overstated given that only three seasons are available.

The authors state that “CH_4 production rates and fluxes were higher in seagrass sediments than in sandy sediment” but then note that “autumn 2022 presented an exception”. However, this exception is huge (sandy autumn flux = 388.9 ± 382.8 and seagrass autumn flux = 105.3 ± 284.2), and strongly influences the annual average, which weakens the broader claim that seagrass is the dominant hotspot.

Reply: We agree that describing the seagrass sediment fluxes as "relatively stable" overlooks the substantial 156% increase in autumn, and that "episodic" implies a frequency that a three-season dataset cannot fully substantiate. To address this, we have completely removed both terms from the manuscript and rephrased the text to more accurately describe the observed trends as a contrast between baseline conditions and discrete, storm-driven responses.

Revised Text now reads: “Meanwhile, sandy sediments maintained low baseline rates during spring and summer but exhibited a distinct spike that coincided with storm events in autumn 2022 with production rates of 972.2 ± 957.1 μmol m^{-3} d^{-1} and a flux of 388.9 ± 382.8 μmol m^{-2} d^{-1}.” This suggests that although seagrass meadows emit CH_4, their root systems help stabilize the sediments. Consequently, when physical disturbances such as storm-induced mixing occur, seagrass sediments are less affected than sandy sediments, resulting in lower benthic CH_4

fluxes."

In addition, the extremely large standard deviations reported in autumn 2022 should be discussed explicitly, as they indicate substantial temporal and spatial variability and uncertainty in the seasonal extrapolations.

Reply: We thank the reviewer for this insightful comment. We agree that the large standard deviations in autumn 2022 warrant explicit discussion regarding their underlying causes and their implications for seasonal extrapolations. To address this, we have expanded our discussion in the revised manuscript to explicitly acknowledge this uncertainty and to caution against over-extrapolating these storm-influenced autumn values across broader, storm-free periods.

The added text as follows: "Specifically, the large standard deviation observed in sandy sediment during autumn 2022 reflects stark variations between baseline seawater CH_4 concentrations (measured during calm periods) and the highly elevated concentrations induced by a major storm event. This storm-driven spike was likely enhanced by intense sediment disturbance and subsequent gas release. Because this single event captured a transition from baseline to episodic peak conditions, it naturally introduced substantial temporal and spatial variability into our autumn dataset. While this inherently increases the uncertainty of our fixed seasonal extrapolations, we believe it represents a critical, real-world snapshot of how episodic weather events drive CH_4 dynamics."

Section 3.4

The two statements in the first sentence are not fully supported by figure 6. Spring 2022 shows a distinct pattern, with stronger methane concentration in the sand. This makes the following interpretation too strong. Similarly, the description of a "steady decline" below 12 cm is overstated, as some profiles clearly show increases at depth.

Reply: We completely agree with the reviewer's observation. Our original text overgeneralized the trends and overlooked the specific variations present in the depth profiles, particularly during Spring 2022.To address this, we have removed the words "consistently" and "steady decline" from the text. We have rephrased it to accurately present the depth-dependent variations and explicitly highlight the distinct trend observed in the sandy sediments during Spring 2022.

Revised Text now reads: "CH_4 concentrations varied with depth, with average values generally higher in the upper 0–12 cm across the sampling campaigns. Seagrass sediments exhibited greater values in autumn 2022 and summer 2023; however, a distinct pattern emerged in spring 2022, when higher CH_4 concentrations were recorded within the sandy sediment profiles (Fig. 6)."

The reference to Tang et al. 2025 should be explained in more detail. This study is highly relevant to the present work but is only mentioned briefly here. It should be placed into clearer context, particularly regarding differences in sampling periods.

Tang et al. sampled in March-May 2023, whereas the present study was conducted in June 2023.

Reply: We completely agree with the reviewer that Tang et al. (2025) provides essential background context for our data and that the temporal relationship between the two sampling campaigns deserves explicit discussion.

We have revised the text to place Tang et al. (2025) into clearer ecological and chronological context. Specifically, we have clarified that their spring campaigns (March–May 2023) characterized the baseline sedimentary environment (showing an average TOC of 0.40% driven by aquatic plants and microbial processing) directly preceding our summer campaign (June 2023). This temporal progression indicates that the organic matter accumulation and priming characterized by Tang et al. in the spring likely served as the primary substrate fuel driving the enhanced methanogenic activity we observed in early summer.

The text now reads: 'According to Tang et al. (2025), sediment core samples collected during the March–May 2023 spring transition showed an average total organic carbon content of 0.40%, primarily derived from aquatic plant material and microbial processing. This accumulation of organic substrate during the spring likely provided the necessary fuel for the elevated microbial methanogenesis and subsequent high porewater CH_4 concentrations captured during our subsequent peak summer deployment in June 2023.'

The rest of the paragraph is a bit hard to follow because it mixes processes derived from literature and analogies with the present study. Some references are presented in a way that suggests direct observations in the present study. For example, lines 235-236 mention bubbles observed by Sun et al 2022, although these observations were made in a different environment.

Reply: We thank the reviewer for this helpful comment. We agree that the original text did not clearly distinguish between processes inferred from previous studies and observations from the present study, which may have caused confusion. In particular, the description of bubble observations cited from Sun et al. (2022) could be misinterpreted as direct observations from our study. To address this issue, we will revise the manuscript to clearly separate our results from literature-based interpretations. In addition, following the reviewer's suggestion, we will restructure the manuscript by separating the Results and Discussion sections, which will improve the clarity of the presentation and ensure that references to previous studies are clearly identified as supporting evidence rather than observations from the present study.

Section 3.5

The calculation of the annual methane emission of 78.3 moles is based only on three seasons which do not form a continuous annual cycle, excludes winter conditions and includes a storm in autumn. This limitation should be acknowledged more clearly and the wording should be moderated.

Reply: We thank the reviewer for this important comment and fully agree with the concern. The original annual methane emission estimate of 78.3 moles was derived from 3 seasonal measurements that do not represent a complete annual cycle, as winter conditions were not sampled and the autumn dataset included a storm event that could disproportionately influence the extrapolation. We agree that extending these observations to an annual budget introduces substantial uncertainty and may overstate the robustness of the estimate.

To address this issue, we have removed the 78.3-mole annual methane emission calculation from the manuscript, together with all references to annualized projections and annual budgets. Rather than attempting to qualify the extrapolation, we believe it is more appropriate to focus on the observed seasonal variability captured during our sampling campaigns. The revised manuscript therefore presents the methane fluxes within the context of the specific measurement periods and explicitly acknowledges the temporal limitations of the dataset, including the absence of winter observations and the influence of episodic storm conditions.

Line 251: It is the first time that missing winter data is acknowledged. This should be mentioned earlier.

Line 253: This sentence puts too much emphasis on oxidation. Lateral transport may imply that methane is eventually emitted to the atmosphere outside the meadow rather than oxidized locally. I suggest rephrasing to “This imbalance between sediment production and atmospheric emission suggests that a substantial fraction (here ~94%) of sediment-derived CH_4 was either oxidized within the water column or transported laterally before reaching the atmosphere.”

Reply: We completely agree with the reviewer’s distinction between local water column oxidation and physical lateral transport. Attributing the entire missing fraction solely to oxidation overlooks the significant role of hydrodynamic exporting pathways in coastal environments.

Following your excellent suggestion, we have rephrased the sentence to properly balance both potential fates of the un-emitted methane.

The comparison with other studies in Table 3 is very useful and valuable. However, including water depth for each study would improve the comparison.

Reply: We thank the reviewer for this excellent suggestion. We agree that including water depth provides critical ecological context for comparing methane and greenhouse gas dynamics across different seagrass systems.

As suggested, we have thoroughly re-examined the cited literature and added a new column for "Water Depth (m)" to Table 3. For several studies, specific water depth values were not explicitly reported by the original authors; in these cases, we have denoted the missing values as "Not Available" (NA) or provided general environmental descriptions (e.g., "Intertidal") where available.

Conclusions:

The conclusion should reflect the corrections previously suggested. In addition, it would benefit from a clearer distinction between methane concentrations and methane fluxes, as these concepts are occasionally mixed throughout the discussion.

Reply: We have thoroughly revised the Conclusion section to reflect all previous corrections (such as removing annualized scaling calculations and shifting to daily areal rates). Furthermore, we have performed a comprehensive text sweep to ensure that "concentrations" and "fluxes" are decoupled and applied correctly.

Technical corrections:

Line 54: Remove “the” before “CH4 generated in sediments”

Reply: We thank for the reviewer’s suggestion. We have modified it.

Figure 1: The squares representing the zoomed areas are difficult to see. I suggest making them thicker and red, and adding labels a, b and c to each panel. This figure would also benefit from locations, following Tang et al. 2025

Reply: We thank for the reviewer’s suggestion. We have modified the Figure 1 and add a, b and c.

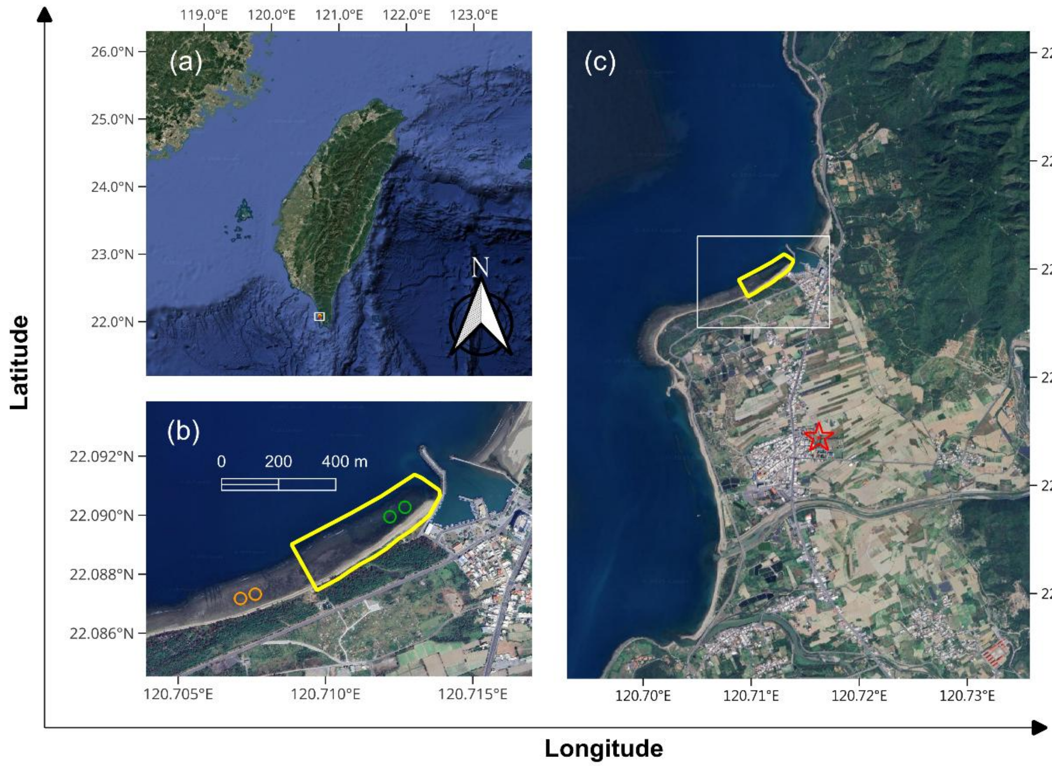

Figure 1. Study area and sampling locations at Haikou, southern Taiwan. (a) Location of the study site in Taiwan. (b) Detailed view of the Haikou seagrass meadow (yellow polygon) and the in situ incubation sites. Green circles indicate the seagrass incubation sites, while orange circles indicate the bare sand incubation sites. (c) Overview of the study area showing the geographic location of the seagrass meadow (yellow polygon) and the Checheng Weather Station (red star). The white rectangle indicates the area enlarged in panel (b).

Line 83: Sediment samples? Water samples? Please clarify

Reply: We thank the reviewer for pointing this out. We have updated the text to explicitly clarify that both water and porewater samples were collected during these periods.

We added new sentence read: “Over these periods, both water and porewater samples were collected.”

Lines 83-87: The seasons are introduced at the beginning of the section, followed later by “different seasons”. I suggest switching both sentences for clarity.

Reply: We agree with the reviewer that restructuring the sentence order creates a more logical flow from the general sampling approach to the specific seasons monitored. Following your suggestion, we have rearranged these sentences to establish the seasonal context more clearly at the beginning of the section.

Now the new sentences read:
"In situ cultivation experiments were conducted in different seasons, both during the day and at night, to examine diurnal and seasonal fluctuations in CH_4 fluxes at the sediment-water and water-air interfaces in response to changing environmental conditions. Over these periods, both water and porewater samples were collected.
In situ incubations were conducted from May 19 to 23 (spring) and September 26 to October 4 (autumn) in 2022, as well as from June 13 to 17 (summer) in 2023. Due to severe winter weather conditions, in situ incubations could not be performed."

Lines 144-145: Cite Figure 3b after the salinity range, and Table 1 after mentioning seasonal averages, since Figure 3 only shows night and day values.
Reply: We agree that Table 1 is the correct reference for the overall seasonal averages, as Figure 3 specifically presents the diel (day and night) variations. Following your suggestion, we have adjusted the citation placements accordingly.

Lines 176-181: These lines simply repeat Table 2 and could be shortened.

Reply: We thank the reviewer for this suggestion. We have revised this section to remove the redundant data points and shorten the text, focusing only on the main trends and the peak values.

Line 224: Wind disturbance should also be mentioned as a contributing factor

Reply: We thank the reviewer for this valuable suggestion. Following your suggestion, we have explicitly incorporated wind disturbance alongside our existing discussion of environmental drivers.

Now the new sentence reads: "Seasonal variability was evident, with the highest concentrations, production rates, and benthic fluxes in seagrass meadow in autumn and summer (Fig. 5), reflecting enhanced microbial activity and organic matter decomposition, though seasonal wind disturbance likely also acts as a contributing factor by influencing sediment dynamics and flux rates during these periods."

Figure 6: Please explain why error bars are absent from some porewater profiles

Reply: The error bars correspond to the range calculated from duplicate core samples. For certain specific depth intervals, error bars are absent because only a single sample was available for analysis, leaving no statistical range to plot.

To ensure this is clear to readers, we have added this explanation directly to the Figure 6 caption. Revised Figure 6 Caption:“...Error bars represent the range of duplicate samples; error bars are absent for depth intervals where only a single sample was available.”

Line 240: Refer to Table 1

Reply: We thank for the reviewer’s suggestion. We have modified it.

Line 243: Refer to Table 2

Reply: We thank for the reviewer’s suggestion. We have modified it.

Line 248: Consider adding “may also intensify”

Reply: We agree that this phrasing provides a more appropriately moderated and objective tone for our forward-looking climate projections. Following the reviewer's excellent suggestion, we have updated this exact wording.

Now the text reads: “With climate change projected to increase the frequency of extreme weather, benthic CH_4 release from unvegetated sandy areas may also intensify.”

Line 304: Correct typo “approximarely”

Reply: We thank the reviewer for spotting this error. We have modified it.