RESPONSE TO COMMENTS

Remarks from the preceding review file validation

1) Please ensure that the colour schemes used in your maps and charts allow readers with colour vision deficiencies to correctly interpret your findings. Please check your figures using the Coblis – Color Blindness Simulator (https://www.color-blindness.com/coblis-color-blindness-simulator/) and revise the colour schemes accordingly. --> Figs. 3, 4, 5, S1, S2

Our response:

We thank the editorial team for this important suggestion. In response, we revised the color schemes of Figures 3, 4, S1, and S2, and updated their legends accordingly, to ensure accessibility for readers with color vision deficiencies. We verified the changes using the Coblis – Color Blindness Simulator. Figure 5 was not modified because, in addition to color, it contains explicit visual cues (text labels and markers) that make it interpretable regardless of color vision.

Reviewer 1 (RC1)

General comments

Peatlands are globally important carbon (C) sinks and storage through their significant uptake of carbon dioxide (CO_2) from the atmosphere and accumulation of undecomposed plant material as peat. However, peatlands also emit CO_2 as well as another potent greenhouse gas methane (CH_4.). These gas flux dynamics in peatlands are regulated by many environmental variables, such as temperature and water level, that are impacted by the ongoing climate change, and thus there is an urgent need for better understanding of the C cycling of the peatlands and their climate feedback under the warming climate. More studies are especially still needed about spatio-temporal variation of the fluxes in different peatland ecosystems for more accurate climate modeling. This technical note introduces a new version of the previously presented novel measurement method called "skirt-chamber" that can be used for greenhouse gas flux measurements, even in remote locations. Compared to the commonly used dynamic chamber method, the skirt-chamber is more cost-effective and non-invasive as it does not require collars for air-sealed chamber closure. The new "modulated-light skirt-chamber" is specifically designed to determine photosynthesis-irradiance (PI) curves by measuring CO_2 flux rates under different light levels, to which it seems to fit well. The authors have polished the chamber design and carefully thought through the measurement set-up as well as the flux calculation method. The resulted PI-curves are showed to be comparable with previous models and eddy covariance measurements. It is also noted that the method of temperature measurements used in the current set-up still requires improvement. Thus, I find that the authors have done comprehensive work with improving their new chamber method for suiting net ecosystem exchange (NEE) measurements and are aware of the remaining limitations of their method.

The manuscript is well written, and its overall quality is good. The abstract is concise and details successfully the central background, methods and results. The introduction flows nicely and highlights the advantages and limitations of different GHG flux measurement methods. The aims of the study are clearly stated. Materials, especially the new version of the skirt-chamber design, as well as measurement methods and mathematical formulae for flux calculation are explained in detail. The authors have also tested several different shading steps to optimize their method regarding the use of different light intensity levels. Moreover, the PI curve generation is validated by comparing two different existing models. All the figures and tables are informative, clear, and include comprehensive captions. Furthermore, the supplementary material is well made giving further information about the chamber design, mass balance calculations, and result validation. I have only a few comments and questions regarding the measurement protocol, chamber design, and sampling. I recommend this manuscript to be accepted after minor revision. Please, see my more detailed comments below.

Our response:

We sincerely thank Reviewer 1 for the careful review and positive evaluation of our work. The comments provided were constructive and insightful, and they helped us improve the quality of the manuscript. We are particularly grateful that the reviewer evaluated both the current study and our previous publication (Thalasso et al., 2023; https://doi.org/10.5194/bg-20-3737-2023), thus providing an informed and coherent assessment of the skirt-chamber method and its development. Below, we provide detailed responses to the six specific comments raised. We are confident that the clarifications and revisions made have further enhanced the clarity and robustness of the manuscript.

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1. Study site, campaign, and flux measurements, lines 140-148: In the description of the study site and flux measurements the studied bog is said to have different microforms from hummocks to bare peat surfaces without living Sphagnum cover, and that the measurements covered random locations across different vegetation covers and topographies. Did you also measure the bare peat surfaces or other relatively wet surfaces?

Even though the targeted bog is described not to be submerged, with the water table typically between 10 – 60 cm below surface, it seems that it could still have some wet spots. As I mentioned in my previous review of the author's first technical note regarding the skirt-chamber, bare peat surfaces in bogs can especially be very wet or event water-saturated in my experience, which can make them tricky to measure with chambers. Even if not directly applicable to the studied bog here, I am still curious about how well the authors think the enhanced skirt-chamber would work for measurements in more wet peatland conditions?

As one of the main advantages of the skirt-chamber compared to traditional dynamic chamber is that it is does not need any collars, it could still be difficult to conduct the measurements without causing disturbance at the measured site without boardwalks and by placing down the chamber, especially when the water table is high.

Our response 1 – Measurement coverage across topography:

We confirm that the chamber was deployed across a representative range of topographic conditions, including hummocks, hollows, transitional zones, and bare peat surfaces. In response to this comment, we have added a new supplementary table (Table S2) listing the 27 chamber deployment sites together with the dominant vegetation or surface condition. We also added a sentence in the Materials and Methods section to reference Table S2 (see below) and to highlight the diversity of sites sampled.

Text added (L158): "Over the course of the campaign, 27 sets of measurements were taken at random locations across different vegetation covers and topographies, with three sites measured twice to assess repeatability (Table S2, dominant species and type of relief)".

Table S2: Site characteristics showing the dominant plant species and their relative cover (%) at each measurement location. Type of relief refers to the microtopographic position: hollow, hummock, or transition. Transition refers to the sloping areas between hollows and hummocks.

Site	Dominant species (% cover)	Type of relief
1	*Tetroncium magellanicum* (99.6)	Hollow
2	*Tetroncium magellanicum* (66.3)	Hollow
3	*Tetroncium magellanicum* (95.8)	Hollow
4	*Tetroncium magellanicum* (50.9)	Hummock
5	Ericaceae (93.9)	Hummock
2	*Tetroncium magellanicum* (66.3)	Hollow
7	*Sphagnum magellanicum* (78.3)	Hummock
8	*Sphagnum magellanicum* (65.4)	Hummock
9	Ericaceae (59.7)	Transition
10	Ericaceae (95.8)	Transition
11	*Sphagnum magellanicum* (50.7)	Hummock
12	*Tetroncium magellanicum* (95.8)	Hollow
13	*Nothofagus antarctica* (46.3)	Hummock
14	Lichens (79.5)	Hummock
15	Ericaceae (51.5)	Hollow
16	Ericaceae (51.5)	Hollow
17	*Sphagnum magellanicum* (90.2)	Hummock
18	*Tetroncium magellanicum* (80.3)	Transition
19	*Sphagnum magellanicum* (50.0)	Hummock
20	Ericaceae (100.0)	Hummock
21	*Sphagnum magellanicum* (100.0)	Hummock
22	Bare peat (64.6)	Hollow
23	Ericaceae (97.7)	Hummock
24	Ericaceae (88.1)	Hummock
25	Ericaceae (77.6)	Transition
26	Bare peat (76.6)	Hollow
27	Ericaceae (47.9)	Hollow

Our response 2 – Applicability to wetter conditions and submerged sites:
The studied peatland section presented in this manuscript did not include permanently submerged sites. In response to the reviewer's comment, we have added a paragraph in Section 3.4 explicitly noting this limitation and discussing the expected performance of the chamber in submerged or near-saturated areas. We anticipate that under such conditions, the skirt would form a seal with the water surface, and the chamber would function similarly to a static closed chamber, with gas accumulating inside due to little or no leakage. We also noted that deployment time should be limited to avoid large CO_2 concentration changes that could affect respiration and photosynthesis kinetics. Finally, we emphasized that direct testing under these conditions would be an important next step to extend the applicability of the method.

Test added (L326): "An important question regarding the applicability of the chamber is whether the method can be used in submerged areas, a common feature in many peatlands. Our study sites did not include permanently inundated conditions, and we cannot confirm chamber performance under such circumstances. We anticipate that in submerged or near-saturated zones, the skirt would form a seal with the water surface, and the chamber would function similarly to a static closed chamber, with gas accumulating inside due to little or no leakage. In such cases, deployment time should be limited to avoid large CO_2 concentration changes that could alter respiration or photosynthesis kinetics. Direct testing under these conditions will be an important next step to extend the applicability of the method".

Our response 3 – Site disturbance:
We agree that a potential limitation of the skirt-chamber is that it requires the presence of an operator, which may lead to site disturbance during deployment — particularly in wet or water-saturated areas where pressure is readily transmitted through the peat matrix. In a separate study (not part of the present work), we observed that operator proximity influenced ebullition events: gas release was triggered when the operator stepped close to the chamber but was avoided when the operator maintained a distance of 40–50 cm. In the revised manuscript, we have explicitly added this drawback to the discussion of the method's limitations and recommended mitigation strategies such as the use of snowshoes (as applied in this study) or pressure-distributing boards.

Test added (L333): "Another potential limitation of the skirt-chamber method is that it requires the presence of an operator, which may cause site disturbance when stepping close to the chamber, particularly in wet or water-saturated areas where pressure is readily transmitted through the peat matrix. In a separate study (not part of this work), we observed that operator proximity could influence ebullition events: gas release was triggered when stepping close to the chamber but avoided when maintaining a distance of 40–50 cm. To mitigate this issue, we recommend practices that distribute operator weight, such as the use of snowshoes (as applied here) or pressure-distributing boards. Although this effect does not compromise the chamber design itself, it highlights the importance of maintaining sufficient operator distance to minimize disturbance during measurements".

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2. Related to the possible disturbances and difficulties when measuring greenhouse gas fluxes in wet and intermediate peatland microforms, did you detect any ebullition during the measurements this time?

Our response – Ebullition:
We did not detect any sudden increases in methane or carbon dioxide concentrations that would indicate ebullition events during this study. We attribute this to the fact that all measurements were conducted in non-submerged areas, where the water table was below the peat surface. Under such conditions, any gas bubbles formed in deeper layers are likely to be gradually released and diluted as they pass through the unsaturated peat and vegetation, reducing the likelihood of detectable ebullition at the surface.

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3. 2.3 Measurement protocol, lines 127-138: It is said that all PI curve determinations followed the same four-stepped protocol, with the third one being the chamber closure, during which two to four light conditions were tested. Do I understand correctly that the chamber was not ventilated between each light level, but the light conditions were altered during one chamber closure? If so, how often the chamber was ventilated? What are the benefits of not ventilating the chamber between each light level? What about the possible disadvantages or issues?

Was there any condensation in the chamber during a closure?

<u>Our response 1 – Chamber closure and light modulation without ventilation</u>:
Yes, the reviewer understood correctly: the chamber remained closed (not ventilated) for three to four minutes, during which two to four light conditions were tested. The main reason for not ventilating between each light level was to ensure accurate determination of the chamber gas residence time (θC; Section S2) after each chamber opening/closing, achieved by injecting a methane pulse and monitoring methane concentration over the longest possible time for improved precision. Since the methane injection did not interfere with CO_2 concentration inside the chamber, θC could be determined precisely while applying different light conditions within the same closure phase. This approach increased the accuracy of θC determination and reduced data processing effort by minimizing the number of θC determinations required.

Text added (L142): "This procedure avoided intermediate ventilation between light levels, which ensured a more accurate determination of θ_C. Because a methane pulse was injected after each chamber closure and its decay monitored over the entire closure period, θ_C could be quantified with higher precision while simultaneously applying different light conditions. This approach also reduced the number of θ_C determinations required, thereby minimizing data processing effort (see Section S2)".

<u>Our response 2 – Condensation during measurements</u>:
The reviewer raised a valid point. We did observe occasional condensation on the chamber window, but only under the highest light condition—direct sun exposure without shading fabric. This condition never lasted more than two minutes, and only slight condensation was observed. Although this may have slightly altered incident light by scattering irradiance or reducing transmission, the effect was accounted for because light intensity was measured inside the chamber. Given the short duration and limited extent of condensation, we considered its impact on the PI curve measurements to be negligible.

Text added (L340): "A practical issue that may arise is condensation on the chamber window under high irradiance. In our field tests, this was only observed during the highest light condition (direct sun, without shading fabrics), and it lasted for less than two minutes, producing only slight condensation. Such condensation could, in principle, scatter direct irradiance and reduce overall transmission, but in this study any potential effect was minimized because light intensity was measured inside the chamber. Given its short duration and limited extent, the impact on PI curve determination was considered negligible.

4. Did you also monitor the light intensity in real time in addition to the two light/temperature data loggers (so that you could see what PAR was at any given moment) or did you only filter through it later during the data processing? On the lines 189-190 it is said that 26% of the measurements failed, e.g., due to fluctuating or limited solar irradiance. This percentage is pretty high (1/4 of the measurements), and at least for the light it can easily be improved by monitoring PAR also in-situ so that the measurement can be stopped and started from the beginning if the light intensity changes too much during the chamber closure.

Our response – Real-time light monitoring:
We greatly appreciate the reviewer's suggestion, which indeed represents a valuable improvement to the current implementation of the skirt-chamber method for PI curve determination. In the present study, light intensity was logged inside the chamber, and the data were processed afterward during analysis. We agree that real-time PAR monitoring would provide immediate feedback on irradiance conditions, enabling the repetition of measurements when sudden fluctuations occur. This comment was also raised by Reviewer 2.

Text added (L317): "Another common reason for failure to determine PI curves was fluctuating or insufficient irradiance under cloudy conditions. One weakness of the way we applied the skirt-chamber method is that light intensity was logged inside the chamber and processed afterward during analysis. Although this provided accurate irradiance values for PI curve construction, the lack of real-time monitoring limited the operator's ability to respond to rapid irradiance fluctuations. Real-time PAR monitoring would provide immediate feedback on irradiance conditions, allowing operators to repeat measurements when sudden changes occur".

Please note that this comment was included in a new section on possible causes of PI curve determination failures (L314). This section now discusses issues related to real-time irradiance monitoring (this comment), temperature effects (see response to comment 6), as well as the influence of specific vegetation types and the absence of plant cover (bare peat).

Text added (L314): "A weakness of the method is exemplified by the 26% of failed deployments (Fig. S3). Part of these failures were attributable to excessive leakage that increased measurement noise. This excessive leakage was linked to the vegetation itself: some vegetation types, such as Ericaceae (Table S2), formed a dense layer of intertwined fibrous and lignin-rich tissues, through which air flowed easily, thereby increasing gas exchange between the chamber and the atmosphere. Another common reason for failure to determine PI curves was fluctuating or insufficient irradiance under cloudy conditions. One weakness of the way we applied the skirt-chamber method is that light intensity was logged inside the chamber and processed afterward during analysis. Although this provided accurate irradiance values for PI curve construction, the lack of real-time monitoring limited the operator's ability to respond to rapid irradiance fluctuations. Real-time PAR monitoring would provide immediate feedback on irradiance conditions, allowing operators to repeat measurements when sudden changes occur. Notably, not all failures in determining PI curves can be ascribed to methodological weaknesses. Two of the failed cases occurred in bare peat areas (Table S2), where little or no photosynthetic activity was expected. Overall, while these issues reflect practical challenges of field measurements in heterogeneous environments, they do not undermine the overall reliability of the method".

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5. The presented modulated-light skirt-chamber seems to work well for estimating PI-curves based on CO_2 measurements under different light levels. Despite the different base for flux calculation, modulated-light skirt-chamber method requires a gas analyzer for measuring CO_2 and a selected tracer gas concentrations. In the example study, CH_4 was selected as the tracer gas since it was also detected by the used gas analyzer. Nowadays there are quite many portable gas analyzers that commonly measure CO_2 and CH_4 at the same time. However, in the peatland gas exchange studies it is often interesting to be able to measure both of these gas fluxes at the same time, which saves time and effort from the "old-traditioned" measurements, when CO_2 and CH_4 needed to be measured in separate campaigns in the absence of the modern gas analyzers. Are there some other gases that the authors would recommend as potential tracer gas for the measurements for the scientists who wish to also use the CH_4 data as it is and not to interfere with it by injecting CH_4 into the chamber?

<u>Our response – Other tracer gas</u>:
The reviewer raised an important point regarding the possibility of using an alternative tracer gas, particularly when simultaneous measurement of CH_4 and CO_2 emissions is of interest. We acknowledge that this aspect was not clearly explained in the original manuscript. Importantly, the use of CH_4 as a tracer in our method does not prevent the determination of CH_4 emissions. In our previous study (Thalasso et al., 2023; https://doi.org/10.5194/bg-20-3737-2023), we showed that modifying light conditions for PI curve construction had no effect on CH_4 fluxes. Therefore, any segment of the CH_4 concentration data recorded prior to the CH_4 pulse injection can be used to calculate CH_4 emissions. In the present study, following each chamber closure, CH_4 concentrations were monitored for approximately one minute before the CH_4 pulse injection. This time window was sufficient to estimate CH_4 fluxes, although extending it by an additional 30 seconds in future applications would improve accuracy when CH_4 emissions are a core objective. Each chamber closure also provides an independent opportunity to estimate CH_4 fluxes, allowing multiple emission values to be derived from a single deployment. From our perspective, this approach is more practical than switching to an alternative tracer gas, which would inevitably increase cost and equipment weight, potentially compromising the portability of the method. This was taken into account as follows;

Text added (L345): "Although CH_4 was used as a tracer gas to determine the chamber residence time (θC), this did not preclude the estimation of CH_4 fluxes. Fluxes were calculated from the CH_4 concentration record prior to the pulse injection, during which concentrations were monitored for approximately one minute. This time window was sufficient for flux determination, and it can be extended in future applications when CH_4 emissions are a core objective".

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6. Have you been considering the possibility to add a cooling system to the skirt-chamber? In my experience, temperature in the chamber can increase significantly already in a couple of minutes especially in sunny weather with high light intensity, which alters the conditions for the gas fluxes that are targeted with the measurements. However, many chamber systems do not have a cooling system to regulate the possible warming effect of the chamber. Did the temperature in the skirt-chamber change during the chamber closures?

Our response – Impact on temperature, cooling system

We fully agree with the reviewer's concern regarding potential temperature increases inside the chamber during closure. In the manuscript, we already acknowledge (around L307) that one limitation of our study was the use of a suboptimal temperature sensor inside the chamber. As a result, we were unable to provide a reliable assessment of temperature dynamics during chamber closure. In the revised manuscript, we kept the discussion in Section 3.4 to emphasize the importance of using a more appropriate air temperature sensor for future applications. We also added a short discussion of possible strategies to limit temperature increases, including the use of active cooling systems such as Peltier elements, as previously suggested by Jentzsch et al. (2024; https://doi.org/10.5194/bg-21-3761-2024). These improvements would enhance the ability of the skirt-chamber to maintain near-ambient conditions during measurements.

Text added (L309): "In addition, strategies to further limit chamber warming should be considered. Active cooling systems, such as Peltier elements, have been proposed in recent studies (e.g., Jentzsch et al., 2024) and could be adapted for use in the modulated-light skirt-chamber. Incorporating such systems would help maintain near-ambient conditions during measurements, thereby reducing the risk of temperature-induced biases in gas flux estimates".

Reviewer 2 (RC2)

General comments

Chamber-based measurements have long been used to determine greenhouse gas (GHG) fluxes in peatlands. As globally important carbon stores that are sensitive to environmental conditions such as air/soil temperature, they are susceptible to being turned from carbon sinks into carbon sources when environmental conditions change (e.g. as a result of climate change or anthropogenic land-use conversion). In near-natural peatlands carbon dioxide (CO_2) and methane (CH_4) are the dominant GHG that decide over the GHG balance of the ecosystem. Because of constraints of traditional chamber designs, such as the (semi-)permanent installation of collars into the soil as a measurement base, GHG measurements with chambers in remote areas remain limited. The installation of collars into the soil also constitutes a spatial constraint for measurements and can potentially create pseudo-replication and, thus, misleading statistical results. The proposed novel "modulated-light skirt chamber" builds on the previously introduced "skirt-chamber". Both chamber-types allow to minimise invasion into the ecosystem and can relatively easily be deployed in remote locations as they do not require the installation of collars into the soil ahead of GHG flux measurement. The new chamber and study design outlined in this technical note improves on the initial skirt-chamber design in that it tries to minimize shading inside the chamber and allows to build photosynthesis-irradiance curves. The design concepts for the chamber and flux calculation methods used are well-described in the manuscript. The authors also compare the results produced with their new chamber-design to values calculated via the well-established eddy covariance method for the same peatland, as well as values from other peatland studies for validation. They outline remaining limitations within their study, such as an unsuitable temperature sensor chosen in their measurement set-up.

Overall, the manuscript is well-written and easy to follow. It successfully outlines the thought-process behind the new chamber design and which calculation procedures were used, with additional details provided in the supplementary materials. The abstract summarizes the study well. The materials and methods section provides ample information about the chamber design, measurement protocol (including different levels of shading) and mathematical background for flux calculations. It also describes the PI curve models used in this study in sufficient detail. I have some remarks about the introduction and the strengths and weaknesses of the method within the results and discussion section in particular. While these parts of the manuscript are equally well-written as the rest of the manuscript, I do wonder if there is too much of a focus on the new chamber design filling a gap between the ecosystem-level eddy covariance and leaf scale measurements. Chamber-based studies at the intermediate level with the more commonly used dynamic chamber method are fairly frequent in peatland ecosystems (e.g. in Canada and Europe). There might not be so much of a scale-gap that needs to be bridged, rather than existing chamber methods that have limitations and can be improved upon. I am aware that the authors focused a bit more on this aspect in their previous manuscript when they introduced the skirt-chamber, so it might be a good idea to at least make a mention of this facet and reference the previous manuscript here. My second concern is that the introduction section focuses on peatlands in general, but I would argue that the current chamber design is better suited to being used in sphagnum-dominated bog ecosystems rather than fen ecosystems which can have taller vegetation that might limit the use of the newly developped chamber and make sealing the chamber-base to the ground more difficult. Even though

I would like to see these two points addressed, I do recommend the manuscript for publication after minor revision. Please see below for my specific comments.

Our response:
We thank Reviewer 2 for the kind evaluation and thoughtful feedback on our manuscript. Below, we address each of the two general comments and ten specific comments, outlining the revisions that have been made in response. We are confident that these improvements have further strengthened the manuscript.

Our response to general comment 1: Scale-gap and chamber method:
We fully agree with this comment regarding the actual benefits of the skirt-chamber for PI curve determination. After revisiting our manuscript, we recognized that our initial presentation may have overstated the existence of a scale gap, rather than focusing on the specific methodological advances of our chamber design. In the revised manuscript, we now present the three main approaches currently used (Eddy Covariance, leaf-level measurements, and chamber methods), highlighting their respective advantages. We also clarified that the modulated-light skirt-chamber is a refinement of our previous design—offering specific improvements over standard collar chambers—rather than a solution to a scale gap.

The new Introduction includes now (from L41): "Several methods have been used to assess the impact of irradiance on photosynthetic rates at different spatial scales. Among these, aboveground techniques such as Eddy Covariance (EC) continuously measure net ecosystem exchange (NEE) of CO_2, allowing inference of gross primary productivity (GPP) and ecosystem respiration (Reco; Baldocchi et al., 2024; Holl et al., 2019). Overall, EC methods provide broad spatial and temporal coverage but cannot resolve fine-scale flux variability, such as photosynthetic activity, as they integrate fluxes over larger areas. At the leaf scale, PI curves have been determined using infrared gas analyzers (IRGA), which directly measure CO_2 assimilation, or chlorophyll fluorescence methods, which provide an indirect assessment of photosynthetic efficiency (Herrmann et al., 2020; Ye et al., 2013). These methods allow for controlled assessments of photosynthetic responses to varying light conditions at the leaf scale but face challenges in extrapolating localized measurements to the ecosystem scale due to plant diversity and spatial heterogeneity in peatlands (Kangas et al., 2014; Bengtsson et al., 2016). A third method uses chambers, which are enclosures positioned on the ground surface where changes in gas concentration provide information on CO_2 exchange (emissions or uptake). With the addition of light sensors, chambers can also be used to evaluate the effects of irradiance on photosynthesis (Frolking et al., 1998; Bubier et al., 1998; Badorek et al., 2011; Perez-Quezada et al., 2010). Chamber-based measurements have therefore been particularly useful in assessing photosynthetic activity at a scale that bridges leaf-level measurements from IRGA systems and ecosystem level fluxes from EC. This approach provides important insights into the complex dynamics of peatland bogs and fens, which are characterized by diverse plant species, distinct microhabitats, and underground processes that influence gas exchange at the local scale (Rydin and Jeglum, 2013).
Despite their utility, chamber methods often require relatively complex and costly setups. They typically involve specialized sensors, precise environmental controls, and airtight enclosures installed on collars that penetrate the ground. The use of collars frequently necessitates vegetation cutting and trenching, which can disturb gas exchange; a common strategy is to introduce a delay period of one or more days before measurements begin. Thus, both the complexity of chamber

setups and the time required for installation limit the number of sites that can be sampled during a campaign. To address these challenges, Thalasso et al. (2023) introduced the skirt-chamber, a minimally invasive and portable chamber for measuring CO_2 and CH_4 exchange in peatlands. This design, based on a chamber with a plastic film skirt expanded around it and sealed to the ground by a steel chain, avoids trenching or cutting vegetation and enables reliable determination of greenhouse gas fluxes without a delay period and at lower cost compared to standard chambers. The present study builds on that initial design by introducing a modulated-light skirt-chamber, which allows natural light penetration and controlled light modulation using screens of varying transparency. This new chamber retains portability while enabling in situ PI curve determination under natural light conditions, accounting for the entire plant community and the complex underground processes enclosed within the chamber perimeter. While the concept of the skirt-chamber is broadly applicable, the design tested in the present study is best suited to Sphagnum-dominated bogs with low vegetation, where sealing to the ground is straightforward. Its application in fen ecosystems with taller vegetation may require design adaptations. We tested this chamber in a Sub-Antarctic Sphagnum magellanicum bog on Navarino Island, Chile (54.9° S), to assess its feasibility for field applications.

Our response to general comment 2: Chamber suitability for bog versus fen ecosystems:
We thank the reviewer for highlighting this important distinction. In the revised introduction, we now explicitly note that the chamber is particularly suited for Sphagnum-dominated bogs with low vegetation, while its application in fen ecosystems with taller or denser vegetation may require modifications. This point has also been integrated into the subsection 3.4. "*Strengths and weaknesses of the method*" to clearly acknowledge ecosystem-specific applicability.

Text added (L357): "Finally, we note that the modulated-light skirt-chamber tested in this study is particularly suited to Sphagnum-dominated bogs with low vegetation. In fen ecosystems with taller or denser vegetation, obtaining effective measurements may require design modifications and/or adaptations of the method".

Please note that these general comments from Reviewer 2 required a modification of the abstract. The revised version now reads as follows (L13); "Peatlands play a crucial role in the global carbon cycle, and among several key processes, it is essential to characterize photosynthesis–irradiance (PI) curves, which describe the relationship between light availability and carbon assimilation through photosynthetic activity. Traditional approaches such as eddy covariance, portable photosynthesis systems, and chambers provide valuable data at ecosystem, leaf, and mesoscales, respectively. Chamber-based measurements are particularly useful at intermediate scales, as they capture photosynthetic activity of whole plant assemblages while integrating microhabitat and belowground processes. However, conventional chambers typically require the installation of collars, involving cutting and trenching of vegetation that may alter fluxes; this often necessitates a delay period before reliable measurements can begin and reduces the portability and applicability of chamber methods in remote peatlands. In a previous companion study, we introduced the skirt-chamber, a minimally invasive method for greenhouse gas flux measurements. Building on that design, we developed a modulated-light skirt-chamber specifically for PI curve determination. This chamber enables in situ characterization of photosynthetic responses under natural light conditions using adjustable shading screens, while preserving portability and minimizing disturbance. Field tests in a subantarctic Sphagnum bog demonstrated that the generated PI curves fit established models and closely matched eddy covariance measurements. The modulated-light skirt-chamber therefore provides a cost-effective and flexible tool for studying carbon dynamics in low-stature peatland ecosystems, with promising applications in heterogeneous landscapes".

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1. 2.1 Modulated-light skirt chamber concept, line 74: as mentioned above, chambers are already not only used to measure soil but also ecosystem fluxes, so the latter should be mentioned here as well

Our response – Chambers for ecosystem studies:
We have updated the text at line 79 (previously L74) to emphasize that chambers are used not only for soil flux measurements but also for ecosystem-level flux studies.

Modified text (L78): "Although similar to chambers commonly used to measure soil and ecosystem fluxes (Heinemeyer et al., 2011), it differs in that it does not use a collar, a rigid frame inserted into the ground to create a sealed interface on which the chamber itself is mounted. In standard chambers, collars are indeed commonly used to prevent direct gas exchange between the chamber volume and the atmosphere.

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2. 2.1 Modulated-light skirt chamber concept: While the new chamber design allows for very flexible spatial deployment anywhere in the peatland, the lack of platforms around the measurement site might lead to unwanted effluxes of soil gases while putting the chambers on the ground but also if someone walks around the chamber during measurements. Is wearing snowshoes (as described in their previous technical note) enough of a preventative measure to avoid this?

Our response – Ebullition and site disturbance:
We acknowledge this important point, which was also raised by Reviewer 1 (see RC1, Comment 1). In the revised manuscript, we explicitly mention the use of snowshoes (as applied in this study) and other possible mitigation measures, such as pressure-distributing boards, to minimize disturbances during chamber deployment. This limitation and the corresponding practical guidance are now included in the discussion of the method (Section 3.4).

Modified section (L333): "Another potential limitation of the skirt-chamber method is that it requires the presence of an operator, which may cause site disturbance when stepping close to the chamber, particularly in wet or water-saturated areas where pressure is readily transmitted through the peat matrix. In a separate study (not part of this work), we observed that operator proximity could influence ebullition events: gas release was triggered when stepping close to the chamber but avoided when maintaining a distance of 40–50 cm. To mitigate this issue, we recommend practices that distribute operator weight, such as the use of snowshoes (as applied here) or pressure-distributing boards. Although this effect does not compromise the chamber design itself, it highlights the importance of maintaining sufficient operator distance to minimize disturbance during measurements".

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3. 2.2 Modulated-light skirt chamber design: I wonder if the authors can elaborate a bit more on which advantages they think their chamber design has over more traditional cylindrical or cubical chambers that are made fully of transparent PVC. It seems to me that their chamber has more of a risk of creating unwanted shading within the chamber if not deployed properly. With their new design it seems to me that any type of chamber could be used on top of their skirt-base, so why not use a more traditional design that has been tried and tested?

Our response – Chamber design: Reviewer 2 raises a legitimate question. In the revised manuscript, we elaborated on the advantages of our chamber design, including its circular section (which allows the chamber to be rotated without disturbing the skirt-base) and its truncated cone shape (which permits selection between shaded and direct light). We also acknowledged that, based on our experience, other chamber geometries—including traditional transparent cylindrical or cubical models—could also be effectively combined with a skirt-base, provided that they allow easy opening, closing, and aeration. This discussion has been added to Section 3.4, as follows:

Added text (L349): "The modulated-light skirt-chamber was designed with several attributes in mind. First, it was built in two sections so that the chamber could be rotated without disturbing the skirt-base, allowing the operator to select between shaded and direct sun exposure. Second, the truncated cylinder shape was selected to optimize light exposure inside the chamber. Third, the chamber was made fully 3-D printable to simplify fabrication and ensure reproducibility. Fourth, the truncated cylinder design was selected to reduce the surface area exposed to sun, compared to a cubic shape, thereby minimizing potential temperature issues. Nevertheless this careful design, our field experience indicated that the practical benefits of the selected design were less pronounced than expected, and alternative geometries—including conventional transparent chambers—could also be effectively combined with a skirt-base, provided that they allow for easy opening, closing, and aeration".

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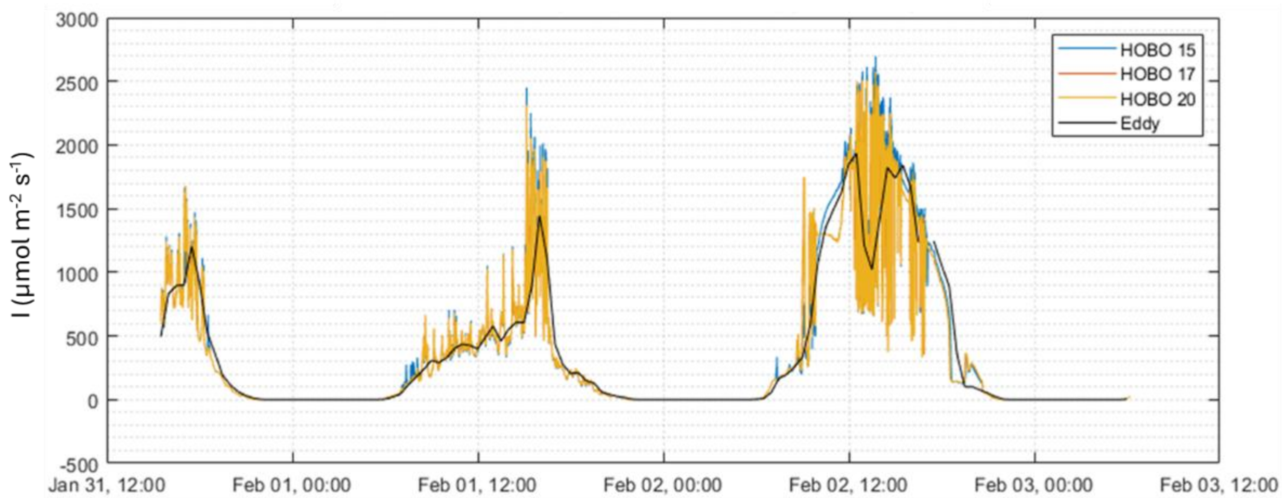
4. 2.2 Modulated-light skirt chamber design: What is the author's reasoning to not use a sensor that measures PAR directly and rather choose a sensor that measures lux and needs to be calibrated against a PAR sensor? Would it be possible to include the results of this calibration in the supplementary materials in order to better be able to assess the quality of the light intensity measurements?

Our response – Lux vs PAR sensors:
This is an important point. Our choice of a lux-based sensor (HOBO MX2202) was primarily guided by availability, but also by its compact size, durability, self-logging capability, and ease of deployment within the chamber. In the revised manuscript, we have now included the calibration data collected over 60 hours of continuous operation against a PAR quantum sensor (LI-190R, LI-COR, USA). The calibration equation, associated statistics, and mean error are presented in Figure S1 of the supplementary materials, thereby allowing assessment of the quality of the light intensity measurements.

Figure S1. Irradiance measurements obtained during a 60 h field deployment using one PAR quantum sensor (LI-190R, LI-COR, USA) and three HOBO light/temperature data loggers (MX2202, HOBO, USA). HOBO light data (lux) were converted to PAR (µmol m^{-2} s^{-1}) using the best-fit relationship PAR = 0.0201 × lux, with a standard deviation of standard deviation of 0.0002 and a mean error of -4.3 µmol m^{-2} s^{-1} relative to the LI-COR reference sensor.



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5. 2.4 Study site, campaign, and flux measurements, line 141: should either read "-54.940° N, -67.644° E" or "54.940° S, 67.644° W"

<u>Our response – Errors in coordinates</u>:
We thank the reviewer for pointing out this error. In the revised manuscript, we have corrected the site coordinates to the standard notation: "54.940° S, 67.644° W."

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6. 2.6 Data treatment and statistical analysis: is there any particular reason Michaelis-Menten-type rectangular hyperbolic function proposed by Falge et al (2001) was not tested for creating the PI curves? Originally proposed as a gap filling strategy for eddy covariance data it has also been used to model the relationship between GPP and PAR in many chamber-based European peatland studies.

<u>Our response – Monod or Michaelis-Menten type function</u>:
Reviewer 2 will certainly agree with us that there is no substantive difference between the Monod and Michaelis–Menten hyperbolic functions, which are mathematically equivalent. The choice of terminology (Monod vs. Michaelis–Menten) mainly reflects convention rather than differences in data treatment or model fitting. In the revised manuscript, we have clarified this point and included a reference to the widely cited study of Falge et al. (2001) to acknowledge its relevance.

Modified section (L176): "Among the various PI curve models published in the literature, we compared several models that can be grouped into two categories: those that consider photoinhibition and those that do not. Given the similarity among models within each of these categories, we selected one representative model from each. Specifically, we chose the model of Bernard and Rémond (2012), depicted in Equation 3, and a Monod-derived model (Jones *et al.*, 2014), which can be analogously applied to the relationship between light intensity and photosynthetic rates, depicted in Equation 4. The latter is mathematically equivalent to the

Michaelis–Menten-type hyperbolic function widely applied in ecological studies, including for modelling PI curves in eddy covariance and chamber studies (Falge et al., 2001)".

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7. 3.1 PI curves: Labelling of the x-scale seems to be missing for figure 2, having labels would be beneficial to better be able to visualize temporal information regarding chamber closure times/ventilation periods described in the text.

Our response – Error in Figure 2 label:
We thank Reviewer 2 for this helpful observation. The missing x-axis label in Figure 2 has now been corrected in the revised manuscript to clearly display temporal information regarding chamber closure times and ventilation periods.

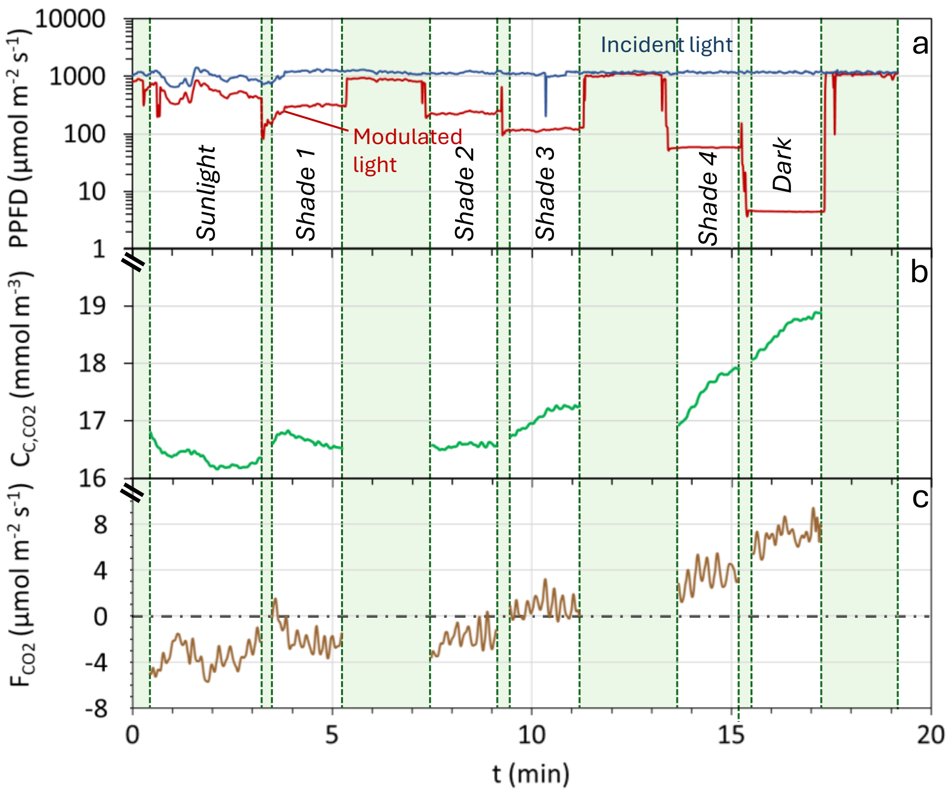

Figure 2: Example of data obtained during the determination of a Photosynthesis-Irradiance (PI) curve. (a) Irradiance (Photosynthetic Photon Flux Density) inside the chamber (red continuous line) and outside the chamber (blue continuous line). (b) CO_2 concentration within the chamber (green continuous line). (c) Flux of CO_2 (F_{CO2}) measured during the experiment. The green-shaded areas represent exclusion periods, which are transition periods between different levels of shading and/or chamber openings for ventilation.

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8. 3.3 PI curves and model parameters, lines 245-247: I expect there should be more than two studies out there reporting these values for peatland ecosystems, so it would be nice to include the results of a few more studies to solidify the comparison.

Our response – Literature comparison:
We appreciate the reviewer's suggestion to broaden the comparison with additional reported values of the initial slope (α). While this would certainly strengthen the ecological context, the primary objective of our manuscript is to present and evaluate a new methodological approach rather than to provide a comprehensive synthesis of photosynthetic activity values in peatlands. Accordingly, we revised the section to compare our α estimates to the theoretical maximum quantum yield of photosynthesis. We hope Reviewer 2 will find this presentation to strengthen the plausibility of our results against established physiological expectations while maintaining the focus of the manuscript on the method itself.

Modified section (L258): "The slope at the origin of the PI curves is a crucial parameter that reflects how efficiently a plant or ecosystem can convert light into chemical energy (via photosynthesis) under low light conditions. This is particularly relevant for C3 plants, such as many moss species with low photosynthetic activity that are commonly found in peatlands (Aro and Gerbaud, 1984). This parameter is expressed as α in most models, including the Bernard-Rémond model, and as β in the Monod model. In our study, the mean values of α (0.027 ± 0.021) and β (0.028 ± 0.021) showed no significant difference. These values fall within the ranges previously reported in peatlands, including 0.009–0.036 from northern bogs and fens (Shurpali et al., 1995; Suyker et al., 1997; Satriawan et al., 2023). Moreover, our results are consistent with theoretical expectations: the maximum possible quantum yield for terrestrial plants is approximately 0.1 µmol CO_2 fixed per µmol photons absorbed (Farquhar et al., 1980; Björkman & Demmig, 1987). Thus, the values obtained here represent realistic light-use efficiencies for peatland vegetation under field conditions.

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9. 3.3 PI curves and model parameters, lines 261ff: Respiration rates should get their own subsection within the results and discussion section as they fall neither under the categories of PI curves or model parameters in my opinion; alternatively, the section header should be changed to include respiration rates.

Our response – Respiration:

We fully agree that ecosystem respiration is distinct from PI curve parameters and warrants separate discussion. Accordingly, we created a new subsection "3.4 Respiration rates" in the revised manuscript

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10. 3.4 Strengths and weaknesses of the method: Even when relying on natural light, it should be possible to optimize PI curves by planning campaigns well (e.g. try to measure at different times of the day in cloudless conditions). I do understand that having limited field time in a remote location might not allow to always conduct measurements in ideal, cloudless weather. It would therefore be beneficial to monitor irradiance levels while taking measurements so that measurements can immediately be repeated in case irradiance was too changeable during a measurement.

Our response – Planning and real time monitoring:

We appreciate this important suggestion, which aligns with a similar point raised by Reviewer 1 (see RC1, comment 4). As noted in the manuscript, light intensity was monitored inside the chamber and processed post-measurement. We agree that real-time PAR monitoring would be beneficial by providing immediate feedback to operators and allowing measurements to be repeated during unstable irradiance. In the revised manuscript, we highlighted this as a recommendation for future applications of the skirt-chamber method.

Modified section (L318): "One weakness of the way we applied the skirt-chamber method is that light intensity was logged inside the chamber and processed afterward during analysis. Although this provided accurate irradiance values for PI curve construction, the lack of real-time monitoring limited the operator's ability to respond to rapid irradiance fluctuations. Real-time PAR monitoring would provide immediate feedback on irradiance conditions, allowing operators to repeat measurements when sudden changes occur".