Rebuttal of ACP manuscript; **Amazon rainforest ecosystem exchange of CO_2 and H_2O through turbulent understory ejections**

We kindly thank the reviewers and the editor for the time they invested in improving the manuscript, and for their appreciative general remarks. We have addressed individual comments in blue, and will upload a track changes manuscript to indicate how we incorporated the feedback.

Comments from reviewer 1

While I have a basic understanding of turbulent fluxes, I am not an expert in canopy issues. Overall I see this as an interesting paper illustrating aspects of turbulent fluxes through and above the Amazon rainforest canopy.

It would be good to see some statements and ideally profile information on mixing ratios of CO_2, H_2O and ^2H_2O below, through and above the canopy in day and night time if any of these are available. The ejection concept seems to say that, above the canopy in daytime, there is generally a downward flux of CO_2 but when material is ejected from below the canopy, and turbulent fluctuations CO_2' and H_2O' are both > 0 it is implied that the sub canopy can be a CO_2 source while the canopy itself is a sink. It could be interesting to see fluxes below the canopy, as well as above, to see if there is absorption of sub-canopy CO_2 as it passes through the canopy.

Reviewer 1 recognises the implications of our method and findings entirely correctly. Indeed, canopy mole fraction and / or flux profiles can help us understand the multiple in-canopy processes. While some profile data was available, we chose not to incorporate it in this manuscript as argued below. We realise that this argumentation is not fully laid out in the manuscript, while it would be insightful to the reader, as Reviewer 1 points out.

Firstly, stable stratification within the canopy causing increased concentrations of H2O and CO2 below the canopy top, due to daytime respiratory processes, are a relatively well-known feature of forest ecosystems (see references in the introduction at l. 26). They are the rule, and not an exception, which is why we did not feel the need to prove their presence in this manuscript.

The diurnal evolution of the vertical profiles of potential temperature, CO2 and H2O during our campaign is described in detail by González-Armas et al. (2025) . Note that these in-canopy profiles were collected at an ecosystem site at a distance of ~1km from the main tower at ATTO, from which we performed the flux measurements. DHO profile measurements are only available for a different time period, due to instrument down-time during the campaign period. Averaging over time windows, and multiple days (aggregate of 6 days), was necessary to retrieve these smooth profiles from point measurements. These profiles are representative of a diurnal boundary layer transitioning from clear conditions to shallow convection around 10 LT.

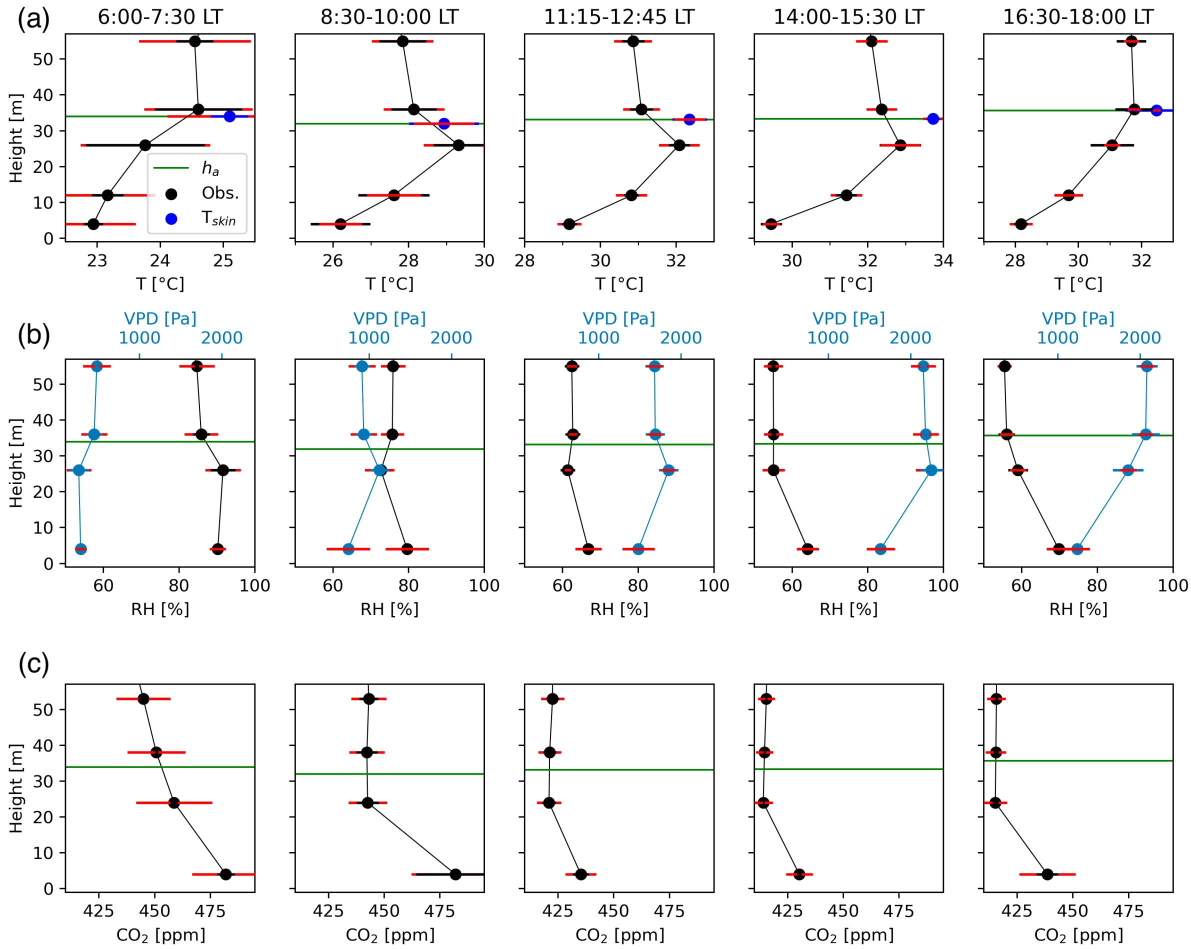

Figure A: From González-Armas et al. (2025, accepted preprint).

In line with the literature and the expectations formulated in our introduction, we observe a strong stable temperature inversion in the canopy. In addition, we find a buildup of CO2 in the stable below-canopy layer, notably during daytime. Relative humidity is also highest in this stable layer. Note that RH is not a conserved variable, thus it is not optimal for indicating a buildup of water vapor. The same is true for the VPD shown in panel 2, which has a strong temperature dependence.

Importantly, profile data from a canopy with spatially heterogeneous stability, are of a very local horizontal scale (~100m2 footprint). Our measurements of ejections (far) above canopy are representative for the ecosystem scale (~100,000m2 footprint). Therefore, local profiles cannot be linked directly to ecosystem scale ejections. This is especially true for the short timescales (min) we investigated.

Given these insights, the following changes were made to the manuscript:

- (L.45)

- We refer to the work of (González-Armas et al., 2025)
- We specify the ecosystem scale of our measurements and indicate that direct links to profiles were not considered insightful.

- (L.240 (discussion))
  - We mention the temporally averaged local profile data based on the six-day aggregate as presented in Gonzales-Armas et al (2025), which confirm a stable layer in the canopy with a visible respiratory signature.

Nighttime seems less certain while Fig 2 shows a positive CO_2 flux in early morning. The discussion in Section 3, focussed on quadrant analyses from Figures 1 and 2 is very good.

Indeed, at nighttime, the quadrant fluxes and net flux is uncertain. In the early morning, when the stability above the canopy is broken (7:00 – 10:00), a large positive CO2 flux is observed at 57 m. We understand that this comment was a confirmation of our findings and does not require adjustment.

Links to cloud cover are explained and are interesting.

Detailed comments.

Abstract Was the "the depleted water vapor isotopic compositions" measured in understory air? or just leaf and soil samples?

This question points out a misleading statement in the original manuscript. No understory air samples were used in our analysis. We intended to refer to the aggregates of the isotopic compositions of the water samples taken from the soil and the leaves. This has now been clarified.

Changes:

- (L.8) Remove "vapor". Clarify that only liquid leaf and soil samples were taken.

p3 The quadrant analysis in Figure 1, and especially 1c represents the important information presented here. As I read it there should be 36,000 points in each of Figs 1a,b,c (30 min each) but only 7200 (4Hz) isotopic composition measurements.

Figures 1a,b,c, all contain 30 min, 10 Hz data, meaning 18000 data points are present. The subsampling from the 20 Hz raw wind field measurement was chosen to match the 10 Hz frequency of the CO2 isotope analyser. These data were ultimately not used in our analysis, due to uncertainties related to the instability of the instrument.

A second subsampled wind dataset was made to relate to the H2O isotope analyser, which had a 4Hz sampling rate. As a consequence, all H2O isotope - wind related analyses are performed at 4Hz (thus 7200 data points). Still, we chose to display the ejection dynamics at the higher 10Hz frequency. We agree that the original 20Hz dataset might have been used as well to display the ejection dynamics, but we did (and do) not see enough added benefit over using the 10Hz dataset which we had already generated and analysed.

Changes:

- (L.58) The subsampling of EC data dependent on the isotope analyser measurement frequency is specified.

Note that our strategy for isolating the data points which we consider 'ejections', in which we combined the vertical velocity w, the orthogonal distance regression fit of H2O and CO2, and the ejection duration (dt), was implemented for both the 4Hz and 10Hz datasets. For example, the 4Hz representation instead of the 10Hz representation of the data underlying Fig 1c was used as input for Fig 3a, since 4Hz water isotope data was required. While minor differences might occur between the ejection classifications in the 4Hz and the 10Hz representations, we believe these are insignificant for our analysis.

I am not sure what is meant by "a hyperbolic isolation function".

The "hyperbolic isolation function" is the function that we use to define when a signal is distinct from the bulk exchange mode. It is a recognised method for finding respiration signals in CO2 – H2O quadrant analysis (Thomas et al., 2008). The function is shown in Fig. A5, in the caption of which we explicitly provide the function definition and specify the threshold. We acknowledge that "isolation" is not a clear term and changed the name to hyperbolic cut-off.

Changes:

- (L.74) Add function definition as eq. 2 to the explanation in Sec. 2.1
- (L.76) Add reference to Fig. A5 (u'w' plot) in Sec. 2.1
- Changed the name of the concept to "hyperbolic cutoff".

To explain the basics; the concept of the "hyperbolic isolation function" is taken directly from Thomas et al (2008). It provides a solution to an inherent problem with quadrants in turbulence data: Many data points are near the origin of the reference coordinates. When outliers from a dominant exchange mode are to be detected, we are instead interested in data points further from the origin. A hyperbolic function, namely, the multiplication of the normalised H2O and CO2 mole fractions in one quadrant, provides an extra dimension to deny or accept data points near the origin. The threshold, 0.2 in the case of Fig. A5, specifies the sensitivity.

Note; In Thomas et al. (2008), the hyperbolic function by which respiration data points are isolated, is referred to as a “hyperbolic deadband”. We do not believe that a deadband, which generally describes a range in one dimension, is a logical term when describing a hyperbolic cutoff in 2D.

Also the acronym ODR for the best fit straight lines, in the caption to Fig 1c, could be explained in section 2.1.

Thanks for the suggestion, this has been added

- (L.77) Acronym ODR added to explanation.

p3,5 The definition of an understory ejection as 0.5s with w > 0 and above a regression line, seems a little arbitrary. Were other criteria tried?

The concept of ejections being somewhat persistent in time made us start with longer ‘minimal durations’, of tens of seconds. Ultimately, we realised that short intense gusts were eliminated, while they can still be considered ejections, and carried physically relevant information. Our chosen limit of 0.5 s includes such shorter ejections.

p4 Figure A3 might need more explanation, or at least a forward reference to Figure 3.

Section 2.2, where the method is described, clarifies (the need for) figure A3 and refers to figure A3. We recognize that inversely, section 2.2 should be referenced in the caption of figure A3. A forward reference to figure 3 (main text) is already present in the caption of figure A3.

Changes:

- (cap Fig. A3) reference to section 2.2 added.

p7, 9, Fig 3, Was it a 13 day or a 14 day campaign? Could impact the number of data points averaged in Fig 3. It might also be useful to say how many days had sufficient "frequent understory ejections" in the 30 min time slots. What was the limit for data in Fig 1D - looks like about 6%.

This is well spotted. The reliable data period used for our analysis runs from August 8th in the morning to August 20th in the evening, so covers 13 full days. Fortunately, our averaging function for deriving composites was not dependent on a manually specified number of days.

As for the ejections, each day contributed at least minor ejections, and we have added this to the manuscript. Larger ejections, of long durations, were more rare.

Fig 1D provides an accumulation of the duration of all these occurrences, in 30 min bins. We did not apply a limit for the data in Fig. 1D.

Changes:

- (L.156, L.209) Change 14 to 13 days.
- (L.143) Specify that all days contributed.

References

González-Armas, R., Rikkers, D., Hartogensis, O., Quaresma Dias-Júnior, C., Komiya, S., Pugliese, G., Williams, J., van Asperen, H., a-Guerau de Arellano, J., & de Boer, H. J. (2025). Daytime water and CO2 exchange within and above the Amazon rainforest. *Agricultural and Forest Meteorology*, *Preprint*.

Thomas, C., Martin, J. G., Goeckede, M., Siqueira, M. B., Foken, T., Law, B. E., Loescher, H. W., & Katul, G. (2008). Estimating daytime subcanopy respiration from conditional sampling methods applied to multi-scalar high frequency turbulence time series. *Agricultural and Forest Meteorology*, *148*(8–9), 1210–1229. https://doi.org/10.1016/j.agrformet.2008.03.002