General Response to Referee #2

Original referee comments are in blue.
Our responses are in black with regular font format. Text from the updated manuscript:

Appears in italics with 1⁄2 inch indentation with the removed parts exhibited with a ~~strikethrough~~ and red color while new text added is shown in green.

Summary of RC2 comments:
Major comment: To discuss the limitations of the findings due to the small sample size. Additionally, to implement resampling techniques like bootstrapping to provide a more robust assessment of the statistical significance of the results. This would help in validating the study's conclusions despite the constraints posed by the sample size**.**

In fact, applying a statistical method that considers the small sample size enhances the quality of our analysis. As recommended by the reviewer, we used the bootstrap method with 50,000 resamples to improve the statistical robustness of our findings in section 4 (Environmental conditions), covering the main regime category analysis. By calculating both the mean and the standard deviation of these bootstrap sample means, we obtained a more reliable estimate of the population's central tendency and the uncertainty of our sample mean. This approach addresses potential limitations due to our original sample size, improving the confidence in generalizing our results.

Furthermore, it is important to mention that most results are very similar to those in our previous version, except for MLCIN and MLCAPE, which exhibited more significant differences.

Given this new application, the following text updates were made:
Line 114:
~~The error bars in each figure represent the standard deviation of the composite.~~
To account for the small sample size associated with the classification of the convective regime (fig. 4), we employed the bootstrap method, utilizing 50,000 samples to estimate the mean and standard deviation for each composite. These are represented by the new line and error bars in each figure in this section.

As desired by the reviewer, this sentence introduces the bootstrap method while also addressing concerns related to the small sample size and our approach to managing it.

For the conclusion, we also included one additional sentence to emphasize our resample approach:

Line 407-409: Unlike previous studies, we used an objective and reproducible method to identify and exclude days dominated by organized convection. Additionally, the bootstrap resampling method was employed in analyzing the environmental controls of each convective regime, permitting a robust assessment of the statistical significance of the results despite the relatively small sample size. The Deep regime is characterized by early morning moister conditions extending from the surface to the lower free troposphere.

To update the change in the mean values and uncertainties with the bootstrap method, we made the following updates in the manuscript:

Line 238: while the ShCu and Cong regimes show a decrease of 0.80 and 1.0~~1~~2 mm

Line 244-246: The PBL height among the convective regimes differs the most at 14 LST, where the convective boundary layer roughly coincides with the LCL or cloud base height (not shown), being about ~~300~~ 500 m lower for the Deep (~~1.09 km~~ 1535 m) than the ShCu (~~1.37 km~~ 1998 m) regime.

Note: These changes seem very large because we were incorrectly stating the height of the LCL instead of the PBL. This is now fixed, and the reported values are for the PBL-Height based on the bootstrap method.

Line 238: At 14 LST, MLCAPE for the Deep regime (~~1237~~ 1074 J kg^{-1}) and Cong regime (~~1111~~ 986 J kg^{-1}) significantly exceed the value for the ShCu regime (~~671~~ 558 J kg^{-1}). The change in MLCAPE from afternoon to early evening (MLCAPE(20 LST) - MLCAPE(14 LST)) is negative for the Deep (~~-390~~ -138 J kg^{-1}), ~~almost neutral~~ and positive for the Cong (~~-62~~ 139 J kg^{-1})~~,~~ and ~~positive for the~~ ShCu (~~398~~ 644 J kg^{-1}) regimes.

Line 272-273: Conversely, the convergence of vapor and evaporation exceeds the precipitation term on Deep days, resulting in a net accumulation of 1.~~7~~8 mm in column water vapor

Minor comment:

1. To include the error propagation formula for the CONV term in the budget equation. This formula involves implicit assumptions, such as a lack of correlation among the terms ∂tCWV, ∂tLWP, EVAP, and PREC, which may not be immediately apparent. Explicitly stating these assumptions should enhance the clarity of the manuscript. Similarly, the authors should provide an explanation of how the standard error of the PREC term was obtained from the three considered data sources. Including this information will further improve the understanding of the methodology employed in the study.

To provide these clarifications, the following updates were made:

Line 145-148: Precipitation is obtained utilizing different sources, namely, aerosol observing system data, a tipping bucket, and a laser disdrometer (Section 2.1). We determine the mean of these sources and calculate the standard deviation from this sample mean. The water vapor convergence term is estimated using the mean composites for ∂CWV/∂t, ∂LWP/∂t, EVAP, and PREC. The standard deviation of mean convergence is estimated from the standard deviation of the mean $\partial_t CWV$, $\partial_t LWP$, EVAP, and PREC, i.e.,

$\sigma_m = \sqrt{\sigma_m(\partial_t CWV)^2 + \sigma_m(\partial_t LWP)^2 + \sigma_m(EVAP)^2 + \sigma_m(PREC)^2}$. Although this formula involves implicit assumptions, such as a lack of correlation among the variables in the square root, the uncertainty in the water budget is primarily attributed to $\partial_t CWV$ (see fig. 9). Consequently, the uncertainty in the convergence term can also be roughly approximated by this term, with other terms contributing minimally.

2. The manuscript includes several speculative statements which are permissible because observations often cannot measure all factors influencing certain variables. However, it is essential to label these statements as speculative by using qualifiers like "likely" or "presumably," rather than presenting them as definitive without adequate evidence. As a reference, the following statements (lines 148-152) serve as examples: “... are uniform around the experimental site”, “CWV and LWP relate to regions associated with the domain average of a cloud size scale”, “our water balance is consistent for a temporal-spatial scale of ~ 1 hr and ~ 10 km.”

We agree with this point, although subjective. Sometimes statements are used solely to describe results, and are specific to those results. In the discussion or conclusion sections, however, no such definitive statements are made.

For the examples mentioned in the comment, we modified the related paragraph to be more accurate with our hypothesis:

Previous text:
Line 148-152:
~~**Note that we only employed local surface measurements. Surface fluxes depend primarily on the surface properties, which are uniform around the experimental site, at least up to 10 km away. Surface rain gauges and the microwave radiometer perform point measurements. However, since we are applying hourly averages for the water budget datasets and the composites average over many days, the mean precipitation, CWV, and LWP relate to regions associated with the domain average of a cloud size scale. Therefore, our water balance is consistent for a temporal-spatial scale of ~1 hr and ~10 km.**~~

Updated text:
Note that we only employed local surface measurements and applied hourly averages for the water budget datasets. Hence, the water balance is consistent over a temporal scale of an hour and a spatial scale on the order of meters. However, surface fluxes depend primarily on surface properties, which are approximately uniform around the experimental site, at least up to a distance of a few kilometers. Precipitation, CWV, and LWP may not change significantly directly above the cloud scale (~1-10 km, from shallow to deep). Therefore, our analysis is likely to generalize well across a spatial-temporal scale of an hour and a few kilometers.

3. The text on lines 223 and 233 uses the phrase "little statistical significance." It is advisable to avoid referring to the statistical significance of results unless they have been objectively analyzed through parametric statistical tests or resampling strategies.

The text was updated as follows:
Above 3 km, the differences in moisture profile for all regimes ~~have little statistical significance~~ are minimal.

4. The authors have argued that the results remain consistent when using different rain coverage thresholds for the convection regime classification, other than the 2% threshold mentioned in the paper. While it may not be practical to present all possible analyses, mentioning this consistency in the text would add value to the discussions and support the robustness of the findings.

Thank you for the suggestion. Analyzing the manuscript structure, we believe that the best place to include further support for the 2% threshold is in the methods section. We added the following sentence in the manuscript:

Line 177-179: The classification essentially depends on the cloud evolution during the diurnal cycle. The threshold of 2% used to calculate rain cover is based on Zhuang et al. (2017), who manually tested several parameters. Their results indicated that shallow rain cover never exceeds 2%, a criterion we adopted in our definition of minimum rain cover for identifying congestus or deep clouds. The exclusion of any relevant early morning disturbance (06-10 LST) associated with important pre-convective activity guarantees that nighttime MCSs do not cause significant preconditioning.

5. The comment made during the previous review round about the statement “A mixed-layer parcel from the surface to 100hPa is used...” might have been unclear. To clarify, it is suggested that this statement could be rephrased as “the 100-hPa layer immediately above the surface” to provide better context and understanding.

Thank you for the clarification. This recommendation is now reflected in:

Line 112-113: A mixed-layer parcel ~~from~~ immediately above the surface to 100 hPa is used as the initial state for the parcel’s ascent Stull (2016).

6. The authors have clarified that they neglect ice in their analysis; however, the manuscript still states “neglecting the time-variation of ice,” which should be revised to “neglecting ice” for clarity. Additionally, the authors justify this neglect by stating that the time variation in LWP is negligible in the budget analysis. Since ice water path was not considered in the study, further clarification is needed to support this justification. It appears that the authors assume $\partial_t IWC < \partial_t LWP$ in general, but this assumption is neither evident nor explicitly mentioned in the manuscript. To ensure transparency, the authors should provide a justification for this assumption within the manuscript.

Line 137-139: For the sake of this analysis, we neglect ~~the time variation of the~~ ice ~~term~~ and express all terms in units of mm hr^{-1} . As we show later (section 4.3), the results indicate a minor contribution of the liquid water term in the water budget, which supports ignoring the ice water term. Note that ice water paths are not necessarily smaller than liquid water paths; however, they still encompass values of comparable orders of magnitude.

7. In Section 2.3, it is recommended to clarify the term “rain” in “rain coverage” to specify that it refers to radar echoes exceeding a given threshold, regardless of whether the phase is ice or liquid. This will provide better context for the readers and improve the understanding of the methodology.

To provide further clarification, the text was updated as follows:

Line 162-164:
The rain coverage is calculated as the fraction of reflectivity pixels > 20 dBZ, regardless of whether the phase is ice or liquid (see Section 2.1). The echo-top is defined as the highest level where rain coverage is greater than 2%.

8. In the caption for Figure 6, it would be helpful to provide clarification on how the error bars for panels c and d were obtained.
Suggestion accepted. The caption was changed to:

Figure 6. Atmospheric conditions. (a) Potential temperature (K) and (b) water vapor mixing ratio (g/kg) at 08 LST radiosonde observations. The corresponding convective regime differences (Deep-ShCu and Deep-Cong) for potential temperature (, c) and mixing ratio (rv, d) are also included. The error bars on panels c and d are obtained from the bootstrap standard error of the convective regimes, i.e.,

$$\sqrt{SE(Deep)^2 + SE(ShCu\ or\ Cong)^2}\ .$$

9. Line 320 and Fig. 14’s caption: 2.5 J/g= 250 J/kg.

We corrected them.
2.5 J g^{-1} (2500 J kg^{-1})

10. The author’s effort in explaining the interpretation of Zhuang et al. (2017)’s results in their response is appreciated. However, the original intent of the comment was to recommend revising the explanation within the manuscript (lines 390-393) for improved clarity and understanding.

Thanks. We found that our previous text was not clear enough to state what we wanted to say. Thus, it was modified as follows:

Previous Version:

Line 390-394: ~~**Using GoAmazon2014/5 observations, Zhuang et al. (2017) reported a similar pattern of bulk wind shear during the wet season. However, their interpretation differs from ours. They suggested that strong wind shear would favor convection. Nevertheless, during the wet and transition seasons, Deep days are associated with weaker upper-level shear. Thus, they suggested that wind shear may have no impact or could even hinder convection. Here, we have shown that low-level shear has the greatest correlation with convection.**~~

Updated Version:
Using GoAmazon2014/5 observations, Zhuang et al. (2017) reported a similar pattern of bulk wind shear during the wet season. They suggested that strong wind shear would favor convection. However, during the wet and transition seasons, Deep days are associated with weaker upper-level shear. Thus, they suggested that wind shear may have no impact or could even hinder convection. Here, our results support that strong wind shear at lower levels favors convection, while weaker shear at upper levels plays a minor role in convection. Therefore, low-level wind shear may facilitate the development of convection during the wet season.

11. Line 27: "deep convection in either..." should be "deep convection either..."

Done

12. Line 62: It is recommended to use an alternative term for "sensitivity," such as "assess correlations," to more accurately describe the intended analysis and avoid potential misinterpretations.

Done

13. Figure 1's caption: It is recommended to clarify the intended meaning of the phrase: "The dotted circle describes the S-band radar domain with available measurements.".

We replaced:
~~**The dotted circle (radius of 202 km) centered over the T1 site describes the S-band radar domain with available measurements.**~~

With:
The dotted circle (radius of 202 km) centered over the T1 site indicates the domain covered by S-band radar measurements.

14. Line 107: It would be helpful to clarify the assumptions made in the vertical integration up to 200 hPa, in cases where the sounding only reaches up to 8 km.

Thanks for the observation. Soundings covering up to 8 km are used in the atmospheric profile analysis (fig. 6). The calculation of CWV considers soundings extending up to 350 hPa (and not 200 as mentioned, we updated this threshold in the latest manuscript version).

Line 104-105: For consistency, we ~~only~~ analyze the atmospheric profile (potential temperature and humidity) only for soundings that extend from the surface to at least 8 km, and we linearly interpolate the profiles to a fixed 50 m vertical grid.

Line 106-107: The total column water vapor (CWV) is determined by integrating the water vapor mixing ratio from the surface to ~~200~~ 350 hPa. For consistency, here we only analyze soundings that extend from the surface to at least 350 hPa (approximately 8.5 km). Similarly, the partially-integrated CWV is calculated for the layers 1000-850 hPa …

15. Line 244: The term "mixed-layer MLCIN AND MLCAPE" contains redundant elements, as the "ML" prefix already indicates that these variables refer to the mixed-layer. Consider revising this to "MLCIN AND MLCAPE" for conciseness and clarity.

Done

16. Line 261: The phrase "Changes in CWV" should be represented as ∂tCWV for clarity. Regarding "changes in condensate," please specify if this refers to ∂tLWP. Furthermore, it appears that "as" might be a more appropriate choice than "whereas," and "low" instead of "lower." Please review and revise the wording accordingly. It is important to note that negative CONV (or divergence) is not solely due to the mentioned factors, as EVAP is actually the dominant term. Please adjust the explanation to accurately reflect this information.

Yes, changes in condensate refers to ∂tLWP. We modified the text as suggested. Indeed, 'as' and 'low' are the right words. We have omitted evaporation from our analysis because it exhibits similar patterns across all convective regimes, despite its large values.

We replace:

~~The daytime of ShCu and Cong days shows mostly water vapor divergence. This is primarily due to more significant negative changes in CWV and lower precipitation rates, whereas changes in condensate exert a minor influence on the water budget.~~

With:

The daytime of ShCu and Cong days shows mostly water vapor divergence. This is primarily due to more significant negative changes in ∂tCWV and low precipitation rates, as evaporation shows smaller differences among the convective regimes and changes in ∂tLWP exert a minor influence on the water budget.

17. Figure 9: It is recommended to use a symmetric logarithmic scale for the y axis.

We are not sure if the reviewer pointed to the right figure. Using a log scale for the water budget figure is not suitable.

18. Line 282: The phrase “more significantly affected by PBL growth” can be reworded as “likely more influenced by PBL growth compared to other regimes” to enhance clarity and accurately convey the intended comparison.

Done

19. Line 285: It is recommended to add “respectively”, at the end of the phrase.

Done

20. Line 309: The term “more robust” in this context requires clarification. Elaborate on what is meant by “robustness” and how it is measured or determined in this case, as larger standard deviation typically indicates a higher level of variability, which might be interpreted as less robustness. Providing additional context will help readers understand the intended meaning.

Thank you for pointing that out. As noted, the phrase needed to be clarified, given that larger uncertainty corresponds to less robustness. We updated as follows:

Previous version

~~**For the 0-6 km layer, only ShCu days exhibit a distinct wind shear, which is more robust and has a standard deviation that can reach more than 1 m s^{-1}.**~~

Updated version

For the 0-6 km layer, the Cong and Deep regimes exhibit similar patterns, while ShCu days are characterized by larger wind shear values and greater variability.

We hope these answers provide clarifications and responses to the comments raised in this revision.