Review of MS. MS No.: EGUSPHERE-2025-6531

Title: Estimation of Nocturnal Boundary Layer Height in the Central Amazon, Supported by Gas Concentration Profiles

Editor decision: Publish subject to minor revisions (review by editor)

Public justification (visible to the public if the article is accepted and published):

I have received input from two reviewers; one recommended "rejection "and the other "major revision". Analyzing both reviewers comments they both appear to think the original manuscript was lacking mainly in two aspects: 1) Putting the results in a longer climatological perspective, and; 2) A more in-depth analysis and assessment of the physics leading up to the results. One reviewers also had a number of metodological comments on how the measurements were treted and how the analysis was carried out.

Reading the author's response to both reviewers in detail and browsing the track-change version of the revised manuscript, I conclude that the authors have made a major revision. They have attempted to expand the scope with a longer climatological perspective. Hampered with a lack of a complete data record for the longer period, the authors have attempted to use what they have of other observations that can be used in the interpretation. There is also a substantially extended text and new figures in support of the analysis on the underlying physics and an added new discussion section. The authors also provided a slightly extended description of the data and analysis methods used.

Editor Comment:

My main objection at this point is in for the Conclusions; this section that does not fulfil the specifications for publishing in ACP. The authors should avail themsleves of the author instructions that clearly indicates that a conclusion section must be included that encapsulates all of the following:

* Summary: Summarize the main results and relate them to the objectives, questions, or hypotheses of the study. The summary should include the main quantitative results.

* Synthesis/interpretation: Explain and interpret the results concisely to enable readers to make sense of them as a whole.

* Comparison and context: Compare the results with previous studies to put them in context. Explain consistencies, inconsistencies, and advances in knowledge.

* Caveats and limitations: State how these affect confidence in the overall results, and where future work is needed.

* Implications: Discuss what the results mean for our understanding of the state and/or behaviour of the atmosphere and climate, which is the main requirement for publication in ACP.

I am therefore not position to accept this manuscript until a proper conclusion section is presented.

Dear Editor Dr Michael Tjernström,

We thank you for the careful assessment of our revised manuscript and for acknowledging the substantial revisions made in response to the reviewers' comments. We also thank you for clearly identifying the remaining issue with the Conclusions section.

In response to your comment, we have substantially rewritten the Conclusions section to comply with the ACP author instructions. The revised section now explicitly includes: (i) a summary of the main results, including the main quantitative estimates of hn, and relates them to the objectives of the study; (ii) a concise synthesis and interpretation of the physical mechanisms controlling the observed variability; (iii) a comparison with previous Amazonian studies, highlighting consistencies and the advances of the present work; (iv) the main caveats and limitations, including how they affect confidence in the results and where future work is needed; and (v) the broader implications of the findings for understanding the nocturnal lower atmosphere, trace-gas transport, and the representation of stable boundary layers over tropical forests in atmospheric and Earth-system models.

We believe that the revised Conclusions section now addresses all the elements requested in the ACP guidelines and provides a clearer synthesis of the scientific contribution and implications of the study.

The Conclusions section has been fully revised in the manuscript. Please see Lines 351-388 in the revised version.

5 Conclusions

This study investigated the seasonal, interannual, and hourly variability of the Nocturnal Boundary Layer height (hn) above the central Amazon using vertical profiles of turbulent sensible heat flux measured at the ATTO site during a La Niña year (2022) and an El Niño year (2023). The objective was to estimate hn from turbulence profiles and to examine whether its variability is reflected in the vertical distribution of CO and CH_4 above the forest. The results show substantial variability in hn between seasons, years, and hours of the night. The deepest nocturnal layers occurred during the Wet season of 2022, with mean values of approximately (270 $\pm$ 40) m, whereas the shallowest layers occurred during the Dry season of 2023, with mean values of approximately (100 $\pm$ 27) m. A systematic decrease in hn was observed during the night: in 2022, hn decreased from about 274 to 151 m in the Wet season and from about 223 to 100 m in the Dry season, while in 2023 it generally ranged between about 172 and 100 m.

The variability of hn reflects the combined influence of nocturnal radiative cooling, atmospheric stability, cloud cover, thermal stratification, and mechanically generated turbulence. Stronger radiative cooling and enhanced stability, especially during the Dry season and the El Niño year, favoured shallower and more decoupled nocturnal layers. In contrast, weaker stability and reduced thermal stratification allowed wind shear and low-level jets to maintain deeper and more vertically connected layers.

During nights with shallow hn, enhanced CO and CH_4 concentrations above the nocturnal boundary layer did not penetrate efficiently toward the canopy, producing strong vertical gradients along the tower profile. During nights with deeper hn, the CO and CH_4 profiles were more vertically homogeneous, consistent with stronger coupling between the canopy layer and the air above. Thus, trace-gas profiles provide observational support for the turbulence-based hn estimates.

By resolving the hourly evolution of hn, this study shows temporal variability in the NBL above the central Amazon that had not yet been resolved at this resolution. Using direct turbulence based estimates, we quantified clear seasonal and interannual differences in hn. We also show that this variability affects the vertical dispersion of trace gases: shallow nocturnal layers limit vertical exchange and produce strong CO and CH_4 concentration gradients, whereas deeper layers favor stronger coupling and more vertically homogeneous profiles. The mean hn values obtained here are consistent with those reported by Mendonça et al. (2025) and Huitema et al. (2026), supporting the robustness of our results. Thus, while previous studies provide important reference values for hn, our study adds a new temporal and atmospheric-composition perspective by linking hourly hn variability to trace-gas dispersion above the Amazon forest.

Some limitations should be considered. The main analysis was restricted to 2022-2023, when the complete turbulence profile up to 325 m was available at ATTO. Therefore, the contrast between 2022 and 2023 provides valuable insight into nocturnal boundary-layer variability under different climatic conditions, but should not be interpreted as a full climatological assessment of La Niña and El Niño effects on hn. Finally, the interpretation of CO and CH_4 profiles was based on selected case studies and can also be influenced by background air masses, biomass-burning plumes, wetland emissions, and concentration structures established during previous days.

Overall, these findings highlight the importance of the nocturnal boundary layer for the state and behaviour of the lower atmosphere over tropical forests. Because hn controls the depth over which heat, moisture, aerosols, and greenhouse gases are mixed or stored during the night, errors in its representation can affect simulations of atmospheric composition, surface-atmosphere exchange, and carbon-cycle processes over the Amazon Basin. Improving the representation of nocturnal turbulence, canopy-atmosphere coupling, and shallow stable layers in atmospheric and Earth-system models is therefore essential for reducing uncertainties in weather, climate, and biosphere-atmosphere interaction studies in tropical forest regions.

Sincerely,

Cléo Quaresma Dias-Júnior,

on behalf of all co-authors