Reply to Reviewer #1's comments

In this paper, the authors used machine learning technique to produce a best-estimate PBLHT by integrating four PBLHT estimates derived from remote sensing measurements at the DOE ARM Southern Great Plains observatory. The paper is generally well written, and I have some minor comments for the authors to consider.

Answer: We thank the reviewer for these suggestions and comments. We carefully revised the manuscript according to the reviewer's comments.

Line 101: There is not 'absolutely true PBLHT' because there is no unique definition of boundary layer height. Different definitions or looking at different aspects of atmospheric boundary layer could lead to different boundary layer heights.

Answer: We agree with the reviewer that there is no unique definition of boundary layer height. We changed the sentence to '…valuable information on improving PBLHT estimates …'

Table 1: 'PBLHT-sonde' should be 'PBLHT-Sonde' to be consistent with other places.

Answer: We changed it as suggested and double-checked through the manuscript to keep consistent.

Line 134: 'the Heffter method (PBLHT-Heffter) determines PBLHT as the height of the base of the lowest inversion layer' seems is not consistent with PBLHT-Heffter in Figure 1, which shows that PBLHT-Heffter is obvious higher than the base of the inversion layer.

Answer: We thank the reviewer for pointing out the issue. We changed the sentence to "the Heffter method (PBLHT-Heffter) determines PBLHT as the lowest height where the potential temperature difference between a given height and bottom of an inversion layer first reaches 2 K".

Line 139: define delta s.

Answer: in line 143, we added a sentence 'where δ_s is the minimum strength of the inversion layer' to define delta s.

Line 184: delete 'the'.

Answer: It is deleted as suggested.

Figure 1c: PBLHT-Heffter seems missing.

Answer: Thanks for pointing it out. We checked the issue and found that PBLHT-Heffter and PBLHT-Liuliang had the same PBLHT estimate at 12:30 LT in Figure 1c. We added a note in the text to clarify the confusion in line 169.

Line 206: delete 'a'

Answer: Thanks for pointing out the typo. We deleted 'a' in the text.

Line 217: need to clarify what is 'local gradient minima'. Does it mean the smallest gradient which is close to 0?

Answer: We added a sentence 'i.e., the strongest decrease of ceilometer backscatter with respect to altitude' in line 236 to clarify.

Line 225: Is each quality index different with others? What if there are more than one PBLHT candidate that have the highest quality index?

Answer: Different PBLHT candidates could have the same quality index. We added a sentence 'If there are more than one PBLHT candidates that have the highest quality index, the lower altitude PBLHT candidate is selected as the ceilometer-estimated PBLHT' in line 245.

Line 284: Why did the PBLHT-THERMO only use the Heffter method? Did you try the Liu-Liang method and Bulk Richardson number method? In addition, it is the exactly the same as PBLHT-SONDE because PBLHT-SONDE uses three methods.

Answer: We thank the reviewer for the great suggestion. It is correct that PBLHT-THERMO currently uses only the Heffter method. We appreciate the reviewer's suggestion to incorporate the Liuliang and Bulk Richardson number methods. The Heffter method identifies the PBLHT primarily by detecting potential temperature inversion layers, making it more robust to random temperature uncertainties. In contrast, the Liuliang method relies on calculating the temperature gradient at each level, which requires higher-quality temperature data. Additionally, the Liuliang and Bulk Richardson number methods depend on low-level horizontal wind information to estimate PBLHT. Although the ARM Doppler Lidar (DL) does provide horizontal wind retrievals, these measurements are affected by the lidar overlap effect at low altitudes and are limited by coarse spatial and temporal resolution. Therefore, we did not include the Liuliang and Bulk Richardson number methods in PBLHT-THERMO. We added a sentence in lines 308-310 to illustrate this.

Line 289: This might also because PBLHT-THERMO uses the Heffter method, which overestimate PBLHT at large PBLHT as shown in Figure 2a.

Answer: We agree with the reviewer that the overestimation from PBLHT-THERMO is likely related to its use of the Heffter method, which is known to overestimate PBLHT under convective boundary layer conditions. Figure r1 compares PBLHT-THERMO with both PBLHT-SONDE Median and PBLHT-SONDE Heffter estimates. As shown, the comparison with PBLHT-SONDE Heffter reveals a smaller overestimation by PBLHT-THERMO, suggesting consistency between the two methods. However, the KDE distribution remains broadly scattered under convective conditions, supporting our conclusion that the overestimation is also influenced by large uncertainties in temperature retrievals and weaker potential temperature gradients

at higher altitudes. To address this, we have added the following sentences between lines 337 and 340: "The overestimation of PBLHT is likely due to the use of the Heffter method in PBLHT-THERMO, which tends to yield higher values compared to PBLHT-Median, as shown in Figure 2a. Additionally, greater uncertainties in temperature retrievals and weaker potential temperature gradients at higher altitudes may further contribute to the overestimation."
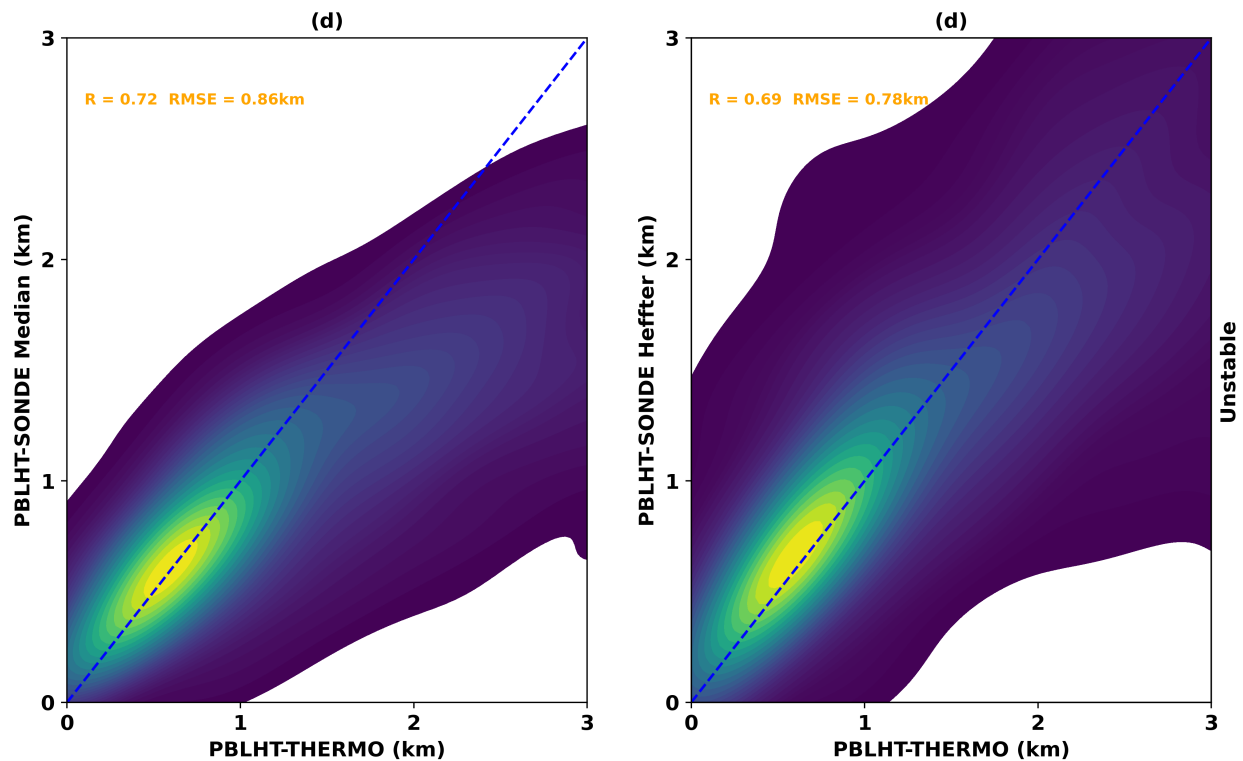

Figure r1. Comparisons of PBLHT-THERMO with PBLHT-Sonde Median and PBLHT-Sonde Heffter using kernel distribution estimate (KDE) under unstable PBL conditions.

Figure 4d, again the overestimation from PBLHT-THERMO might be caused by using the Heffter method.

Answer: We agree with the reviewer and have incorporated several sentences into the text, as discussed above.

Line 418: delete 'However'.

Answer: We deleted it as suggested.

Line 440: Change "Gain." to "Gain".

Answer: We changed it as suggested.

Line 457: Please be specific what does 'PBLHT-THERMO' dominates?

Answer: We added 'the feature importance' in line 497.

Line 461: I believe other environmental variables presented in the previous section should also be included as inputs to the ML models.

Answer: We added 'and environmental variable listed in Table 1' in line 501.

Line 506: change it to "and use it to evaluate the predicted PBLHT-BE-ML".

Answer: We changed the sentence as suggested.

Line 569: change the comma to 'and'.

Answer: We changed it as suggested.

Line 574: water vapor profiles are not used in the study.

Answer: We removed the phrase "and water vapor" from the text.