Atmos. Chem. Phys. Discuss.,
https://doi.org/10.5194/acp-2020-963-AC1, 2021

Atmospheric Chemistry and Physics Discussions

Interactive comment on "Characteristics of convective boundary layer and associated entrainment zone as observed by a ground-based polarization lidar" *by* Fuchao Liu et al.

Fuchao Liu et al.

lfc@whu.edu.cn

Received and published: 3 January 2021

Referee's Comments: This manuscript presented case studies of convective boundary layer (CBL) and entrainment zone observed by a ground-based lidar. The evolution of CBL has been described by four stages. The values of CBL depth and entrainment zone thickness (EZT) are reported under different stages. However, the paper only discusses a few cases. Meanwhile, the meaning and significance of this study are not clear. Therefore, this paper needs major revisions before publication.

Authors' response: We greatly appreciate this Referee for the thoughtful considerations and pertinent comments on the current manuscript. Following the Referee's construc-

tive suggestions, we have added another two typical clear-day cases; besides, we have revised the Abstract and Introduction parts to point out the meaning and significance of this study. In response to the Referee's concerns, all necessary modifications are made point by point in the revised manuscript.

Specific Comments: 1. The characteristics of CBL and entrainment zone are widely reported in numerous previous papers. I do not find the new characteristics of CBL in this study. The authors may carefully consider the title. The title also should include the measurement location (Wuhan).

Authors' response: We thank the Referee for the suggestion of a more appropriate title for concluding the current work. Now the title has been changed to "Characteristics of clear-day convective boundary layer and associated entrainment zone as observed by a ground-based polarization lidar over Wuhan (30.5°N, 114.4°E)" to state that the conclusions are limited to clear-day weather conditions and to the observational location of Wuhan (30.5°N, 114.4°E).

The CBL depth is analyzed in this study according to its four evolution stages and it is found "The instantaneous CBL depths exhibited different fluctuation magnitudes in the four stages and fluctuations at the growth stage were generally larger", which we believe is distinctive from previous studies.

2. The introduction part needs improvements. Currently, this section introduced some related works, but did not state the limitations in previous studies. This section also did not tell readers the novelty of this work.

Authors' response: We thank the Referee for the constructive comments on the introduction part. Along these valuable suggestions, the sentences "However, the above two introduced methods yield EZT values with large differences (e.g., Pal et al., 2010); the choice of specific percentages of air having the FA characteristics for the definition of EZ bottom height is variable (between 5% and 15%) among different researchers (e.g., Deardorff et al., 1980; Wilde et al., 1985; Flamant et al., 1997; Cohn and Angevine, 2000; Pal et al., 2010). Moreover, considering that variations of ABL depths can result from not only entrainment but also non-turbulent processes (e.g., atmospheric gravity waves and mesoscale variations in ABL structure), the methods depending on variations of ABL depth might not really characterize the true EZ (Davis et al., 1997). So far, no universally accepted approach exists for the determination of EZT (Brooks and Fowler, 2007)" are added to review on the limitations of the current EZT determination approaches. Besides, the last paragraph of the introduction part now reads "Currently, studies are generally concentrated on the CBL while relatively rare on the EZ. The basic physical processes governing entrainment and their relationship with other boundary layer properties are still not fully understood (Brooks and Fowler, 2007). Besides, the general grid increments of state-of-the-art weather forecast and climate models are too coarse to resolve small-scale boundary layer turbulence (Wulfmeyer et al., 2016). Therefore, continuous and high-resolution measurements at various observational locations to infer detailed knowledge on both CBL and associated EZ, especially small-scale boundary layer turbulence therein, are of significant importance to boundary layer related studies including land-atmosphere interaction, air quality forecast and almost all weather and climate models (Wulfmeyer et al., 2016). In this work we present the high-resolution measurement results of the CBL and associated EZ using a recently-developed titled polarization lidar (TPL) over Wuhan (30.5°N, 114.4°E). The TPL is housed in a specially-customized working container and capable of operating under various weather conditions (including heavy precipitation). The TPL has an inclined working angle of 30° off zenith and routinely monitors the atmosphere with a time resolution of 10 s and a height resolution of 6.5 m. The equivalent minimum height with full overlap for the TPL is ∼173 m above ground level (AGL). Based on the TPL-measured backscatter, a new approach has been developed for determination of the EZT. The small-scale characteristics of the CBL and associated EZ have also been investigated which can contribute to the improvement of understanding the structures and variations of the ABL, as well as parameterization of the EZ. The instrument, methodology, observational results and summary and conclusions are stated succes-

sively in following sections" to state the meaning, significance and novelty of this work. We feel that the introduction part has been greatly improved after modification.

3. The manuscript classified the evolution of CBL into four stages. However, it is a well-known feature, which is well discussed by Stull. (1988). I suggest the authors refer such classifications to the previous papers.

Authors' response: Following the Referee's suggestion, the excellent work by Stull (1988) has now been referred to in the revised manuscript for classifying the evolution of CBL into four stages.

4. The determination of EZT is a highlight in this study. Nonetheless, there is a lack of validations of EZT retrievals derived from FWHM. The limited cases also cannot support the robustness of this method.

Authors' response: We thank the Referee for suggesting validation of the EZT from the FWHM method. We believe this FWHM method to be physically sound as it directly reflects the mixing history of the aerosols (tracer) in the EZ. However, direct validation of the EZT retrievals is difficult as reviewed in the Introduction "So far, no universally accepted approach exists for the determination of EZT" and the existing approaches have their own deficiencies. A comparison with EZT result determined by its theoretical definition that corresponds to the vertical region with mean negative buoyancy flux might be favoured in future. Besides, two more clear-day cases are added in the revised manuscript to support the robustness of this method.

Along the Referee's suggestions, a special paragraph is now added to discuss on this issue in an added subsection "4.3 Discussion on the clear-day EZT statistics and the FWHM method". It reads "Note the proposed FWHM method utilizes the FWHM of the variance profile of the ABR fluctuations to quantify the EZT. We believe it to be physically sound as it directly reflects the mixing history of aerosols (tracer) in the EZ. When applying it to lidar data, it definitely determines the EZ (and consequently the EZT) when turbulence is dominating and the variance profile of ABR fluctuations has clearcut edges. However, caution must be taken when turbulence is weak and the variance profile of ABR fluctuations suffers from interference of residual layer and/or advected aerosols. The retrieved EZT values for the four typical clear-day cases mostly fall into the 50-150 m range with a percentage of ≥67%, while the overall EZT values range from 0 to 340 m. Pal et al. (2010) reported the lidar-derived EZT retrievals for a summer case using the cumulative frequency distribution method, which had mean values of 75 m and 62 m and magnitude ranges of 10-230 m and 0-200 m for the quasi-stationary and growth stages, respectively. While for the early autumn case in this work, the EZT results had mean values of 113 m and 123 m and magnitude ranges of 41-279 m and 39-289 m for the quasi-stationary and growth stages, respectively. These observational results differ obviously for the mean EZT values and magnitude ranges. But this comparison seems not rigorous as the EZT results were obtained at distinct observational locations. For a better validation of the reliability of the FWHM approach, comparisons with EZT values retrieved by co-located intensive radiosonde or by synergy of high-resolution temperature lidar (Behrendt et al., 2015) and Doppler lidar (Ansmann et al., 2010), in which situation the EZT might be determined by its theoretical definition that corresponds to the vertical region with mean negative buoyancy flux (Driedonks and Tenneke, 1984; Cohn and Angevine, 2000), shall be favoured in the future".

5. Page 15, line 457. The statement is not appropriate. The ratio of EZT to CBL depth cannot support the accuracy of the retrieved EZT values.

Authors' response: We agree with the Referee and now the sentence "Considering the observed ratios of EZT to CBL depth mostly have values of <20%, the retrieved EZT values seem reasonable" has been deleted in the revised manuscript.

6. The authors may consider revising the manuscript type as "Measurement Report", which more fit the scope of this study.

Authors' response: Following the Referee's suggestion, we change the manuscript type as "Measurement Report" to fit more the scope of this study.

Please also note the supplement to this comment:
https://acp.copernicus.org/preprints/acp-2020-963/acp-2020-963-AC1-supplement.pdf

Interactive comment on Atmos. Chem. Phys. Discuss., https://doi.org/10.5194/acp-2020-963, 2020.