Manuscript: amt-2023-80

Title: Deep-Pathfinder: A boundary layer height detection algorithm based on image segmentation

Dear Reviewer:

Thank you for your time and effort to carefully comment on the manuscript. The manuscript has been thoroughly revised based on all comments. Furthermore, your feedback has been acknowledged in the 'Acknowledgements' section of the paper:

"The authors would like to acknowledge the anonymous reviewers for their valuable feedback, which helped improve the quality of the original manuscript." (see lines 448–449)

Reviewer 1, summary:

This paper addresses a very interesting topic and proposes an interesting solution, which can be applied in several ceilometers stations. However, some conceptual points need to be better described/commented.

A point-by-point response to your feedback is provided below.

General comments:

1. Line 123: This is a conceptual error. The Mixing Layer does not exist during the night. After sunset, due to a stable regime, the ML becomes Stable Boundary Layer and Residual Layer.

This has been corrected. For consistency with existing studies, the same layer definition has now been applied in our paper.

The following has been added to the Introduction section:

"Various sub-layers can be identified within the ABL, each with different properties. For example, one of the processes observed in the ABL is the vertical mixing of air. In our study, the same definition to characterise layers is used as described in Kotthaus et al. (2023). The term mixing boundary layer (MBL) is used to refer to the ABL sub-layer closest to the ground. Its height (MBLH) may indicate either the convective boundary layer (CBL) height or stable boundary layer (SBL) height, whichever is present at the given moment. The MBLH terminology is applied when no information on atmospheric stability is available to differentiate between SBL and CBL (Kotthaus et al., 2023, p. 435)." (see lines 21–26)

Further, the sentences mentioned in the comment were changed as follows:

"During nighttime, the pollution rich layers may drop to very low altitudes into the incomplete-overlap region of the CHM15k ceilometer and vertical mixing in fact ceases to exist. However, the concentration levels of pollutants remain layered and, therefore,

Cabauw mast measurements were used to aid in the identification of the presence and height of nocturnal layers." (see lines 170–173)

2. Line 126: The MLH only occurs during the daytime, because it is a convective process.

MLH has been changed to MBLH, corresponding to the definition added in the Introduction section (see our response to comment #1).

3. Line 127: How is possible to identify the Stable Boundary Layer from RCS if such a layer has only a thermodynamic definition? RCS provides the top of different aerosol layers, which in some cases can be coincident with a stable layer top, but it is not a rule. It is necessary a temperature and/or wind speed profile to identify a stable regime.

This description has been corrected.

The following has been added to the manuscript:

"Note that the attenuated backscatter retrievals during nighttime are not equivalent to the SBL or nocturnal boundary layer (NBL) defined by thermodynamics. Our MBLH definition (see Sect. 1) has been adopted for consistency with existing methods for MBLH detection and for comparison of results with these reference methods." (see lines 164–167)

4. Figure 7: MLH only occurs during the daytime. The MLH does not decrease it becomes Residual Layer and Stable Layer, it is important to present such division in this picture.

In the caption MLH has been changed to MBLH, corresponding to the definition added in the Introduction section (see our response to comment #1).

Technical comments:

5. Line 26: "throughout the low atmosphere"

The manuscript has been changed according to this suggestion. (see line 32)

6. Line 26: I recommend changing "Further" per "Consequently", because you used "further" other time in the same phrase

The double use of "further" in this phrase has been corrected. (see lines 32–34)

7. Figure 2: It is necessary to correct this figure, because the Mixing Layer only occurs during the daytime.

We agree that the mixing layer occurs during the daytime. However, being able to differentiate and track different sub-layers during the night is still important as it reviews

characteristics of the ABL development, and being able to consistently follow selected layers is a crucial step for layer attribution and further quality control/flagging.

Other MBLH detection methods also provide profiles for the entire day (e.g., the STRATfinder and Lufft algorithms described in the paper). Therefore, the definition of the mixing layer has been updated to MBLH for consistency with the reference methods (see our response to comment #1). The caption of the figure has also been updated.

8. Line: 119: MLH only occurs during the daytime

MLH has been changed to MBLH, corresponding to the definition added in the Introduction section (see our response to comment #1).

9. Line 124: nocturnal MLH : MLH only occurs during the daytime

The phrase "of the nocturnal MLH" has been removed from the manuscript. (see line 173)

10. Line 125: nocturnal MLH : MLH only occurs during the daytime

This sentence has been changed as follows in the manuscript:

"When RH at various height levels were similar, we considered this to be a more or less homogeneous nocturnal layer, and the layer height was approximated as the altitude where the RH values of higher layers with respect the lower layers started to diverge." (see lines 173–175)

11. Line 139: nocturnal MLH : MLH only occurs during the daytime

This has been revised as follows in the manuscript:

"The transition region from the daytime convective (mixed) boundary layer to a neutrally stratified residual layer (RL) with a stable NBL below, may not be clear from aerosol data (Schween et al., 2014). To complete the annotations in this region, the thermodynamic data informed the gradual decline towards the nighttime MBLH." (see lines 188–190)

Reference:

Schween, J. H., Hirsikko, A., Löhnert, U., and Crewell, S.: Mixing-layer height retrieval with ceilometer and Doppler lidar: from case studies to long-term assessment, Atmospheric Measurement Techniques, 7, 3685–3704, https://doi.org/10.5194/amt-7-3685-2014, 2014.

12. Line 140: Is the figure number correct?

This figure number was indeed incorrect. The order of figures 2 and 3 has been swapped during the revision process, so the reference in the text is now correct. (see line 192)

13. Line 222: This phrase is redundant because the convective boundary layer only occurs during the daytime

This has been corrected by removing "during daytime" from the manuscript.

The adjusted sentence is:

"The CBL was typically captured well by all three methods, with minimal differences in MBLH between them." (see lines 277–278)

14. Line: 225: nocturnal MLH : MLH only occurs during the daytime

MLH has been changed to MBLH, corresponding to the definition added in the Introduction section (see our response to comment #1).

The corresponding sentence in the manuscript has been changed as follows:

"Deep-Pathfinder and STRATfinder identified the nighttime MBLH around 100–200 meters altitude, although STRATfinder estimates were at a constant level slightly above the actual MBLH due to guiding restrictions in the algorithm." (see lines 279–281)

15. Line: 255: nocturnal MLH : MLH only occurs during the daytime

The corresponding paragraph has been rewritten as follows:

"Table 3 shows that the mean absolute difference between Deep-Pathfinder and STRATfinder was lowest during the evening, night and early morning growth phases. In contrast, the early and late afternoon is where they were least similar (see explanation above). The Lufft algorithm obtained higher estimates than both other algorithms during the evening, night and early morning growth phases, as it had a tendency to follow aerosol or moist layers in the residual layer (see Sect. 3.1)." (see lines 321–324)