Response to Anonymous Referee 1

Referee comments are indicated in *italic*, followed by our reply.

The publication by V. Vakkari and co-workers presents a novel approach for detecting the top of shallow mixed/mixing layers by using scanning Doppler lidars. Based on two measurement campaigns, the authors explain the new technique in detail, show various comparisons and finally present results of the derived MLH. The results presented are very interesting and indicate that often very shallow mixing layers are present at the measurement locations which can be captured only by applying the new method. Beside some exceptions, the paper is well written and methodology and results are well discussed. Thus, I conclude that the paper is of major interest, both in terms of technical and scientific nature, for the community and I recommend it for publication after minor revisions.

We would like to thank the referee for his good comments, which have improved the manuscript.

General statements:

-The authors selected the threshold for the detection of the mixing layer top to 0.05. This "setting" seems a little bit arbitrary because no explanation is given. Is there a theoretical background or is it just the threshold which seems to be the best working? What is your experience when changing the threshold - is there a high sensitivity in MLH determination? You just show 4 case studies, but how stable is this threshold for a longer times series, do you think this threshold can be applied for very different locations? Please discuss this. I personally have no problem with applying a threshold which has been chosen after testing different thresholds for the data set. However, in this case a little sensitivity study would be much more convincing that the chosen threshold is the "right" one. For example, modify the threshold by +-0.01 and show the corresponding numbers (e.g. percentages in sec. 3.3 etc.) also for the varied threshold. If this makes no sense, explain why. Even better if the threshold was chosen on a physical meaningful basis. But then please explain its meaning.

We have added the following discussion on the VAD-based MLH estimate sensitivity as a new section after Sect. 3.2.

"To check the sensitivity of the MLH determination to the choice of threshold, we varied the VAD-based MLH detection threshold by ±0.01 $m^2 s^{-2}$. Increasing the σ^2_{VAD} threshold value decreases the MLH estimate; at Limassol, applying a threshold of 0.06 $m^2 s^{-2}$ leads to, on average (mean), MLHs that are 16 m lower in the 30° elevation angle VAD data. For the 10° elevation angle VAD at Limassol the higher threshold gives MLH 9 m lower on average. Additionally, at Limassol, the increased σ^2_{VAD} threshold indicates MLH to be below the lowest usable range gate on 10 % of the cases when the 0.05 $m^2 s^{-2}$ threshold still indicates a non-zero MLH.

In the Loviisa data set increasing the VAD-based MLH threshold has a smaller effect: for the 15° elevation angle VAD the MLH estimate decreases by 11 m on average, and for the 4° elevation angle the MLH estimate decreases by 3 m on average. There a fewer cases at Loviisa when the increased σ^2_{VAD} threshold indicates MLH below the lowest usable range gate: 4 % of cases in the 15° elevation angle VAD, when the 0.05 $m^2 s^{-2}$ threshold gives a non-zero MLH; and 1% of cases for the 4° elevation angle VAD when the 0.05 $m^2 s^{-2}$ threshold gives a non-zero MLH.

Decreasing the σ^2_{VAD} threshold increases the MLH estimate. At Limassol, decreasing the σ^2_{VAD} threshold from 0.05 $m^2 s^{-2}$ to 0.04 $m^2 s^{-2}$ increases the 30° elevation angle VAD-based MLH estimate on average by 29 m. For the 10° elevation angle VAD-based MLH estimate the mean increase is 17 m. At Loviisa, the respective mean increase in the 15° elevation angle VAD-based MLH estimate is 15 m and in the 4° elevation angle VAD-based MLH estimate 4 m.

Compared to the scatter between the 30° elevation angle VAD-based MLH and the TKE-based MLH in Fig. 8, the changes in the VAD-based MLH due to ±0.01 $m^2 s^{-2}$ changes in the σ^2_{VAD} threshold are small. For applications where accurate MLH detection is of critical importance a more sophisticated MLH detection scheme than the flat threshold used here would be appropriate. The flat threshold is clearly a reasonable and robust initial estimate, and the selected threshold of 0.05 $m^2 s^{-2}$ gives the best agreement with the MLH inferred from the TKE profile with a threshold of 10^{-4} $m^2 s^{-3}$."

-I do not understand what is shown in table 3 and the explanation for that in the text is not sufficient. What is the reference mixing layer height? Is that a mean? Please extend caption of table 3 and the corresponding text in the manuscript for that comparison and write scientific clearly! For example: 12230, "… VAD based mixing heights agree reasonably well with the vertically-pointing measurements at the lowest vertically-pointing range gate." What does agree well? The VAD based mixing height with ??? What do you want to express?
Or: 12230: "Mixing heights from 4° and 15° elevation angle VADs also compare well for the lower altitudes of the 15° elevation angle VAD". What compares well to what? You talk 2 times of the 15° VAD…I simply do not understand.
Or: Caption tab 3: What is meant with lowest gate?

We clarified the comparison in the Sect. 3.2:

Page 12230, lines 19-22, re-written as: "However, when the vertically-pointing measurements indicate MLH at the lowest usable range gate (i.e. a MLH of 120 m a.s.l. at Limassol and a MLH of 159 m a.s.l. at Loviisa), the 10° and 15° elevation angle VADs also indicate a MLH in the same range, as indicated in Table 3."

Page 12230, lines 28-29, rewritten as: "MLH from 4° and 15° elevation angle VADs also compare well when the 15° elevation angle VAD indicates MLH of 55 m a.s.l. (Table 3)."

We have also rewritten the Table 3 caption:

"Table 3. Comparison of VAD and vertically-pointing MLH estimate. For Limassol data the 25th, 50th and 75th percentile of the VAD-based MLH are presented for the cases when the nearest-neighbour TKE-based MLH is 120 m a.s.l.. For Loviisa data, the 25th, 50th and 75th percentile of the VAD-based MLH from the 15° elevation angle VAD are presented for the cases when the nearest-neighbour TKE-based MLH is 159 m a.s.l.. The 25th, 50th and 75th percentile of the VAD-based MLH from the 4° elevation angle VAD at Loviisa are presented for the cases when the nearest-neighbour 15° elevation angle VAD -based MLH is 55 m a.s.l.."

We also changed the "Reference mixing height" into "Vertically pointing MLH".

Specific comments:

Preface: Even if it seems that most of the comments below are niggling, I am convinced that phrasing in scientific publications should be unambiguous. Therefore the sometimes colloquial language in the text should be rephrased, so that also a reader without precognition can understand everything clearly. Below, find some examples; most comments are in the introduction which seemed to be written last…

We would like to thank the referee for his thorough review. These comments are valuable in improving the manuscript.

-12220, 1: The authors use several expressions for the mixing layer height, e.g. also mixing height, mixed layer height, mixing layer top, MLH etc... I would appreciate very much if the authors could use a scientific correct expression (mixing height is not the one) and use this the always in the text. I.e. MLH was defined but never used - so probably go for mixing layer height and use MLH always after definition of the abbreviation.

We have replaced all different expressions for MLH with MLH.

-12220, 2: "its" instead of "the" before diurnal, or what diurnal variability you want to capture?

Corrected.

-12220, 15, word 1: Mixing of what? I guess you mean turbulent atmospheric mixing? Please rephrase correctly.

Corrected.

-12220, 16 "Turbulent mixing is regarded as a significant player in aerosol microphysical processes and in cloud microphysics". Please explain the connection to MICROphysical processes. This is not straight clear.

The presence of turbulence causes local supersaturation, directly involved in new particle formation rates (aerosol) and cloud droplet formation, and also impacts cloud droplet collision/coalescence through clustering. These topics, and others, are all discussed in the references, and are therefore not so relevant to include here.

-12220: "representing" instead of "to represent"

Corrected.

-12220, 21: "stable layers": Stable concerning what? What layers? Do you mean thermodynamically stable stratified air layers?

We mean thermodynamically-stably stratified layers and have now referred to these as "stably stratified" throughout the text, in common with the standard literature.

-12221, 5: same as above

Please see the previous reply.

-12223, 7: 30° instead of 30

On line 27 one ° was missing, which is now corrected.

-12223, 28: Please bring reference or explanation of DBS even if not used in the paper or leave out as it is not of interested.

The following phrase, with reference, has been included in the text ‘, an alternative method for retrieving the vertical profile of horizontal wind (e.g. Lane et al., 2013);’

-12224, 6 and several times below: “24-point VAD”, points = radials, i.e. azimuthal directions? What do you mean with points? This is not clear. Please state clearly.

By points we mean here the number of azimuthal directions. We have replaced “point” in this use with “azimuthal direction” throughout the paper.

-12225, 18: “a high correlation indicates that the residuals are dominated by flow patterns in a length scale that is large compared to the 30m radial resolution of the instrument.” Please explain why a high correlation indicates this! It is not simply evident to me.

Here the reasoning is that if ΔV_R correlates with ΔV_{wind}, then ΔV_{wind} must be large compared to ΔV_{turb}. Hence, to get the correct ΔV_{turb}, ΔV_{wind} has to be calculated from the vertical wind profile. However, as the method can be described without this point being explicitly made, we have decided to remove Fig 2c and related discussion.

-12226, 7: Why is a high correlation an evidence for the need of considering the height profile of the wind? Explain in more detail.

Please see the previous reply.

-Figure 2d is never referenced nor explained.

We have added a reference to Fig. 2d in connection to Eq. 9.

-12227, 3-5: It took me quite some time to figure out how you came up with this formula (Eq. 9). Finally, I realized that the text and the formula are not fitting together. Therefore you should modify the text as follows: Thus the proxy variable for identifying turbulent mixing is the variance of the difference of residuals from two consecutive elevation levels in a VAD subtracted by the variance of the corresponding measurement uncertainty.

Corrected.

-12227, 9, Eq. 10: I think the squared (ˆ2) is not at the correct place as you do not square (r+30m) but sigma(r+30m).

Corrected.

-12227,17. 24 points, see comment above

Corrected, see reply above.

-12227, end: So finally you get a VAD profile, right? So what is the difference between VAD and the so-called PPI scans? Please also state, that you use the whole profile in the following and not only the ONE at distance r.

In principle, PPI and VAD scans are the same – conical scans at a constant elevation angle. If the scan is close to the horizontal (typically an elevation angle < 5 degrees from horizontal) then the scan is termed a PPI, scans with higher elevations angles are termed VADs.

Please see also the reply to the next comment.

-12227, end: So for Cyprus you really used the 360°, right?

Yes. We have added the following sentence to the end of page 12227: "For 10° and higher elevation angle VADs we used the full 360° to determine the σ^2_{VAD} and MLH."

-12229, 1-5: The 4° figure is not discussed, why?

We have included Fig. 3d in the discussion here in reply to Referee 2.

-12232, 14: "…below the lowest measurement at vertical" Please rephrase. Simply "at vertical" is not correct in my opinion.

This has been rewritten as:

"below the lowest usable range gate in vertically-pointing measurement mode."

-12232, 16: ";" instead of ":"

Corrected.

-12232, end: A short discussion, if the technique could be also used on flat continental sites would be interesting. Or at least give a short statement.

We chose the two coastal locations to develop the methodology simply because one would expect low MLH more frequently at a coastal location than at a continental location. We have added the following sentence on page 12231, line 21:

"Although the method was developed based on measurements at coastal locations, it is applicable to any environment that meets the criteria discussed in Sect. 2.2."

Caption, Fig 9: again rephrase "below vertical" , i.e. below the minimum range gate during the vertical pointing measurements.

We have replaced "minimum range at vertical" with "the lowest usable range gate in vertically-pointing measurement mode" in the caption.