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Comment on amt-2021-295

Anonymous Referee #2

Referee comment on "Boundary-layer height and surface stability at Hyytiälä, Finland, in ERA5 and observations" by Victoria Anne Sinclair et al., Atmos. Meas. Tech. Discuss., https://doi.org/10.5194/amt-2021-295-RC1, 2021

Comments on « Boundary-layer height and surface stability at SMEAR II, Hyytiälä, Finland in ERA5 and observation" by Sinclair et al.

This study provides stability and planetary boundary layer height estimations from various methods (bulk Richardson with two critical thresholds, Heffter (1980), Liu and Liang (2010), MWR software) and various time series (Radio-sounding, Microwave Radiometer and ERA5 reanalysis) at a background site in Finland. The BAECC campaign in 2014 provide a 7.5 months of radio-sounding data and the MWR is operated since 2018. No comparison between RS and MWR is therefore possible. A comparison between methods and instruments as a function of the atmospheric stability is presented as well as a long-term climatology of the ABLH based on ERA5 (1979-2019) and of the surface-layer stability (1997-2019). Finally, the spatial representativeness of the ABLH measurement is derived from the spatial correlation of ERA5 results. The use of the atmospheric stability as a main variable for the comparison between methods and instruments as well as for the climatology is a strong point of this study.

Main comments:

- The parcel method is a commonly and widely used method in the CBL determination. It is applied by the automatic BL detection from the MWR but not on RS. A comparison of this method with the already applied on RS would have been worth. Similarly, the Heffler and part of LL10 methods applied on RS could also be used for MWR.
- The MWR has data since June 2018 leading nowadays to a 3 years time series. A one-year time series is presented in Fig. 8. A climatology with these measurements (at least the year presented) would also be very valuable and allow a comparison with the ERA5

long-term time series.

- The radiosondes data are only available from February to mid-September. What would be the impact of the October-January (i.e. most of the fall and winter periods) on the comparison between the methods ? On the validation of ERA5 ? If ERA5 cannot be considered as validated for Fall and Winter, should the comparison between ERA5 and MWR and the climatology be discussed differently ?
- Discussion of Fig. 5, 6 and 7:(§ 5.1, 5.2 and 5.3) : the comparison between the methods as a function of time and of stability is very interesting. The description is fine and could be published as it. It could however be largely improved if the structure of these § would rely on the differences between methods. E.g. 1) The largest differences are found between Heffler and the other methods in very unstable cases à due to the required temperature difference of 2K. Is it possible to improve this Heffler detection by lowering the required T difference in case of unstable situation ? 2) ERA5 has the large discrepancy in case of very stable situations à is it due to the lower vertical resolution, due bias in T profile or in wind profiles ?, 3) ERA5 agree better with Ri0.5 for very unstable cases à due to the lower vertical resolution (L457-463). 4) at 00 UTC or in case of stability, LL10 leads to higher MLH à inherent to the used method since LL10 estimate ~the top of the stable layer or the LLJ and the Ri a very shallow height that does not really correspond to a physical layer. 5) ERA5 > MWR in very unstable cases à Ri gives higher MLH than the parcel method. 6) ERA5 << MWR in case of stability à MWR measures the top of the stable layer and Ri another usually shallower layer. I am aware that a reorganization of the section represents a lot of work but I think that it would improve the manuscript. An alternative would be to enhance these points in the discussion.

Minor comments (some of them are just similar to main comments):

- L 17: please mention that the climatology rely only on ERA5 time series
- L 220: what is the initial vertical grid of the radio-sounding? What are the reasons for sub-sampling RS vertical profiles and the potential consequences on each PBLH detection method?
- L 222-229 H80: Is the PBLH very sensitive to the chosen potential temperature difference of 2K and to the 15 hPa vertical resolution?
- L 230-240: For convective BL, LL10 has a large similarity with the parcel method. The differences between both methods are 1) the parcel method take the potential temperature at ground (2 m) and LL10 at 150 m, 2) the parcel method use an instability threshold of 0 (and 0,5 for LL10) and 3) LL10 takes the first level with the potential temperature gradient > 4.0 K km^{-1} higher than the level with the potential temperature difference with the one at 150 m < 0.5. Differences 1) and 3) lead to lower and higher PBLH than the parcel method, respectively. Are the PBLH sensitive to the various thresholds ? What is the difference between LL10 and the parcel method in case of unstable situations ? This is important since the MWR use the parcel method.
- L249: -9999 corresponds to a missing value but it's real value is not important and differs as a function of the programming language.
- Figure 2: The RS profile corresponds to the 5 hPa or 15hPa vertical resolution? a plot of the bRi number could also help to understand the difference between the threshold and explain the failure of this method at 12 UTC. A smaller vertical extend of the y scale for

the 00 UTC case could help to see the differences between the methods.

- L 306: it would help to know what are the potential reasons leading to underestimation by the Ri methods. It has also to be mentioned that ERA5 (also a Richardson number-based method) is ok contrarily to Ri applied to RS.
- L324-325: the subject of "is within the range…" is not clearly defined.
- L348-349 and 353-355: the fact that the nocturnal (or stable) BL are different between MWR and ERA5 rely mostly on the applied method. ERA5 uses Ri that gives a MLH almost at ground in case of atmospheric stability; the layer given by Ri during the night is however physically/thermodynamically not well defined. MWR search for the vanishing potential temperature gradient corresponding to the top of the stable layer. Both methods cannot be directly compared in such a case.
- L377- 378: this is not obvious. The same data are used but the comparison is between BLH.
- L391-393: grammatical problems.
- L396-399: Per definition, the parcel method always detect a lower BLH than the Ri. The cases LL10>Ri and LL10<Ri should then be discussed as a function of the differences (see comment L230-240) between LL10, the parcel method and the Ri one.
- L 420-421: "The LL10 scheme and especially the H80 method produce the deepest BLs when the surface layer is very unstable." It seems then that in case of large unstability, the LL10 "over-shooting parcel" is responsible of the higher BLH than the Ri method. Is my assumption right ?
- L427-428 + Fig 6:" When weakly stable and near-neutral stable conditions are considered, the LL10 scheme has the shallowest BLs and the narrowest distributions": From which stability threshold the LL10 method apply the neutral and the stable detection method ? This info can help interpreting Fig. 6.
- L504-510: For high stability the Ri (ERA5) leads per definition higher MLH than the parcel method (MWR) à this explain the results (see main comment 4)
- L518-519: "These statistical results from the very stable case support our finding from the case study (Section 4.2) that the height of the BL diagnosed by the MWR under stable conditions can be significantly overestimated": I do not agree with this formulation. The method applied to MWR in stable cases is just different and try to measure another sublayer than ERA5. This sublayer corresponds also not to aerosol layers measured by ceilometers.
- L542-544:" Note that the stable BL height values from the MWR have been filtered out, so most of the MWR BL heights during summer nights are not seen in Figure 8." Why ? I expect (due to the applied methods) that the removed MWR BL were higher than the ERA5. Is this right ?
- L563-564: do you have a tentative explanation for these kind of cases ?
- L566-572: it is however very important here to consider (and write a reminder for the reader) that most of the fall and winter periods (15 september-January) were not taken into account in the comparison between RS and ERA5. ERA5 was then considered as a good BLH retrieval method for spring and summer, when the atmospheric stability is very different than during fall and winter. MWR remains a measuring system and ERA5 a reanalysis, so that MWR results cannot be discarded without any clear reason. In fact, you wrote in the discussion (L728-729) "Thus, ERA5 still cannot capture the depth of very stable BLs accurately, which is likely due to deficiencies in the BL parameterization of lack of resolution". It is then very important to take this conclusion into account when describing and discussing the climatology.
- L574: Fig. 8 shows a complete year of MWR data. Why not at least provide the seasonal cycle of this first year of measurement?
- L575 as explained in a previous comment, ERA5 was validated only for spring and summer. In fall and winter (as seen in the climatology) weakly stable and near-neutral stable cases are much more frequent. In these cases, Ri can be largely influenced by the wind component (see results L584-586). This should be discussed anywhere.
- L638-645: same comment as for L575: the night seasonal cycle of BLH should also be discussed as a function of the wind compound in Ri method.

- L660-661: this conclusion is right only if Ri method is the right method to resolve BL height.
- L752-754: "A key outcome of our analysis is that the MWR does not reliably estimate the BL height under stable conditions, which at Hyytiälä, occur commonly at night between April and September." Once again, ERA5 and MWR just apply different methods estimating different sublayers in case of stable conditions.
- L760: once again, ERA5 was validated mostly in spring and summer. This should also be taken into account in the discussion.
- 4: would it be possible to color dots of c), e) and f) with EC stability ? (or all plots with EC stability)
- 7: since the MWR time series appears thereafter, I would indicate in the legend the period of comparison.
- 9: please also indicate the used period of time.
- Fig 11: mention that a) and b) correspond to ERA5 BL heights
- 12 (and similar figure in the supplement): it's not clear if all the plotted correlations (r>0.75) are statistically significant. Are correlations with r>0.75 sometimes also statistically significant ?
- Bigger font size in Figure S1 would be nice