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Interactive comment on "Comparison of aerosol LIDAR retrieval methods for boundary layer height detection using ceilometer backscatter data" *by* Vanessa Caicedo et al.

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We thank Referee 2 for carefully reading our manuscript and for the suggestions for revising and improving our work. Below we provide the Referee's review (in bold) followed by our response to individual comments. For reference and help to find the modifications made, we appended a revised version of the manuscript to our responses.

The subject of this paper is the comparison of three algorithms used for estimation boundary layer height (BLH) from a ceilometer CL31 produced by Vaisala. The comparison is performed with an independent dataset of BLH estimates obtained from colocated radiosonde profiles. The algorithms applied to the ceilometer signals are: the Vaisala Corp. BL Matlab v1.3, a cluster methodology

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Discussion paper

as proposed by Toledo et al. 2014, and a Haar Wavelet method. The methodology for retrieving BLHs from the ceilometer are described enough, as well as the methodology used for estimating the BLHs from the radiosondes. The results show a good agreement for all the methods considered. However, as also referee 1 suggests this is an obvious result when considering BLHs during daytime in cloud free conditions. The results obtained are a confirmation of those obtained by Haman et al. (2012). Unlike similar works Milroy et al. 2012, Haeffelin et al. 2012, Schäfer2011, the comparison is performed using only one optical instrument. In their conclusions the authors suggest further studies involving more instruments. However, the authors should include a discussion on how their results can be considered if comparing with other instruments: the CL31 was used in several campaigns together with other ceilometers and lidars. We appreciate the reviewer's suggestion. The goal of our study was to arrive at the most reliable automated method testing the same method as Haman et al. (2012) plus the additional two methods we have tested. Our results showed to be the most reliable without using cloud signals (Figure 13). We have added references of some studies that have used our 3 retrieval methods selectively with other instruments in order to evaluate the efficiency of the method on the selected instruments. These references are cited throughout the paper: Toledo et al. (2014) used the cluster analysis on a MicroPulse LIDAR. Compton et al. (2013) applied the wavelet algorithm across 3 instruments: an elastic LIDAR (Elastic Lidar Facility) a MicroPulse LIDAR, and a wind profiler. Lastly, Scarino et al. (2013) used the wavelet method for the NASA High-Spectral Resolution LIDAR. To our knowledge, the gradient method described in our paper, has not been tested on other LIDARs expect for the Vaisala ceilometers (CL31, CL51, LD40 etc.), as it is Vaisala proprietary. These studies tested one of our algorithms across different instruments while we sought to arrive at the most automated method for the retrieval of the BLH using the CL31. We have also added references to the Haeffelin et al. (2012) (p.2, l.16-18), Schäfer et al. (2011) and Milroy et al. (2012) studies (p.2, l.9-11) since they contain valuable information of BLH retrieval methods using various LIDAR instruments and additional BLH retrieval methods than those used in our study for the CL31 ceilometer.

On my opinion, the most relevant aspect of this paper is the use of the cluster method, which unfortunately seems to be the one performing less well than the other two. The Haar Wavelet method used is the one that performs better. Also this conclusions is perfectly in line with the literature on this topic. In particular the issue of having multiple candidates and the selection methods are explored is a known issue since Endlich 1979 for the gradient method and Davis 2000 for the HaarWavelet. However, the authors do not face this issue directly, as they use a reference sample, which presents conditions of fully developed boundary layer (13:00 CST). We have added Figure 1, which shows the seasonal and launch time distribution of the radiosondes used. As shown in Figure 1 launch times were not restricted to 13:00 CST, only. We have also added Figure 8, which displays a time series of all algorithms showing their performance.

On Fig. 5 the authors present all the results obtained. However, few things are missing: A cross-method comparison showing the 3 methods agreement with each other. A time series of BLHs estimates, which would be very useful for characterising the site. We have added Figure 7 a method comparison for all three methods with each other and Figure 8 a time series sample of BLHs calculated by each method.

It would be useful to know in which season-month there is the highest number of reference BLHs. And more in general, as also referee 1 suggest, a climatology information in this work is missing. We have added both Figures 1 and 8 to further expand on these issues. Figure 1 shows launches used with the highest frequency in the months of May, June, September and October and Figure 8 shows a time series for all methods showing their performance and ability to retrieve the diurnal evolution of the BL. In addition, all our findings are consistent with other climatological studies as those done by Haman et al. (2012) and Rappengluck et al. (2008) in the study area.

Another aspect stressed in the discussion needs to be considered. The Comparison is performed after filtering the data that exceeds a threshold in in the t-test. However, the way the uncertainties for the retrieved BLHs are estimated. Instead of the standard deviation of a sample of retrieved BLHs, the authors should use a more signal related error, like the one proposed in Biavati et al. 2015. This method could be used also for estimating the errors on the BLHs retrieved from the skew-T log-P method. The Biavati et al. (2015) offer an excellent method to quantifying sensor uncertainties such as measurements from radiosonde and LIDAR measurements. However, we feel these uncertainties will not aid in the purpose of our study of arriving at the most reliable BLH detection algorithm. As Biavati et al. (2015) state the study's goal was to "estimate a reasonable uncertainty for one singular estimate of MH that depends only on the signals used and their uncertainties" and did not serve to "evaluate the uncertainties that the MH has due to the choice of a method... nor to perform a general study on the best way to estimate mixing height". The uncertainties calculated by Biavati et al.'s approach would not provide us with further information on why the algorithms are correctly or incorrectly identifying the BLHs since our uncertainties largely come from the physics/thermal dynamics in the BLH rather than uncertainties from the sensor. Another point to make is our inability to use this statistical method across all BLH retrieval methods use since the Vaisala aerosol gradient method does not give us the exact individual aerosol backscatter profiles used for the BLH calculation, as it is Vaisala proprietary. The statistical analysis will therefore be incomplete if we cannot evaluate all retrieval methods used in our study equally. For future reference we have cited the statistical method of Biavati et al. (2015) as an excellent method to use in the determination of signal related uncertainties in p.8, l.1-4.

I consider that this work should go through a major revision in order to include: more works where the CL31 was used, a BLH climatology at the site, and a more robust way to assess the uncertainties. On the other hand I agree with the referee 1 and I am not going to repeat the details he already underlined. We have elaborated modifications for the issues stated here. Please refer to above comments and also to the responses made to reviewer 1.

Biavati, G., Feist, D. G., Gerbig, C., and Kretschmer, R.: Error estimation for localized signal properties: application to atmospheric mixing height retrievals, Atmos. Meas. Tech., 8, 4215-4230, doi:10.5194/amt-8-4215-2015, 2015. We have added this references as it offers a novel new method to estimate instrumental/sensor uncertainties (p.8, l.1-4).

Milroy C., Martucci G., Lolli S., Loaec S., Sauvage L., Xueref-Remy I., Lavrič J. V., Ciais P., Feist D. G., Biavati G., and O?Down C. D.: An Assessment of Pseudo-Operational Ground-Based Light Detection and Ranging Sensors to Determine the Boundary-Layer Structure in the Coastal Atmosphere. Adv. Meteor., 2012:18, 2012. We have added this reference as a sample of using LIDAR instrumentation for BL studies(p.2, l.9-11).

Haeffelin M., Angelini F., Morille Y., Martucci G., Frey S., Gobbi G. P., Lolli S., O'Dowd C. D., Sauvage L., Xueref-Rémy I., Wastine B., and Feist D. G.: Evaluation of Mixing- Height Retrievals from Automatic Profiling Lidars and Ceilometers in View of Future Integrated Networks in Europe. Bound.-Layer Meteor, 143(1):49?75, 2012. We have added this study to our references as it also compares different aerosol backscatter algorithm for BLH detection (p.2, l.16-18).

Schäfer K., Emeis S., Höβ M., Friedl R., Münkel C., and Suppan P.: Comparison of continuous detection of mixing layer heights by ceilometer with radiosonde observations. SPIE, 8177:817707?817707?8, 2011. We have added this reference as a sample of studies usingvarious LIDAR instrumentation for BL studies(p.2, l.9-11).

Davis, K. J., Gamage, N., Hagelberg, C. R., Kiemle, C., Lenschow, D. H., and Sullivan, P. P.: An objective method for deriving atmospheric structure from airborne lidar observations. J. Atmos. Oceanic Technol., 17, 1455-1468, 2000. This reference was originally included in our paper. This has been kept in our references.

Seibert, P., Beyrich, F., Gryning, S. E., Joffre, S., Rasmussen, A., and Tercier, P.: Review and intercomparison of operational methods for the determination of the mixing height. Atmos. Environ., 34, 1001-1027, 2000. This reference was also originally included in our paper. This has been kept in our references.

Endlich R., Ludwig F., and Uthe E.: An automatic method for determining the mixing depth from lidar observations. Atmos. Environ., 13(7):1051?1056, 1979. We have added this study to our references as an important reference which addresses the limitation of the gradient method BLH detection using aerosol backscatter signals p.8, l.21.

Please also note the supplement to this comment:
http://www.atmos-meas-tech-discuss.net/amt-2016-340/amt-2016-340-AC2-supplement.pdf

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