Dear Editor,

We are very grateful to referee #1 and the Associate Editor for their additional constructive suggestions and for their proposed corrections. We have addressed all issues raised and have modified the paper accordingly. We have also submitted a revised version of the paper where all these changes have been incorporated. We believe that, thanks to these precious inputs, the quality of the manuscript has sensitively improved. Below is a summary of the changes we carried out and our specific responses to the referee' comments and recommendations.

Summary of the changes
(in black is the original comments of the referee and in red our responses)

« Inter-comparison of ABL height estimates from different profiling sensors and models in the framework of HyMeX-SOP1" by Summa et al.
The manuscript greatly improved and I do appreciate the large effort of the authors to improve the content, the structure, the figures and the language of the paper. To my opinion, this second version reaches the quality of a first submitted version. There is however still a lot of scientific inaccuracies

The scientific inaccuracies to which the reviewer is referring to have been removed also based on the specific suggestions from his side in this direction.

such as e.g. error in the sign of the mean bias,

We removed this inaccuracy based on the specific suggestion from the reviewer. Specifically, the following text was corrected/introduced: "More specifically, very smallest biases are found to characterize the ABLH estimates obtained through the application of the Richardson number method (18.2 m /7.4 % for the IGRA radiosondes, 20.5 m/8.15 % for the Raman lidar BASIL, and -28 m/-2.97 % for ECMWF-ERA5 analysis), while slightly large bias values are found to characterize ABLH estimates from the wind profiler (47 m/21.7 %) and ABLH estimates from elastic backscatter lidar signals (61.6 m/26.4 %). The slightly smaller ABLH values characterizing ECMWF-ERA5 analyses are probably to be attributed to the systematically smaller values of the water vapour mixing ratio and the wind V component from ECMWF-ERA5 with respect to those from other sensors. Another possible motivation for the negative systematic bias affecting ABLH estimates from ECMWF-ERA5 is represented by the missed assimilation of the on-site radiosondes in ECMWF-ERA5." See below more specific comments/replies with reference to specific "minor comment" from the reviewer in L258.

designation of the weather as "clear-sky" when clouds are presents,

We removed this inaccuracy based on the specific suggestion from the reviewer in this direction Specifically, the corresponding sentence was modified as follows: "The analysis was also focused on one specific case study, covering an extended time interval from 09:00 on 18 October 2012 to 19:00 UTC on 19 October 2012, including two daytime portions, the first one characterized by the presence of high scattered clouds between 3 and 4 km and the second one characterized by the present of low stratiform clouds between 1 and 2 km, which allowed to assess the performance in the characterization of the short-term variability of the ABLH in variable weather conditions." See below more specific comments/replies with reference to specific "minor comment" from the reviewer in L395.

the description of a pressure measurement by the Raman Lidar

We removed this inaccuracy based on the specific suggestion from the reviewer in this direction. Specifically, the following sentences were modified/integrated as follows: "Vertical profiles of *T(z)*, and $\chi_{H2O}(z)$ are available from all sensors/models involved in the inter-comparison effort, namely the Raman lidar, the radiosondes launched on-site and those from the closest IGRA radiosonde station and the ECMWF-ERA5 analysis data, with the only exception of the wind profiler. For most sensors, vertical profiles of *P(z)* are obtained by vertically extrapolating the surface pressure value P_0.". See below more specific comments/replies with reference to specific "minor comment" from the reviewer in L109-111.

or the attribution of potential WPR problem to insects by citing studies on radar with much lower wavelengths.

We removed this inaccuracy as in fact the corresponding erroneous sentence in the paper has been deleted. See below more specific comments/replies with reference to specific "minor comment" from the reviewer in L183-185).

The first main problem mentioned (see below) concerns the description of Figures 5 and is directly linked to the first main comment of the first review: "The notion of ABL height is used in the whole introduction and attributed to several "heights" measured by various instruments and methods. The authors should really attribute the right ABL (sub)structure to the right layer height detection."

The main result of the present paper is represented by the demonstrated capability to use different sensors and models to measure the ABLH over extensive periods of time. These sensors and models were applied to an entire mouth period (the month of October 2012). In the paper, detail analysis, supported by a comprehensive statistical analysis, is carried out with the aim to properly assess the performance of different sensors and models used to estimate the ABLH over an extensive period. Illustrated results and the quality of the inter-comparison demonstrate the reliability of the combined use of these approaches over extended periods of time. In this regard, the specific case study on 18-19 October 2012 was aimed to provide a preliminary assessment of the applicability of these approaches in quantifying the short-term variability of the ABLH in variable weather conditions. So this case study is to be considered as a test-bed to assess the accuracy of these approaches, which are usually considered for a more operation use over extended measurement periods, when applied to monitor short-term ABLH variability in complex weather conditions. This analysis does not intend to be neither comprehensive nor definitive, but to represent only a first step forward in the direction of estimating the ABLH short-term variability in variable weather conditions.

However most of the criticism of the reviewer focuses not on the main part of the paper (sub-section 4.1 “Climatological variability throughout October 2012”), by only on this more ancillary part of the paper, i.e. the analysis of the short-term variability in the period on 18-19 October 2012. Authors are available to remove this portion of the paper, if the reviewer is not happy with it, but it should be underlined that the case study on 18-19 October 2012 was only considered with the aim to illustrate the performance of operation approaches to a highly variable weather situation and was not aimed at solving all possible problems related to the short-term variability of the aerosol, cloud, wind, temperature and humidity fields. Furthermore, the operational use of the discussed approaches is in no extent compromised by the failure of their application in the monitoring of the ABLH short-term variability in variable weather conditions. This aspect is now explicitly mentioned in the conclusions, where the following sentence has been introduced: “This final analysis, while providing preliminary encouraging results, has in no extend to be considered as a thorough demonstration of the applicability of the considered approaches to variable complex weather conditions as in fact a more comprehensive and extensive study has to be carried out in the future in this direction.”

The authors clearly describe now the methods and the instruments, but the ABL structure in clear-sky, cloudy conditions as well as with precipitation cannot rely only on the two quite general § of the introduction.

The introduction has been extended in the direction to properly include the different ABL weather scenarios indicated by the reviewer and illustrate the potential of the different approaches and strategies used to characterize the ABLH variability in these cases. For this purpose, specific new references have also been cited in the Introduction and the following new paragraph has been introduced in the Introduction:

“However, accurate estimates of the ABL height and structure in complex terrains or under complex meteorological conditions remain problematic. A variety of authors have tried to address this challenging issue. Among others, Herrera-Mejía and Hoyos (2019) studied the spatio-temporal evolution of the ABL in a narrow, highly complex terrain located in the Colombian Andes, where convective activity, as a result of aerosol dispersion, increases the uncertainty affecting the estimate of ABLH. Staudt (2006) provided a comprehensive analysis of the ABLH variability over complex terrains in the Bavarian Alpine foreland, based on the use of multi-sensor data collected during the field experiment SALSA 2005. Che and Zhao (2021) assessed the effectiveness of different approaches to characterize the summer ABLH variability over the Tibetan Plateau, this region being characterized by elevations exceeding 4000 m and complex land surface processes and boundary layer structures.

Coming to the characterization of the ABLH in cloudy conditions, Dang et al. (2019) investigated different approaches, with a specific focus on reducing the interference of the residual and cloud layers on ABLH determination. Manninen et al. (2019) demonstrated the capability of Doppler lidars to determine the ABLH in both clear-sky and cloud-topped conditions, with some reservations in precipitation. Furthermore, Liu et al. (2022) proposed an approach to estimate ABLH from elastic backscatter lidar data under complex atmospheric conditions based on the use of machine learning methods.

However, both the results from these previous papers and the conclusions reached in the present paper clearly indicate that a proper characterization of the ABL height and structure in all weather conditions requires the combined application of different approaches and data sets. This approach allows to overcome the possible dependence of each single sensor/method from a specific meteorological parameter, thus drastically reducing potential biases affecting ABLH estimates (Dai et al., 2014b). Additionally, multi-sensor approaches have demonstrated to be more robust and better performing in variable stable and unstable weather conditions (Joffre et al. 2001)."

New references

Che, J. and Zhao, P.: Characteristics of the summer atmospheric boundary layer height over the Tibetan Plateau and influential factors, Atmos. Chem. Phys., 21, 5253–5268, https://doi.org/10.5194/acp-21-5253-2021, 2021.

Dai, C., Wang, Q., Kalogiros, J.A. et al. Determining Boundary-Layer Height from Aircraft Measurements. Boundary-Layer Meteorol 152, 277–302 (2014b). https://doi.org/10.1007/s10546-014-9929-z

Dang, R.; Yang, Y.; Li, H.; Hu, X.-M.; Wang, Z.; Huang, Z.; Zhou, T.; Zhang, T. Atmosphere Boundary Layer Height (ABLH) Determination under Multiple-Layer Conditions Using Micro-Pulse Lidar. *Remote Sens.*, *11*, 263. https://doi.org/10.3390/rs11030263, 2019a.

Dang, R.; Yang, Y.; Hu, X.-M.; Wang, Z.; Zhang, S. A Review of Techniques for Diagnosing the Atmospheric Boundary Layer Height (ABLH) Using Aerosol Lidar Data. *Remote Sens.*, *11*, 1590. https://doi.org/10.3390/rs11131590, 2019b.

Herrera-Mejía, L, Hoyos, CD. Characterization of the atmospheric boundary layer in a narrow tropical valley using remote-sensing and radiosonde observations and the WRF model: the Aburrá Valley case-study. Q J R Meteorol Soc. 2019; 145: 2641–2665.https://doi.org/10.1002/qj.3583.

Liu, Z.; Chang, J.; Li, H.;Chen, S.; Dai, T. Estimating BoundaryLayer Height from LiDAR Dataunder Complex AtmosphericConditions Using Machine Learning.Remote Sens. 2022, 14, 418.

Manninen, A. J., Marke, T., Tuononen, M. J., & O'Connor, E. J. (2018). Atmospheric boundary layer classification with Doppler lidar. Journal of Geophysical Research: Atmospheres, 123, 8172– 8189. https://doi.org/10.1029/2017JD028169.

Staudt, K., Determination of the atmospheric boundary layer height in complex terrain during SALSA 2005, Dissertation thesis, Department of Micrometeorology, University of Bayreuth, September 2006.

Main comments:

- The situation measured during the 18-19 October is a very complex one regarding ABLH. The authors described carefully the meteorological conditions with high clouds, precipitation and virga topped by a drier layer on the 18th, a change in wind direction on the 19th in the morning, a stratiform cloud cover with shallow orographic precipitation during the second day. The authors have to refer to scientific publication to explain what is the expected behavior of the ABL under these complex conditions.

More information is now provided concerning the expected behavior of the ABL under complex weather conditions. This is done also making use and referring to scientific publications on this topic (Che, and Zhao, 2021; Dai et al., 2014; Dang et al., 2019a; Dang et al., 2019b; Herrera-Mejía, and Hoyos, 2019; Liu et al., 2022; Manninen et al., 2018; Staudt, 2006).

Additionally, as already specified above, the introduction has been reinforced based on the inclusion of a number of new citations properly addressing the topic of the applicability of different instruments/methods/models in different meteorological and environmental conditions. The following new paragraph has been introduced:

"However, accurate estimates of the ABL height and structure in complex terrains or under complex meteorological conditions remain problematic. A variety of authors have tried to address this challenging issue. Among others, Herrera-Mejía and Hoyos (2019) studied the spatio-temporal evolution of the ABL in a narrow, highly complex terrain located in the Colombian Andes, where convective activity, as a result of aerosol dispersion, increases the uncertainty affecting the estimate of ABLH. Staudt (2006) provided a comprehensive analysis of the ABLH variability over complex terrains in the Bavarian Alpine foreland, based on the use of multi-sensor data collected during the field experiment SALSA 2005. Che and Zhao (2021) assessed the effectiveness of different approaches to characterize the summer ABLH variability over the Tibetan Plateau, this region being characterized by elevations exceeding 4000 m and complex land surface processes and boundary layer structures.
Coming to the characterization of the ABLH in cloudy conditions, Dang et al. (2019) investigated different approaches, with a specific focus on reducing the interference of the residual and cloud layers on ABLH determination. Manninen et al. (2019) demonstrated the capability of Doppler lidars to determine the ABLH in both clear-sky and cloud-topped conditions, with some reservations in precipitation. Furthermore, Liu et al. (2022) proposed an

approach to estimate ABLH from elastic backscatter lidar data under complex atmospheric conditions based on the use of machine learning methods.
However, both the results from these previous papers and the conclusions reached in the present paper clearly indicate that a proper characterization of the ABL height and structure in all weather conditions requires the combined application of different approaches and data sets. This approach allows to overcome the possible dependence of each single sensor/method from a specific meteorological parameter, thus drastically reducing potential biases affecting ABLH estimates (Dai et al., 2014b). Additionally, multi-sensor approaches have demonstrated to be more robust and better performing in variable stable and unstable weather conditions (Joffre et al. 2001)."

For example, the ABLH increase at around 00:00 does it correspond to a real change in atmospheric boundary layer height or to a change in advected humidity/aerosol due to wind direction change ?

We are now we are now properly interpreting the ABLH increase observed around 00:00 UTC. This is associated to a real change in the ABLH caused by advection of air masses with different thermodynamic and compositional properties, associated with a wind direction change and altering the stability and turbulent state of the atmosphere. Similar considerations were reported by Pal and Lee (2019), who suggested that contrasting air mass advection associated with onshore and offshore flows may explain the significant variability in ABLH.

This aspect is now more extensively illustrated in the paper, where the following sentence was introduced: "This change in the ABL structure is caused by advection of air masses with different thermodynamic and compositional properties associated with the wind direction turning, ultimately altering the stability and turbulent state of the sounded air masses. A similar abrupt ABLH variability had been reported by Pal and Lee (2019), who revealed the important role played in coastal areas by advection via onshore and offshore flows."

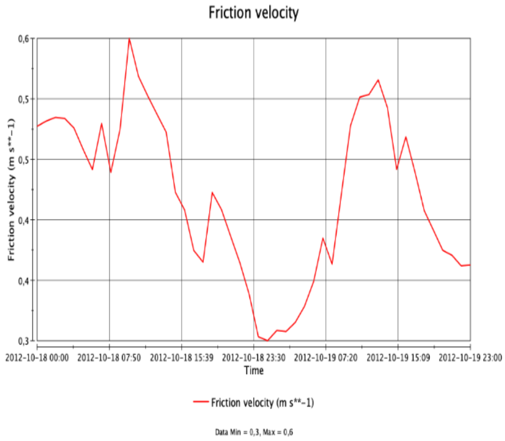
Pal, Sandip & Lee, Temple. (2019). Contrasting Air Mass Advection Explains Significant Differences in Boundary Layer Depth Seasonal Cycles Under Onshore Versus Offshore Flows. Geophysical Research Letters. 46. 10.1029/2018GL081699.

It is also important to know the stability conditions and how do the precipitation/clouds affect the various measurements/detection methods?

Stability conditions have been carefully investigated, based on observations and model data, which indicate that a higher correlation is present in case of stable weather conditions. An additional graph (new figure 5) has been added that distinguishes stable days from unstable ones. Specifically, figure 5 illustrates the percentage bias of the different ABLH estimates with respect to the one obtained through the application of the Richardson number approach to the on-site radiosonde profiles, expressed as a function of the atmospheric stability conditions. More than 50 % of the cases can be classified as stable condition, while the reminder cases can be classified as unstable. For the unstable conditions mutual deviations between the different/sensors methods are approximately 30% larger than in the case of stable conditions. A lower dispersion of the bias values implies a higher correlation among the different ABLH estimates in case of stable weather conditions.

Intense measurements during these days allows having temperature, humidity, wind and aerosol backscatter profiles. I'm e.g. very interested in an analysis allowing to know which of the used T, RH and wind profiles leads to the rapid change in ABLH at 00:00 detected by the bulk Richardson method?

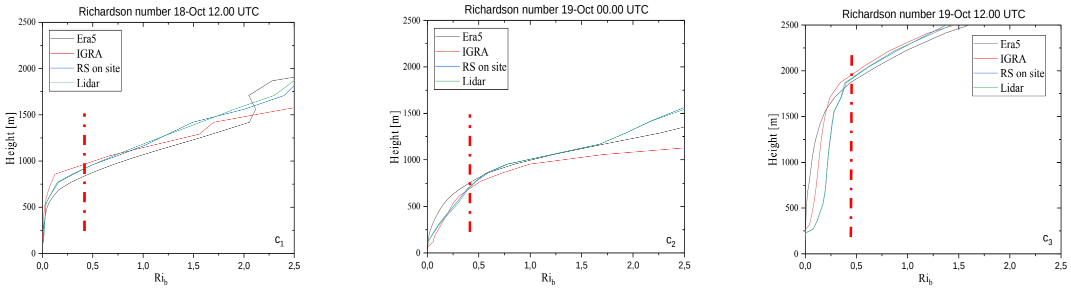
We have verified that in this specific case the variability of temperature has limited effects on the calculation of R_{ib}, while large are the effects of the wind V component, varying significantly starting at 23.30 on 18 October. This translates into with friction velocity abruptly rising starting at 23.30. Below follows a plot of friction velocity, where this abrupt increase is illustrated.



We also computed the mean deviations between the ERA5 and the on-site radiosondes for water vapour mixing ratio, temperature and the wind V component throughout the month of October 2012. A 50 % mean deviation, with ERA5 underestimating the on-site radiosondes, is found for the water vapour mixing ratio; a 20 % mean deviation, with ERA5 again underestimating the on-site radiosondes, is found for the wind V component, while deviations in terms of temperature are negligible. The above mentioned negative biases translate into a systematic underestimation of the coefficient R_{ib}, which determines a systematic underestimation of the ABLH when using ECMWF-ER5 data. This aspect is now properly illustrated in the paper, where the following sentences have been introduced: "The slightly smaller ABLH values characterizing ECMWF-ERA5 analyses are probably to be attributed to the systematically smaller values of the water vapour mixing ratio and the wind V component from ECMWF-ERA5 with respect to those from other sensors. Another possible motivation for the negative systematic bias affecting ABLH estimates from ECMWF-ERA5 is represented by the missed assimilation of the on-site radiosondes in ECMWF-ERA5."

I have also some doubts: the largest RCS gradient at 9:00 on the 18th October seems visually (Fig 5a) to be at ~1200 m and not at 800 m. Similarly I would put the RCS gradient at 00:00 at ~600 m in the continuity of the previous ABLH. Are some conditions on the size/altitude of the gradient applied?

The referee is right about these altitudes. We reviewed few specific profiles, i.e. those at 9.00 and 12.00 UTC on October 18 and at 00:00 on October 19, and we realized that the new values are closer to those indicated by the reviewer. Specifically, it can be seen that, after this last revision, the ABLH value at 9:00 becomes slightly higher, i.e. around 1140 m, while the values at 12:00 on October 18 and at 00:00 on October 19 becomes slightly lower. These new values are now included in the modified version of figure 5. For the purpose of clarity here follows the three plots of Rib at the above mentioned times.



- The Raman lidar is probably measuring during most of the month of October 2012. ABLH "standard" diel cycle could be then compared to the complex case of 18-19 October. The wind compound could then be taken from the WPR or the parcel method can be applied.

Authors are not sure they completely understand what the reviewer is suggesting to do here. However, ABLH "standard" diel cycle for the days 18 and 19 October, i.e. the values obtained in sub-section 4.1 for the climatological assessment throughout October 2012, are already available and introduced in figures 2 and 3 and in Table 2 (former table 1). These values reasonably well compare with those determined in figure 5 with a much higher temporal resolution. Specifically, values of the ABLH from the six sensors/models/approaches at 12:00 on 18 October 2012 and at 00:00 and 12:00 on 19 October, determined for the purpose of the climatological analysis, are 948 m, 1000 m and 1806 m, respectively, while corresponding ABLH from the six sensors/models/approaches at these same times from the short-term analysis are 750 m, 800 m, 1750 m, respectively.

- A more precise analysis of the ABLH overestimation/underestimation of the various instruments/method/model as well as the potential reasons is expected.

A new table (new Table 1) has been introduced for the purpose of providing a more comprehensive analysis of the performances of the various instruments/model/methods. More specifically Table 1 provides PROs and CONs of the considered instruments/reanalysis and their potential sources of bias.

- Explanation of expected effect of CAPE and the relative humidity from ERA5 on ABLH should be given in order to understand why the authors chose these parameters.

We investigated the potential influence of CAPE and relative humidity on the ABLH. We are now providing supporting arguments and references to explain the effects of CAPE and relative humidity from ECMWF-ERA5 analysis on the ABLH and its variability. The following new text has now been introduced: "CAPE is strongly controlled by the ABL properties, with their coupling holding in both convective and non-convective conditions (Donner and Phillips, 2003). Additionally, the response of the boundary layer to relative humidity is investigated although it is known that it involves competing mechanisms (Ek and Mahrt, 1994), with the net effect on relative humidity being difficult to disentangle. The effect of relative humidity on the ABLH and its variability has been investigated in a variety of literature papers, with higher ABLH values typically found for high surface temperature and low humidity values, which implies surface sensible heat fluxes being dominat over latent heat fluxes and leading to increased buoyancy (Zhang et al., 2013)."

In support of the above new argument, the following new references have been introduced:

Donner, L. J., and Phillips, V. T. (2003), Boundary layer control on convective available potential energy: Implications for cumulus parameterization, J. Geophys. Res., 108, 4701, doi:10.1029/2003JD003773, D22.

Ek, M., & Mahrt, L. (1994). Daytime Evolution of Relative Humidity at the Boundary Layer Top, Monthly Weather Review, 122(12), 2709-2721. Retrieved Mar 8, 2022, https://journals.ametsoc.org/view/journals/mwre/122/12/1520-0493_1994_122_2709_deorha_2_0_co_2.xml

Zhang, Y., Seidel, D. J., & Zhang, S. (2013). Trends in Planetary Boundary Layer Height over Europe, Journal of Climate, 26(24), 10071-10076. Retrieved Mar 8, 2022, from https://journals.ametsoc.org/view/journals/clim/26/24/jcli-d-13-00108.1.xml

- The result section could be divided into some subsections

As suggested by the reviewer, we are now dividing the results section (section 4) into two separate subsections: subsection "4.1 Climatological variability throughout October 2012" and "4.2 Short-term variability over the two-day period18 and 19 October 2012".

Minor comments:

- L21:"and in the range 0.95-1.03" for nighttime comparisons? for all data ?

This aspect is now clearly specified in the text, where the corresponding sentence was modified as follows: "Values of the slope of the fitting line in the regression analysis applied to the different sensor/model pairs are in the range 0.91-1.08 for daytime comparisons and in the range 0.95-1.03 for night-time comparisons, which testifies the very small biases affecting all five ABLH estimates with respect to the reference AHBL estimate, with slightly smaller bias values found at night."

- L66: concerning the previously described methods, it is not mentioned if they also allow a detection in both daytime and nighttime. Is it the case?

This is now clearly specified in the text, where the corresponding sentence was modified as follows: " Such approach, extensively used in the present inter-comparison effort, both in day and night time, is described in detail in the following section."

- L97-98: how do you determine if the conditions are stable or convective ?

For the general application of the Richardson number method, the threshold Richardson number R_{ibc} is typically taken equal to 0.25 in stable boundary layers and equal to 0.45 in unstable boundary layers. In the previous version of the paper there was a misprint as in fact we intended to mean "unstable boundary layers" and not "convective boundary layers". We considered the layers to be generally stable during the evening, night and early morning periods, while layers were assumed to be unstable during the late mornings and afternoons, in clear air conditions. These conditions were verified through the use of atmospheric stability indexes from ERA5 model analysis data. Specifically, we considered the "lifted index" LI, where negative values indicate instability - the more negative, the more unstable the air is - and positive values indicate stability.

The period September-November 2012 was selected for the field campaign because of the specific interest and focus on convection of the Hydrological cycle of the Mediterranean Experiment first Special Observing Period (HyMeX-SOP1). Within this three-month period, Intense Observation Periods (IOPs) were typically selected when convective instability conditions were present. Thus, the number of cases characterized by unstable layers is predominant in this dataset. Conditions are found to be persistently unstable during the IOP on October 18-19 and in the period October 16-22. A new figure (new figure 5) has been introduced to properly identify stable and unstable cases. These aspects are now clearly specified in the text, where the corresponding sentence was modified as follows: "We generally considered the layers to be stable during the evening, night and early morning periods, while layers were assumed to be unstable during the late mornings and afternoons in clear air conditions. The period September-November 2012 was selected for the field campaign because of the specific interest and focus on convection of the HyMeX-SOP1. Within this three-month period, Intense Observation Periods (IOPs) were typically selected when convective instability conditions were present. Thus, the number of cases characterized by unstable layers is predominant. Conditions are found to be persistently unstable during the IOP on October 18-19 and in the period October 16-22. The presence of stable or unstable conditions was verified based on the use of a specific atmospheric stability index, i.e. the “lifted index”, obtained from ERA5 model analysis data (see forthcoming figure 5).”

- L109-111: Does the Raman lidar really measure P(z) ? Most of the present radiosondes also do not measured P(z) but deduce it from the pressure at the ground and the altitude. Is it the case for your radiosonde?

In principle, pressure profiles are measured by the Raman lidar BASIL based on the combined use of the temperature profiles obtained through the rotational Raman technique and the density profiles obtained through the Rayleigh integration technique. However, we realized that the pressure profiles from the Raman lidar are often too nosy for theie effective use in estimating potential virtual temperature profile. Consequently, after having carefully checked the presence of a good agreement between the pressure profile measured by the Raman lidar and those obtained by vertically extrapolating the surface pressure value, this latter profile was used to estimate potential virtual temperature profiles to be associate to lidar measurements. This aspect is now clearly specified in the text, where the corresponding sentences were modified/integrated as follows: “Vertical profiles of $T(z)$, and $\chi_{H2O}(z)$ are available from all sensors/models involved in the inter-comparison effort, namely the Raman lidar, the radiosondes launched on-site and those from the closest IGRA radiosonde station and the ECMWF-ERA5 analysis data, with the only exception of the wind profiler. For most sensors, vertical profiles of $P(z)$ are obtained by vertically extrapolating the surface pressure value P_0.”

- L129-133: I appreciate very much the large effort of the authors leading to a much better description of the used method. I doubt however that the elastic lidar equation is needed here. It is described in a lot of textbook. Anyhow, the authors are completely free to leave it.

We agree with the reviewer that the elastic lidar equation is described in a variety of test books and so its inclusion here is not essential. However, we decided to keep it here because, in its present formulation, it includes specific terms that are not always carefully described when discussing measurement accuracy. Among these is the term P_{bgd}, which represents the background signal associated with solar irradiance and detectors’ noise, which is one of the major driver of the measurement uncertainty.

- L183-185: The WPR used in this study works at 1,274 GHz (□ 23.3 cm). The radar descripted by Chapman (last publication in 2015) are radars working at much higher frequencies corresponding to wavelength between 3.2 cm and 9 mm. Gauthreaux’s paper (2008) used Doppler weather radar. The weather radars usually work at frequency between 12.6 and 2 GHz (depending on the C, S or X bands) corresponding to 0.32-15 cm. Insects are detected by radars with wavelengths corresponding to the size of the insects. WPR with a wavelength of 23.3 cm detects, to my knowledge, birds. However I will be very interested if the authors can send me a reference where insects are detected by WPR.

The present incorrect sentence has now been removed.

- L213: please add a space: radiosonde are

Corrected in the way proposed by the reviewer.

- § 3.3 and 3.4: is the vertical resolution of the launched radiosonde in Candillargues the same as the one of IGRA in Nimes-Courbessac? If not, what is the impact on ABLH?

The IGRA radiosondes are characterized by a lower resolution than the Vaisala RS92 radiosondes. Consequently, data from the two radiosondes had to be interpolated to a common height array. The deviations associated with the interpolation procedure have been verified to be negligible. This aspect is now clearly specified in the text, where the corresponding sentence was modified as follows: "The IGRA radiosondes are characterized by a lower resolution than the Vaisala RS92 radiosondes. Consequently, data from the two radiosondes have been interpolated on a common height array, with the deviations associated with the interpolation procedure having been verified to be negligible."

Figures 2c1 and 2c2: please add a smaller graduation of the y-axis (and perhaps horizontal lines) so that the relative bias can be easily estimated. Figure caption should be revised by the inclusion of some abbreviations.

Both the figures layout and the caption were modified in the way suggested by the reviewer.

- L245-246: ABLH differences in daytime are comprised between -400 to +600 m (approximately -30% to +50%). ABLH differences in nighttime are comprised between -300 to +300m (~-40 to +120%). Is it a “good agreement” in all cases?

The reviewer is right: the agreement between the six different estimates cannot be considered good for all sensors/models pairs, especially when considering both daytime and night-time conditions. The term “good agreement” was modified into “general good agreement” and the corresponding sentence now reads: “Results reveal a general good agreement between the six different estimates both in daytime and night-time, all of them revealing the major features associated with ABLH monthly variability.”

More considerations are now carried out and introduced in the text. Specifically, it is to be noticed that percentage differences may be large especially during the night, when the ABL is very shallow. In our specific case, ABLH values are found to not exceed 300 m throughout most part of the month of October 2012, i.e. the period considered in our study. Nevertheless, percentage bias values in excess of 100 %, as those mentioned by the reviewer, are found only 2 times (2 data points) throughout the month of October 2012, in the comparison of the ABLH estimates obtained from the Raman lidar BASIL with those obtained from the on-site radiosondes, considered as reference. These large values are to be attributed to the limited sensitivity of Raman lidars below 250 m, where overlap effects degrade the signals and a blind vertical region is present. These aspects are now more clearly specified in the text, where the following new sentences have been introduced: "However, percentage differences may be large especially during the night, when the ABL becomes shallow. During the month of October 2012, approximately 60 % of the night-time ABLH values are found to not exceed 300 m. Percentage differences in excess of 100 % are found only 2 times in this period and characterize the comparison of BASIL vs. the on-site radiosondes, with the former of these two sensors having a limited sensitivity below 250 m, as a result of the presence of overlap effects and a blind vertical region."

- L253-254I just count the number of Basil RCS cases with a relative error > 20% at 12:00 (Table 1 first column): 12 cases (39%). Can we consider 39% as "few data points"? I didn't count the number for the other columns.

The text has been reformulated here, with the modification of the previous sentence and the introduction of a new one: Now the text reads. "Most deviation values are within ± 200 m and ± 20 %. Again, larger deviation values are found to characterize those comparisons considering lidar-based estimates of the ABLH, as a result of the above mentioned overlap effects and the presence of a blind vertical region."

- L255: please mention "with absolute mean bias" and "relative (instead of percentage) mean bias".

The sentence has been corrected in the way proposed by the reviewer.

- L258: the mean bias are negative for ERA5 and not positive as mentioned. Please correct and try to explain why ERA5 underestimate ABLH. The radiosonding at Nice is assimilated in ERA5 ?

The reviewer is right: there was a misprint in the text as in fact values reported in Table 2 (formerly Table 1) of ERA5 vs RS at night [00:00 UTC] are negative (-28 m/-2.97 %q, but are reported in the text as positive (28 m/2.97 %). This misprint has now been corrected. Additionally, we are now trying to explain why ERA5 underestimate ABLH. The following new sentence has been introduced: "The slightly smaller ABLH values characterizing ECMWF-ERA5 analyses are probably to be attributed to the systematically smaller values of the water vapour mixing ratio and the wind V component from ECMWF-ERA5 with respect to those from other sensors. Another possible motivation for the negative systematic bias affecting ABLH estimates from ECMWF-ERA5 is represented by the missed assimilation of the on-site radiosondes in ECMWF-ERA5."

- L262: please rephrase "also at night"

This portion of sentence has been rephrased as follows: “Again, smaller biases are found to characterize night-time ABLH estimates obtained through the application of the Richardson number method … ”

- L269-274: the description of the linear regression could be shortened

The description of the linear regression has been shortened by approximately 30 % and now reads: “A linear fit is applied to the data points, using a linear regression function passing through zero, with the form $Y = A \times X$. X are the ABLH reference values and Y are the values from the five reminder ABLH estimates. The term A represents the slope of the fitting line and provides an alternative estimate of the bias of each of the five ABLH estimates with respect to the reference, while the correlation coefficient R^2 of the linear fit quantifies the degree of agreement between the compared ABLH estimates.”

- Figure 3 and Table 2: the values in Table 2 could be directly reported in Figures 3. The one-one line in all figures could also help (see first version of the manuscript).

We agree that values in Table 2 could be directly reported in the different panels of Figure 3, as it was in the first version of the manuscript. However, the request to the introduce a separate table summarizing all results from the regression analysis was coming from one of the other reviewers during the previous revision round and a removal of this table now would represent a disregard of that specific reviewer request.

For clarity reasons, please use the word “slope” instead of the A throughout the manuscript.

Now the term “slope” in used in substitution to the term “A” throughout the manuscript.

- L278: AHBL □

This misprint was corrected.

- L280-295: a more dynamic description of the results would be gratefully accepted.

We have rephrased the paragraph in between L280-295 in order to make it more readable. The text has been changed as follows: “More specifically, figure $3a_1$ compares with the reference values daytime ABLH estimates obtained through the Richardson number method (RNM) applied to the Raman lidar data, with R^2 being equal to 0.98 and slope being equal to 1.02. This result confirms the small bias (2 %) affecting ABLH estimates from the Raman lidar data when compared with the reference estimates. Identical values of R^2 and slope are found in the night-time comparison (figure $3a_2$). Figure $3b_1$ compares with the reference values daytime ABLH estimates obtained through the RNM applied to the IGRA radiosonde data, with R^2 being equal to 0.94 and slope being equal to 1.01. This result confirms a very small bias (1 %) affecting ABLH estimates from the IGRA radiosonde data when compared with the reference estimates. Very similar values of R^2 and slope, 0.95 and 0.98, respectively, are found in the night-time comparison (figure $3b_2$). Figure $3c_1$ compares with the reference values daytime ABLH estimates obtained through the RNM applied to the ECMWF-ERA5 analysis data, with R^2 being equal to 0.98 and slope being equal to 0.91. This result confirms a small bias (9 %) affecting the ABLH estimate from the ECMWF-ERA5 analysis data when compared with the reference estimate."

It would also be much more interesting to tentatively describe why the comparisons are better during night (caution: the relative differences are larger during night than during day), why detection based on Basil RCS and WP lead to larger (and expected) bias, what are the effect of the various vertical resolution of the profils, than to summarize the list of slopes and R2 values.

We are now providing additional information on the results, with a specific focus on the differences between day and night and with specific considerations on BASIL RCS and the Wind Profiler. The following new text has been introduced: "Results clearly reveal that absolute biases are smaller during the night than during the day. This is most probably due to the fact that night-time portions of the measurement records are typically characterized by higher stability conditions. However, percentage biases are typically larger during the night, when the ABL may become very shallow. In fact, in the presence of shallow ABLs, ABLH values become comparable with the measurement uncertainty and this makes percentage biases intrinsically high. In our specific case, ABLH values are found to not exceed 300 m throughout most part of the month of October 2012. With a specified vertical resolution of 150 m, the uncertainty affecting the estimate of the ABLH is 50 % when sounding ABLs with heights not exceeding 300 m. As already anticipated above, the bias affecting the ABLH obtained from the range-corrected elastic backscatter lidar signals is possibly generated by the limited sensitivity of this sensor below 250 m, as a result of the presence of overlap effects and a blind vertical region. Furthermore, the negative biases observed in ERA5 ABLH estimate are most probably associated with the negative bias affecting ERA5 water vapour and wind V component data."

- L301-305: long sentence.

The present long sentence has now been splitting into two shorter sentences. The text now reads: "The above results reveal that the different ABLH methods considered in the paper, which refer to different definitions and physical (dynamic and thermodynamic) processes, ultimately lead to ABLH estimates that are in very good agreement among them. This conclusion, which need to be confirmed over longer time series including a complete seasonal cycle, confirms that turbulent air motion and vertical mixing, induced by shear and buoyancy forces (Stull, 1988), cause rapid fluctuations of several physical quantities, such as flow velocity, temperature, moisture and aerosol concentration, which are strongly correlated one with the other."

Please mention that your conclusion is valid for one month of measurement at one place. It cannot be extended to an absolute statement without longer time series including a complete seasonal cycle.

The reviewer is write and this aspect is now explicitly specified in the text, where the corresponding sentence has been changed as follows: “This conclusion, which need to be confirmed over longer time series including a complete seasonal cycle, confirms that turbulent air motion and vertical mixing, induced by shear and buoyancy forces (Stull, 1988), cause rapid fluctuations of several physical quantities, such as flow velocity, temperature, moisture and aerosol concentration, which are strongly correlated one with the other.”

- L316: The correlation between the friction velocity and ABLH is difficult to see from Figure 4. Why don’t you directly plot one parameter as a function of the other?

Following the suggestion of the reviewer, we introduced a new plot (new figure 6) correlating ABLH with the friction velocity. This plotter was introduced the only for a BL8 sugar system friction velocity as correlations of the ABLH with the other ERA5 parameters, namely the CAPE gradient and relative humidity, had been found to be smaller. In new figure 6 the scatter plot used for the purpose of correlating ABLH with the friction velocity includes separate data points for daytime and night-time. The following new sentences have been introduced in the text: “In order to further underline the correlation between ABLH estimates and corresponding friction velocity values, a scatter plot of ABLH vs. friction velocity-ABLH) for the month of October 2012 is illustrated in figure 6. In order to reveal the higher correlation during night-time, data points are plotted separately for both daytime (red dots, 12:00 UTC) and night-time (black dots, 00:00 UTC).”

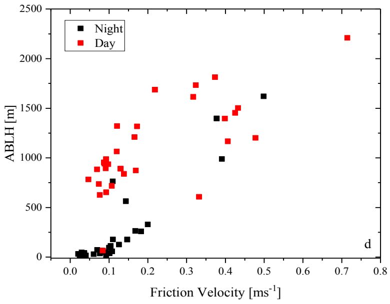


Figure 6: Scatter plot of ABLH vs. friction velocity for the month of October 2012. Results are reported for both daytime (red dots, 12:00 UTC) and night-time (black dots, 00:00 UTC).

- L320-322: The high stability during most of the month is probably a cause of the very good correlation between all methods and with the model. Did you compare the bias as a function of the atmospheric stability? Please comment.

Figure 5 illustrates ABLH values for the different instruments/methods/models as a function of the atmospheric stability. Indeed, a higher correlation appears to be present in case of stable weather conditions. More specifically, more than 50 % of the cases can be classified as stable condition, while the reminder cases can be classified as unstable. For the stable conditions mutual deviations between the different/sensors methods are approximately 30% larger than in the case of unstable conditions. This aspect is now clearly specified in the text, where the following sentences have been introduced: “The above results reveal the role of atmospheric stability in limiting the variability of the ABLH. The high stability during most of the month of October is probably one of the main drivers of the very good correlation found between the different sensors/models/methods. Figure 5 illustrates the percentage bias of the different ABLH estimates with respect to the one obtained through the application of the Richardson number approach to the on-site radiosonde profiles, expressed as a function of the atmospheric stability conditions. The presence of stable or unstable conditions was verified based on the use of the “lifted index” obtained from ERA5 model analysis data, with negative values for this index indicating instability - the more negative, the more unstable the air is - and positive values indicating stability. More than 50 % of the cases can be classified as stable condition, while the reminder cases can be classified as unstable. For the unstable conditions mutual deviations between the different/sensors methods are approximately 30% larger than in the case of stable conditions. A lower dispersion of the bias values implies a higher correlation among the different ABLH estimates in case of stable weather conditions.”

- L322: did you expect a correlation between the relative humidity and ABLH?

The correlation between relative humidity and ABLH was verified in order to assess the potential role of water vapor in feeding convective activity and consequently in determining an increase of the ABLH when triggering mechanisms are present. This aspect is now more clearly specified in the text, where the following sentences have been introduced: "The correlation between relative humidity and ABLH was verified in order to assess the potential role of water vapor in feeding convective activity and consequently in determining an increase of the ABLH when triggering mechanisms are present".

- L324: If I understand it correctly, the CAPE gradient = (CAPE(dayn+1)-CAPE(dayn))/24 h? Do you expect that a change in stability will correlate with the absolute value of ABLH? Why ?

We checked if changes in stability conditions were correlating with ABLH values again because, as already specified above (in the point before the previous one), we expect atmospheric stability to play a role in limiting the ABLH variability.

- L327-329: Are these different results than the ones described in the previous § ?

We are not sure we properly understand the comment/request from the review here. The results illustrated in lines 227-229 refer to the correlation between ABLH and ERA5 estimates of CAPE, friction velocity and the relative humidity. These results are reported here for the first time in the paper as previously reported results wear dealing with the correlations between the different ABLH approaches.

The previous paragraph (L316-322) was describing the time evolution of the ERA5 reanalysis data for CAPE, friction velocity and relative humidity for the entire month of October 20212 and how these parameters compare with the ABLH estimate.

Maybe the reviewer intends to refer to the fact that the correlation results are introduced here without any reference to a specific plot. In this regard, we have now corrected the corresponding sentence as follows: “We also tried to quantitative correlate ABLH estimates with the variability of CAPE, friction velocity and relative humidity. A linear fit was applied to the time series of CAPE day-by-day gradient, the friction velocity and the relative humidity values in the time period 1-31 October 2012 vs. the corresponding ABLH estimates (plots not shown here).”

- L354: chances?

This misprint was corrected

- L 395: two “complete daily cycles” are not included.

The reviewer is right in underlying that two “complete daily cycles” are not present in the measurement record. The authors had used an erroneous wording: the expression "daily cycle" had been improperly used to mean the daytime portion of the day. We are now properly specifying in the text that we refer to two daytime portions. The corresponding sentence has been changed as follow: " The analysis was also focused on one specific case study, covering an extended time interval from 09:00 on 18 October 2012 to 19:00 UTC on 19 October 2012, including two daytime portions, the first one characterized by clear sky conditions and the second one characterized by the present of low stratiform clouds, which allowed to assess the performance in the characterization of the short-term variability of the ABLH in variable weather conditions."

- L 395: Fig. 5a and the text do agree to describe a high altitude cloud cover during most of the 18th of October with some precipitation. How can you refer here to “clear sky conditions”

We are sorry for this erroneous wording. The corresponding sentence has been changed as follows: “The analysis was also focused on one specific case study, covering an extended time interval from 09:00 on 18 October 2012 to 19:00 UTC on 19 October 2012, including two daytime portions, the first one characterized by the presence of high scattered clouds between 3 and 4 km and the second one characterized by the present of low stratiform clouds between 1 and 2 km, which allowed to assess the performance in the characterization of the short-term variability of the ABLH in variable weather conditions.”