AUTHORS' STATEMENT: *The authors would like to thank the referees for the time and care they devoted to review this manuscript, and for their constructive comments. We have made substantial revisions to both the analysis and the presentation of the results. We hope that our responses and the significant modifications have satisfactorily addressed the concerns raised and improved the overall quality of the manuscript. Referee comments are listed below, and our responses are provided in* red font*. Line numbers in our responses refer to the revised version.*

ANONYMOUS REFEREE 2

Summary

The paper describes boundary layer (BL) height characteristics over the subtropical northern Atlantic off the coast of Africa, as derived from CALIPSO observations, ECMWF/IFS reanalysis, and ground-based observations comprising of two ground-based lidars and radiosonde observations. Ten-year BL height climatological values over two regions are analyzed and intercompared using CALIPSO observations and ECMWF reanalysis. The ground-based lidars and their respective BL height retrieval algorithms are evaluated and compared against CALIPSO using data from Cabo Verde. Furthermore, two test cases over Cabo Verde are evaluated showcasing distinct interactions between the BL and the Saharan Air Layer (SAL). The first case shows stronger BL inversions and suggests clear separation between SAL and BL, whereas the second case exhibits weaker inversion and shows dust aerosols mixed throughout the BL.

I commend the authors for assembling and performing analysis of several different datasets. The topic is interesting, and the figures are engaging, although the figure fonts should be substantially enlarged. The writing is largely clear and understandable, with only sporadic improvements of style required. The paper shows potential, although in my opinion the paper it falls short on meaningfully investigating the impact of dust on the Atlantic BL. It seems to me rather showcasing a collection of measurements and datasets, with little and inconclusive analysis of their strengths and disadvantages. Here are a few specific complaints:

Major comments:

1. Climatological analysis of collocated CALIPSO and ECMWF (sections 3.1 and 3.2).
The results section starts with analysis of climatological values of BL height in Area 1 and 2. Over Area 1, CALIPSO and ECMWF are in general agreement, with ECMWF being slightly higher than CALIPSO. However, in Area 2, and especially over land, we see very large differences in BL heights. The authors argue, that "CALIPSO in some cases detects the mixing layer height rather than the residual layer and the entrainment zone (Liu et al, 2018)", an explanation that is vague and unsatisfactory. The large differences between datasets require more in-depth analysis. For example, how many profiles were used in each of the bins in Fig. 6? How often CALIPSO misidentifies BL height in these cases (the error bars on CALIPSO data suggest it is a systematic bias rather than occasional misidentification)? Why two over-land bins agree within the error bars, but six bins do not? For nighttime data CALIPSO is systematically higher than ECMWF. This is very interesting, but it is not mentioned in the manuscript and no explanation is provided.

We sincerely thank the reviewer for these fruitful comments. We have performed major revisions to the manuscript and repeated parts of the analysis to address these concerns.
We paid particular attention to the averaging of CALIPSO data. The large differences and high variability in CALIPSO BL heights needed careful handling. To increase SNR of Calipso data, we averaged all profiles over ±100m around the point of interest. This averaging is a common technique in satellite data and significantly reduced variability. The updated discussion in Section 3.2 reflects these changes, as well as the better consistency of the two datasets.
For reference, this averaging resulted in 432 profiles for Figure 6 and 549 profiles for Figure 5. Additionally, the methodology section has been updated, and a statistical analysis has been added in the Appendix. The revised discussion in Section 3.2 now also addresses the systematically higher CALIPSO

BL heights during nighttime, as observed by the reviewer, along with other modifications to improve clarity and interpretation: *In the daytime plot (Figure 6-left), the two datasets show better agreement over the ocean compared to over land. Over land, the variability increases significantly for both CALIPSO and ECMWF, sometimes reaching up to 40% (e.g., at lon = -8°), particularly for the ECMWF dataset. This increased variability can be attributed to the diurnal evolution of the boundary layer: the data include all BL tops from 06:00 to 18:00 local time. Since the boundary layer over land grows and decays throughout these hours, typical for continental and desert areas, averaging over this period naturally results in large standard deviations. A similar behavior is observed in the CALIPSO retrievals, which also show substantial variability above land. It is also worth noting that CALIPSO tends to detect lower BL tops than ECMWF over land. This difference likely arises from the way to define the BL top: ECMWF relies on thermodynamic criteria, while CALIPSO identifies a decrease in aerosol concentration. Consequently, aerosols detected by CALIPSO are mostly confined within the mixed layer, whereas ECMWF's BL height may include the residual layer or even the entrainment zone above it.*

In the nighttime plot(Figure 6-right), the retrieved BL tops are as expected significantly lower over land for both datasets. Over the ocean, the agreement between ECMWF and CALIPSO remains good. Over land, however, a different pattern emerges: the ECMWF dataset shows little variability but reports lower BL heights than CALIPSO, particularly further inland (lon ¿ -10°). This again can be explained by the use of thermodynamic criteria to identify the BL top in ECMWF. In contrast, CALIPSO often detects aerosols residing in the residual layer or within the stable nocturnal boundary layer, resulting in systematically higher BL than ECMWF. An additional factor to consider is the quality of the CALIPSO nighttime profiles. The CALIOP instrument has different signal-to-noise characteristics during day and night: while solar background noise degrades daytime profiles, nighttime profiles suffer from lower photon count rates, which makes them noisier, especially over land. This effect is consistent with our findings in Appendix A2, where the correlation between ECMWF and CALIPSO is low.

Overall, the two datasets show generally good agreement over the ocean, where both daytime and nighttime results are consistent. This aligns with the findings from section 3.1 (Area 1). The agreement is also stronger during the daytime compared to the nighttime, reflecting the limitations of the satellite nighttime measurements. Over land, however, discrepancies emerge due to the strong diurnal cycle and the different methodologies used to define the BL top.

2. Correlations between CALIPSO and ECMWF, PollyXT Lidar, and Halo Lidar over Cabo Verde (Section 3.3).

In Section 3.3 the authors compare CALIPSO BL height retrievals against ECMWF, PollyXT Lidar, Halo Lidar, and Radiosonde datasets over Cabo Verde. Even though the number of data points is rather small (e.g. 13 for CALIPSO collocations with PollyXT), this still would be an interesting opportunity to evaluate the strengths of different BL height measurement methods. Instead, the analysis part (lines from 261 to 274) is rather short and often seems inaccurate. The slopes of 0.66 and 0.63, in my view, do not indicate good agreement between datasets. There is no Halo lidar data that would suggest overestimation at lower values of BL height (the data fits are simply inconclusive). ECMWF does not retrieve BL height (it uses a parameterization based on vertical profiles of atmospheric parameters). It would be interesting to see how distance from ground observations (PollyXT, Halo, Radiosonde) and CALIPSO affects comparisons (the islands affect BL structure and CALIPSO measurements can be as far as 150 km away).

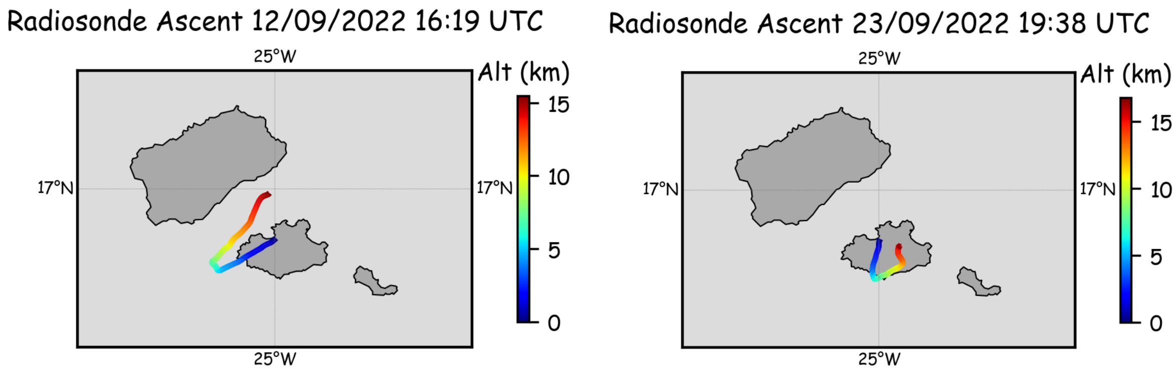
We thank the reviewer for the valuable comments. We have added the correlation coefficients to the plots to better represent the agreement between the datasets, rather than focusing on the slopes, and we have revised the discussion in Section 3.3 accordingly: *The correlation coefficient for PollyXT (red) and ECMWF (blue) lines, are r=0.69 and r=0.75 respectively, indicating that CALIPSO data present a rather satisfactory agreement with the model and the ground-based lidar. However, given their small positive intercepts (0.22 and 0.11), these datasets tend to estimate slightly lower BL compared to CALIPSO, even when their trends are generally aligned. The Halo lidar results, with the lowest correlation coefficient (r=0.37), show the weakest correlation with CALIPSO and the fit is inconclusive. The collocated cases may be limited, but suggest that CALIPSO generally captures the same variability in BL height as ECMWF and PollyXT, although with some systematic differences. The inconsistencies between Halo and CALIPSO BL results, reflect methodological differences, since Halo estimates the MLH from turbulence parameters while CALIPSO relies on gradient-based detection of layering. Similarly, ECMWF uses a thermodynamic approach (according to ECMWF ch.3), which may also contribute to discrepancies. The best agreement is found between the two aerosol lidars, highlighting that the choice of parameter used to define the BL height is critical for the assessment. CALIPSO and Polly use aerosols as tracers, identify-*

ing the BL top from the sharp reduction in aerosol load at the transition to the free troposphere, whereas the Halo determines the BL height from turbulence, calculated through vertical velocity variance. Moreover, given the limited radiosonde data points collocated with the CALIPSO, we included a comparison between all the collocated radiosonde-PollyXT BL heights during the campaign (N=40, r=0.87). We also appreciate the suggestion to examine how the distance between CALIPSO overpasses and ground-based observations affects the comparisons. While this would indeed be an interesting analysis, given the extensive revisions already undertaken and the scope of the current manuscript, we consider addressing this aspect in future work.

3. Two case studies over Cabo Verde
The two cases presented in the manuscript are quite interesting and properly illustrate different interactions between the BL and free atmosphere. However, I find the atmospheric profiles and BL height measurements rather inconsistent in these two cases, and the authors do not provide a satisfying analysis and explanation of the datasets. The authors refer to the virtual potential temperature in Figs. 9a and 11a, but it clearly appears to be the regular temperature (it drops systematically with height within the BL). In the first case (dust above BL), the BL height is well characterized by radiosonde observations (Fig. 9a), but all the other datasets indicate lower, sometimes considerably, BL heights (Fig. 9b, c). Halo lidar measurements are almost half the radiosonde value. There is no attempt to reconcile these discrepancies. In the second case (desert dust within BL), the BL height determination is more complicated and the discrepancies between methods could be more justifiable. The radiosonde BL height should be included in both Figs. 9b and 11b.

We thank the reviewer for pointing this out. We have replaced the temperature profiles with the virtual potential temperature in Figures 9a and 11a, and we have included the radiosonde-derived BL in Figures 9b and 11b.
We do not consider the BL results inconsistent across the two case studies; rather, the differences highlight interesting features of the BL structure under different conditions. In the first case, the radiosonde indicates a relatively deep layer, while the lidars and the model show a shallower layer. This apparent discrepancy can be explained by the presence of a shallow layer (approximately 750–1000m) beneath a residual or elevated inversion around 1km, resulting from either large-scale forcing or the previous day's atmospheric structure. The lidar detects the top of the aerosol layer, whereas the radiosonde responds to the thermodynamic inversion top, which may be displaced horizontally during the ascent. Radiosondes drift with the wind during as they lift and can sample air parcels several kilometers away, potentially encountering a different boundary layer structure. In contrast, the lidar provides a vertically local measurement. Strong wind shear or the presence of an entrainment zone can also create layered aerosol structures that do not necessarily coincide with the thermodynamic layer top.
At the first case, the NNE wind was very strong (up to 14m/s), directing the radiosonde toward Monte Cara, which reaches an altitude of 490m (see map below). We believe that the discrepancy is primarily due to this horizontal displacement and does not represent the boundary layer structure directly above the Observatory. In the second case, however, the radiosonde ascends through the central part of the island that does not have orography, and results in a closer agreement with the lidar measurements.

We have revised and enriched the discussion of sections 3.3.1 and 3.3.2, and we hope that this analysis satisfactory explains the datasets and the discrepancies that arise.



(a)

(b)

Figure 1: Maps with the trajectory of the radiosonde balloon during its ascent for two case studies. Left: 12 September 2022 and Right: 23 September 2022. The color along the trajectory indicates the altitude of the radiosonde.