Reply to the referee's comments

We thank the referee for the useful comments, which helped us to improve the quality of our manuscript.

In the following, the referees' comments are given in black.

Our point-to-point replies are marked by "R" and are in blue.

Changes to the manuscript text are in green.

Comments by referee #2

This is a quite complete paper about the evolution of the planetary boundary layer and its relationship with the recorded concentrations at a polluted site in Germany. Stuttgart was the selected site and the period investigated extended for February 5^{th} to March 5^{th} in 2018. Although this period is short, the equipment used is formed by a scanning aerosol lidar, an aerosol mass spectrometer, an aethalometer, a condensation particle counter, an optical particle counter, trace gas sensors and meteorological sensors. Measurements of these devices are presented. Moreover, experimental observations are contrasted with model simulations. The paper focused on the planetary boundary layer evolution during certain days and the role played by clouds. Additionally, a longer database, which extended form January 1st 2020 to January 1st 2022, was used to present the daily evolution of PM10 concentrations and the boundary layer height. Consequently, the paper merits to be published in Atmospheric Chemistry and Physics after the introduction of the following minor changes.

Since the period investigated is short, only one month, the results representativeness could be questioned. Hence, the authors should indicate if their results are robust enough.

R: Although the investigated period is short, we collected a comprehensive dataset which allow us better to understand the evolution of the planetary boundary layer (PBL) and associated aerosol concentrations through case studies. Furthermore, the meteorological conditions during the measurement period can be considered as quite typical winter conditions under high-pressure system influence. In addition, the correlation between boundary layer and aerosol distribution revealed by this short-term dataset fitted well with a 2-years dataset, which supports the robustness of our results. Finally, we need to be careful about the uniqueness of our result. As the measurement site located at a special topography in a step valley, the special topography may have impact on the boundary layer evolution and on accumulation of ground level aerosol concentrations. This is also the reason why we chose Stuttgart to investigate this topic.

Although the investigated time period is relatively short, the correlation between boundary layer and aerosol distribution revealed by this dataset fitted well with a 2-year dataset, which supports the robustness of our results. Furthermore, the meteorological conditions during the measurement period can be considered as quite typical winter conditions under high-pressure system influence. Therefore, our results have sufficient representativeness to compare with e.g. other seasons.

Moreover, some orthographic features are in the surroundings. The authors should comment the influence of such features on the planetary boundary layer evolution following varied wind directions. A short comment about possible processes such as anabatic or katabatic winds would increase the value of this paper.

R: Thank you for pointing on this. Actually, we have seen the phenomenon that anabatic or katabatic winds have impact on the boundary layer height. We have added the following text into manuscript to point this out.

Furthermore, the boundary layer heights measured by radiosonde is higher than those derived from lidar measurements, in contrast to case 1 (Figure 4). The possible reason for the differences in boundary layer height for case 2 can be explained as follows: the radiosonde site (SB, 321 m a.s.l) is at a relatively higher altitude compared to the lidar site (RSP, 247 m a.s.l.), as shown in Figure 1b. Additionally, the wind speed is much higher (2.2 ± 0.6 m/s) for case 2, as shown in Figure S8. This higher wind speed can induce updrafts, causing an increase in the boundary layer height.

Daily evolution of PM10 and boundary layer is presented by a two-year database. The authors should explain discrepancies between this evolution and that observed in their one-month period.

R: The correlation between boundary layer and aerosol distribution revealed in our short-term study fitted well with the 2-year dataset, which supports the robustness of our results. However, there are still some discrepancies which need to be discussed. The seasonal analysis shows that the ground-level PM_{10} concentrations are correlated with boundary layer heights from 04:00 to 08:00 (UTC) for all datasets. However, the strength of the correlation is different for different seasons. The spring (MAM) shows the strongest correlation (Pearson correlation coefficient: 0.83) while the winter (DJF) shows the weakest correlation (Pearson correlation coefficient: 0.26). In addition, the summer has the highest mixing layer height (1283 $\pm$ 399 m) while the winter has the lowest mixing layer height (682 $\pm$ 542 m) as expected due to the solar radiation being strongest in summer while weakest during winter. The ground-level PM_{10} aerosol concentrations are anti-correlated with mixing layer heights and show the highest concentrations during winter (33 $\pm$ 32 $\mu g/m^3$) and the lowest concentrations during summer (16 $\pm$ 7 $\mu g/m^3$).

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The authors should indicate the reasons to select some specific days, such as February 13^{th} or 14^{th}.

R: The two cases were chosen due to their characteristic atmospheric conditions. The case from February 13^{rd} to February 14^{th} was selected due to the low wind speed (0.76 $\pm$ 0.35 m/s). The low wind speed minimizes the impact of horizontal transport, allowing for more accurate analysis of local atmospheric conditions. Additionally, the clear skies during these two days ensured sufficient solar radiation to fully engage the boundary layer dynamics. In contrast, the case from February 24^{rd} to February 25^{th} was chosen due to the presence of clear skies but with relatively stronger wind speeds (2.2 $\pm$ 0.6 m/s). This selection allows for a comparative analysis of these two cases, highlighting the differences that wind speed can introduce to atmospheric conditions under otherwise similar solar radiation conditions.

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Finally, future research lines could be introduced at end of conclusions.

R: In future work, we plan to conduct more sensitive test experiments and to analyse physical and chemical processes in aerosol transformations in comparison with refined PALM-4U model results.

Regarding future work related to this study, this model version did not consider the aerosol chemical composition and only $PM_{2.5}$ and PM_{10} were predicted via prognostic scalar transport equations. Hence the formation of secondary aerosol generated by chemical reactions is not considered in this work and it would be the next step of our work to include this. In scope of this study we did not have computational resources and manpower to set up and test a full SALSA aerosol physics simulation. Given that we attempted the first winter evaluation of PALM's aerosol simulation behavior in complex urban terrain, our objective was to mostly check for plausible boundary layer dynamics and spatial patterns. More research is needed with more resources to address this in detail. Also, we acknowledge that the current utilization of the model is somewhat limited and we are aware of the substantial potential of the PALM-4U model for a more detailed comparison with our comprehensive observations. For instance, we plan to conduct sensitivity tests on the impact of clouds on boundary layer evolution, on the aerosol mixing processes as well as aerosol physical and chemical transformation processes. Finally, in an upcoming study we aim to present more details of the model simulations in the context of different dynamic processes.

Minor remarks:

1. Figure 1. Indicate if 1 km and 10 m are the network resolutions. Moreover, magnitudes and units in scales

must be introduced.

R: We have added the grid spatial resolution in caption and the magnitudes and units in scales is shown in "x-lable" and "y-label".

Two meter temperatures (contour) and ten meter winds (vectors) from the WRF simulation over the shaded model topography height in m above sea level are shown in (a). The white labels serve for orientation and the white lines mark the approximate domain boundaries. **The "5 km" and "1 km" shown in the left-upper corner of boundaries represent grid spatial resolution**. Around Stuttgart the PALM-LES domain boundaries are shown by a small white box. In (b) the PALM-4U domains are presented using the same type of visualization for the same model output time. Shown are potential temperature and horizontal winds on the second model level above surface, (i.e., 15 meter a.g.l.). The labels indicate measurement site locations and the white line indicates the aerosol laser scan beam, while the orange line indicates the location of the vertical section evaluated from PALM-4U (RSP = Rosenstein Park). **The "40 m" and "10 m" shown in the left-upper corner of boundaries represent grid spatial resolution.**

2. L. 148.Replace "haar" by "Haar".

R: We have replaced "haar" by "Haar".

3.L. 154. Replace "Zmin" by "zmin".

R: We have replace "Zmin" by "zmin"

4. L. 250, Replace "labled" by "labeled".

R: We have replaced "labled" by "labeled".

5. L. 301. Replace "conclud" by "conclude".

R: We have replaced "conclud" by "conclude".

6. Figure 9. Labels should be introduced.

R: We have added the introduction of the labels in the caption.

Range-height cross of $PM_{2.5}$ concentrations from scanning aerosol lidar (a, c) and PALM-4U simulation (b, d) at two different periods on February 14^{th}, 2018. (a, b: 09:12 - 09:20 **(early morning)**; c, d: 16:07-16:15 **(later afternoon)**

7. References should follow the journal style.

R: We have checked the reference carefully to follow the journal style.

8. L. 716. Replace "Fro¨hlich" by "Fröhlich".

R: We have replaced "Fro¨hlich" by "Fröhlich"