Dear Editor,

Below we include our response to all the reviewer's comments that include descriptions of the changes made to the manuscript. The manuscript submitted to ACPD is now available as a preprint with DOI and the citation was updated. In addition, we have changed the color map from batlow to viridis.

Natalie Kaifler

Reviewer #1

We thank the reviewer for acknowledging the potential of this type of data for atmosphere dynamics studies and the positive review.

On the impact of a gondola swing (section 2): It is true that the buoyancy motion of the balloon also induces a swing of the gondola that affects the zenith angle of the laser beam pointing. We investigated this effect by determining the angle of the horizon in images taken with a side-viewing camera. More accurately, the swinging can be quantified by evaluating the star positions in the PMC Turbo camera images. A validated astrometry data product is still in work, but based on the horizon measurements we estimated the uncertainty induced on the laser beam zenith angle to be less than 0.1 degree on average. This is the uncertainty given in l. 77, translating to 80 m horizontal distance within the PMC layer (l. 82). We slightly modified the sentence in line 77 to: "... was pointed 28 deg off-zenith, with an uncertainty of about 0.1 deg caused by the mentioned buoyancy oscillations."

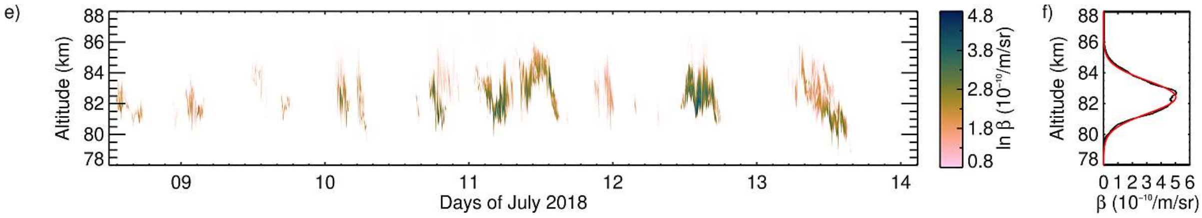
On the influence of PMC on the background (l. 118): It is true that the background is determined well above the PMC layers. There is however an indirect effect of PMC on the background, in the sense that the sky brightness increases when PMC are present. The background is thus not solely determined by the solar zenith angle (that is determined by local time), as is evident in Fig. 5a. For high altitudes where there is no contribution from scattered laser light any more, the lidar works like a photometer that measures the sky brightness at the position of the gondola. The following text was added to the revised manuscript: "... but is also influenced by PMC as they increase the sky brightness, too."

In line 150 we described our analysis in words in order to prevent confusion about the units, and to clarify how this was implemented. The text was changed to: "We only evaluate z_c for profiles where the sum of all ln beta values exceeds a value of 0.04."

We added "Evolution of PMC parameters during the 6-day flight of PMC Turbo:" to the caption of Fig. 5. The grey areas in Fig. 5b were supposed to aid a visual estimation of PMC occurrence frequency: grey areas are with PMC detections and white areas are without. This was mentioned in the text in line 162, but was missing from the caption, so we added ", with the light grey areas indicating times with finite beta_int for a better visual impression of PMC occurrence frequency, ".

The problem with Fig. 5e not showing beta values at times where beta_max exists was possibly an image resolution problem. The panel was replaced with a high-resolution plot of the data, and panel e and c now agree with regard to detection times as shown below.

The beta profile in Fig. 5f was a flight-mean profile normalized by the total flight time and thus includes periods of time with no PMC detections. Therefore, the absolute values were lower. We agree that it is more common to normalize by periods with PMC detections, and the updated curve exhibits a maximum of beta=5, as shown below.



We thank the reviewer for spotting errors that we overlooked: additional blanks (l. 35), wrong longitudes (l. 169), wrong titles in the citations (l. 260) and citations that have been updated in the meantime (l. 262-263). This has all been corrected in the revised manuscript. L. 171 was changed to “interannual”. L. 144 “to hint at sth.” is, we believe, not a typo, but a copy editor may help.

In Fig. 1, the width was increased as suggested, and the overlapping labels for 95% significance removed; instead, the information is included in the caption, which makes the figure better to read without losing information. Fig. 2 was put into an appendix as suggested, improving the readability. Fig. 4 was changed to identical y-scalings as suggested. A color bar in Fig. 5e was added. In Fig. 7 and 8 the vertical axis labels have been added and the minor tick numbers reduced as suggested.

Reviewer #2:

Two of the manuscripts which we cited and were not yet available online at the time of review are now published. The two companion papers on multi-scale Kelvin-Helmholtz instability dynamics observed by PMC Turbo on 12 July 2018 can be found at

https://agupubs.onlinelibrary.wiley.com/doi/abs/10.1029/2021JD036232

https://agupubs.onlinelibrary.wiley.com/doi/abs/10.1029/2021JD035834

and the updated citations are:

Kjellstrand, C. B., Fritts, D. C., Miller, A. D., Williams, B. P., Kaifler, N., Geach, C., Hanany, S., Kaifler, B., Jones, G., Limon, M., Reimuller, J., and Wang, L.: Multi-Scale Kelvin-Helmholtz Instability Dynamics Observed by PMC Turbo on 12 July 2018: 1. Secondary Instabilities and Billow Interactions, Journal of Geophysical Research: Atmospheres, 127, e2021JD036 232, https://doi.org/https://doi.org/10.1029/2021JD036232, e2021JD036232 2021JD036232, 2022.

Fritts, D. C., Wang, L., Lund, T. S., Thorpe, S. A., Kjellstrand, C. B., Kaifler, B., and Kaifler, N.: Multi-Scale Kelvin-Helmholtz Instability Dynamics Observed by PMC Turbo on 12 July 2018: 2. DNS Modeling of KHI Dynamics and PMC Responses, Journal of Geophysical Research: Atmospheres, 127, e2021JD035 834, https://doi.org/https://doi.org/10.1029/2021JD035834, e2021JD035834 2021JD035834, 2022.

The manuscript by Kaifler et al. on “Signatures of gravity wave-induced instabilities in balloon lidar soundings of polar mesospheric clouds” submitted to ACPD under acp-2022-572 is currently awaiting reviewer’s reports and are hopefully available online within few days.

“If possible, a brief description of data analysis methods on how to use your dataset to obtain small-scale features (such as vortex rings, instability structures, and so on) would be helpful for readers. “

The data can be subjected to a variety of analysis methods that are suitable to detect patterns like correlations, feature detections or spectral methods. The chosen method will likely depend on the specific goal of a study and may also depend on the case, i.e. the characteristics of the event to be studied. For guidance, the cited publications analyzing PMC Turbo or ALOMAR RMR lidar data are useful. It would be desirable to be able to define the identified small-scale features well enough such that they can automatically be pulled out of a lidar dataset by a standard algorithm. Possibly, the natural variability and different viewing geometries and wind speeds make it necessary to evaluated the dynamics case by case. The work by Kaifler et al. submitted to ACPD mentioned above employs a general method based on the evaluation of gradients at high resolution to locate small-scale features, and then discusses examples that are grouped by morphology and the likely underlying dynamics, for which tailored methods can be developed in the future.