Response to RC1: 'Comment on egusphere-2023-1856', Anonymous Referee #1, 25 Sept. 2023

Major

I suggest to add more detailed definitions and method descriptions. One example is the vertical extent (l. 307). Is this the distance from the lowest to the highest altitude with significant PMSE detection? Is it the same as h1 (Fig. 7)? I also didn't find the resolution in altitude and time, i.e. the size of the "PMSE-pixels". This is an important information for someone who tries to replicate the work. As the patterns were detected manually, it is crucial to describe the process as detailed as possible for someone to repeat it. How exactly were meteor occurrences and system-induced artifacts discriminated from "good" data (l. 119)? How often did these artifacts occur? Please give more details on how the manual search was carried out (e.g. 20 min periods, +- 15 m/s, look for a minimum distance between h0 and h1, or for simultaneous up- and downdrafts of x m/s amplitude?). Some of it was described around l. 344, but it should be put into a dedicated paragraph in the Method section.

- ➔ Thank you for your feedback! In response to your suggestions, we will include a dedicated paragraph in Chapter 2 to clarify the maximum vertical extent and its relationship to h1. We will also provide information on the temporal and spatial resolution of our measurements. The process for manually identifying patterns and discriminating meteor occurrences and system-induced artifacts from 'good' data will be described in more detail.

Were there up- and downdrafts that were not simultaneous but slightly shifted?

- ➔ Yes, indeed. This is precisely why we use the term "quasi-simultaneous".

It would also be interesting to see a compilation of all or the most extreme events, e.g. those with a widening of 7 or beta of 6. Maybe this can be shown in a supporting information, or a zip file. It could be helpful for future research.

- ➔ We will consider including this data in a supporting information file for future reference.

The discussion leaves the impression that the work is unfinished, as it is a bit vague and unfocused (e.g. "the significance is yet to be determined", or the vague comparison with Hozumi et al., 2019). Suggestions for analysis that would be required to explain the origin of the structures are made but not carried out. How many events have simultaneous lidar data, and does that indicate temperature inversion layers? (For further investigations, it could be helpful to provide a list of the dates and times of the 707 events). Is there data on horizontal wind?

- ➔ Thank you for your input! In the discussion, suggestions are given for possible approaches to the investigation of the physical causes, which are, however, not provided for in the scope of the present work. So far, we do not know for which observed events, measurements of other instruments like e.g. lidars or satellites are available. Despite the peak frequency of lidar measurements coinciding with our observation period, which transpires during the summer months, the ALOMAR lidar system is constrained by daylight conditions, limiting its altitude coverage to a maximum of 80 km. Other instruments as airglow imagers are contingent on nighttime conditions, which, regrettably, do not coincide with the observation of PMSE. Data on horizontal wind can and will be used in a follow-up paper including case studies for which we will look into those background conditions.

It says "kilometer-scale" in the title, but no horizontal dimensions of the structures are estimated in the text.

➔ Your finding is certainly correct. While the text does not provide specific measurements of the horizontal dimensions of the structures, the motivation for this study stemmed from the work of Chau et al., which did present radar imaging plots that demonstrated the spatial dimensions of similar events. The radar beam width imposes limitations on the observed area, and the presence of both upward and downward movements followed by 'no movement' (green) suggests that the areas traversing the beam with high vertical velocities cannot exceed a certain size. If the entire atmosphere within the observation volume were in motion, the patterns in the velocity plots would indeed look quite different. This provides context for the 'kilometer-scale' description in the title

Inter- and intraannual variation of the occurrences of the structures are shown but remain fully unexplained.

➔ It is our considered view that the current sample of events under examination may be insufficient in size to derive definitive conclusions. We must acknowledge that our observations are heavily contingent upon the presence of Polar Mesospheric Summer Echoes (PMSE), and thus, we exercise caution in formulating any conclusions. It is quite conceivable that high velocity events in the mesosphere, as visualized by our PMSE observations, occur throughout the year and show significant diurnal, seasonal or annual variability compared to our current findings.

The diurnal variation of the occurrences of the structures is shown together with the diurnal variation of PMSE (Fig. 6), but the relative occurrence would be more interesting. Is there, or isn't there a significant diurnal or semidiurnal variation left when accounting for PMSE occurrence? Sect. 4.3 should be rewritten based on relative occurrences. Attention should be paid to units or resolution when stating occurrence rates. It is better to say "structures were observed on 33 out of 100 days on average" instead of "33%" (l. 245), because when counting occurrence or non-occurrence not on scales of days but on scales of 20 min or less, the occurrence rate is much smaller than 33%.

➔ We appreciate your comment. We will explore the possibility of showing diurnal variations in relative occurrence and will revise and add to Section 4.3 accordingly. Your emphasis on units and resolution of occurrence rates is noted, and we will ensure that our reporting is more accurate.

Comments by line number

l. 11 please add the total duration of the events, is it about 200 hours?

➔ We can definitely add this value, thank you.

l. 17 "highlighting their extreme nature": if so, you could mention that the distribution is non-Gaussian

➔ Thank you. The fact is included as follows: Notably, a careful examination of the vertical velocities associated with these events confirmed that approximately 17% surpassed the 3σ threshold, highlighting their non-Gaussian distribution and extreme nature.

Fig. 4 The examples show different numbers of oscillations, e.g. three in Fig. 4a. I would thus label t0, t1, t2,… (and not t0, t0, t0) to include a counter for this number in addition to your "d = duration" which is actually the period of one oscillation.

➔ Thank you for your input, but we would prefer to maintain the current labeling. The intention behind the sketches is to illustrate how each individual event was identified. Even within a 'pair' or 'group,' each event is counted as a single occurrence.

In Fig. 4c, only a slight variation can be seen in the evolution of the upper boundary, but the velocity measurements show a clear oscillation for several periods. The amplitude of these oscillations could also be an interesting parameter (it can be seen in the color, but a color bar is missing).

➔ You are right, and indeed, the amplitude of these oscillations could be an interesting parameter to consider. However, implementing this change would extend beyond the scope of this current work..

l. 120 Modelling is mentioned briefly, but it doesn't become clear what exactly was expected in terms of occurrence rate from the modeling.

➔ Thank you for bringing this to our attention. In Feraco et al., it was found that 1 in 1000 events included vertical velocities outside the Gaussian reference. We will provide additional information on the expected occurrence rates in the upcoming sections. .

l. 185 in addition to the mean and standard deviation, the kurtosis and skewness could be stated, that indicate in what way the distribution differs from a Gaussian.

➔ We appreciate your suggestion. We will certainly explore the inclusion of kurtosis and skewness to better elucidate how the distribution differs from a Gaussian one. Thank you for this valuable input.

Fig. 6b please calculate and give the percentages of the one-, two- and three-oscillation classes in the text, e.g. 80 %, 15 % and 5 %, and the same for the high-velocity subset.

➔ Thank you for your suggestion. We will consider calculating and providing the percentages.

Fig. 8a A logarithmic y axis might show better the extreme events with low counts.

➔ Thank you for the recommendation. While a logarithmic y-axis might enhance the visibility of extreme events with low counts, it's worth noting that it could potentially create a misleading impression that these extreme values occur more frequently than they actually do.

Fig. 8a Please add the Gaussian to Fig. 8a. Then one can directly see where it differs. I expect to see long tails, i.e. the extreme values are much more frequent than if the distribution would follow a Gaussian.

➔ Thank you, we appreciate your input. However, it appears there may be a misunderstanding. In Fig. 8a, the distribution is intended to follow a Gaussian pattern, rather than differ from it. We will ensure this aspect is clarified in the text.

In Fig. 8b you could show the Gaussian with the same vertical axis as on the left (so not scale it to fit in the window). So the peak will be way outside the plot, but then you can compare the tails, which is the interesting part. I think it is fine to show 8a with log y axis and 8b with linear y axis from 0 to 60 counts.

➔ Thank you for your suggestions. We would prefer to maintain the current presentation for the same reasons as previously mentioned..

Fig. 8b if the figure shows the histogram of the "maximum vertical velocities of varicose-mode events", then the total number should add up to 707. There are however many more. Is this the maximum w per profile? If so, what is the temporal resolution of a profile?

➔ Thank you for your inquiry. Each 'wing' in the histogram does indeed add up to 707, as it should. This histogram represents two values for each event: the maximum updraft velocity and the maximum downdraft velocity. We will make sure to clarify this in the text. The temporal resolution of a profile will also be included for better context.

Minor

Your suggestions and the responses have been considered. If you have any more comments or questions, please feel free to ask.

l. 105 the last part of the sentence is missing

➔ Thank you! We missed that. We completed the sentence as follows …, which already modifies the temporal resolution and f_N of the measurements.

Fig. 4 Is it intentional that the colors appear somewhat unsharp? If not, my hint is that it is related to a problem with resolution when converting to or from postscript.

➔ Thank you for your observation and suggestion regarding Fig. 4. The appearance of somewhat 'blurred' colors is, in fact, intentional. It's utilized to convey the signal strength, with brighter colors indicating stronger signals. This effect is particularly prominent in areas where the signal-to-noise ratio is lower.

Fig. 4 please add a colorbar

➔ Thank you for your suggestion to add a colorbar to Fig. 4. We will accommodate this request, although it's worth noting that the primary purpose of this figure is to illustrate the structural aspects rather than the velocities. Nevertheless, we will include a colorbar for additional clarity.