Dear Reviewer 2,

Thank you for your time in reviewing the manuscript. Please find responses to your comments below in bold.

Best regards,
The Authors

Reviewer 2

This manuscript describes a statistical method for deriving neutral density variations in the mesosphere and lower thermosphere from 1.4 million meteor head echoes observed by the MAARSY HPLA radar between 2016 and 2023. The authors report fluctuations of 20–40% with a 3-day temporal and 2 km altitude resolution, consistent with atmospheric model predictions and influenced by geomagnetic and atmospheric events.

A fundamental concern, however, is that the work falls outside the scope of Atmospheric Measurement Techniques. The journal is explicitly dedicated to advances in measurement methodologies, including the development, intercomparison, validation, or simulation of remote sensing, in situ, and laboratory techniques. This manuscript does not present any such advancement. Rather, it applies an established radar technique to derive neutral density variations, without contributing innovation in measurement methodology, error analysis, or instrument simulation. While the scientific topic may be of interest, the absence of methodological novelty or development renders the work misaligned with the stated aims and objectives of the journal.

AC: This comment has been addressed in a previous reply (included at the end of this document). We consider this work to be within the scope of Atmospheric Measurement Techniques, with a focus on "techniques of data processing for information retrieval for the atmosphere".

Equally serious is the manuscript's reliance on an overly simplistic assumption that meteor detection altitude depends solely on V^3. The authors themselves acknowledge this limitation in the introduction:

"With this technique the height variations are determined as an average quantity with a neutral density isocontour assumed to follow this altitude variation. This provides a general overview of atmospheric neutral density variations, but provides minimal information about differences between altitudes for the same time."

Such an assumption is physically unsound. A more rigorous treatment would account for kinetic energy, since the ablation profile—and thus detection altitude—of a large, slow particle may closely resemble that of a small, fast one. Furthermore, the astronomical origin of the meteoroids, and therefore the entry angle, exerts a significant influence on detection altitude, as do local atmospheric conditions (e.g., Dawkins et al., 2024). Equally, the physical composition of the meteoroids has been shown to play a decisive role in ablation behaviour in optical studies (e.g., Kikwaya et al., 2011a,b). That the authors chose not to employ a comprehensive ablation model, despite the ready availability of such tools, is a serious shortcoming that undermines the robustness of the presented analysis.

AC: We do not assume that the meteor detection altitude depends solely on V^3, we assume that statistically the other factors should be similar for a population of meteors measured on the same day-of-year (DOY). Therefore the primary difference for the same DOY corresponds to atmospheric density.

Many of the factors listed in the comment consider a single meteor event, but here we consider the statistical population of meteors. Factors such as the entry angle and the composition of meteors should be relatively consistent statistically for the same DOY between years. It is due to the numerous meteor head echo events made available with this MAARSY dataset that it is possible to perform the analysis in this study.

In addition to these two fundamental flaws, there are numerous further issues which must be addressed:

Throughout the manuscript the authors refer to “measuring the neutral density”. This is incorrect; the study concerns variability in neutral density, which is conceptually distinct.

AC: We agree that we should clarify that we are determining neutral density variations, and have made the corresponding changes to the text.

Page 3, line 34: The claim that “Measurements of the meteor head plasma provide more details on the meteor ablation and trajectory, but require HPLA radars” is outdated. This has not been true for some time (see Janches et al., 2014; Panka et al., 2021).

AC: We have rephrased this to “… but require HPLA radars to consistently make measurements of microgram sized ablating meteoroids, which greatly increases the number of meteor head echo detections.”

Page 3, line 77: The statement “This suggests that meteoroids with higher velocity are, on average, detected at higher altitudes” is not a suggestion—it has long been established (e.g., Janches & ReVelle, 2005; Vondrak et al., 2008). Moreover, as noted earlier, detection altitude depends on several other parameters, particularly in the context the authors are attempting to present.

AC: We have removed that it is suggested.

Page 3, line 84: The authors state that “Throughout the year, the radiant distribution of meteors observed by a radar changes (e.g., Janches et al., 2006; Kero et al., 2012).” This is correct but incomplete. The variability is highly location dependent; at equatorial sites, for example, such changes are minimal.

AC: We have added that the variability is location dependent.

Page 5, lines 95–100: The discussion presented is already well established in the literature, and the variability again depends strongly on geographical location. For example, such variability has not been measured at equatorial latitudes (see Sparks & Janches, 2009a,b). The authors should clarify and reference the prior work properly.

AC: We have added a reference and included some discussion about variability being location dependent.

Page 5, line 102: The repeated reference to the “background model” is ambiguous. It is not clear what background the authors are referring to, and this requires clarification.

AC: We have clarified what is referred to by the “background model”.

In its present form, the manuscript suffers from serious conceptual, methodological, and contextual shortcomings. Most importantly, it does not offer an advance in measurement methodology and therefore lacks relevance to Atmospheric Measurement Techniques. The paper may be more appropriately considered by a journal focused on atmospheric dynamics or variability, rather than one dedicated to the advancement of measurement techniques.

AC: We respectfully disagree. As we have stated, this study uses techniques of data processing for information retrieval for the atmosphere, which falls within the scope of Atmospheric Measurement Techniques. The applied technique to this dataset is novel, and provides a new method of tracking neutral density variations as a function of altitude between years. This technique will provide new opportunities for scientific studies, some of which are briefly discussed in the manuscript.

References

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Initial Response:

Dear Reviewer,

Thank you for your time in reviewing the manuscript. We wish to respond to your comment that this work is not within the scope of AMT. We respectfully disagree.

While the measurement of meteor head echoes is established, here we leverage the extensive dataset available to showcase a novel analysis technique applied to meteor head echoes to derive atmospheric neutral density variations between years for the same day-of-year. To quote the AMT landing page (https://www.atmospheric-measurement-techniques.net/), "The main subject areas comprise the development, intercomparison, and validation of measurement instruments and techniques of data processing and information retrieval for gases, aerosols, and clouds." The work we present falls well within the subject of techniques of data processing for information retrieval for the atmosphere.

We also wish to emphasize that the methodology presented has not been applied previously to meteor head echo measurements. We are able to perform this analysis due to the extensive dataset of greater than 1 million meteor head echo detections made with the MAARSY radar system on a consistent basis between the years of 2016-2023. To the authors knowledge, no other meteor head echo dataset of this magnitude is available globally.

The remaining comments will be addressed during the response phase.

Best regards,
Devin Huyghebaert