Dear Dr. Joel Younger,

We thank you for your helpful comments and suggestions. Please find responses to each item below in bold.

Best regards,
The Authors

Reviewer 1

This paper describe the use of a large data set of radar echoes from meteor head ionization to infer density fluctuations at altitudes around 90-110 km. The work is well explained and presented and adequately cited. Of particular interest is the authors' use of velocity cubed as a proportional proxy for atmospheric density. The writing is of an overall high quality and figures are both easy to read and complimentary to the text. The paper provides a useful introduction to the authors' methodology and will serve as a useful foundation for their future publications on the topic. It is recommended for publication with the following minor changes.

General: This is perhaps pedantic, but "bulk density" may be more appropriate than "neutral density" While the atmosphere is relatively lightly ionized in the meteor ablation region, collisional heating at entry speeds does not distinguish between neutral molecules and those missing a full complement of electrons. It is recognized that "neutral density" is commonly used in literature, but this may be an opportunity to use more precise language.

AC: We agree that both ionized and neutral atmospheric constituents will play a role. That stated, the neutral density is the heavily dominant factor. To be consistent with previous literature, we have decided to keep 'neutral density'.

Line 20-21: It would also be worth mentioning Yi et al. 2018 (doi: 10.1002/2017JA025059)

AC: The reference has been added

Line 27 change "signal" to "line of sight vector" or similar

AC: Changed

Should define MST acronym at first use in main text.

AC: The acronym has now been defined.

Line 54: remove "A", use commas

AC: Changed

Line 84-85: It would be good to also cite the work of Campbell-Brown in generating precise maps and models of the sporadic background e.g. Campbell-Brown et al. 2008 (doi: 10.1016/j.icarus.2008.02.022)

AC: Added the citation

Line 85: Maybe use autumn instead of fall to avoid confusion.

AC: Changed to autumn

Line 103/figure 2: Is this mean detection altitude or mean initial detection altitude?

AC: This is mean initial detection altitude. It has been clarified in the text.

Line 110a/section 4: This assumes that the size distribution and composition of meteoroids remains constant throughout the year. While this may be a reasonable assumption for the sporadic sources, it is less so for shower sources. This raises the possibility of transient contamination of the results during strong shower activity.

AC: This is true. We have clarified this in the text. This is also related to the comment on Figure 2 below – during meteor showers the trajectory and composition of the population will be more uniform, resulting in some contamination or bias. This is why the same DOY is analyzed as a tracer for the neutral density variations.

Line 110b: Equation 1 describes the energy balance of collisional heating, radiation, and vaporization, but does not describe the amount of plasma generated or the reflectivity near the meteoroid. Readers would benefit from an expression describing meteor head plasma density and echo strength at the wavelengths considered. It also seems important to mention the aspect sensitivity of meteor head echoes, which may affect the average seasonal results. This only affects the absolute terms in figures 1 and 2, but not the later figures, which portray relative fluctuations between years.

AC: We have added some discussion on the meteor head echo plasma and radar echo strength. The aspect angle is not expected to have a significant effect on the meteor head echo detections (e.g., Kero et al. 2008). It is also generally accepted that that majority of the plasma generated in the vicinity of the meteor is from the ablated meteoroid material (currently mentioned on lines 75-77 and references Dimant and Oppenheim, 2017; Sugar, 2018).

Kero, J., C. Szasz, G. Wannberg, A. Pellinen-Wannberg, and A. Westman (2008), On the meteoric head echo radar cross section angular dependence, *Geophys. Res. Lett.*, 35, L07101, doi:10.1029/2008GL033402.

Dimant, Y. S. and M. M. Oppenheim (2017), Formation of plasma around a small meteoroid: 1. Kinetic theory, *J. Geophys. Res. Space Physics*, 122, 4669–4696, doi:10.1002/2017JA023960.

Sugar, G., Oppenheim, M. M., Dimant, Y. S., & Close, S. (2018). Formation of plasma around a small meteoroid: Simulation and theory. *Journal of Geophysical Research: Space Physics*, 123, 4080–4093. https://doi.org/10.1002/2018JA025265

Line 114: Would substitute "plasma density" for "ablation rate". The latter refers to material loss rate, not specifically generation rate of detectable plasma

AC: We have made the change.

Figure 2: These are well constructed and easy to read plots. The correlation in the top panel is clear, but the deviation of the 60 and 40 km/s heights from associated iso-density contours in the bottom panel for the first half of the year goes unremarked in the text, except the disclaimer in lines 108-

109. Do the authors think that this could be a shortcoming of the MSIS model, dynamical features of the atmosphere, or something to do with temporal changes in head echoes?

AC: It could be due to multiple different factors. One is meteor showers, where the Eta Aquariids could be affecting the results as they have relatively large velocities. There could also be effects from the atmosphere, such as sudden stratospheric warmings.

Line 120: "…panel of the background…"

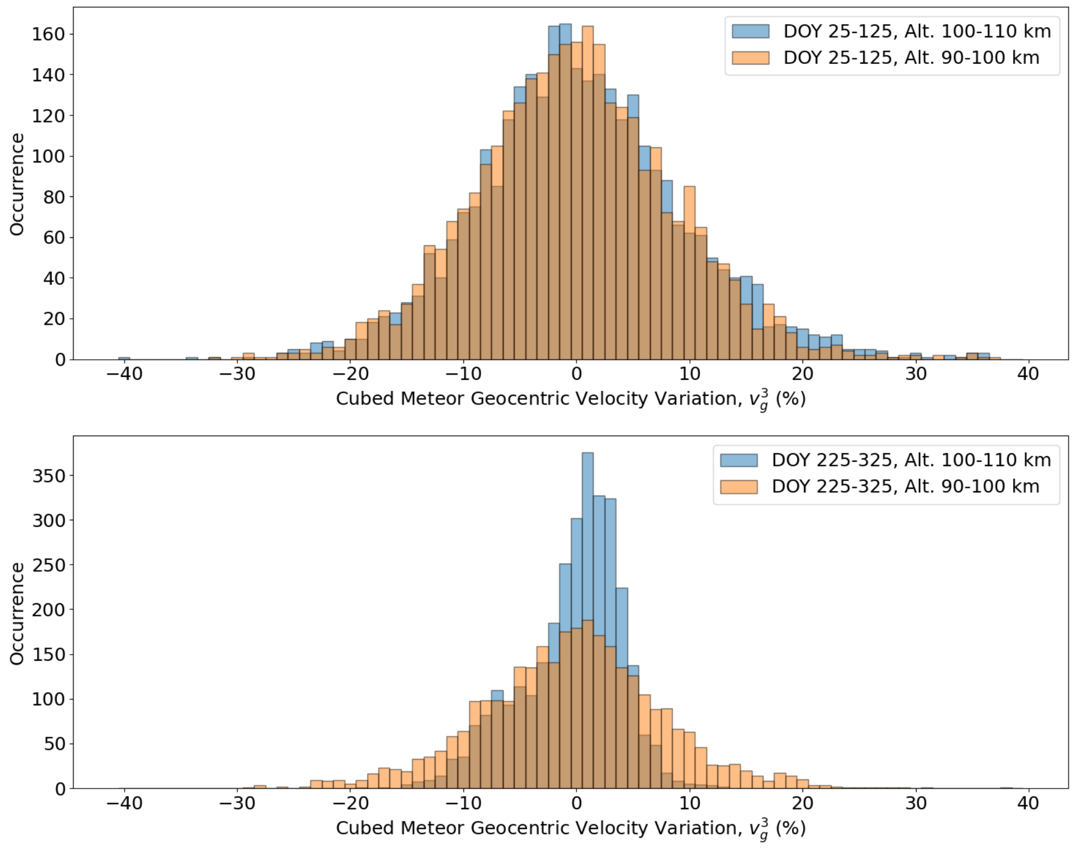
AC: Changed

Line 129: incomplete sentence ending in "…to compare with."

AC: Corrected the sentence

Section 4.4: The summer/autumn reduction in density above 100 km is not obvious to me in figure 3. Is there some other way of presenting the data to make this claimed feature stand out?

AC: We have added Histograms of the variation values for days 25-125 and 225-325, separated into the altitudes of 90-100 km and 100-110 km (Figure below). The figure shows a clear change in the density variations above and below 100 km for the second half of the year. We consider that this is due to a reduction in variations in the atmospheric density between years at these altitudes that affect the meteor ablation rates, and could be related to the turbopause altitude. More investigation is required to say definitively why this change in density variation occurs.



Section 4.5: This section could benefit from the inclusion of a wavelet spectrogram that should clearly show the presence of planetary waves. Alternatively, a line plot showing the velocity cubed ratio variation at a fixed height may provide readers with a clearer depiction of oscillations.

AC: We have added a further figure showing the planetary wave activity with the zoomed in figure below. A wavelet analysis is beyond the scope of the current manuscript, but it is something planned in the future.