The authors would like to thank the referee for his/her valuable comments. The organizations of the paper are substantially revised to address the referee's comments.

Referee 2

Interactive comment on "Neutral air turbulence in the mesosphere and associated polar mesospheric summer echoes (PMSEs)" by Alireza Mahmoudian et al. Anonymous Referee #2 Received and published: 18 January 2021 The paper is devoted to investigation of polar mesospheric summer echoes (PMSE) and aims at comparing simulations with radar observations. The title suggests that the main subject of this study will be the neutral air turbulence. The abstract further defines several key points which should be addressed in this work:

1. "four radar frequency observations of the PMSE region under varying neutral air turbulence conditions."
2. "effect of neutral air turbulence on the generation and strength of PMSE" as a function of "dust parameters"
3. "neutral air turbulence in presence of heavy dust particles, can largely explain the observed radar cross-section at four radar frequencies"
4. "effect of initial turbulence amplitude" as dependence on "of various dust parameters"
5. "Several key parameters in dusty plasma responsible for the PMSE observations are determined"

The paper is badly organized, difficult to read, and contains vast of misleading formulations (wrong definitions and descriptions). As a result, it is difficult to follow the authors ideas and interpretations. I did not find satisfactory answers on most of the defined above problems and cannot suggest a simple way of improving this manuscript. Therefor I suggest rejection. General structure of the manuscript must be improved by separating model description, simulation results, its comparison with measurements, and conclusions. Currently everything is mixed in two sections 3 and 4. PMSE study at three radar frequencies can be found in work of Rapp et al. (2008), where it was quantitatively shown based on measurements, that turbulence in presence of heavy aerosols well explains PMSE strength and frequency (Bragg scale) dependence. Also, scattering of radio waves as dependence on turbulence parameters was addressed in detail by Lübken (2014). Therefore, authors must show what is new in their paper. However, I may admit that if measurements shown here were made in a true common volume (which is not clearly said in the manuscript) they are quite interesting and I would encourage authors to submit a more consistent and detailed study based on these data. In what follows I give some more specific comments.
As the authors mentioned in his/her comments, our work (the present paper) is the first true common volume observations of PMSE source region with 4 radars. This is one of the main advantages of the present data in comparison with the previous works cited by the referee (such as Rapp et al., 2007) that probed different region of PMSE (130 km difference in PMSE location). Another main advantage of the present work is including the HF PMSE observations at 7.9 MHz (corresponding to 20 m wavelength). This is critical to make a correct judgment on the applied theories such as neutral turbulence with high Schmidt number.
There are numerous in-situ rocket observations in recent years that have probed PMSE source region in different months of the year, they unanimously have shown that the particles in the region are much smaller than what claimed in the conclusion of the paper cited by the referee. The referee argued in the referenced paper (Rapp et al., 2007) that dust particles of the size of 20 nm are required to get the best agreement with the observations and theoretical model.

Almost all recent in-situ rocket observations of PMSE source region in different months have shown dust/ice particles at much smaller radius are responsible for the radar echoes. Moreover AIM satellite observations have shown the similar concept. The present paper uses the state-of-the-art numerical model capable of simulating the PMSE source region including all physic processes considered. The results presented in the paper have shown that even small dust particles are capable of producing the radar echoes at the same level as those observed in the experiment. Therefore, the proposed model and the novel observational results presented in this paper are advancement to the field and previous works.

The authors agree with the referee that the paper could benefit from reorganization. Therefore, author take this comment into full consideration by rewriting the vague parts of the paper as well as reorganizing the paper through separating the model description, comparison between observational and numerical results, clearly explain the difference with the previous work and novel results provided by this paper.

• To point 1 above: I did not understand from the article how the "turbulence conditions" were "varying" during measurements and how it was inferred from those measurements. I've got an impression, that turbulence was not estimated from the measurements, however it might be possible, e.g., from spectral width of the radar measurements.

The experiments conducted in different days and years that impose the variation of turbulence condition. Even the radar echoes presented in the paper clearly show the variation in the strength of radar echoes in associated frequency bands.

• The same is also valid for the second goal claimed in the abstract (point 2 above). Also, as I understand, the authors use "dust density fluctuation amplitude" as a measure of turbulence intensity. However, this relation is not justified or explained in the paper (e.g., at least by assessment of time constant). Also, I did not find, "effect on PMSE generation", e.g., range of "dust parameters" and turbulence intensity when PMSE is not generated, or threshold values, whatsoever.

The referee mentioned two different thing that are totally un correlated. The initial amplitude of dust density fluctuations in the dust density is considered to be 50 or 100 percent with respect to the background dust density. The values used in this paper are based on recent observations and available theories. The model then let the physical processes including the competing charging and diffusion process to advance. The charging on to the dust particles intends to increase the electron density fluctuation amplitude. The diffusion process tends to have an opposite impact. Therefore, the final amplitude of electron density fluctuation that corresponds to the radar echoes is calculated by letting the simulation to reach the steady state. In other words, "dust density fluctuation amplitude" is just an input parameter that could reflect the strength of the turbulence. But what the model calculates and matters the most is the electron density fluctuation amplitude in presence of various dust density and radius.

• In abstract stated: "neutral air turbulence in presence of heavy dust particles, socalled fossil turbulence" (point 3 above). It is wrong formulation. You can name it dusty turbulence, but not fossil. Fossil turbulence can be characterized by presence of turbulent-like structures in scalar fields whereas the velocity field became laminar. Also, as mentioned above, this point was much better addressed by Rapp et al. (2008).

We appreciate the referee's comment on using the term Fossil turbulence. We corrected this for clarification. We have explained the weaknesses of the reference proved by the referee. We have also mentioned a detailed comparison as well as the advantages of our model in comparison with the previous studies.

• To point 4 above: The term "various dust parameters" must be explained better, e.g., by a table of these parameters, or by sub-sectioning the paper explaining these dependencies subsequently. Also practical meaning of the "initial turbulence amplitude" in this study is unclear. Is it a pure feature of simulations or it can be used for interpretation of measurements?
A new table will be added to the paper to explain the dust parameters used in the simulations. The criteria for using such parameters have been provided in the text. The initial turbulence amplitude has been explained in the response to the previous comments. It can be definitely used with the common volume observations at 4 frequencies to interpret the measurements.

• The last point in the list of goals mentioned above is not answered in this paper as well. However, this is already answered in numerous works published so far.

References Lübken,
F.-J., Turbulent scattering for radars: A summary, Journal of Atmospheric and SolarTerrestrial Physics, 107, 1 – 7, doi:https://doi.org/10.1016/j.jastp.2013.10.015, 2014.

Rapp, M., I. Strelnikova, R. Latteck, P. Hoffmann, U.-P. Hoppe, I. Häggström, and M. Rietveld, Polar Mesosphere Summer Echoes (PMSE) studied at Bragg wavelengths of 2.8 m, 67 cm, and 16 cm, J. Atmos. Solar-Terr. Phys., 70, 947–961, doi:10.1016/j.jastp.2007.11.005, 2008.

The weaknesses of the above-mentioned references have been pointed out in our response. Moreover, the above-mentioned references admit the limitation of their work. It has been clearly stated that ultimate proof of their concept (Schmidt number between 2500 to 5000 which requires as large as 20 nm) requires direct measurement of ice particle sizes in a PMSE environment. Our study provides the first common volume observations of PMSE source region with 4 radars including the 7.9 MHz radar for the first time in such study. Having a low frequency radar corresponding to high wavelength in the fluctuations is critical to make a solid conclusion to explain the source of irregularities as well as provide an exact estimation of background dusty plasma parameter (including dust radius and density) to achieve the radar echoes at level observed at 4 frequencies. Unlike the similar past works that had limitation in the experiments including uncorrelation in the probed region by different radars, no observations in the HF band, as well as using simple theories of neutral turbulence in the presence of dust particles that required high Schmidt number associated with large dust particles, the present work uses the full computational model to study microphysics of this region and evolution of radar echoes in response to the background dust parameters. Therefore, the finding of the paper has shown for the first time that smaller dust particles could also explain the radar echoes. Moreover, estimation of background dust parameters along with neutral turbulence is another advantage of the present work.