Dear Editor,

We are pleased to have been given the opportunity to again revise our manuscript entitled, *"Characteristics of layered occurrence ratio of polar mesosphere summer echoes observed by EISCAT VHF 224 MHz Radar".* We thank you and the referee and appreciate the effort of all of you to review our paper and providing us very insightful and constructive comments. Herein we explain how we revised the paper based on reviewer comments and recommendations.

We uploaded the following files,

[1] Point-by-Point reply manuscript: in this file replies to comments are given.

[2] Revised Manuscript: this is the clean and 'revised version' of the paper. In this file all the changes made in previously submitted manuscript is 'highlighted' with 'yellow color'.

[3] Track changes manuscript: In this file, there are two kinds of writing:

(a) The 'underline' writing represents the corrected and newly added words and sentences.

(b) The 'strikethrough' writing represents the deleted words and sentences.

We again appreciate the careful review and constructive suggestions of all of you. Below is our reply to comments.

Reply to Editor comments:

Reply to comment: before to reply this comment, first the authors would like to thanks your careful works and valuable comments. The comments and suggestions are very useful for our manuscript. We have addressed these comments and suggestions, and made (tracked) changes in the manuscript.

Minor Comments:

(a): Pg. 1, Throughout the manuscript: earth -> Earth.

reply: It is done. In "Revised Manuscript" we have replaced earth by Earth.

(b): Pg 2, line 14: ... (1) these echoes are summer phenomena.

reply: It is done. In "Revised Manuscript" the correction is at page 2, line 16.

(c): Pg 3, lines 5-6: Please, verify the citations

reply: It is a typo. In "Revised Manuscript" the correction is at line page3, line 7.

(d): Pg 3, lines 9-11: This statement is confused, please, re-write it.

reply: It is done. In "Revised Manuscript" the re-written statement is at page3, line 10-14.

(e): Pg 4, lines 3-4: The authors have mentioned 6 modes of the radar operation. However, they

describe only two of them. Maybe they could explain shortly the difference among all operation modes.

reply: Thanks for suggestion. We have expanded Table 2 to give the parameters of 6 modes of the EISCAT VHF 224MHz radar.

(f): Table 3: Please, put the units into the brackets, i.e., (min) instead of /min

reply: It is done. In "Revised Manuscript" the correction is at Table 3.

(g): Pg 7. lines 9-11. Please, give a meaning for the Spearman rank coefficient, in this case.

reply: It is done. In "Revised Manuscript" the correction is at Pg8, lines 7.

(h): Pg. 16. line10. "But, we still can not. . .."

reply: It is done. In "Revised Manuscript" the correction is at Pg17, lines 27.

Major Comment:

(a) The authors must clarify their contribution with this study. They are using an almost solar cycle of data to study PMSE occurrence and the data is really valuable to understanding some unsolved points on this topic.

reply: By analyzing the EISCAT VHF radar data, we found that mono and double layer OR is higher than the tri-layer OR. In addition, a seasonal variation of the OR between these three layers is noticed. Furthermore, we have proposed a new method to estimate the characteristics of the layered PMSE OR. Results obtained from this new method is used to understand the solar cycle dependency and geomagnetic variation dependency of the layered PMSE OR. The relationship between layered PMSE OR and $F_{10.7}$ and between layered PMSE OR and K values also be analyzed. We used the $F_{10.7}$ and K values corresponding to the occurrence of PMSE with threshold of $N_e > 2.6\times10^{11}m^{-3}$. So that, the correlation of PMSE with solar and geomagnetic activities is not expected to affect by discontinuous PMSE. The study of relations between PMSE and solar activities and between PMSE and geomagnetic activities are significative.

(b) Page 8. Line 7. As the author has only o solar cycle, it is not prudent to say that the layered OR has a period of 7-8 year. More data are necessary to conclude about the periodicity that seems to follow the solar activity.

reply: Thanks for suggestion. Fig.2 shows that the gap between two peaks of PMSE OR is about 7 or 8 years. It is true that we cannot explain that the layered OR has a period of 7-8 year. It is necessary to need more data to conclude about the periodicity that seems to follow the solar activity. We have removed the description form manuscript.

(c) Figures 3 and 4. Why do the authors fit a polynomial curve to the PMSE OR? Is not a

sinusoidal curve more appropriated?

reply: As described in the paper, Fig. 3 illustrates the mean seasonal variation of the mono- (blue bars) double- (yellow bars) and tri-layer (red bars) PMSE OR and quartic polynomial fitting (black dot-curve) and sine fitting (red dot-dash curve) for the monolayer PMSE OR during 2004-2015. The fitting equation of quartic polynomial fitting is $f(x)=1.448\times10^{-6}x^4-9.715\times10^{-4}x^3+0.2182x^2-17.82x+332.7$ and the fitting degree R=0.5316. The fitting equation of sine fitting is $f(x)=23.67\text{-}11.5\bullet\cos(0.04509\omega)+24.79\bullet sin(0.04509\omega)$ and the fitting degree R=0.5287. According to the fitting results, a quartic polynomial fitting with a relatively high degree of fit is used.

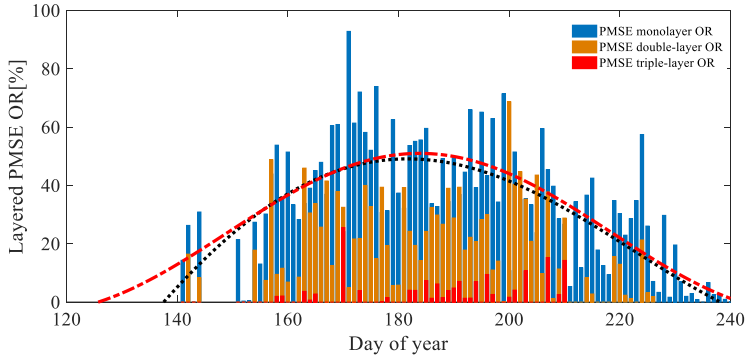
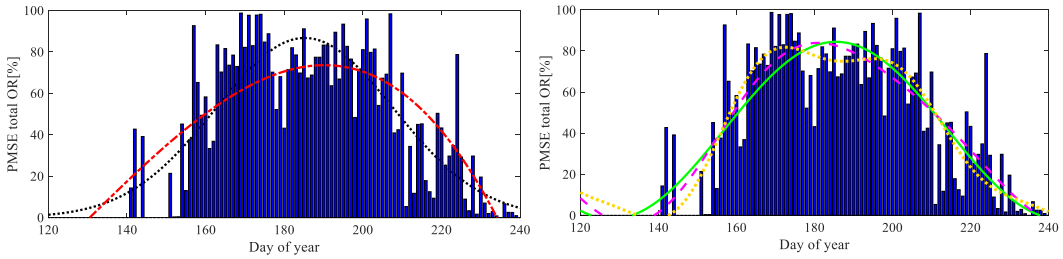


Fig. 3 Mean seasonal variation of the PMSE mono-(in blue), double-(in yellow), triple-layer (in red) occurrence ratio at Tromsø using observations from 2004 to 2015.

Fig. 4(a) (b) shows the mean seasonal variation of PMSE total OR (blue bars) and curve-fitting for total PMSE OR during 2004-2015. We used a variety of curve fitting methods. In Fig. 4(a) the fitting equation of gaussian fitting (black dot-curve) is $f(x)=86.75\bullet\exp(-((x-185.2)/32.02)^2)$ and the fitting degree R=0.7579. The fitting equation of cubic polynomial fitting (red dot-dash curve) is $f(x)=-1.693\times10^{-4}x^3+0.06584x^2-6.671x+125.5$ and the fitting degree R=0.6912. In Fig. 4(b) The fitting equation of 1/ π harmonic function (green solid curve) is $f(x)=41.36\text{-}32.72\bullet\cos(0.05462\omega)\text{-}28.05\bullet sin(0.05462\omega)$ and the fitting degree R=0.7714. The fitting equation of 2/π harmonic function (pink dash curve) is $f(x)=42.37\text{-}23.39\bullet cos(0.0562\omega)\text{-}35.91\bullet sin(0.0562\omega)+5.37\bullet cos(0.0562\omega)\text{-}0.3935\bullet sin(0.0562\omega)$ and the fitting degree R=0.7816. The fitting equation of 3/π harmonic function (yellow dot curve) is $f(x)=43.4\text{-}8.496\bullet cos(0.05832\omega)\text{-}42.14\bullet sin(0.05832\omega)+5.826\bullet cos(0.05832\omega)+2.218\bullet sin(0.05832\omega)$ $\text{-}5024\bullet cos(0.05832\omega)\text{-}4.666\bullet sin(0.05832\omega)$ and the fitting degree R=0.7896. According to the fitting degree and the editor's suggestions. We choose the 3/π harmonic function fitting. The method is higher goodness of fit and has its applicability.



(a) (b)

Fig. 4(a) (b) Mean seasonal variation of the PMSE total occurrence ratio.

(d) Further explanation on Subsection 4.1 and Figures 5, 6 and 7 are necessary. The main point released by the authors was not clear to me, i.e., that there is not direct relation between the PMSE OR and solar activity. The same comment above can be extended to Figure 8. on Subsection 4.1.

reply: Thanks for your suggestion. We main study layered PMSE OR in the paper. The legends on the figure4,5,6 is the average of PMSE occurrence rate in three time periods separated by the black dashed line. It is well known that 2006 is solar minimum and 2012 is solar maximum, the legends on the figure4,5,6 shown the PMSE mono- and double-layer average OR is not consistent with solar activity. So, we say that there has no correlation between PMSE mono- and double-layer OR and solar activity. To prove the conclusion, we calculate the correlation coefficient between PMSE layered OR and solar activity and between PMSE layered OR and geomagnetic activity in next section. Then the conclusion is convinced. We have made improvements to make Fig5-8 easier to understand in revised manuscript.

(e) Another concern is regarding to the usage of the threshold to determine the PMSE OR. The authors have not explained why they are using those assumptions. The main conclusion of them are based on these analysis, then it must be clear.

reply: Thanks for your suggestion. In order to obtain the correlation between mono, double and triple layer PMSE OR, we defined 5 electron density thresholds. Of course, you can define other threshold values. Smirnova et al. (2010) found that the choice of the threshold does not influence the shape of the variation curves for PMSE OR. Zeller and Bremer (2009) indicated that different threshold values are for the investigations of the influence of geomagnetic activity on PMSE, however, of less importance. Because, we will calculate the correlation coefficients between layered PMSE OR and $F_{10.7}$ and between layered PMSE OR and K index. The aim of choosing 5 different thresholds is to increase the number of samples for correlation coefficient calculations.

We give a more detailed explanation in revised manuscript at page13, line 6-16 for this problem.

Reference

Smirnova, M., Belova, E., Kirkwood, S., and Mitchell, N.: Polar mesosphere summer echoes with ESRAD, Kiruna, Sweden: Variations and trends over 1997–2008, Journal of Atmospheric and Solar-Terrestrial Physics, 72, 435-447, doi:10.1016/j.jastp.2009.12.014, 2010.

Zeller O. and Bremer J., The influence of geomagnetic activity on mesospheric summer echoes in middle and polar latitudes, Annales Geophysicae, 27(2): 831-8372, DOI: 10.5194/angeo-27-831-2009, 2009.