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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Small scale density variations of electrons and charged particles in the vicinity of polar mesosphere summer echoes" *by* M. Rapp et al.

M. Rapp et al.

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1. Reply to Referee 1

We appreciate the referee's comments on our manuscript and his general positive judgement on our work on the understanding of PMSE. In the following we address the referee's concerns point by point.

Major points:

1. The referee claims that equation 2 cannot be expected to give a measure of the radar signal since the radar signal should not be proportional to the particle

charge number density $Z_A N_A$.

By closer inspection of equation 2 it becomes clear that we have never claimed that the radar signal is proportional to $Z_A N_A$ (neither is the radar signal proportional to N_e):

$$\tilde{\eta}_A = (Z_A N_A)^2 \cdot PSD(\frac{\Delta Z_A N_A}{Z_A N_A}, \lambda/2) \quad (1)$$

$$\propto (Z_A N_A)^2 \cdot \left| \int e^{-ikz} \frac{\Delta Z_A N_A}{Z_A N_A} dz \right|^2_{k=\frac{2\pi}{\lambda/2}} \quad (2)$$

$$= \underbrace{\frac{(Z_A N_A)^2}{(Z_A N_A)^2}}_{=1} \cdot \left| \int e^{-ikz} \Delta Z_A N_A \, dz \right|^2_{k=\frac{2\pi}{\lambda/2}} \quad (3)$$

Note that in our notation $N_A Z_A$ represents the mean aerosol charge number density that certainly does not contain any spectral power at scales around $\lambda/2$ (hence $1/Z_A N_A$ can be moved in front of the integral). Hence, the radar signal is certainly only proportional to the spectral power of the ABSOLUTE fluctuations in both the electron and the charged aerosol number density.

The reason for writing our equations 1 and 2 as they appeared in our original manuscript is mainly of traditional nature since this notation has been used in the early work on this subject (e.g, Ulwick et al., J. Geophys. Res., 93, 6989-7000, 1988; Lübken et al., Geophys. Res. Lett., 20, 2311-2314, 1993).

However, we certainly see the potential confusion created by this notation and have now changed it in our revised manuscript to: $\eta \propto PSD(\Delta N_e, \lambda/2) \propto PSD(\Delta Z_A N_A, \lambda/2)$.

2. Concerning the question why there can be a PMSE when an electron number density close to zero is observed, we completely agree with the statements

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pointed out in the comment by Dr. Gumbel on our manuscript: While the radar beam probes a volume of roughly 10 km in diameter (= the beam width) and 300 m in thickness (= one radar range gate) the rocket probes a much smaller volume ,e.g., typical probe diameters are only 5-10 cm (see also: Rapp et al., J. Geophys. Res., 108(D8), doi: 10.1029/2002JD002650, 2003). Hence, a one to one correspondence in all details between the radar and the rocket measurement cannot be expected if for example the layers are tilted or patchy (see the comment by Dr. Gumbel). Nevertheless, rocket measurements of the electron number density yield so far the best possible characterization of the radar refractive index at these altitudes and are certainly useful to test our theoretical understanding. In our view, the very good general agreement between $\tilde{\eta}_e$ and the radar SNR shown in Figure 5 supports this view.

Nevertheless, we agree with both the reviewer and Dr. Gumbel that this particular point should be discussed in our paper and we have added an additional paragraph with a short discussion of this topic to section 4.

Minor comments:

1. We have clarified in the Figure caption that we show profiles of $PSD(\Delta N_e, \lambda/2)$ and $PSD(\Delta Z_A N_A, \lambda/2)$.

2. Finally, the referee asks us to give more details on the statement that there is no transfer of spectral power between the different Fourier modes once neutral turbulence has stopped. As we have explained in the paper, each Fourier component $A(k,x) = \tilde{\Gamma}(k) \cdot cos(k \cdot x + \phi_k)$ subject to a diffusion process (see equation 5) shows a temporal behaviour given by (our equation 6):

$$A(k,x,t) = \tilde{\Gamma}(k) \cdot cos(k \cdot x + \phi_k) \cdot e^{-D_A k^2 t} \quad (4)$$

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Hence, $A(k,x,t) = A(k,x) \cdot e^{-D_A k^2 t}$, i.e., k doesn't change during the temporal development due to diffusion and hence there is no transfer of spectral power from one Fourier mode (=one k) to the other. We have added a short sentence to further clarify this point.

2. Reply to short comment by Dr. J. Gumbel

We are grateful to Dr. Gumbel for this very constructive comment on our paper and we completely share his view. As already expressed under our reply to referee 1 we have added a short discussion of the principal problem of comparing radar and rocket measurements to section 4 of our paper. In addition, we have added a remark on the need to characterize the horizontal structure of electron biteouts together with a reference to Dr. Gumbel's short comment.

Interactive comment on Atmos. Chem. Phys. Discuss., 3, 3469, 2003.