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Reply on RC1

Margaretha Myrvang et al.

Author comment on "Modelling the influence of meteoric smoke particles on artificial heating in the D-region" by Margaretha Myrvang et al., Ann. Geophys. Discuss., https://doi.org/10.5194/angeo-2021-39-AC1, 2021

Response to Anonymous Referee #1

We would like to thank the Anonymous Referee #1 for their constructive comments and suggestions.

As suggested by the referee, we include a study on how the more uncertain aspects of meteoric smoke particles influence HF heating of electrons. In the revised version, we discuss the results for different values of the electron attachment efficiency and for summer and winter meteoric smoke conditions. We have included all the referee's suggestions for the technical comments. We address all the technical comments below. The referee report is marked in bold, while our answers are marked in normal text.

We have added a paragraph to line 18 (abstract) to summarize our findings on the different values of the electron attachment efficiency and for summer and winter meteoric smoke conditions:

"We also investigate model runs using MSP number density profiles for autumn, summer and winter. The night-time electron temperature is expected to be 280 K hotter in autumn than during winter conditions, while the sunlit D-region is 8 K cooler for autumn MSP conditions than for the summer case, depending on altitude. Finally, an investigation of the electron attachment efficiency to MSPs shows a significant impact on the amount of chargeable dust and consequently on the electron temperature."

In line 50 (section 1, introduction) we have added:

"In addition, we investigate the seasonal variation of the MSPs abundance, as well as the role of the electron attachment efficiency to MSPs for the heated electron temperature."

We have added a paragraph describing the electron attachment efficiency to line 178 (section 3, background ionospheric model):

"For the charging of a MSP by electrons, the electron attachment efficiency is the probability of a MSP capturing an electron. This probability is size-dependent. Megner and

Gumbel 2009 assume a probability of zero for sizes less than 0.25 nm, a probability of 1 for sizes larger than 1.5 nm and for sizes between 0.25 and 1.5 nm, they assume a probability that increases linearly. Baumann et al. 2013 applies the electron attachment efficiency () from Megner and Gumbel 2009 to the ionospheric model. Megner and Gumbel 2009 proposed this charging efficiency based on a laboratory study on the charging of water ice clusters. The size dependence of the charging efficiency is probably a function of dust composition. Therefore, we add two alternative scenarios of this efficiency to study its possible impact on the electron heating. Table 2 summarizes the different electron attachment efficiencies applied in our study." Note that we have also added a table that describes the different electron attachment efficiencies.

At line 196 (section 3, background ionospheric model) we added a line that mentions the different MSP number density profiles (autumn/summer/winter conditions):

"We ran the ionospheric model with different MSP number density profiles: Autumn conditions (8. September), winter conditions (1. January) and summer conditions (20. July). The model runs with different MSP number densities are performed with the following autumn ionospheric conditions: autumn MSP distribution for night and day conditions, winter MSP distribution for night conditions and summer MSP distribution for day conditions. The MSP winter and summer distribution come from Megner et al. 2008."

We have added a paragraph to line 229 (section 4, results) that describes the results for MSP summer/winter conditions:

"In Fig. 7 we show results for MSP winter distribution (night ionospheric conditions) and MSP summer distribution (day ionospheric conditions). Panel a) shows electron density, while panel b) shows heated electron temperature. For model run with MSP, a comparison of electron densities in panel a) of Fig. 7 and Fig. 4 show a slightly higher electron depletion below 80 km in the winter case compared to the autumn case. However, above 80 km, the electron depletion is higher for the autumn case. For the winter case, the reduction in electron density extends to around 90 km, while it extends to around 100 km for the autumn case. In Fig. 5, the heated electron temperature for the autumn case is higher above 80 km compared to the winter case in panel b) of Fig. 7; the difference is less than 280 K. Our results in Fig. 7 for the summer case are quite similar to the autumn case. This applies to the behaviour of both the electron density and the heated electron temperature. The difference between the heated electron temperature for the summer case and the autumn case is less than 8 K. "

At line 239 (section 4, results) we have added a paragraph that describes the result for different electron attachment efficiencies:

"Figure 8 shows model results for different cases of electron attachment efficiencies of MSPs, where panel shows a) electron density and panel b) shows heated electron temperature. In this study, we concentrate on three different scenarios for size-dependent probabilities of electron attachment to MSP: 'MSP, I' - the probability is 1 for all MSP sizes. 'MSP, II' - the probability is zero for MSP sizes below 0.25 nm, between 0.25 nm to 1.5 nm the probability increases linearly and for sizes larger than 1.5 nm the probability is 1. 'MSP, III' - the probability is zero for MSP size below 1.5 nm and 1 for sizes larger than 1.5 nm. See also table 2 for more details. We see in panel a) that the magnitude of the reduced electron density depends on the electron attachment efficiency. In the case 'MSP I', the electron density is severely reduced because more MSPs are available to be charged. If there is no charging for sizes below 1.5 nm, the electron density is quite similar to the electron density when no MSP are present. This applies to the electron temperature in panel b) as well. For the case where the probability is 1 for all sizes (MSP, I), the heated electron temperature remains almost constant from 90-120 km. The temperature difference between 'MSP, I' and 'MSP, III' goes up to 750 K."

At line 292 (section 5, discussion) we added the following:

“Our results in Fig. 8 for the different electron attachment efficiencies indicates that the heated electron temperature height profile is very dependent on the amount of chargeable MSPs. Increasing the amount of chargeable MSPs leads to a nearly vanishing electron density at altitudes between 80 and 100 km. This aspect of MSPs is not very well known and could be investigated further. Note that the electron density profile in case 'MSP,I' might be unrealistically low since it is around one order of magnitude below the electron density measured during ECOMA-7 rocket flight (between 80-95 km), which is the lowest electron density ever measured at auroral latitudes (Friedrich et al. 2012). Given that the case 'MSP,I' is indeed very unlikely, indicates that there are either not that many small MSP (sizes below 0.25 nm) or that the smaller MSPs are not charged. The modelling with different electron attachment efficiencies (different charging) and with different MSP number density profiles indicates that the night-time D-region electron temperature varies with the number of chargeable MSP, which again varies with the MSP number density and the charging efficiency.”

At line 333 (section 6, conclusion):

“Furthermore, we model with different MSP number density profiles for autumn, summer and winter. The results show 280 K hotter night-time electron temperature for autumn compared to winter, while for the daytime electron temperature, the autumn case is 8 K cooler than the summer case. However, this varies with altitude. Finally, our results shows that the electron attachment efficiency influences the heated electron temperature by impacting the amount of chargeable MSPs. In future studies, we will model the D-region electron temperature during artificial heating with a non-Maxwellian electron velocity distribution, possibly combining it with our study about artificial heating and MSPs.”

Title: I suggest to remove the first “of”.

As suggested by the referee, we have removed the first “of” in the title since this improves the flow of the title. The title is changed to: “Modelling the influence of meteoric smoke particles on artificial heating in the D-region”.

Line 175: Reference to SIC model is lacking, and the acronym is never written out.

Here the referee is right and we have added a reference to the SIC model and written out the acronym. We have changed the sentence to: “For the initial conditions, the following parameters are taken from the Sodankylä Ion Chemistry (SIC) model (Turunen et al., 1996).”

Line 211: Well, technically there is a small bite-out, so I suggest to soften the wording.

We agree with the referee, since there is a small electron bite-out at around 70 km. The sentence “We see that the electron bite-outs are not present in Fig. 7” is changed to: “We see that the electron bite-outs are much smaller in Fig. 9 compared to the night condition results in Fig. 4.”

Line 246: Remove “s” in “shows”.

We have now removed the s in “shows”.

In addition, we have made a number of modifications suggested by the other referee.

Please also note the supplement to this comment:
https://angeo.copernicus.org/preprints/angeo-2021-39/angeo-2021-39-AC1-supplement.pdf