Annales Geophysicae

Review of manuscript: angeo-2020-44
On the relationship of energetic particle precipitation and mesopause temperature

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1. The authors set out to investigate whether electron precipitation events lead to changes in the temperature of the mesopause region. They note that there are conflicting reports on this subject, and they set out to resolve the question.

2. To do so they use electron density values from the EISCAT radar, and temperatures from the mesopause region derived from OH emissions both of which are recorded from Svalbard.

3. They start off with over 10,000 hours of radar data which sounds very impressive, but when the selection criteria are applied, it turns out that only eight events remain with which to carry out the investigation. The criteria are clearly stated and the reasons for choosing them are also clear. However, the authors must realise the weakness of undertaking a statistical study with so little data.

4. The next and biggest problem lies in the time resolution of the temperatures. The authors state that the effect of the EPP on temperature (if it exists) is short lived of the order of 30 minutes (page 12, line 217), and they use 30-minute averages of the OH* temperature instead of the more usual 1-hour averages in an attempt to overcome this. Unfortunately, temperature values are missing either immediately before or immediately after five of the eight EPP events selected for study. Why are there so many missing temperature values? Are the OH spectra contaminated by auroral emissions caused by the precipitating electrons?

5. The authors claim to have detected a decrease in OH temperature greater than 10 K (10 - 50 K) following the onset of an EPP in seven out of eight cases.

6. The authors classify the *fifth event* as one of <u>decreasing</u> temperature. This is very strange since the temperature decrease occurs <u>before</u> the occurrence of the EPP, while the temperature has <u>increased</u> by 22 K only ~11 minutes (~02:31 UT) after the maximum value of the EPP (~02:20 UT). This is one of the three events in which there are no missing temperature values either immediately before or immediately after the onset of the EPP. This event should be classified as one of <u>increasing</u> temperature. It is also a pity that no OH temperatures are available after 03:10 UT, since the electron density values remain consistently high until at least 05:10 UT.

7. The mechanism suggested to explain the perceived temperature decrease, originally proposed by Suzuki *et al*. (2010), envisages a depletion in the number of emitting radicals at the upper part of the OH layer, the effect of which depends on the mesopause region temperature profile at that time. The time resolution of the Suzuki *et al*. (2010) report was 1 minute which is in stark contrast with the present study. Suzuki *et al*. (2010) found support for their proposal from OH VER profiles from the SABER instrument onboard the TIMED satellite. As an absolute minimum, the authors of the present manuscript should at least search for SABER temperature and OH VER profiles, or alternatively, Aura MLS temperature profiles close to the time of the eight events to try to support their argument.

8. A depletion of OH emitters in the upper part of the layer, leading to probing temperatures at a lower altitude could have the effect of increasing or decreasing the temperature depending on the gradient of the temperature at the time of the measurement (lines 258/259). The winter mesopause temperature is indeed quite variable as pointed out in (lines 213/214). On

average (see e.g., MSISE-90) however, the gradient in the high-latitude winter temperatures profile tends to be small, and the altitude of temperature minimum tends to be above the OH layer. In this situation, a depletion in the upper part of the layer would give rise to a small increase in the OH temperature, with a corresponding decrease in the integrated emission signal.

9. However, average conditions may not be a lot of help here. At any given time, the mesopause region temperature profile is rarely at the average value, and since the time scale of the EPP effect is expected to be short, and with only eight events available for this study, it is unlikely that assuming average conditions would lead to the correct prediction. Nevertheless, it would be surprising to find a temperature decrease in all cases. As stated already, the OH temperature data do not have sufficient time resolution to make a convincing case.

10. The mechanism proposed for the temperature change (decrease), namely depleting the OH layer from above by the precipitating electrons, would be unlikely to give rise to the magnitude of the changes claimed (20-50 K). An approximate calculation based on a 10 K/km vertical gradient over the entire width of a typical Gaussian layer (which would be an extreme case) with a total depletion of say 30% would only change the recovered temperature by ~11 K. At most, one might expect only a few K change in temperature one way or the other with the proposed mechanism. The authors should address this question in detail, i.e., how much of a depletion would be required for a given temperature profile to achieve the temperature changes claimed with the mechanism proposed.

11. The ideas contained in the manuscript have merit, but the data presented is insufficient to support the claim. The temperature data does not have the time resolution needed, and more data are needed to support the premise before publication is warranted.

Minor comments

P1, line 4; replace “exited” by “excited”.
P1, line 15; replace “events” by “event”.
P2, lines 30/31; suggest moving “was found” from the end of the sentence to after “40 K”.
P2, line 41; is “deepest” the most appropriate word here? Consider “largest” or “strongest.
P2, line 46; to what does “earlier” refer in this sentence. Do you mean previous reports of EPP events? Is it necessary to include “earlier”?
P3, line 71; be consistent in the use of uppercase- or lowercase-R in “EISCAT Svalbard Radar”; see e.g., P1, lines 5 and 6; P14, line 283.
P4, line 93; replace “field of view” by “field-of-view”.
P4, line 107; replace “field aligned” by “field-aligned”.
P4, lines 115/116; replace “M. S. Lehtinen (1996)” by “(Lehtinen and Huuskonen, 1996)”.
P5, line 138; insert “2019” after “January”.
P6, Figure 1, upper panel; omit the text “Produced@DESKTOP- ... 2020”.
P10, line 166; replace “(18°)” by “(18 K)”.

P12, line 213; the sentence beginning “At high latitudes the …” restates information provided already on page 4 in lines 95-97.
P13, line 243; “Figure 3” should be “Figure 2”.