

Interactive comment on “Influence of geomagnetic activity on mesopause temperature over Yakutia” by Galina Gavrilyeva and Petr Ammosov

Anonymous Referee #1

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This paper is very interesting as it present observational evidence of different types of solar influence on middle/upper atmospheric temperatures. I have several recommendations for clarifying the language and would also suggest converting the figures to colour to make them easier to interpret before the paper can be accepted for publication. I have recommended major revisions, but this is mainly due to language improvements and the need to clarify certain aspects of the work before it will be clear enough to be published.

General comments:

Since much of the discussion focuses on the geomagnetic forcing and in particular energetic particle precipitation (EPP) impact on the mesosphere chemistry and the link to temperatures, it would be beneficial to have a short paragraph of the now well under-

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stood effects of EPP in the introduction going into the proposed temperature impacts via ozone modulation in the mesosphere. In the discussion, the link to temperatures is somewhat difficult to follow. I would recommend clarifying this following along the line of these steps:

1. EPP ionisation leads to production of both HO_x and NO_x species. This production can be proxied using indices such as Ap. (This is the main link to the Ap-temperature correlations of this study)
2. HO_x and NO_x contribute to ozone balance in the mesosphere and stratosphere. These effects are well known as demonstrated by the works sited in the existing text.
3. Model simulations have shown that the EPP driven ozone reduction in the polar winter upper mesosphere leads to reduction in long wave (terrestrial outgoing radiation) cooling. This signal is seen as increase of upper mesospheric temperature when comparing simulations with high EPP forcing to those with no, or low EPP forcing.
4. Higher Ap → more EPP → more HO_x and NO_x → less ozone → impact on polar winter mesospheric temperatures. This effect on temperatures is focused on polar winter atmosphere, which seems to be in a good agreement with the results presented in this manuscript.

It is not clear from the text presently how sensitive the layer of excited hydroxyl used for the temperature measurements is to changes in HO_x concentrations i.e. those related to EPP. Could you please add a comment? This I think is needed to clarify to the readers weather the observed temperature changes are likely linked to changes in ozone or in HO_x concentrations.

Specific comments and text revisions:

Page 1 L7: “beginning of the 24th” L11-13: “The maximum of the seasonally averaged temperatures is delayed by 2 years relative to the maximum of flux of radio emission from the Sun with a wavelength of 10.7 cm, and correlates with a change in geomag-

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netic activity. Ap-index as a measure of geomagnetic activity is taken." Change to "The maximum of the seasonally averaged temperatures is delayed by 2 years relative to the maximum of solar radio emission flux (wavelength of 10.7 cm), and correlates with a change in geomagnetic activity (Ap-index)."

L19-20: "The review of Beig et al. (2008) lists numerous studies showing that the response..."

L21: Add the abbreviation F10.7 here as it is used later: "solar radio flux at a wavelength of 10.7 cm in 10-22 W M-2 Hz-1 (F10.7)"

L22-23: "SABER radiometer onboard the TIMED satellite"

L23-24: "100 SFU, in agreement with the"

L26-30: You should make it clearer in this paragraph that the first studies only used a very short period of observations.

L35-36: I recommend revising this to: "As this is similar in scale to the observed delay of 25 months, it was logical to assume that the long-term temperature fluctuation of the subauroral mesopause correlates with the change in geomagnetic activity."

L37: "...between geomagnetic activity (Ap-index) and..."

Page 2 L2: "Mesopause (80-100 km) is the atmosphere region where the mesosphere borders on a thermosphere..."

L4: Does "activated" here refer to "exited"?

L4: "...hydroxyl molecule experiences..."

L8: "optical station Maimaga (63°N, 129.5°E) which is located at a distance of about 120 km to the north of Yakutsk" suggest changing to "optical station of Maimaga (63°N, 129.5°E) located about 120 km north of Yakutsk, Russia." Could you also give the magnetic latitude of the station?

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L10: What is the significance of not having aurora present when the observations are made? This would have an impact on observing the direct EPP effect as particle precipitation can be associated with aurora displays.

L17-19: These 2 sentences are presently not clear.

L27: "...Ap-index mean values are shown..."

L30: "The correlation coefficient of TOH and Ap-index is equal 0.51 ± 0.1 at 95% confidence level." Remove word "equal". What is the correlation of F10.7 and TOH in your present dataset?

Paragraph starting at line 31: How were the two Ap groups selected, what is the transition value of 8 based on?

Page 3 L1: "...many papers have been published on the atmosphere response to solar and magnetospheric proton..."

L6-7: "Observations from satellites confirm that energetic particle precipitation changes the NOx amount in the atmosphere."

L8: "...from satellite measurements during the years 1992..."

L10: ECHAM5/MESSy is the same as the EMAC model, EMAC stands for "ECHAM5/MESSy Atmospheric Chemistry" i.e. 2 of the studies mentioned in the Discussion are from the same model.

L11-12: "They calculated thermospheric NOx fluxes to the mesosphere from precipitation of low-energy electrons using the average annual Ap from 1991 to 2005."

L12-14: "These average annual NOx concentrations were based on the UARS/HALOE measurements reported by Randall et al., (2007)." The NOx model of Baumgaertner et al. was based on the Randall et al. measurements, they were then compared with independent observations by the MIPAS instrument onboard Envisat as reported by Funke et al. (2005) (see reference in Baumgaertner et al., 2009).

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L15-16: I think what you should say is that the authors of that paper demonstrated that Ap works as a good proxy for low-energy produced NOx. That particular paper does not handle HOx at all. But there are others which show the direct impact of electron precipitation on HOx, for example: Andersson, M. E., P. T. Verronen, S. Wang, C. J. Rodger, M. A. Clilverd, and B. R. Carson (2012), Precipitating radiation belt electrons and enhancements of mesospheric hydroxyl during 2004–2009, *J. Geophys. Res.*, 117, D09304, doi:10.1029/2011JD017246.

L17: They demonstrated both mesospheric and stratospheric ozone changes.

L21: “There is a publication series...” change to “There are several publications...”

L27-30: A similar downwards descending signal (in the same model) is already demonstrated by Baumgaertner et al (2011) using Geopotential height anomalies.

L30: “moves”

L32-33: Not all models are limited to this altitude range, but many reanalysis datasets are limited to altitudes below the stratopause. Models have issues in comprehensive inclusion of EPP.

L34: “Therefore, warming in our measurements has to be detected earlier.” I don’t understand why this would have to be the case. These temperature signals can be completely independent. That doesn’t mean they would not be linked to geomagnetic activity or EPP.

Page 3 L16-17: “Warming signal moves down from high altitude to low one.” and most of the last paragraph. This is not necessarily the case and certainly this is not a conclusion you can make based on the present study. Several of the publications you have cited actually argue that the stratosphere temperature signals are driven by changes in dynamics and are not related to in situ changes in ozone.

Figure 1: It is very difficult to tell the two lines apart, I would suggest making the plot in colour or applying an offset to separate the lines.

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Additional typos and general language comments - “Energetic particle precipitation” (and the abbreviation EPP) is the generally used term. It is singular, therefore “EPP is...”. Be careful not to use “energetic particles precipitation” or “particles precipitation”, or “precipitations”.

- NOx and HOx - the x is a subscript
- The commonly used terms for both are NOx = “Odd Nitrogen”, HOx = “Odd hydrogen” instead of “nitrogen oxides” etc.
- The author with two papers in the citation list is “Seppälä”, the name is correct in the citation list but incorrect in the text.

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