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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Will climate change increase ozone depletion from low-energy-electron precipitation?" *by* A. J. G. Baumgaertner et al.

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We thank the referee for his valuable comments, which are addressed below.

1 Specific comments

"... horizontal mixing also plays important role possibly leading to a dilution of EEP NOx"
This process indeed plays a role and we will include this in the discussion in the revised manuscript. It is possible that due to changes in the circulation such

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Interactive Discussion

Discussion Paper

dilution is also changed in a future climate. If we assume that the model captures the dynamics in this region correctly, under present and future conditions, this effect is contained in the simulations and therefore does not adversely affect the results. Quantification of such dilution however is not straightforward and subject to future work.

"The MLT circulation differs from the BD circulation ... " Indeed the MLT region, where the EEP NOx is produced and initially transported downward, is an important region for the EEP NOx issue as a whole. There are, however, several aspects that led us to not discuss climate-change induced changes in this region in the original manuscript. First of all, note that the EMAC model only reaches up to the upper mesosphere and has a very crude resolution above 0.1 hPa (three layers plus a sponge layer). Therefore, the model is not entirely suited for studies of climate change effects in the MLT region. This limited representation of the MLT was also the starting point for the design of the parametrisation of EEP NOx employed here: it was constructed such that it produces realistic amounts in the stratosphere; for the mesosphere the parametrisation has not been evaluated and is unlikely to produce realistic results at least in the upper mesosphere. In general, climate-change related effects on the MLT are still under discussion, e.g. Beig et al. (2003) state for mesospheric temperatures that "The most reliable data sets show no significant trend but an uncertainty of at least 2 K/decade. On the other hand, a majority of studies indicate negative trends in the lower and middle mesosphere with an amplitude of a few degrees (2–3 K) per decade.". Most models used for climate change simulations do not resolve the middle atmosphere at all, and effects are therefore not investigated as vigorously as for the lower atmosphere.

"also extend the analysis showing the simulated changes of the atmospheric circulation using proper quantities" We will include figures of some of the quantities listed by the referee in order to discuss the circulation changes in more detail.

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2 Experimental set-up

SST figures 1 and 2 We will move Figures 1 and 2 to the supplement in the revised manuscript, and only discuss the fact that there is no El-Nino/La-Nina bias in the manuscript.

Figure 3 Unfortunately the caption of Fig. 3 was wrong and ”year 2000 from HadISST1“ should have read ”AMIPIIb climatological“. For the present study we used the AMIPIIb climatological SSTs for the present day, and the year-2100 SSTs from the ECHAM5/MPIOM simulation. Therefore, Fig. 3 shows the difference between the two datasets (each averaged over the 12 individual months that were used) as employed for the simulations.

ECHAM5/MPIOM SST biases A description of MPI-OM is provided by Marsland et al., which also discusses some of the shortcomings of the model. While there is a good overall agreement between model SSTs and observations, Marsland et al. found a too weak North Atlantic poleward heat transport and differences in the observed and modelled Gulf Stream, which leads to the North Atlantic Ocean SSTs probably being too cold. Also note that in a warmer climate ECHAM5/MPI-OM shows a larger ENSO amplitude increase than most other models (Müller and Roeckner, 2008). We will include this discussion in the revised manuscript.

Halogen loading and ozone precursors Chlorine and bromine containing substances as well as ozone precursors were left unchanged between the simulations. While this is unlikely to be realistic, it would be very difficult to distinguish the effects of e.g. changed halogen loading and a Brewer-Dobson circulation change. However, this was not clearly conveyed in the original manuscript and will be explained in the revised version.

Initialization Using age of air, which can reach a 3 to 6 years, would constitute an upper limit on the time until quasi-steady-state is reached. However, we argue

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that tracer transport is slower than energy transport and thus the lower limit is smaller. The most important external factors that distinguish a future atmosphere from today's atmosphere are the SSTs and sea ice as well as the concentrations of radiatively active gases. For the re-initialisation of the dynamics with these variables we believe that three years of spinup is enough. Note that the chemical background, e.g. chlorine compounds, was left unchanged (in order to determine the EEP effect), so a new chemical initialisation is not necessary.

3 More issues

We can exclude halogen loading as a factor for the changes in EEP NOx ozone depletion since it was not changed between the simulations for the reason stated above. Temperature and ozone mixing ratio potentially affect this process, and it is impossible with the available set of simulations to distinguish these effects. However, concerning temperature effects it can be argued that since in the future climate the stratosphere is colder than presently, the NOx cycle will be slower (due to the temperature dependency of the reaction of NO + O3) and thus ozone depletion would be less severe. Since we found increased ozone depletion for the future climate, this effect appears to be less important than other processes. As we show in Fig. 6 ozone is generally enhanced in the future upper stratosphere, and the NOx cycle is unlikely to be limited by the availability of odd oxygen in today's or the future atmosphere.

We will include a discussion of the effects in the Northern Hemisphere as requested.

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4 Compensation

Fig. 8 shows an ozone depletion because this figure was generated from four different simulations as described in the first paragraph of section 3; the reason for this complicated processing was precisely to eliminate the effect of other factors. If only the difference between simulations S-Y2100-EEP and S-PRESENT-EEP was shown, there would be very little ozone depletion. We will show this intermediate step including a figure in the revised manuscript.

5 Future ozone

As mentioned above, halogen loading was not changed between the present day and year-2100 simulations. Therefore, effects presented in Fig. 6 are solely related to greenhouse gas increases.

6 Minor comments

1. We will correct this.
2. We assume that you are talking about the Marsh et al. publication ”Modeling the whole atmosphere response to solar cycle changes in radiative and geomagnetic forcing“ (JGR, 2007), which however looks at present day effects of the combined geomagnetic and solar (spectral) irradiance variations, so this paper is not directly relevant here.
3. We contacted Ted Shepherd again, and he corrected this to ”strengthening of the subtropical jets“.

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4. We were only referring to the availability of Ozone in this statement. If solely the temperature gradient is considered, then the reviewer argues correctly that with decreasing temperatures ozone loss through the NOx cycles slows down, thus the NOx cycle is not so efficient at lower altitudes. We will indicate this in the revised manuscript.

5. This will be moved to the appendix.

6. We will rephrase this to make clear that (NOx, NMHCs, CO, SO2, NH3) refers to surface and boundary layer emissions alike.

7. Indeed there is a larger peak of the Ap index in November/December, termed the Halloween storms. We will rephrase this statement.

8. Thanks for pointing out this error.

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Interactive comment on Atmos. Chem. Phys. Discuss., 10, 9895, 2010.

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