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Atmospheric Chemistry and Physics Discussions

Interactive comment on "A semi-empirical model for mesospheric and stratospheric NO_y produced by energetic particle precipitation" *by* Bernd Funke et al.

Bernd Funke et al.

bernd@iaa.es

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We thank Referee 1 for helpful comments and suggestions. The Referee's Comments are noted first and then we give our reply to the comment.

Main issues: 1. I suggest adding a small section describing very practical aspects of the model applications. In particular I did not find clear description of how to apply ES treatment for free running CCM. It will make easier model use by the interested groups.

Reply: The purpose of this paper is to describe and provide a semi-empirical model for EPP-NOy that can be used as odd nitrogen upper boundary condition (UBC) in chemistry climate models (CCMs). A detailed discussion of practical aspects related

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Discussion paper

to its implementation into CCMs is beyond the scope of this paper, in particular, because there might be model-specific differences at the detail level. Some more general aspects, however, are addressed in Mattes et al. (submitted to GMD).

Regarding the application of the ES treatment in free running CCMs, we will add a paragraph discussing possible strategies (see response to minor issue 11).

Minor issues: 1. Page 1, Line 3: I would rephrase "used in a previous study"

Reply: Will be changed to "used previously".

2. Page 2, Lines 12-16: The authors mentioned that correlation with Ap is high for SH and unperturbed NH winters. After they said that EPP source dominates. I feel some not perfect logic here. If the geomagnetic activity dominates why to work on ES cases later on?

Reply: We will clarify that the EPP source strength is the driving factor of the interannual variability only for such winters (i.e., SH and quiescent NH winters).

3. Page 2, Line 27: And probably the availability of the solar light plays a role.

Reply: We fully agree. Indeed, our ES parameterization takes into account the seasonal dependence of the EPP-NOy in the source region, ruled by solar illumination. In the paragraph around line 27 of page 3, however, we summarize the findings of Holt et al., 2013. In order to make this clearer, we will state:" This behaviour was attributed by these authors to the pronounced seasonal dependence of the strength of the vertical winds following an event."

4. Page 2, Line 30: "To be submitted" is not appropriate and confusing for the reader.

Reply: The paper (Matthes et al.) is now submitted to GMD.

5. Page 2, Line 35: I suggest adding something more recent publications by Malliniemi et al. (2013 or 2014).

Reply: A reference will be added.

6. Page 3, Line 1: "A large number" is too optimistic, I think.

Reply: Will be changed to "an increasing number".

7. Page 3, Line 9: It sounds like the model provides all components of NOy balance. Please, clarify.

Reply: The model provides only NOy (the sum of all reactive nitrogen species). We will omit the word "balance" in the revised version.

8. Page 4, Line 1: Rephrase, in the present form it does not sound good.

Reply: Will be changed to "Here, we use the daily zonal mean climatology of EPP-NOy densities, available on latitudinal bins of 10 deg with global coverage".

9. Page 4, lines 18-19: For some cases the contribution from radiation belt electrons can be important (Andersson et al., 2014; Arsenovic et al., 2016)

Reply: This sentence will be added.

10. Page 27, Line 20: Please, specify pressure level where the not EPP related effects are not negligible. Does it also depend on the season?

Reply: We refer to background NOy as the NOy contribution produced by N2O oxidation and not by EPP. Volume mixing ratios of the background NOy can still be up to a few ppbv in the lower and middle mesosphere (see, e.g., Fig. 1-2 of Funke et al.,

2014, doi: 10.1002/ 2013JD021404). Therefore, we think that it would be misleading to specify a particular pressure level above which the background NOy is negligible. However, we will change the statement “not negligible in the lower mesosphere” to “not negligible in the lower and middle mesosphere”.

The background NOy shows a pronounced seasonal dependence. Particularly for this reason we regress harmonic terms (Eq. 24) to its seasonal composite.

11. Page 30, lines 21-30: I do not clearly understand the paragraph describing the treatment of the ES events. How they can be used this in free running models?

Reply: While the consideration of ES-related enhanced odd nitrogen descent with the NOy UBC is relatively straight forward in nudged model simulations (since the ES onset dates, needed to drive the UBC model, are known beforehand), its consideration in free-running simulations would require to diagnose ES events “online” in a quasi-instantaneous manner, e.g., by analysing the modelled temperature fields averaged over a narrow time window covering the past model day. Then, in case of the detection of an event onset, it would be required to update the NOy UBC (by running the UBC model again, with the “new” ES event accounted for, from the ES onset date to at least the end of the actual NH winter season).

The main task is hence the implementation of the online ES detection scheme into the model system. We have proposed a detection criterion, ΔT30-70 > 53 K, based on the difference of 0–30°N and 70–90°N temperature averages at 1hPa, which allowed for quasi-instantaneous detection of ES event onsets (associated with enhanced odd nitrogen descent) in EMAC simulations. Its application in other model systems, however, might require an adjustment of the detection threshold (which could be achieved by calculating ΔT30-70 from a nudged simulation covering 1980-2014 and tuning the threshold such that it is exceeded only for ES events listed in Table 4).

We will expand the discussion of the ES detection and application to free-running mod-

els along these lines.

12. Page 31, line 13: Does model takes into account changing N2O mixing ratio?

Reply: A N2O emission-related trend is not taken into account in the UBC model. Such a trend would only affect the background NOy contribution (related to N2O oxidation in the stratosphere). The latter has been constructed from MIPAS observations covering a time period of 10 years, being too short for extraction of longterm trends. The main purpose for including a NOy background in the UBC model is to avoid boundary artefacts in CCMs that employ the UBC. Such artefacts could potentially occur close to the upper model lid in polar summer or in the tropics by prescribing zero concentrations, however, would hardly affect the modelled NOy at lower vertical levels. We would like to stress that a N2O emission-related trend has no impact on the NOy transported into the model domain during polar winter (NOy is dominated by the EPP contribution, there). Therefore, we think that the consideration of such a trend is of little importance. Nevertheless, if wished by a user of the UBC model code (in order to improve the NOy representation at the model top) such a trend could easily be incorporated by a slight modification of the IDL program (i.e., by multiplying a emission-driven trend to the background NOy contribution term).

Page 31, line 25: I think using "to be submitted" is not appropriate.

Reply: Now submitted (see above).

14. Page 31, line 26: IDL code is not there.

Reply: The code is now available at http://solarisheppa.geomar.de/solarisheppa/cmip6 (as IDL and MATLAB routines).

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