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Interactive comment

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

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We thank Referee 2 for helpful comments and suggestions. The Referee's Comments are noted first and then we give our reply to the comment.

1) The fit for ES states is based on only two winters. Even if both winters cover a significant amount of variance, they still may not be enough. Have the authors tried to apply the fitting procedure to model data from CCMs that resolve EPP NOy fluxes and have more instances of major sudden stratospheric warming events? This should give some idea of how the fitting performs for observational data.

Reply: We agree that it is not optimal to constrain the EPP-NOy during ES events by

MIPAS observations from only two winters. However, we'd like to point out that NO observations of two additional winters (2011/12 from SOFIE and 2005/06 from ACE) are used to validate the model (see Sec. 6). These four ES winters (2003/04, 2005/06, 2008/09, and 2011/12) are currently the only ES winters with available odd nitrogen observations in the NH polar stratosphere and mesosphere.

We have not applied the fitting procedure to CCM results because EPP-resolving high top CCMs generally tend to underestimate mesospheric and upper stratospheric NOy after ES events (e.g., Holt et al., 2014; Siskind et al., 2015; Randall et al., 2015, Meraner et al., submitted, 2016). This systematic model bias makes it difficult to merge CCM results with observations in order to improve the ES statistics. However, we have qualitatively compared the fitted ES parameters to the WACCM analysis in Holt et al., 2014 (including 17 simulated ES events) and found good agreement with respect to the dependence on the event timing (see 1st paragraph on page 17).

2) Figure 8 indicates that the empirical model overestimates EPP NOy at higher altitudes before the major sudden warming event. This overestimation appears in 2010 and 2011 in the NH and in 2008 and 2009 in the SH as well ((Fig. 3a,b). This seems to be related to the transport time as shown in Figure 1 where the red and blue solid lines (corresponding to the expression used in the model) deviate from the best fit as shown by the open diamonds. What motivated the choice of the expression giving the solid lines shown instead of lines with a tighter fit above 0.3 hPa? Longer transport times are associated with higher concentrations of NOy due to slower flushing given a fixed rate of formation.

Reply: In the semi-empirical model, the EPP-NOy (as shown in Figures 3 and 8) is constrained by MIPAS observations (by adjusting Eq. 5). As a consequence, the model always reproduces the observations **on average** (2002-2012). Model deviations in individual winters (as identified by this Reviewer) are caused by interannual dynamical variability not considered in the semi-empirical model (except for ES events). We'd like to stress that the transport times Γ as shown in Fig. 1 are only used in Eq. 8 to determine the modulation of the geomagnetic variability signal by vertical transport (i.e. the “Ap propagation function”). In principle, Γ should be identical to the transport times derived from vertical velocities (shown as solid lines in Fig. 1). The values of Γ derived from the best fit of the observed Ap modulation (shown by open diamonds) deviate slightly for two reasons:

- The use of a quasi-global minimization strategy (“scanning” of the Γ space) implies discrete “jumps” between the best-fit values of Γ, resulting in a step-type altitude dependence.
- The Ap modulation depends also on Δ, the latter being empirically constrained by Eq. 10. Since Γ and Δ are not independent, differences between the fitted values of Γ and the transport times derived from vertical velocities, particularly in the 0.1 hPa region, could be related to the simplified representation of the Γ- Δ relationship as given by Eq. 10.

Technical comments: p 26, l.3: that -> than

Reply: Thanks. Will be corrected.

p 29, l.8-9: Ap is correlated with the solar wind which maximizes during the declining phase of the solar cycle.

Reply: This will be added as explanation for the phase shift.

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