Influence of energetic particle precipitation on the chemistry of the middle atmosphere and climate

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Abstract

The energetic particles entering the atmosphere are able to affect the composition of the middle atmosphere, ozone and climate. Energetic particles initiate ionization in the atmosphere followed by the NO_x and HO_x production, which has a big impact on ozone chemistry in the stratosphere with further implications for the climate. There are three main sources of energetic particles that enter the atmosphere: solar proton events (SPE), galactic cosmic rays (GCR) and energetic electron precipitation (EEP). While we aim on the study of all sources and their role on the ozone layer evolution during the satellite era, this poster is devoted to the study of the GCR effects. The known Heaps parameterization has been introduced to our 3-D chemistry-climate model SOCOL to describe the source of NO_y and HO_x. We have carried out a 13-year long ensemble run from 1976 to 1988 to simulate the influence of the GCR on the atmosphere. The changes of the main chemical constituents (i.e. NO_y, HO_x and O_3), temperature and dynamics caused by the GCR and their statistical significance will be shown and discussed.

In addition, the influence of SPE effects are implemented in the model. For this, we have use the SPE induced ionization rates compiled by C. Jackman. We have carried out 3-month long ensemble runs to see the short term effects of October 2003 SPE on NO_x, HO_x, O_3 and temperature and dynamics which will be shown and discussed.

Model Description and experimental setup

•The chemistry-climate model SOCOL v2.0 (modelling tool for SOlar Climate Ozone Links) is based on the GCM MA-ECHAM4 (Manzini et al., 1997). It is a spectral model with T30 horizontal truncation resulting in a grid spacing of about 3.75º; in the vertical direction the model has 39 levels in hybrid sigma-pressure coordinate system spanning the model atmosphere from the surface to 0.01 hPa.

•The chemical transport part has the same vertical and horizontal resolution as MA-ECHAM4, and the calculations are performed every 2 hours. The model chemistry scheme treats 54 chemical species of the oxygen, hydrogen, nitrogen, carbon, chlorine and bromine groups, which are determined by 140 gas-phase reactions, 46 photolysis reactions and 16 heterogeneous reactions in/on aqueous sulfuric acid aerosols, water ice and nitric acid trihydrate (NAT).

•The transport of 41 species is calculated using the hybrid numerical advection scheme of Zubov et al. (1999). The scheme is a combination of the Prather scheme (Prather, 1986) applied for the vertical transport, and a semi-lagrangian scheme, which is used for horizontal advection on a sphere (Williamson and Rasch, 1989).

•For the additional NOx sources, the fact the per ion pair 1.25 NO molecules were produced (Porter et al., 1976) has been taken into account. For the HOx sources, the table given by Solomon et al. (1981) has been used.

Experimental setup

We have carried out a 3-month long run from October to December 2003 to simulate the influence of the SPE on the atmosphere.

·The control run covered the whole 3 months without the influence of the solar protons, while for the perturbed run, SPE ionization rates were included from the database provided by Ch. Jackman (available from the following website: http://www.geo.fu-berlin.de/en/mat/ag/strat/research/SOLARIS/input_data/index.html).

Results: geographical distribution of the SPE effect

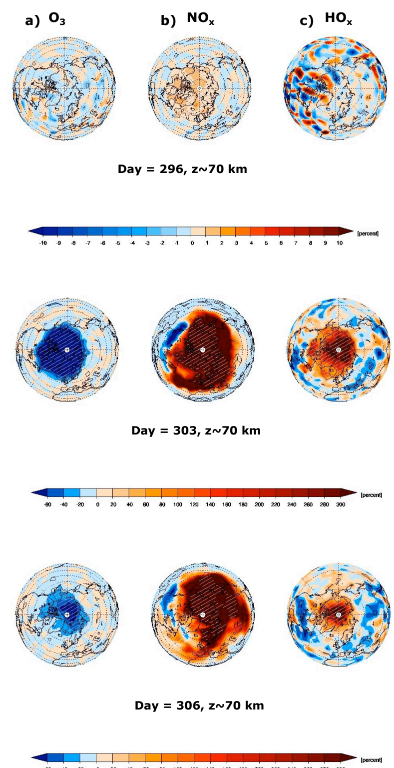

Figure 1. Geographical distribution of a.) O_3 (%), b.) NO_x (%) and c.) HO_x (%) produced by SPE 2003 at 0.05 hPa (~ 70km) for the days 296 (before first major SPE), 303 (during the SPE) and 306 (after major SPE) of 2003 in the Northern Hemisphere. The perturbed run has been subtracted from the control run. Hatched areas show the statistical significance (95 %).

The model simulates a substantial increase in NO_x and HO_x concentrations at ~ 70km for days 303 and 306. The increase is not uniformly distributed around the geomagnetic pole. Most of the enhancement is inside the polar night region.

Ozone depletion is largest on day 303 (~ 60%) but recovers slowly during the following days.

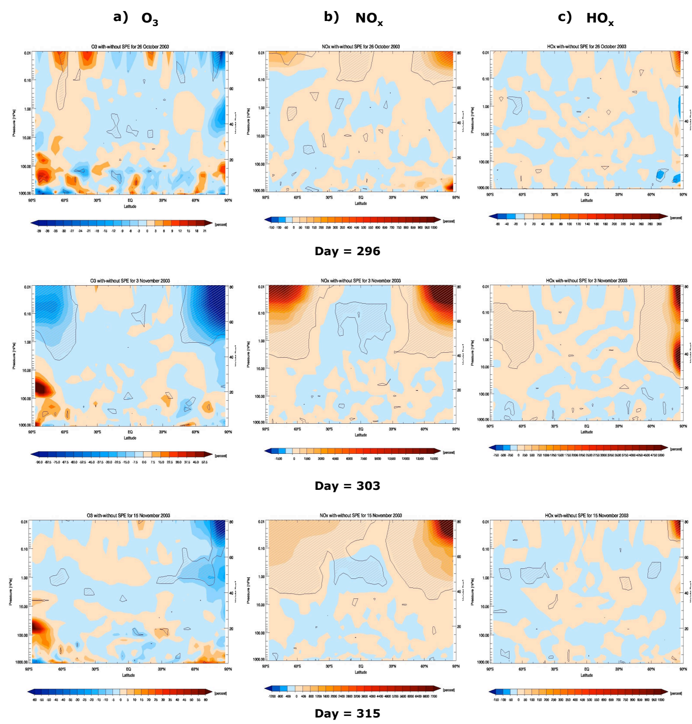

Figure 2. Geographical distribution of a) O_3(%), b) NO_x (%) and c) HO_x (%) produced by SPE for day 296 (before first major SPE), 303 (during major SPE) and 315 (after SPE). Hatched areas show the statistical significance (95 %)

Figure 2a shows that for the northern hemisphere the decrease of ozone lasts longer than in the southern hemisphere due to different atmospheric conditions. The northern hemisphere shows a decrease of about 90 %.

Panel b) indicates the increases of NO_x during this time period. The maximum enhancement is seen on day 303. Like in panel a) the northern hemisphere shows a larger impact of the SPE.

Panel c) shows clearly the increase of HO_x in the northern hemisphere during this time period of more than 5000 %.

Conclusion

- The effects of October 2003 SPE event have been studied using CCM SOCOL v2.0;
- The model showed that the impact on the northern hemisphere is larger than on the southern hemisphere due to different atmospheric conditions;
- The enhancement of NOx and the decrease of ozone resembles the observations;
- The model outputs are similar to Lopez-Puertas et al., 2005;

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