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Influence of a giant solar energetic particle event on atmospheric chemistry

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In a giant Solar Energetic Particle (SEP) event associated with a giant solar flare, high-energy protons bombard the stratosphere with high-energy neutrons and high-energy photons. The SEPs ionize and dissociate nitrogen and oxygen molecules along with their tracks, and subsequent chemical reactions induce the change of chemical compositions. Here we investigate the chemical composition changes in the middle atmosphere caused by a giant SEP event. Our calculation includes detailed ion chemistry for the first time to assess this problem.

The SEPs firstly yield charged products (N^+, O^+, $N2^+$, $O2^+$, and e^-) and neutral atoms ($N(^4S)$, $N(^2D)$, $N(^2P)$, $O(^3P)$, and $O(^1D)$) in the atmosphere. These ions are relatively short-lived, and are soon converted into neutral chemical species. It is suggested[1)], however, that detailed ion chemistry is crucial to understand the chemical composition changes during/after a SEP event. For this, we have considered 12 high-energy radiation processes (radiolysis) and more than 200 chemical reactions as the first step, including ion-molecule reactions, photo-dissociations, ion-ion and ion-electron recombinations, as well as neutral chemical reactions such as NO_x (odd nitrogen radicals), HO_x (hydrogen oxide radicals), and ClO_x (chlorine oxide radicals) cycles. We numerically solve the simultaneous differential equations for these reactions in a reaction network within the so-called box model: a zero-dimensional, *i.e.*, local model where no transport processes are considered. In the box model, climatological temperature for several geometric altitudes between 25 km (lower stratosphere) and 75 km (upper mesosphere) are employed to find the equilibrium state in the concentration of chemical species. The fluence of SEPs is then estimated based on ion-pair production rate calculation[2)], and is introduced into the equilibrium state in the box model as an energy input perturbation. In this talk, chemical composition changes in the stratosphere during/after the event will be reported on the timescale of several *days*, for which the transport processes are not important. In particular, we will focus our attention on the enhancement in the concentration of reactive nitrogen (NO_y) and on the depletion in the concentration of ozone (O_3) in the stratosphere. This is because NO_y species become the source of nitrate that plays an important role when they precipitate, and because O_3 depletion in the stratosphere changes the temperature and the winds thus may be related with the climate change near the surface.

The results of our box model will be combined with a three-dimensional chemistry-climate model (CCM) to study global influence of the giant SEP event. Here the distribution of chemical compositions is investigated on the timescale of several *years*, where the transport processes are essential and are properly considered. We will then briefly discuss some results from our CCM simulations (in more detail, refer to a presentation by Akiyoshi *et al.* in the session "stratospheric processes and their role in climate" of this meeting).

References

1) Funke *et al.*, Atmos. Chem. Phys. **11**, 9089 (2011).
2) Jackman *et al.*, Atmos. Chem. Phys. **8**, 765 (2008).

Keywords: solar energetic particles, atmospheric chemistry, model calculations