Box-model simulation for influence of solar proton events on the middle atmosphere

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In a solar proton event (SPE), high-energy particles precipitate into the atmosphere. A part of the high energy particles can induce an increase in the concentrations of radicals, such as odd nitrogen radicals (NOx) and odd hydrogen radicals (HOx), through ionic and neutral reactions in the middle atmosphere. Furthermore, ozone depletion through subsequent reactions with radicals lasts longer than the SPE. The concentration variations of trace gas components with SPEs have been observed and numerical simulation studies have been performed.[1–5)]

We have developed a box-model of multitudinous and homogeneous gas phase reactions of ionic and neutral chemical species in the middle atmosphere, but without transport processes, to investigate the variation of trace gas composition induced by SPEs.[6–8)] We adopted 79 chemical species including positive and negative ions and 608 chemical reactions including various types of ionic and neutral reactions in the latest version of the box-model. The detailed numbers of adopted chemical species and chemical reactions are listed in Tables 1 and 2, respectively. The simulations were performed using commercial software (FACSIMILE, MCPA Software Ltd).

Figure 1 shows the result for the variation of ozone concentration at an altitude of 50km in the northern polar region for an SPE known as the "Halloween" event, which occurred in October-November 2003. The solid line corresponds to the result of full calculation, and the dashed line corresponds to that of a calculation conducted by taking account only of neutral-species production in initial radiolysis processes. The difference between the two results indicates that ion production in initial radiolysis processes and subsequent ionic reactions are important in the quick ozone depletion in the SPE. In both cases, diurnal oscillations of concentrations are observed.

In the near future, the variations estimated by the box-model simulation during an SPE will be input into a three-dimensional chemical climate model[9)] as perturbations to investigate the spatial and temporal atmospheric influence of the SPE through transport processes, aerosol formation, and so on.

Table 1. The number of chemical species adopted in this model.

Neutral species	45
Positively charged species	17
Negatively charged species	17
Total adopted species	79

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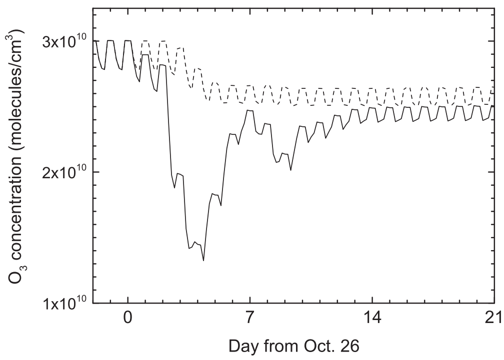

Fig. 1. Variation of the ozone concentration at an altitude of 50km in the northern polar region for the "Halloween" SPE in October-November 2003 (See text).

Table 2. The number of reactions adopted in this model for each reaction type.

Reaction type	# of reactions
Radioysis (initial processes in SPE)	12
Positive ion-neutral reactions	49
Negative ion-neutral reactions	65
Electron attachment on neutral species	8
Collisional and associative detachment	15
Electron-positive ion recombinations	26
Ion-ion recombinations	285
Photodissociation of negative ions[a]	3
Photo-detachment of electrons[a]	5
Solar UV photolysis of neutral species	24
Neutral reactions	116
Total adopted reactions	608

[a] Applied only above 70km.

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