Box-model simulation for variation of atmospheric chemical composition caused by solar energetic particles

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The atmospheric effect of energetic particles from the giant solar flares (solar energetic particles: SEPs) has been attracting attention in recent years. High-energy protons in SEPs can intrude down to the stratosphere and cause dissociation of nitrogen molecules in the middle atmosphere. This induced an increase in reactive odd nitrogen species (NOy) and decrease in ozone through subsequent chemical reactions over a period lasting longer than the SEP events, which typically continue for 3-7 days. The concentration variations of several chemical species with SEP events have been observed, and related simulations have been attempted.[1-3)]

We have investigated the variation of chemical composition induced by SEP protons using the box-model simulation, which includes multitudinous reactions for various ionic and neutral chemical species in the middle atmosphere, but no transport processes.[4,5)] The box-model simulations in the altitude range of 20-65 km were applied to the SEP event in October-November 2003. In this simulation, we adopted 77 chemical species including both positive and negative ions and 482 chemical reactions including various types of ionic reactions for the gas phase chemistry in the middle atmosphere.[5)] The simulation was performed using commercial software (FACSIMILE, MCPA Software Ltd).

The prompt products generated through radiolysis processes by the SEP protons induce subsequent ionic and neutral reactions (SEP-induced reactions). Thus, the production rates of the prompt products are estimated using the G-values (amount of products per absorbed energy of 100 eV)[6,7)] under the assumption that the yield of the prompt products is determined only with the energy deposit in the air. The day-by-day energy deposits with two peaks during the SEP event were estimated through the calculation of daily ion-pair creation rate by the SEP protons[2)]. We also assume that the prompt products are charged and neutral products generated from nitrogen and oxygen molecules.[4,5)]

Figure 1 shows the preliminary results of the energy deposit rate in a unit volume of the air, the variation of the ozone concentration (ΔO_3), and that of the NOy concentration (ΔNOy) at a 50km altitude in the northern polar region for the SEP event in October-November 2003. The variation of each chemical species induced by SEP protons was estimated as the difference between the result considering both SEP-induced and photochemical reactions and that considering only photochemical reactions using the same initial condition. The ΔO_3 responds to the increase in energy deposit very quickly. After the SEP event, the ΔO_3 increases again but does not completely recover to the pre-event value. On the other hand, ΔNOy increases during the SEP event and recovers very slowly after the event, maintaining its value for a few weeks or more. The depletion of ozone after the SEP event presumably remains because of the ozone consumption in the catalytic reaction cycle involving NOy.

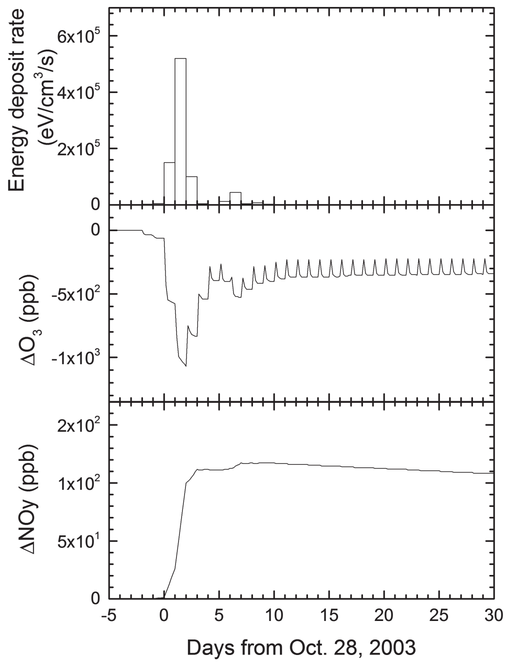

Figure 1. Preliminary results for the energy deposit rate in a unit volume of the air, the variation of the ozone concentration and that of NOy at a 50km altitude, caused by SEP protons. The SEP event started on October 28, 2003.

In near future, the variations estimated by the box-model for a short term will be input into a three-dimensional chemical climate model[8)] as instantaneous perturbation for investigation of the global and long-term influence.

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