Ion-neutral chemical processes in sprite discharges

Yasutaka Hiraki[1]; YASUKO KASAI[2]

[1] Kyoto Univ.; [2] NICT

Sprites are lightning-induced secondary discharges with both lateral and vertical scales of tens of kilometer, appearing at middle atmosphere all over the world. From telescopic imaging observations it is found that the structure of the emission dominates in a cluster of thin channels with scale of 1-10 m called streamers (Gerken and Inan, 2002; Liu and Pasko, 2004). From high temporally resolved observations it is found that the sprite streamers initiate around 70-90 km altitude and develop down to 40 km with velocity of 10^7–10^8 cm/s. Results of spectroscopic observations demonstrated that the emission is due to excitation of N_2(B, C) states and ionization excitation of $N_2{}^+$(A, B) through electron acceleration. Streamer is a highly conducting plasma channel; as the tip propagates with intense electric field and high electron density in its head, a large amount of chemically-radical atoms, as well as ions and electrons, is produced and released over its path, through inelastic collisions with neutral gases (mainly N_2 and O_2 molecules) of electrons accelerated by the field. After propagation of the streamer, various ion-neutral chemical reactions are induced, and the densities of minor species can be perturbed through the relaxation of these radical products.

We presented the first results of this field in the JPGU meeting where the enhancement of NOx and ozone densities by a sprite streamer is discussed (Hiraki et al., 2005). We have updated several input data of our model as compilation of collision cross section and streamer parameters, and calculate longtime variation of these particle densities; cross sections are taken from Itikawa (2006).

In this talk, we present the result of estimation of the concentration changes, caused by a sprite streamer, of ozone and related minor species such as odd nitrogen (NOx) and hydrogen (HOx) families in the upper stratosphere and mesosphere. We evaluate the production rates of ions and atoms using a Monte-Carlo electron kinetics model. Here, we assume the electric field and electron density in the streamer head on the basis of the above observations. We calculate the density variations mainly for NOx, Ox, and HOx species using a one-dimensional ion-neutral chemical model of the middle atmosphere, including the effect of the sprite streamer, on the basis of neutral model by Iwagami et al. (1998). We focus the nighttime condition where most of the events are observed. Results show that the densities of NO, O_3, H, and OH increase suddenly through reactions triggered by firstly produced atomic nitrogen and oxygen, and electrons just after streamer initiation. It is shown that NO and NO_2 still remain over 1 hour by a certain order of increase with their source-sink balance, predominantly around 60 km. For other species, increases in O_3, OH, HO_2, and H_2O_2 still remain for 1 hour in the range of 40-70 km. From this affirmative result of long time behavior previously not presented, we emphasize that sprites would have a power to impact on local chemistry at night. We also discuss comparison with recent studies as Enell et al. (2008) and Sentman (2008, will be published), and suggestion for satellite observations.