Numerical Simulation of Sprites Generated by Winter Lightning above Japan.

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Thunderclouds developing in Japan in winter are quite different from the mesoscale convective systems (MCS) developing in the United States in summer. However, the transient luminous glows in the mesosphere called sprites are generated by both winter lightning in Japan and summer lightning in the United States. We simulated the sprites generated by winter lightning in Japan using the quasi-electrostatic (QE) model proposed by Pasko et al. [1997] (hereafter PA97).

In the QE model, when the thundercloud charge is quickly removed by a lightning discharge, a large quasi-electrostatic field is produced. This temporarily existing electric field leads to the heating of ambient electrons (or ions), resulting in the atmospheric breakdown in the mesosphere, and then inducing optical emissions. The most important physical processes considered in this model are the production and extinction of electrons, because the atmospheric conductivity in the mesosphere and lower ionosphere, which determines the relaxation time of QE fields, depends largely on the ambient electron density. In the same way as PA97, we evaluated the electron density changes due to the impact ionization of O2 and N2, and the dissociative attachment of electrons to O2.

Considering observational data, we determined the parameters of the winter lightning. The initial ambient electron and neutral density profiles adopted for the mean winter profiles in Hokuriku district, Japan are given by the IRI and MSIS E-90 models, respectively.

The obtained results indicated that sprites can be generated by the winter lightning. We also calculated the optical emission intensities of the 1st and 2nd positive bands of N2, and compared them with the results obtained from the photometric and imaging observations of diffuse glows called the "sprite halos" carried out by the Tohoku University group.