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Characteristics of Lightning-induced Sprite Halos and Their Generation Mechanisms.

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Recently, remarkable progress of instruments revealed the existence of a brief diffuse glow called `sprite halo' by observation with a high-speed video system combined with an array photometer. The sprite halo had been sometimes misidentified as elves because of their similarity of shapes and short durations. Nowadays, sprite halos have become known widely and observations using high-speed cameras have been reported. However, their structures, occurrence probabilities and space-time spectral characteristics have not been studied in detail so far. Although sprite halos are considered to be produced by large quasi-electrostatic (QE) fields at mesospheric altitudes following the sudden removal of charges due to CGs, the characteristics of causative CGs have not been understood well.

We investigated the characteristics of sprite halo emissions observed with two sets of multi-anode array photometer (MAP), an image-intensified CCD camera and an intensified isocon video camera during the Sprites'96 and '99 campaigns carried out at Yucca Ridge Field Station (YRFS, 40.7oN, 104.9oW) near Fort Collins, Colorado in 1996 and 1999. Further, we analyzed high-speed camera data obtained at Wyoming Infrared Observatory (WIRO) by the University of Alaska Fairbanks during the Sprites'99 campaign. The MAP has 16 fields-of-view arrayed vertically and high temporal and spatial resolutions. Comparison between the MAP data with high-speed imager data provided the detailed characteristics and temporal evolution of sprite halos. For a statistical study, 35 sprite halo events observed in the Sprites'99 campaign were analyzed in detail. Two events observed by two sets of MAP with red and blue filters respectively were also analyzed to estimate the temperature of electrons inducing sprite halos.

Comparing the MAP data with imager data, we succeeded in distinguishing sprite halos from elves in the different features of temporal and spatial development. Further, we derived the mean altitude, mean horizontal extent, and the speed of descending motion of sprite halos as 80 km, 86 km, and 4.3*107 m/s, respectively. On the other hand, we classified 35 sprite halo events into four cases on the basis of spatial and temporal development: (1) sprite halos alone, (2) sprite halos with a preceding elve, (3) sprite halos with a preceding elve and following sprites, and (4) sprite halos with following sprites. The occurrence probabilities of each case of (1)-(4) are 26, 3, 34 and 37 %, respectively. The peak current intensities of CGs inducing sprite halos were 50-180 kA with a tendency that the peak current intensities of the causative CGs decrease as the time delays from the onset of sferics to the peak of sprite halo emissions increase.

We also estimated the electron temperature of electrons inducing sprite halos using the blue to red intensity ratio from two sets of MAP. The estimated peak electron temperature is in the range 6-23 and 7-16 eV for the assumed Maxwell-Boltzman and Druyvesteyn distribution, respectively. On the other hand, the average electron temperature is in the range 3-10 and 4-10 eV for these two distributions. There is a tendency that electron temperature becomes higher in the lower part of sprite halo. Electron temperature reaches its peak just before the intensity peak of red emission. Further we estimated the absolute luminosity of sprite halos with the assumption that sprite halo emissions come from 40 molecular bands in the major four band systems and calculated the excitation cross section using the estimated electron temperature. The obtained luminosity is in the range 7-56 MR, which is consistent with the model calculation result given by Barrington-Leigh et al. [2001].