

Occurrence probability of sprites and their luminosity based on ISUAL and ELF measurements

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Sprites are discharge phenomena, which are associated with lightning, in the altitude range of 50-90 km. Since the discovery of the sprite in 1989, many studies have been performed to investigate their emission features and characteristics of lightning, which induces sprites. Now we have known the facts that sprites are induced mainly by large-scale positive lightning discharge. Since 2004, the beginning of optical observations with ISUAL/FORMOSAT-2 from the space, global distributions of sprite occurrence has been clarified. The distributions are, however, different from those expected from lightning flash observations from space by OTD and LIS. This suggests regional dependence of lightning characteristics and different occurrence conditions for sprites. The details of the reasons are almost unknown. Since almost all the previous observations of sprites were ground-based ones, optical emissions from sprites are largely absorbed by the air. Therefore, we cannot discuss the absolute luminosity of sprites using the ground-based observation data. There is a compelling theory which predicts that sprite occurrence would be dependent on the quasi-electrostatic field produced by lightning. In such a case, it is speculated that the intensity of the sprite emission should have a correlation with the charge moment of the parent lightning because the strength of the electric field is proportional to the charge moment of lightning. However, the quantitative relations are still unknown.

In this study, in order to investigate the optical characteristics of sprites and their relationship to the parent lightning, we analyze two kinds of data, that is, optical data obtained by ISUAL/Imager and Array photometer, and worldwide ELF data operated by Tohoku University, which enables us to monitor the global lightning activity. We report the results of analysis to estimate the occurrence probability of sprites as a function of charge moment of parent lightning and to estimate the absolute luminous intensity of sprites using the data without atmospheric influence.

We focus the data obtained in 2004, in which both ISUAL and ELF network were operated properly. From the ELF network data obtained at three sites, that is, Syowa in Antarctica, Onagawa in Japan, ESRANGE in Sweden, about 270,000 lightning events were detected and examined. It is found that lightning discharges with charge moment over 200 C km occur at rate of 0.73 /sec in globe and that in Central Africa the occurrence ratio of large charge moment events is larger than in other regions. The global occurrence frequency of sprites detected by ISUAL/Imager and their charge moment values are examined. Comparing the charge moment distribution of sprites' parent lightning with that of whole global lightning detected by ELF network, the occurrence probability of sprites is estimated to be about 50 % for the events about 1200 C km. These values are something different from the about 50 % occurrence probability for events about 600 C km estimated by Hu et al. [2002] for lightning around US. This could be attributed to the detectability of ISUAL/Imager or the accuracy of charge moment estimation, as well as regional and/or seasonal varieties in characteristics of sprites. Absolute optical energies emitted from sprites are estimated for 14 streamer type sprites for the first time, using ISUAL/Array photometer data. The averages are 176 kJ and 119 kJ for N2 1PG and N2 2 PG bands, respectively. Furthermore, the optical energies and the charge moments of their parent lightning estimated by ELF data show high correlation (correlation coefficient = 0.93), which does not conflict with a story of QE model qualitatively. This relationship predicts the 50 % occurrence probability is located at 640 C km, which is consistent with previous study by Hu et al. [2002].