Electrodynamical processes in sprites derived from FORMOSAT-2/ISUAL measurements

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Recent discovery of sprites occurring above active thunderstorms has visualized a new aspect of the electrodynamic coupling between the troposphere and the middle/upper atmosphere. In order to clarify electrodynamical processes in sprites, we have analyzed optical data observed with the newly developed ISUAL/array photometer onboard the FORMOSAT-2 satellite.

The array photometer consists of two optical systems measuring two wavelength ranges of 340-480 nm and 510-750 nm with a vertical resolution of ˜14 km and a temporal resolution of 50 microseconds. During the period from July 4, 2004 to June 25, 2006, the ISUAL has observed 482 sprite events. We have classified these sprite events into three categories based on their morphology: halo events, halo-streamer events and streamer events.

By using blue/red emission ratios observed with the array photometer, we have estimated spatiotemporal-resolved electric field intensities in sprites. We have found a distinct transition at an altitude of ˜75 km, which corresponds to the morphological transition between the upper-diffuse region and the lower-streamer region of sprites. The magnitudes of electric fields in the diffuse region are 0.6-0.8 Ek where Ek is the conventional breakdown field, supporting theoretical expectation that diffuse emissions can be produced without significant ionization process. On the other hand, those in the streamer region are 1-2 Ek, which is a few times smaller than the predicted fields in the modeled single streamer. We have suggested that this discrepancy is due to the long-lasting components such as the lower portions of the upward branches and bead structures in sprites. Furthermore, by combining the array photometer data with the ELF magnetic field data, we have estimated the temporal evolutions of lightning charge moment changes in each sprite category. In the case that time scale is short (˜1 ms), it is found that the lightning discharge with a charge moment value of ˜400 C-km produces a sprite halo while the lightning discharge with ˜1000 C-km produces sprite streamers besides a halo. On the other hand, the lightning discharge with a long time scale (˜10 ms) and a large charge moment value (˜1000 C-km) is found to produce streamers without discernible halo. The obtained results are interpreted considering both the conventional breakdown field necessary for the formation of streamers which is invariable with time and the critical electric field necessary for the optical emissions of halos which increases with time due to the electron attachment process.