Types of wintertime sprites in Japan and characteristics of their parent lightning discharges

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In order to clarify the relationship between the types of winter sprites in Japan and the characteristics of their parent lightning discharges, we analyze 67 sprite events observed during the winter sprite campaigns carried out in Japan every year for the period of 1998-2003. The instruments used for these observations are an image-intensified CCD (IICCD) camera, two sets of multi-anode array photometer (MAP), and a VLF receiver with two orthogonal loop antennas. In addition, we use the data from the ELF (1-100 Hz) observation system operated at Syowa station (69.0S, 39.6E) in Antarctica to calculate charge moment values of lightning discharges. We also use cloud maps from the GMS-5 satellite, weather maps, and lightning network data from JLDN and LPATS to investigate the characteristics of sprite-inducing lightning discharges and thunderstorm systems.

We classify sprite-producing thunderstorm systems into four categories: 1) the cold front over the Sea of Japan, 2) the Japan-Sea Polar-Airmass Convergence Zone (JPCZ), 3) local low-pressure over the Pacific Ocean, and 4) thunderstorms behind the cold front over the Pacific Ocean. Further, we classify winter sprites in Japan into two categories based on their morphology: columniform sprites and carrot sprites. 38 events are classified as columniform sprites, while 8 events are classified as carrot sprites. The types of the rest 21 events are unidentified. During the five winter sprite campaign periods, columniform sprites were induced mainly above thunderstorm systems in the categories [1]-[3], which were located near the coast of the mainland of Japan. On the other hand, carrot sprites were mainly induced above thunderstorm systems in the category [4], which were far from the mainland. These results may suggest that columniform sprite tend to occur above land, while carrot sprites tend to occur above ocean.

We analyze the relationship between peak current intensity and charge moment value on columniform sprite events. It is found that there is little correlation between the values of the peak current intensity and the values of the charge moment with a correlation coefficient of 0.19. Further, it is found that the number of columns in each sprite event is proportional to the peak current intensity of positive cloud-to-ground lightning discharges (+CGs) with a correlation coefficient of 0.90 while the average vertical length of columns is proportional to the charge moment of the causative +CGs with a correlation coefficient of 0.62. Based on these results, it is suggested that electromagnetic pulses (EMPs) radiated from +CGs contribute to the formation of seeds for sprite columns while the QE fields contribute to the development of the columns from the seeds.