Geophysical Research Abstracts, Vol. 8, 06729, 2006
SRef-ID: 1607-7962/gra/EGU06-A-06729

Lightning discharge processes generating carrot and column sprites

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During a thunderstorm on 23 July 2003, 15 sprites were captured by a sensitive LLTV camera mounted at the observatory on Pic du Midi in the French Pyrénées. Simultaneous observations of cloud-to- ground (CG) and intracloud (IC) lightning activity from two independent lightning detection systems and a broadband ELF/VLF receiver allow a detailed study of the relationship between electrical activity in the thunderstorm and the sprites generated in the mesosphere above. We discuss the lightning discharges that precede two clearly different kinds of sprites, the carrot- and column-shaped sprites.

We find that column sprites occur after a short delay ($<$30 ms) from the causative +CG and are associated with little VHF activity, suggesting limited or no direct IC action on the charge transfer process. Carrot sprites happen up to about 200 ms after their causative +CG stroke and are accompanied by a burst of VHF activity in the 25-75 ms preceding the CG stroke. The ELF/VLF sferic durations that indicate prolonged in-cloud breakdown at leader tips of in-cloud lighting are also different for the two classes of sprites: column sprites were associated with short-lasting (less than 30 ms) ELF/VLF sferics, whereas carrot sprites were associated with longer bursts of sferics initiating at the time of the causative +CG discharge, persisting for 50 to 250 ms, in a similar way to the delay times.

In conclusion, the different charge transfer processes in causative lightning flashes have a direct influence on sprite morphology. We may hypothesize that slower removal of charge from the cloud by more extensive lightning causes the mesospheric

breakdown electric field threshold to be reached later but for a longer duration, allowing for vertically more extensive sprites with a higher degree of complexity (carrots).

In addition, we noticed a remarkable difference between SAFIR VHF and broadband ELF/VLF detection of lighting. SAFIR sources matched with sferic activity only before the +CG stroke, but not with the stronger burst of sferic activity following the +CG stroke. This forms a basis for a discussion of the reliability of lightning detection systems based on VHF interferometry.