Geophysical Research Abstracts, Vol. 7, 01930, 2005
SRef-ID: 1607-7962/gra/EGU05-A-01930

VLF perturbations and causative cloud-to-ground discharges observed during *EuroSprite-2003* in association with sprites

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We present results based on VLF observations and MÉTÉORAGE lightning data made during *EuroSprite-2003* when a large number of sprites occurred over France. The sprites were detected with a camera from the Pyrenees over storms monitored with MÉTÉORAGE, the French national lightning detection network. The storms under study were situated in the vicinity of a VLF transmitter (HWV) at Le Blanc, France, whose signal was received on the island of Crete with a narrowband, and nearby at Nançay with a broadband VLF receiver. This study focuses on the issues of: a) detection of early VLF perturbations possibly due to backscatter from a sprite-affected subionospheric region, and b) occurrence of causative positive cloud-to-ground discharges prior to a sprite. With respect to the first issue, early VLF perturbations resulting from narrow angle forward scatter have been observed in Crete in nearly one-to-one association with the sprites. On the other hand, bandpass filtering of the broadband VLF signal revealed that only about 5% of the sprites were escorted by early VLF perturbations, possibly due to backscatter, all originating from a single storm located relatively close to the Nançay receiver. On the second issue, analysis of the time lags of the sprites to the preceding +CG discharges showed that one third of the observed sprites were lagging the +CG discharges by more than 30 ms up to 300 ms. In these cases there were no radio-sferics present during the sprite observation period, in

contrast to the short-delayed sprites which were escorted nearly always by enhanced, burst-like, radio-sferic activity. These observations endorse the notion of long delayed sprites reported in past studies and show that their occurrence is much more frequent than it was thought before.