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Electric field studies: TLE-induced waveforms and ground conductivity impact on electric field propagation

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We review in this paper main results obtained from electric field (from VLF to HF) measurement campaigns realized by CEA in the framework of the Eurosprite program [Neubert et al., 2005, 2008] from 2003 to 2009 in France in different configurations. Two main topics have been studied: sprite or elve induced phenomena (radiation or perturbation) and wave propagation.

Using a network of 4 stations, VLF radiations from sprite have been successfully located at 10 km from the sprite parent lightning, in agreement with possible sprite location, generally displaced from the parent lightning. The MF (300 kHz – 3 MHz) source bursts were identified simultaneously with the occurrence of sprites observed with cameras [Farges et al., 2004; Neubert et al., 2008]. These observations are compared to recent broadband measurements, assumed to be due to relativistic electron beam radiation related to sprites [Fullekrug et al., 2009]. Recently, in 2009, with a new instrumentation, an ELF tail has been clearly measured after the lightning waveform, while sprites were observed at about 500 km from our station. This ELF tail is usually observed at distances higher than thousand km and is associated to sprite generation. This opens the capacity to measure the charge moment of the parent-lightning, using such measurement close to the source.
Farges et al. [2007] showed that just after a lightning return stroke, a strong transient attenuation is very frequently observed in the MF waves of radio transmissions. They showed that this perturbation is due to heating of the lower ionosphere by the lightning-induced EMP during few milliseconds. These perturbations are then the MF radio signature of the lightning EMP effects on the lower ionosphere, in the same way as elves correspond to their optical signature. The experiment also provided the electric field waveforms directly associated to elves, while lightning were not detected by Météorage. Many of them present a double peak feature.

The propagation of the electromagnetic waves generated by lightning has also been studied in the frequency range 1 kHz-1MHz at distances lower than 1000 km from the lightning source. A propagation model has been developed to determine the ground waves which propagate in a homogenous medium using the analytical expression given by Maclean and Wu [1993]. This approach takes into account the electric finite conductivity and the fact that the Earth is spherical, which allow us to deal with over-the-horizon propagation. We installed in 2008 four stations which were more or less aligned - the maximum distance between two stations was about 870 km. Two stations were located close to the Mediterranean Sea and the two others inside the continent, at the centre of France. This station distribution and the observation period (from August to December) allowed statistical and physical studies, such as the influence of the electric conductivity on wave propagation. Comparison of electric field spectra, measured after propagation only over sea and only over ground, showed clearly the effects of ground conductivity on propagation. Comparison between observations and modelling has been used to evaluate the ground conductivity. In the future we will implement the sky-wave inside our model and validate it with the database.