Small scale interferometric network of low frequency radio receivers

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A small scale interferometric network of wide band low frequency digital radio receivers was deployed in Southern France from July to September 2011. The network operated successfully during several nearby sprite producing thunderstorms. Network recordings can provide the 3D detection of different types of atmospheric discharges. Also the network can provide reliable mechanism for association of sprites detected by optical video observations and their corresponding parent lightning discharges, which sometimes are missed by commercial lightning detection systems. Several candidate waveforms of possible runaway electron beams are investigated in detail. The capabilities of the interferometric network of low frequency radio receivers to complement other measurements are discussed.

1. Introduction

Recent observations show that powerful positive cloud-to-ground (CG) discharge can lead to the development of sprites above thunderclouds [1]. The vast majority of sprites exhibit a strong positive CG discharge as a parent event. However observations of sprites without preceding positive CG discharge have been reported [2]. As sprites observations are based on optical video recordings [3], the association of captured sprites with their parent lightning discharges is not always an easy task. The catalogue of lightning discharges provided by a lightning detection system is compared with the sprite time stamps obtained from the video recordings. Sometimes that may be impossible, as the lightning detection system misses discharges with unusual waveforms that cannot be recognized and are rejected by its detection algorithm. There may be also the case when a sprite has no positive CG discharge as a parent event, e.g. an intra-cloud discharge [2]. These unusual cases are of primary interest here. For these purposes optical video observations of sprites are combined with low frequency radio observations.

Sprites initiated by strong positive CG discharges may be also accompanied by runaway electron beams (REBs). According to numerical simulations and recent observations REBs emit broadband electromagnetic radiation characterized by its flat spectrum. These radio emissions occur several milliseconds after the parent positive CG lightning discharge and can be detected by low frequency radio receivers.

2. Interferometric network

This work uses a small scale network of wide band digital radio receivers, which record vertical electric field strengths in the frequency range from ~ 4 Hz to ~ 400 KHz, with a sampling frequency of 1 MHz, an amplitude resolution of ~ 35 µV/m and a timing accuracy of ~ 12 ns [4].

The small scale interferometric network consists of eight radio receivers, which are separated by distances ranging from 1 km up to 30 km. Three additional receivers served as remote reference measurements at distances from 300 km up to 1000 km. The small scale interferometric network enables the detection of lightning discharges and associated events in three dimensions for nearby thunderstorms which are less than 500 km away.

The network was deployed in Southern France from July to September 2011. It was operating successfully during several nearby sprite producing thunderstorms. The recorded waveforms are very consistent and exhibit small time delays which reflect the propagation of the electromagnetic waves across the network. These time delays are used to determine the bearing, elevation angle and distance to the source of the arriving electromagnetic energy. Time differences between the arrival of the direct (or ground) wave and the first hop sky wave allow to determine the altitude of the emitting source.

3. Results and perspectives

During the measurement campaign several tens of sprites were detected by the sprite research community in Southern Europe. Several candidate electromagnetic signatures of possible REBs were recognized and processed. Some unusual waveforms preceding sprites have been detected which are not positive CG lightning discharges.

Possible improvements of the interferometric network for future campaigns and in particular comparison with other instruments, e.g. high speed photometric recordings, will be discussed.

4. References

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