Air heating and infrasound radiation in sprites

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Sprites are large-scale electrical discharges occurring between 40 and 90 km altitude [1]. They are generated by strong quasi-electrostatic fields produced by cloud-to-ground lightning discharges in an underlying thunderstorm. Sprites have been extensively studied through measurements of their optical emissions (e.g., [2]) and remote sensing of their electromagnetic fields (e.g., [3]). In recent years, a new possibility for sprite remote sensing has been realized: infrasound signatures recorded on the ground have been unambiguously associated with sprites [4]. In this presentation, we discuss the physical basis of air heating in sprites and the mechanism of infrasonic acoustic wave radiation.

1. Motivation

The possibility of infrasound generation by sprites was first proposed by *Bedard et al.* [5]. *Liszka* [6] reported the detection of infrasound signatures that were associated with sources at mesospheric altitudes during times of intense thunderstorm activity. These findings were confirmed by *Farges et al.* [4], whose authors have correlated the infrasound recordings (in the frequency range of 0.1-9 Hz) with optical sprite observations. Typical sprite infrasound amplitudes are 0.01-0.1 Pa, as measured on the ground, at distances ~100-400 km from the source [4,7]. Long-range sprite infrasound signatures have a chirp-like feature, with low frequencies arriving at the detector before high frequencies [4].

Farges et al. [4] estimated that energies on the order of 0.4-40 GJ have to be locally deposited by sprites to generate the observed infrasound amplitudes on the ground, far away from the source. These values for energy deposition are well above the ones estimated from optical emissions. For instance, *Kuo et al.* [8] deduced, from the spatially-averaged brightness of the first positive band system of molecular nitrogen (1PN2), that the average energy deposition in sprites is 22 MJ, which is consistent with previous theoretical calculation by *Sentman et al.* [9], of 1-10 MJ.

2. Modeling of the sprite infrasonic source

In order to properly describe the sprite infrasonic source, we have developed a model for analysis of air heating in electrical discharges [10] and we have applied this model to quantify the levels of air heating in sprites [11]. Figure 1 shows a schematic representation of the sprite infrasonic source. The inset in Figure 1 illustrates the waveform of the current flowing in the sprite core, which generates mesospheric air heating and expansion in the form of infrasonic acoustic waves. A key feature of the proposed physical model is the detailed description of fast air heating due to quenching of excited electronic states of nitrogen molecules (e.g., [12]). Our results indicate that >0.01 Pa pressure perturbations on the ground, observed in association with sprites, can only be produced by exceptionally strong currents in sprite cores, exceeding 2 kA. We also point out that infrasound amplitudes are more closely related to peak currents in sprites rather than total energy deposited per sprite event. This modeling study is the first step towards connecting the well-known optical (e.g., [2]) and electrical (e.g., [3]) properties of sprites to their infrasound signatures (e.g., [4,7,13]).

3. References

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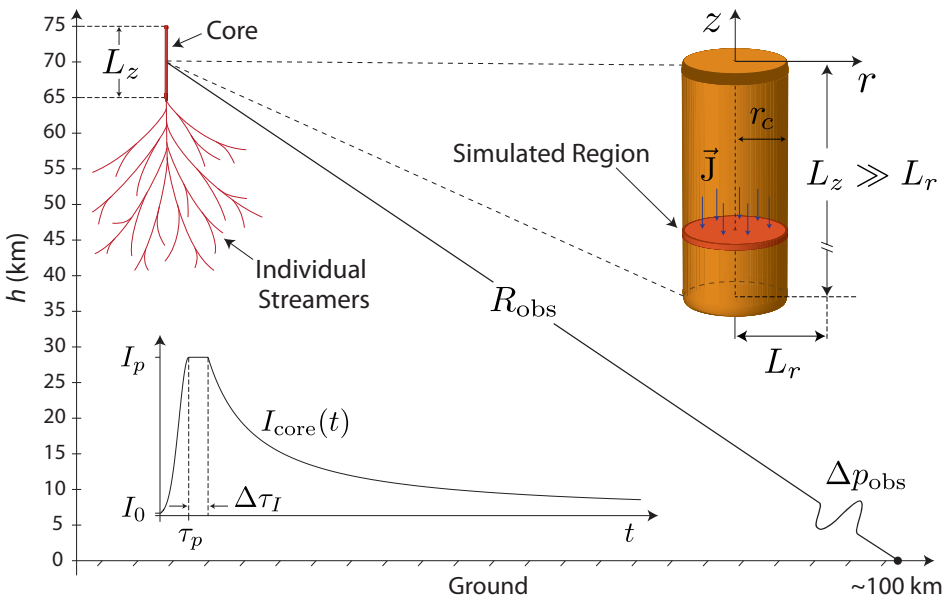

Figure 1. Schematics of air heating in a sprite core leading to generation of infrasonic acoustic waves observed on the ground, far away from the source. The figure highlights the geometry of the simulated region, which describes a cross section of the sprite core at 70 km altitude. The inset shows the waveform of the current flowing through the sprite core. Reprinted from Figure 1a of [11] by permission from American Geophysical Union.

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