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Influence of water conductivity on micro-discharges from raindrops in strong electric fields

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Abstract

The influence of water conductivity on micro-discharges from raindrops has been studied by submitting water drops of different conductivities, falling at terminal velocity, to strong horizontal electric fields. The discharge onset field remains quite unchanged but the micro-discharges characteristics are clearly affected by the nature of water — scarce high amplitude pulses for low water conductivity and numerous low amplitude pulses for higher water conductivity. The influence of water conductivity on the onset streamer pulse mode of discharge is analysed. It is thought that the negative charge at the head of the positive avalanche is faster absorbed by the drop surface with rainwater, thus the reactivation of the pulses is faster. Possible implications of such behaviour are discussed in the light of recent studies on the influence of pollution on lightning activity.

Keywords: Lightning; Atmospheric pollution; Microphysics; Micro-discharge; Water conductivity

1. Introduction

Studying micro-discharges from raindrops is of interest because corona discharges from hydrometeors are supposed to be the first stage of lightning initiation. Electrical corona (also called point discharge) has been treated by many authors. Loeb (1965), in

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particular, has broadly investigated the problem of corona discharge mechanism. He showed that point discharge is initiated near the point by the acceleration of free electrons provided the electric field is strong enough. These electrons then ionise gas molecules and create an electron avalanche. The discharge starts with short duration pulses called burst pulses or onset streamers and can develop into a steady signal while the electric field increases. Whereas Loeb principally considered discharges from metal points, numerous studies have been conducted on corona emission from hydrometeors (English, 1948; Dawson, 1969; Griffiths and Latham, 1972, 1974). One of the latest, carried out by Schroeder et al. (1999), presents a detailed numerical analysis of the phenomenon and shows that positive corona can occur at observed in-cloud electric fields when two drops undergoing collision produce a long liquid filament that highly enhances the local electric field according to Crabb and Latham (1974). However, until now, no experiment has documented the bipolar discharge from raindrops falling at terminal velocity.

Several parameters that govern micro-discharges from raindrops have been largely explored; particularly pressure, and water drop size and charge (Dawson, 1969; Griffiths and Latham, 1972; Georgis et al., 1995). Among these parameters, water conductivity has been seldom considered though its influence has been pointed out for the flashover of water drops on hydrophobic insulator surfaces (Windmar, 1994). Moreover, Griffiths and Latham (1974) noticed an effect of conductivity on ice particles. They showed that there is a critical temperature from which ice conductivity is too weak to allow micro-discharges from ice hydrometeors. Contaminating ice particles with ammonia, which means increasing ice conductivity, leads to decrease this critical temperature below which corona emission is inhibited.

Several recent studies tend to suspect an influence of atmospheric contaminants on lightning. They show a modification of lightning activity over cities (Westcott, 1995; Soriano and de Pablo, 2002; Steiger et al., 2002) or during a fire of biomass event (Lyons et al., 1998; Murray et al., 2000). This modification could originate from several parameters like urban heat island, cloud condensation nuclei (CCN) concentration, but also from moisture according to Smith et al. (2003). Water conductivity that is much affected by pollutants could also play a part.

A laboratory experiment has been performed so as to observe the impact of water conductivity on micro-discharges from raindrops. Using different types of water, we submitted falling drops to strong electric fields. The signals produced by the drops were measured and the different electrical behaviours were analysed. In a second step, laboratory results are attempted to be linked with large-scale electrical phenomenon in order to draw up conclusions about lightning activity.

2. Experimental device and procedure

The experimental device is similar to that used by Georgis et al. (1997) and a change of site allowed us to set up a vertical tunnel 17 m high which ensures all the drops to reach more than 99% of their terminal velocity in still air (see Wang and Pruppacher, 1977). In this way, the generated drops falling at atmospheric pressure are fully aerodynamically