Atmospheric Research 108 (2012) 115–121

Contents lists available at SciVerse ScienceDirect

Atmospheric Research

journal homepage: www.elsevier.com/locate/atmos

Droplet charging by high voltage discharges and its influence on precipitation enhancement

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ARTICLE INFO

Article history:
Received 17 September 2011
Received in revised form 1 February 2012
Accepted 3 February 2012

Keywords:
Electrical discharge
Droplet growth
Cloud seeding
Echo intensification

ABSTRACT

Laboratory experiments were performed to determine the effect of electrical charges transferred on droplets by electrical discharges on their growth by collision and coalescence. A twin cloud chamber was built inside a large cold room and was filled with cloudy air. One chamber was used as the control chamber and, therefore, was left unperturbed. On the other hand, in an experimental chamber, electrical discharges were produced. Droplets grow during a free fall of 1 m, and the droplet spectrum was sampled by microscope slides covered in Formvar. The experimental arrangement could also measure charge on individual drops between 325 and 415 μm in diameter by using small induction rings.

After comparing the spectra from both chambers, a shift towards larger sizes was observed in the cloud that sustained electrical discharge. Also, by measuring the charge on the droplets, it could be observed that the electrical discharge transferred charges of both signs. Discussions about the relevance for cloud seeding and fog elimination are carried out.

1. Introduction

A gush of rain in thunderstorm has often been observed shortly after a nearby lightning stroke (Schonland, 1950; Moore et al., 1962, 1964; Szymanski et al., 1980; Piepgrass et al., 1982). Several mechanisms have been proposed to explain how lightning can trigger precipitation.

One of the early theories was put forward by Schonland (1950) where charged hydrometeors are levitated by cloud's electrical field. When an electrical discharge occurs, the field is reduced and the particles start to accelerate downwards. A numerical model that couples the growth of the particles in a cloud with electrical development was used by Ziv and Levin (1974) to explain the rain gush. They demonstrated that electrical forces in clouds decrease the fall velocities of hydrometeors and inhibit particle interaction, thus when a lightning strike occurs, a rain gush takes place. However Vonnegut (1975), Kamra (1975) and Colgate (1975) suggested that Ziv and Levin's (1974) hypothesis was not completely correct. Next, Jayaratne and Saunders (1984) suggest a different view, precipitation initiates lightning and not vice versa.

Another theory proposed to explain this phenomenon was suggested by Goyer (1965a,b) where radial wind produced by acoustic waves (explosions or lightnings) result in an increase on the rate of coalescence of water droplets, triggering precipitation. Vuković and Ćurić (1998) analyzed the influence of the acoustic waves on rain gushes using a one dimensional numerical model. Their results suggest that the acoustic wave generated by a lightning can shift the mean volume radius of the spectrum from 10 to 25%. According to the authors that increase of the droplet size could be important for further gravitational driven coalescence. This result agrees with the observations by Goyer (1965a,b) carried out in the Old Faithfull Geyser, where gushes of rain were formed after detonating explosive cords near the Geyser plume.

Moore et al. (1964) proposed an interesting rain gush explanation. They suggest that a ground flash leaves a tree-like pattern of electric charge opposite in sign to the original one within the cloud. After this interaction, droplets get charged

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doi:10.1016/j.atmosres.2012.02.006

with different signs within the cloud, and by electrical forces they attract each other and coalesce. After becoming neutralized, these droplets have a greater mass and continue growing by collisions and coalescence while falling through the cloud. The interaction of droplets and streamers has been documented by Oladiran (1981, 1982), Phelps and Vonnegut (1970) and Phelps (1972). These results show that the droplet can have a direct interaction with the streamers where the latter can be completely absorbed, re-emitted, or interact indirectly. This direct interaction between streamers and droplets is not considered by Moore et al. (1964) hypothesis. Laboratory measurements of charge acquired by droplets when they interact with positive corona streamers were carried out by Barker et al. (1983). But the experimental setup in this work could only measure positive charged droplet, thus, it neglected any droplets charged with negative charge.

In order to test the importance of Moore et al. (1964) theory, a twin cloud chamber was built inside a large cold room to measure the influence of electrical discharges in droplets growth. One chamber was used as the control chamber and, therefore, was left unperturbed. On the other hand, in an experimental chamber, electrical discharges were produced. A comparison between the spectra of both chambers shows that electrical discharges shift the spectrum towards larger sizes. In addition, charge measurements on individual drops show that electrical discharges transferred charge of both polarities to the drops. The results obtained support Moore et al.'s (1964) theory.

2. Experimental setups

2.1. Cloud droplet spectrum measurements

Fig. 1 shows the twin chamber setup which was mounted in a walk-in cold room of 2.6 m long, 1.6 m wide and 2.3 m high. This room can reach a minimum temperature of −25 °C and maintain a desired temperature within a range of ±1 °C. The experimental setup consists in two cylindrical chambers with 29 cm in diameter and 50 cm depth. They are connected with a cylindrical pipe of 10 cm in diameter. Through this connecting pipe, the chambers were simultaneously filled with cloud produced by the cloud generator at the bottom.

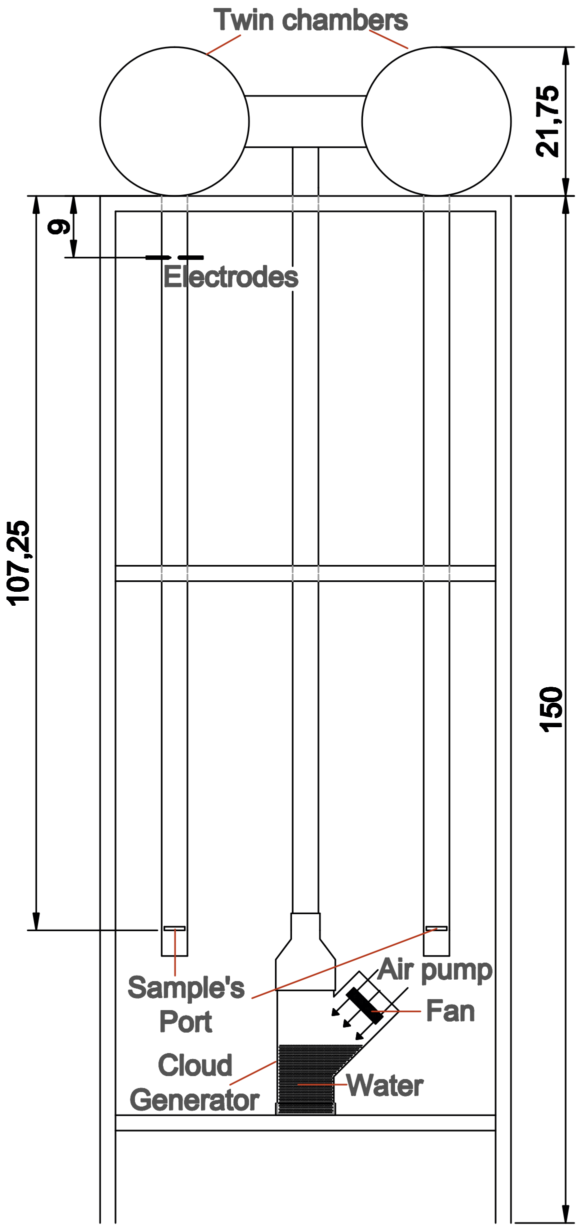

Fig. 1. Experimental setup.

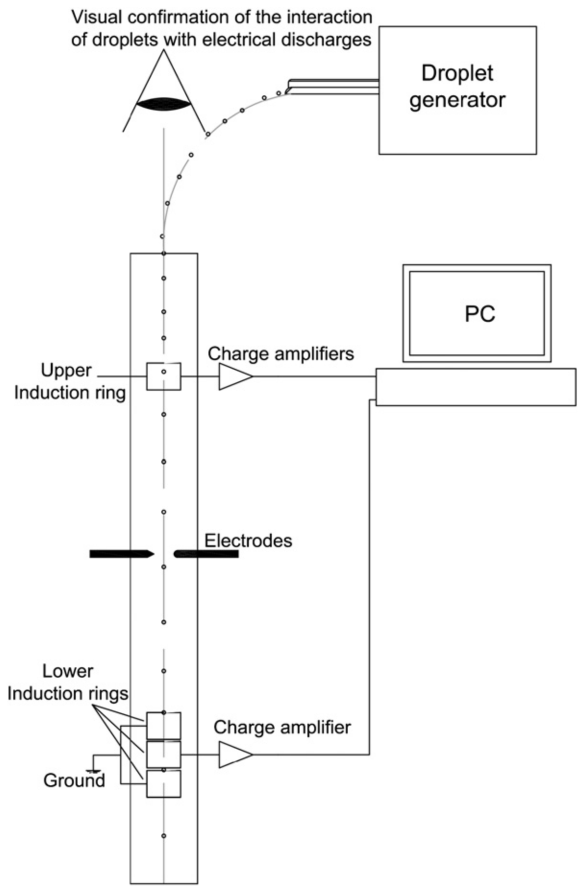

Fig. 2. Charge transfer measurement setup.