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Experiments of artificially triggered lightning and its application in Conghua, Guangdong, China

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ABSTRACT

The Guangdong Comprehensive Observation Experiment on Lightning Discharge (GCOELD) was conducted from 2006 to 2011 in Conghua, Guangdong, China. In GCOELD, the acoustical, optical, electrical and magnetic signals of triggered lightning and natural lightning were measured. For the triggered lightning, the peak current of the return strokes (RSs) ranged from 6.67 to 31.93 kA. The transferred charge within 1 ms after the beginning of the RS ranged from 0.44 to 4.16 C. The peak currents showed different-function correlations with average rate of rise between 10 and 90%, maximum rate of rise, charge transfer and action integral. The 2D propagation speed of the upward positive leader for the triggered lightning was of the order of 10^4–10^5 m s^{-1}. The speed of the downward negative leader involved in altitude-triggered lightning was approximately 10^5 m s^{-1}. The characteristics of induced voltages produced by triggered lightning on a power line and signal line of an automatic weather station were measured and analyzed. The maximum induced voltage generated by the RS on the overhead power line (1200 m in length and 2 m above the ground) exceeded 10 kV. The maximum induced voltage on a vertical 10-m signal line was 3.10 kV. The triggered-lightning technique was also used to test the detection efficiency and location precision of the lightning location system (LLS) in Guangdong. It was explored that the Guangdong LLS yielded detection efficiency and location error of 92% and 760 m, respectively, for triggered flashes. For RSs of the triggered lightning, the peak currents given by the LLS deviated from those measured at the base of the lightning channel by 16% on average.

1. Introduction

The artificially triggered lightning technique can produce a discharge between a charged cloud and the ground in a predictable spatio-temporal range. This approach provides an effective way to directly measure the current at the bottom of the lightning channel, and to conduct integrated simultaneous observations for the electromagnetic field and the optical characteristics of the lightning discharge. The technique has been used in several countries and resulted in numerous significant findings (Rakov and Uman, 2003; Horii, 1982; Liu and Zhang, 1998; Qie et al., 2009).

The triggered-lightning technique has also been used to test the capability of various lightning-protection systems and devices. Horii (1982) first used artificially triggered lightning in an experiment on lightning protection of a low-voltage power system. They found that the electromagnetically induced voltage on the power line located 70 m from the triggered lightning was 25–30 kV for the return stroke (RS)

Abbreviations: AM, arithmetic mean; AWS, automatic weather station; GCOELD, Guangdong Comprehensive Observation Experiment on Lightning Discharge; GM, geometric mean; LLS, lightning location system; RS, return stroke; SLE, Semi-conductor Lightning Eliminator; SPD, surge protective device.

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with 10-kA peak current. Rakov et al. (2002) used triggered lightning to strike the lightning protection system of a residential house in an experiment. Bejleri et al. (2004) studied the interaction of rocket-triggered lightning with the lighting protection system of an airport runway. The lightning was conducted to directly stroke various location of the runway lighting system, and much data on voltages and currents in the system were reported. Zhang et al. (2006) analyzed the response of non-conventional lightning rods (it specially refer to Semi-conductor Lightning Eliminator (SLE) here, which, according to the manufacturer's declaration, can eliminate upward going lightning discharge and hence lighten the damage of downward going lightning discharge due to its current-limiting function. Also see Chen et al. (2000)) to triggered-lightning discharges.

Because electronic components are commonly used now, electromagnetic radiation due to lightning may cause severe damage to electronic equipment. Therefore, it is important to study the electric and magnetic field changes and their effect on electronic equipment in an environment of triggered-lightning discharge. From 2006 to 2011, triggered-lightning experiments, performed as an important part of the Guangdong Comprehensive Observation Experiment on Lightning Discharge (GCOELD), have been conducted termly by the Chinese Academy of Meteorological Sciences (CAMS) and the Guangdong Meteorological Bureau. GCOELD is mainly concerned with comprehensive observations of the acoustics, optics, electricity, and magnetism of the discharge process in triggered lightning and natural lightning, along with the testing of lightning detection equipment and studies of lightning location technology and methods. During the experiment period, a total of 49 lightning discharges were triggered successfully. The lightning protection of an automatic weather station (AWS) was also studied, and the capability of the lightning location system (LLS) covering Guangdong province was tested. In this paper, these experiments and the main results are introduced.

2. Test layout and measuring instrument

In China, Guangdong is one of the provinces yielding the most thunderstorms, with 77 thunderstorm days per year on average. Triggered-lightning experiment site was located in Conghua, north of Guangzhou city. Fig. 1 shows a photograph of the triggered-lightning site. Six launchers were established for launching triggered-lightning rockets. A wire carried by the rocket was connected to a small lightning rod of 4 m in height and with a grounding resistance of 6.7 Ω. The rockets' launch controller and various data acquisition systems were operated in a small house which was covered with iron sheet, located about 90 m northwest to the small lightning rod and connected to a grounding system with a resistance of 7 Ω. The triggering signal was produced and transmitted by a set of fiber system which ultimately opened a 12-V battery to fire the rocket. An AWS with four elements and a lightning rod of 10 m in height were set up at a distance of 20 m from the triggered lightning. An overhead power line, consisting of a live line (L) and a neutral line, supplied power to the AWS. The power lines were supported by wooden poles of 2 m in

Fig. 1. Photograph of the experiment field for triggering lightning.