LIGHTNING DISCHARGES IN THE NORTHEASTERN VERGE OF TIBETAN PLATEAU

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ABSTRACT: In the summer of 2002, a comprehensive observation on natural lightning discharges was conducted in the northeastern verge of Qinghai-Tibetan Plateau. The thunderstorm is usually shows an inverted bipolar charge structure. The stepped leader develops downward to ground with multi-branches with a 2-D velocity of 0.8-1.2×10^5 m/s and more than one striking point on the ground was often observed as a result. The pictures from high-speed digital camera confirmed the bi-level structure of IC discharge. The IC discharge initiates between upper negative charge region and lower positive charge region, and developed downward and upward to the lower positive and upper negative region, respectively.

INTRODUCTION

Since the late 1980s, several unusual electrical features for summer thunderstorms were observed in the Chinese inland plateau area. These features include: (1) when thunderstorms are overhead, the electric field at the ground are usually positive (defined as positive charge being overhead) (Wang et al., 1987); (2) nearly all cloud discharges appear to occur in the lower portion of the cloud to neutralize the main negative charge and the lower positive charge(Qie et al., 2000a; Liu et al., 1989); (3) The ratio of positive ground discharge is much higher than other places (Qie, 1991; Qie et al., 2002); (4) A long duration of IC discharge usually occurs just before negative CG lightning (Qie et al., 2000b); (5) all rocket-triggered lightning are positive with only initial continuous current stages (Liu et al., 1994). These features suggest that the thunderstorms in the Chinese inland plateau may have some unique electrical structures. This motivates us to conduct a simultaneous multiple-site measurement of cloud-to-ground lighting discharges in the area during summer of 2002. This paper reports our preliminary results obtained from the measurements.

INSTRUMENTATION

The 6-site measurement of E-field and E-field changes generated by natural lightning flashes was conducted by using broadband slow antenna and fast antenna system in the summer of 2002 in a mountainous region (101°35′ E, 37°303′ N, 2600 m asl) near Xining, Qinghai province of China, which is located in eastern Verge of Qinghai-Tibetan Plateau. The time constant of the slow antenna and fast antenna system is 5s and 2ms with a frequency bandwidth of 2MHz and 5MHz, respectively. Outputs of the antennae are digitized by a 16-bit A/D converter and recorded by a computer at a sampling rate of 4MHz. The recording length is 2s. The high-speed digital camera with 1ms is also used in this study. A 5-cm wavelength weather radar was installed in 35 km away from the observation site center.

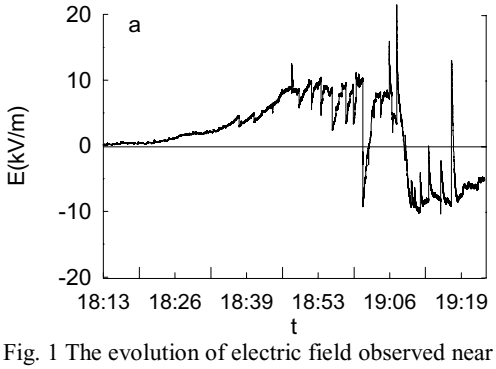

Fig. 1 The evolution of electric field observed near the surface in Site 5 on Aug. 4, 2002.

RESULTS

The thunderstorm on August 4, 2002 develops locally from the southwestern mountainous region at 18:20 Beijing Time, and moved to Site 5 at 19:20. Figure 1 shows the time variation of surface electric field measured by field mill. The surface electric field at Site 5 is positive when the thunderstorm is overhead, indicating the positive charge dominates the surface electric field. After it passes away from Site 5, the surface E becomes negative again. The thunderstorm is weak in intensity and small in dimension. The highest reflectivity shown by radar echo is about 40dBZ. The total duration is about two hours. The flash frequency is lower based on the field mill and slow antenna. A total of 30 flashes were detected during 2 hours. The number of cloud-to-ground lightning flashes is 13 and positive flash ratio is 15.4%.

During the observation, a total of 8 thunderstorms passed over at least one site. The surface E field shows negative for 3 overhead thunderstorms and positive for 5 overhead thunderstorms.

Flash 190228

Flash 190228 is a single-stroke flash. The distance from Site 1 is 4.4km. Figure 2 shows the slow E change, fast E change and relative luminosity. The discharge lasts about 500ms. Long duration of IC discharges is observed just before and after the stepped leader-return stroke process. The two IC discharges last about 140ms and 320ms, respectively.

The stepped leader lasts about 30ms. Figure 3 shows one of the progression pictures of stepped leader from high-speed camera. The stepped leader developed with one main channel in the beginning, and then it progresses toward the ground in multi-branches with a slower speed. The progressing speed for four grounding channel branches is 0.85×10^5m/s, 0.85×10^5m/s, 0.85×10^5m/s and 0.95×10^5m/s from left to right. The four channels are connected to the ground at 29ms, and induced four return strokes. The time difference between two adjacent peaks is 8μs, 14μs and 10μs according to E filed changes.

After the ground discharge, K-changes occurred intermittently, corresponding to the stepped change in the slow E change, impulsive changes on fast changes and luminosity changes are observed, and the discharge channel can be observed clearly in the cloud.

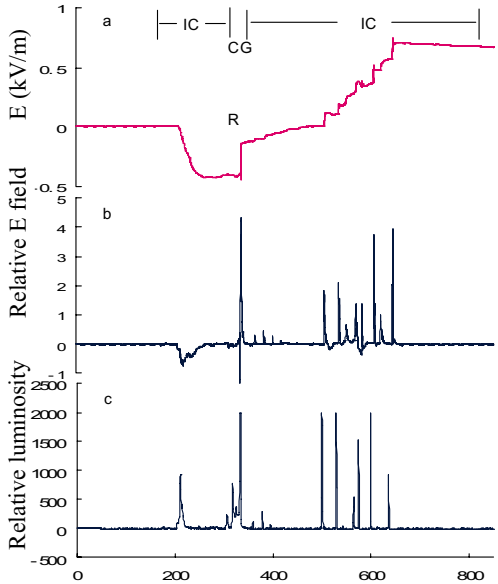

Fig. 2 Surface electric field changes and relative optical intensity produced by 190228. (a) Slow antenna, (b) Fast Antenna, and (c) Relative optical intensity.

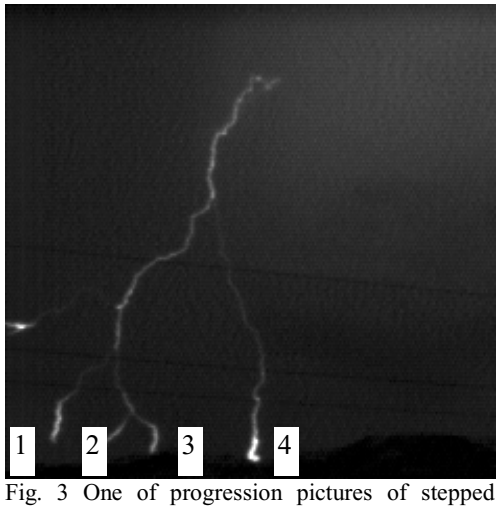

Fig. 3 One of progression pictures of stepped leader form high-speed camera.

Flash 190848

Figure 4 shows the slow E change, fast E change, and the relative luminosity of flash 190848. The distance from Site 1 is 7.4km. The discharge lasts about 500ms. The IC discharge just before the stepped leader lasts about 90ms. The discharge channel is hindered by the cloud during this stage. The following stepped leader lasts

about 26ms. The discharge also shows multi-branch channels with large horizontal developing component. The 2-D speed of the stepped leader is 1.18×10^5m/s, which is similar to flash 190228. There are at least two multi-ground points which are 10μs apart in time.

The high speed camera observation confirmed that there was an IC discharge with inverted polarity after the CG flash. It started at about 104ms after the return stroke. The IC discharge channel initiated between the upper negative charge region and the lower positive charge region, and it reached the lower positive charge region in 5ms. Then the discharge developed in the lower part of the positive charge region, and the channel progressed slowly forward for about 8ms. This discharge process is corresponding to negative breakdown, and more branches are observed during this stage. During the development of the channel in the positive charge region, three recoil streamers were observed clearly in the main vertical channel, and corresponding to a large E-field change and an obvious enhancement of the channel luminosity. Then the horizontal channel disappears gradually, and the vertical channel shows luminous continuously for another 136ms. Figure 6 shows the luminosity pictures of the discharge channel from 105ms to 120ms. The luminosity between 121ms and 256ms is similar to 120ms, but with weak luminosity. At 222ms, 238ms and 239ms after return stroke, a horizontal discharge channel was observed in right of the upper end of vertical discharge channel. From 256ms – 371ms after the return stroke, no obvious luminous was observed. At 372ms another saturation frame was observed. The discharge process afterward is similar to the IC discharge at the beginning. The channel progress toward the observation site from the left side, the developing speed is faster than the former discharge and without branches. The similar processes repeated 3 times, and the luminosity can be observed in between, but the channel was hided. This process is quit similar to the IC discharge observed by interferometer and TOA technique (Zhang Y. et al., 2002; Shao et al., 1996).

It should be noted that, the slow E change caused by the IC discharge at 384ms is similar to the continuing current between return strokes both for the lasting time and the magnitude. During this slow change, many VHF radiation pulses are observed, corresponding to air breakdown processes, and indicating the channel progresses continuously in the cloud. It was inferred from the high-speed camera that this continuing IC discharge lasts about 136ms, corresponding to upward development of the channel. The discharge is just overhead of E site, and caused a positive field change of 2.12kV/m, corresponding to the negative charge going upward.

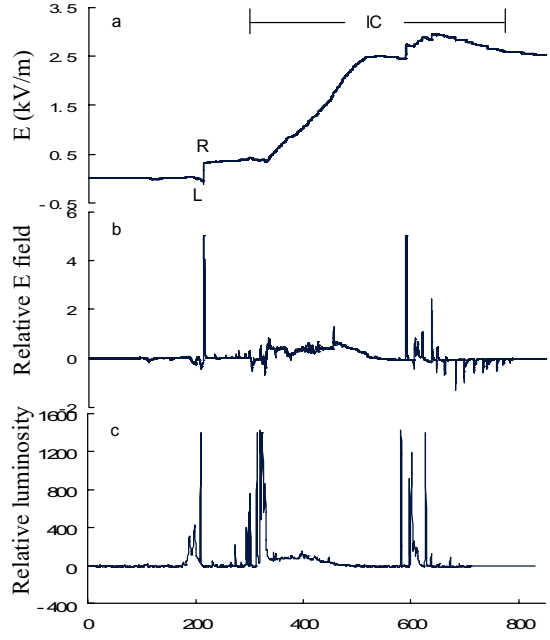

Fig. 4 Same as Fig. 3, but for flash 190848.

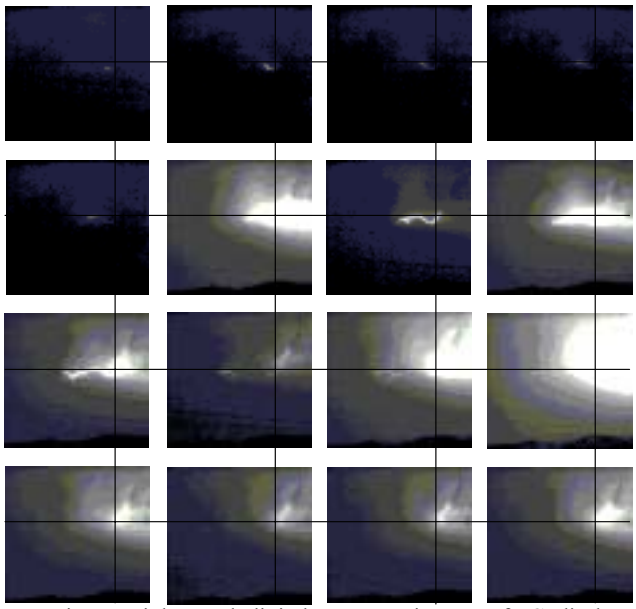

Fig. 5 High-speed digital camera pictures of IC discharge during late stage of flash 190848 corresponding 105-120 ms after return stroke. The time interval between two frames is 1 ms.

DISCUSSION AND CONCLUSION

A lot of lightning data have been collected to study the charge structure of thunderstorm and discharge characteristics of lightning discharges in Qinghai area. It is concluded that the surface E field just underneath the thundercloud could be controlled by positive charge or negative charge in the cloud and resulting a positive or a negative E surface field, and with the former produced a larger positive CG flash percentage.

The channel structure of the stepped leader channel in the observation area is complicated. The negative stepped leader usually developed with more branches, and similar to the development of the spider flash with a 2-D speed of about $0.8\text{-}1.2\times10^5$m/s. This kind of multi-branch development is correlated to the special space charge layer in the mountainous region. Because of the existence of numerous trees, the space charge layer caused by corona discharge from the natural points is very complicated, and many pocket charge center may exist between cloud and the ground. More branches of stepped leader could be observed as a result. More than one grounding point will be induced by the multi-branches, and the time difference between each grounding points is about 10μs.

The high speed digital camera observation confirmed that the inverted-polarity IC discharge shows a bi-level structure corresponds to the positive charge region below and negative charge region above. The main IC discharge channel initiated between the upper negative charge region and the lower positive charge region. When the discharge reached the main charge regions, it develops in the lower part of the positive charge region. During this stage, the discharge is corresponding to negative breakdown, and more branches are observed. Then the vertical channel shows luminosity continuously, and the lower horizontal channel disappears. Then the channel developed horizontally in the upper end of the channel.

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