Common features of return stroke optical propagation waves and their interpretations

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Knowledge of return stroke propagation speeds is very important for return-stroke modeling. Usually, the speed is measured through high-speed optical records based on either film photography or digital imaging systems. When the speed is measured, a common difficulty is to choose which is the real starting point of a return stroke propagation wave. For the same return stroke, different people could choose different starting points and therefore obtain different speed values. This is very confusing and has bothered authors for years. The main reason for such things to happen is that the underlying physical processes of return stroke propagation waves are unknown. In this paper we first present the common features of the return stroke optical propagation waves and then interpret their reasons by pointing out several possible physical processes ignored previously.

Return stroke optical signals are remarkably asymmetric in waveforms. Their rising fronts usually last several microseconds; while their decreasing stages could last several hundred microseconds. During the rising fronts, usually a slow rising appear first and is then followed with a sharp rising. All return strokes do not contain any so called characteristic points which can be used to identify the starting point of the return strokes without ambiguity. On the other hand, since return strokes are preceded with either stepped leaders or dart leaders, their waveforms are usually contaminated with the optical waves due to the leaders. This brings additional difficulty to identify the point of the transition from leaders to return strokes. For measuring the return stroke speeds, the starting points are practically chosen with some kinds of subjective judgments. During the decreasing stages, usually a hump occurs and its starting point can not be identified either.

Some optical events recorded by us look like return strokes; however, even their propagation direction can not be identified.

To interpret the reasons of the features observed, we think that the following processes ignored previously should be included.

(1) When a return stroke occurs, its propagation should involve not only the ionization wave propagating along the discharge channel but also the electromagnetic wave in free space since such electromagnetic wave could excite appreciable current when it encounters the conductive discharge channel. The two waves should interfere each other and make the propagation of a return stroke very complicated. A return stroke ”tip” may propagate at a speed near the light speed but it can never be really measured. The speed measured optically could only be an apparent and approximate speed depending on many factors.

(2) The discharge processes for neutralizing the space charge deposited by leaders produce many pulse waves which propagate back to the return stroke channel and then to the ground. A total effect of these pulses accounts for mostly the decreasing stage of a return stroke waveform.

(3) Prior to return strokes, there are already pulse discharges propagating backward during leader stages. Such pulse discharges certainly cause some effects on the following return stroke waves. Dense pulse discharges may deform the following return stroke waveforms and make them apparently undetermined in propagation directions.