1. Types of lightning discharges and lightning terminology
Types of lightning discharge from cumulonimbus

Fig. 7.3. A local or convective thunderstorm at Socorro, New Mexico. (Courtesy, Marx Brook, New Mexico Institute of Mines and Technology) (Uman, 1986)

Cloud discharges (~67%)

Intracloud

Cloud-to-cloud

Cloud-to-ground (~33%)

Cloud-to-air
FIGURE 8.11  The apparent evolution of lightning with time in a thunderstorm, based on a variety of observations in different storms. See text for explanation. The dendritic structure of the lightning has been guessed in all cases except for the multicellular intracloud discharge of part e. The dotted region in the dissipating part of the storm in parts e and f represents the radar brightband from melting snowflakes.

(Krehbiel, 1986)
Fig. 11. Plan and elevation views of flash 139, using symbols A through Z to denote the coarse time scale shown in Figure 10. The U axis is indicated on the plan view. A total of 1486 sources were located. (Proctor et al., 1988)

Obscured occasionally by errors in the measurement of source heights. Height error magnitudes were 1.4 km rms for sources near ground below A and 370 m rms at (10, 5, 3) km. These errors were not the cause of our locating several exceptional sources which became active at the end of the leader process. 1 - 1.5 km directly above the leader origin. The second stepped leader, EF, began 26 ms after the first return stroke B. (The sequence of events is shown by Figure 10). The origin of the second leader was 780 m away from the origin of A. One of the leader branches, F, was 6 km long; and this branch progressed down before it turned through a wide loop to travel upward. It reached a height of 4.5 km agl and its terminus was 3 km.
branch RSTUVW traveled toward A until time W, when it turned to progress away from A.

9.7. Seventh Case Study: Flash 62, Recorded at 1834:45:5 on March 27, 1979

Although this unusual flash is not representative of the majority, it has several features that are worthy of mention. One of these concerned some anomalous changes in electric field which were not accompanied by radio noise. (This happened in three of 150 flashes). The auxiliary record, Figure 24, shows that the field changed measurably during the second interstroke interval, despite the almost complete absence of radio noise during the latter part of this interval. Small and gradual changes in electric field also occurred immediately after the first return stroke and again during the latter part of the third interstroke interval, without radio noise accompanying either event. These anomalous changes in electric field were not continuations of a gradual change that had been in progress when the flash began.

The electric field change produced by the first stepped leader is shown magnified fivefold.
Categorization of cloud-to-ground lightning

1 (≥ 90%)

2

3 (≤ 10%)

4
Fig. 6.1a. Lightning initiated by an upward-moving leader from a tower on Mt. San Salvatore near Lugano, Switzerland. The spot directly beneath the bottom of the lightning channel is a tower light. Upward-initiated lightning is branched upward in contrast to the downward branching of the usual cloud-to-ground lightning flash. (Courtesy, Richard E. Orville, State University of New York at Albany) (Uman, 1986)
Object-initiated lightning

Objects electrically connected to ground

"Classical" triggering (LRSG)  "Altitude" triggering (LRSA)

Positive leader

Grounded wire

Positive leader

Un-grounded wire

Non-conducting line

Negative leader

Figure 8 General features of triggered lightning pictures: (a) classical; (b) anomalous; (c) TIPSY (Hubert, 1984)

LRSAG technique: a short length of grounded wire below the non-conducting segment.
Cloud-to-stratosphere discharge

Distance ~ 2000 km
Length ≥ 31 km

Fig. 1. This video frame was captured during the shuttle STS-31 mission at 0135:59 UTC 28 April 1990 using a shuttle payload-bay low-light-level TV camera while the shuttle was on its 55th orbit over Mauritania, northwest Africa. The payload-bay TV camera was pointed to the southeast of the orbital ground track so that thunderstorm complexes near the Earth's limb could be observed. Seen in this image is an arc of the Earth's airglow, a vertical line, which is the shuttle's rudder, five clouds that are illuminated by lightning in the foreground, and a single cloud located on the horizon with a vertical discharge; various stars can be seen above the arc of the Earth's airglow. The storm, which had a vertical discharge, was located at approximately 7.5°N, 40°E and was about 2000 km from the shuttle. The length of the discharge is estimated to be at least 31 km. (Vaughan et al., 1992)

Figure 5. Schematic which suggests that the form of the CS discharge may change from channel to fan-like plume with decreasing pressure. (Lyons and Williams, 1993)

Low-light-level TV image of the upward discharge in Minnesota (Franz et al., 1990)
Distance - 250 km
Duration - < 30 ms
Length - 20 km

Hundreds of images were obtained in 1993:
Average duration ~ 100 ms
Maximum height ~ 50-80 km
Significant horizontal extent (up to tens of kilometers)
Natural (downward) lightning

Fig. 1.6 (a) A drawing of the luminous features of a lightning flash below a 3-km cloud base as would be recorded by a streak camera (Section C.4; Fig. C.3). Increasing time is to the right. For clarity the time scale has been distorted. (b) The same lightning flash as would be recorded by a camera with stationary film. Adapted from Uman (1969). (Uman, 1987)

Tower-initiated lightning

Still-camera photograph of flash

Fig. 12.2 Drawing of streak-camera photograph illustrating usual lightning from the Empire State Building. Adapted from McEachron (1939). (Uman, 1987)

Rocket-and-wire triggered lightning

Fig. 1 Schematic streak photograph of a typical classical, triggered flash of negative polarity. (Willett, 1992)
Global circuit of atmospheric electricity

To maintain about 300 kV between the Earth and the electrosphere, the Earth has about $10^6$ C of negative charge on its surface, and an equal positive charge is distributed throughout the atmosphere. The charge of the Earth is continuously leaking off into the conducting atmosphere and would disappear (if not re-supplied) in less than an hour. The Earth is apparently recharged by the action of thunderstorms (roughly 2000 are in progress at any one time over about $10^6$ km²).

Total current $\sim 1500 \text{ A}$ (of the order of $10^{-12} \text{ A/m}^2$)
Total resistance $\sim 200 \text{ } \Omega$