Chapter 9. Cloud Discharges

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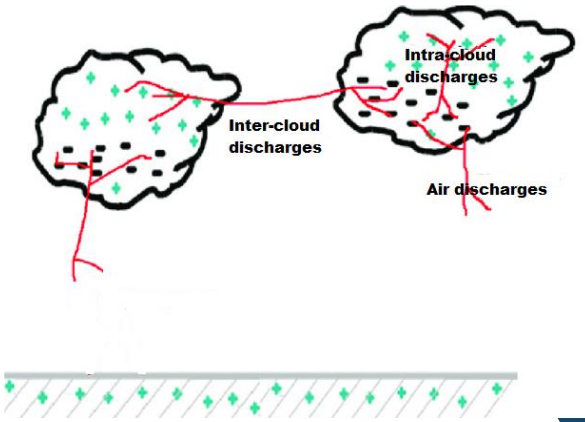
What to expect!

- Cloud discharges, what are they?
- Phenomenology of cloud discharges inferred from VHF-UHF imaging systems
- Characterization of various stages of cloud discharges
- Electric and Magnetic field pulses associated with these stages
- Cloud discharges versus ground discharges

Cloud discharges

- Intracloud discharges
- Intercloud discharges
- Air discharges

- It is estimated that about three-quarter of the total lightning discharges do no touch the ground. This depends on the nature and stage of development of the thunderstorm



Hazard to ground-based systems

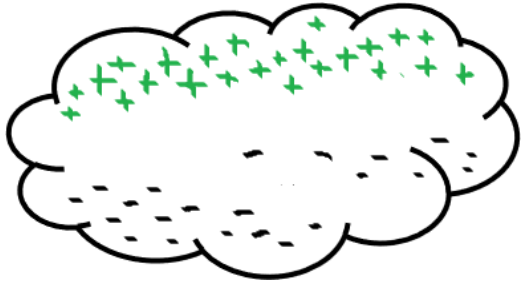
- Relatively little or no effect

Major concern

- Safety of vehicles that operate at that altitude

Cloud discharges

Stages of development



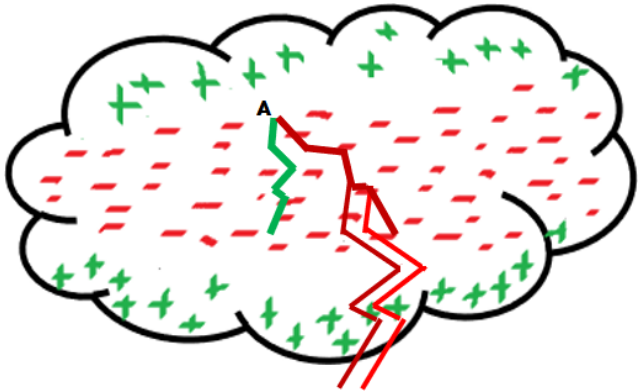
- Early or active stage
- Late or final stage

Early or active stage

- Duration: Between tens to a few hundreds of milliseconds
- Negative channels **extends in an intermittent manner**, with an **average speed of ~ 10^5 m/s**
- The early stage process is similar to the **initial breakdown** processes in **negative cloud-to-ground lightning** discharges although in the -CG lightning discharges, the dominant polarity of the initial breakdown pules is **positive** whereas the dominant polarity of the initial breakdown pulse for IC is usually **negative**.

Cloud discharges

- Cloud discharge is assumed begin as a **bidirectional leader**
- Positive section of the leader pervading the negative charged region
- Effectively **supplying negative charges**, through the **charge origin** to the **negative section** of the leader that extends to **positive charge regions**



- The transition from the active to final stage of the cloud discharge is thought to be associated with the loss of connection between the positive and negative sections or the negative and positive charge regions

Cloud discharges

Late or Final stage

- known as J-type stage because the associated physical process is similar to the **J-processes in ground discharges**.
- J-process redistributes charges in the cloud.
- Often viewed as a relatively slow (order ~ 10^4m/s) **positive leader extending from the flash origin into the negatively charge region.**

Cloud discharges

Reference	Location	Average or typical value	Remarks
Flash duration, ms			
Pierce (1955a)	England	245 (685)	Mean value; negative field changes[a]
Takagi (1961)	Japan	300	
Isikawa (1961)	Japan	420	
Ogawa and Brook (1964)	New Mexico	500	Excluding short-duration field changes at very close ranges
Mackerras (1968)	Australia	480	
Bils *et al.* (1988)	Florida	660 (89)	Mean value
Charge transfer, C			
Workman and Holzer (1942)	New Mexico	32 (16)	Eight stations
Reynolds and Neill (1955)	New Mexico	21 (35)	Mean value; 11 stations
Isikawa (1961)	Japan	32	
Wang (1963a)	Singapore	15	
Ogawa and Brook (1964)	New Mexico	30	

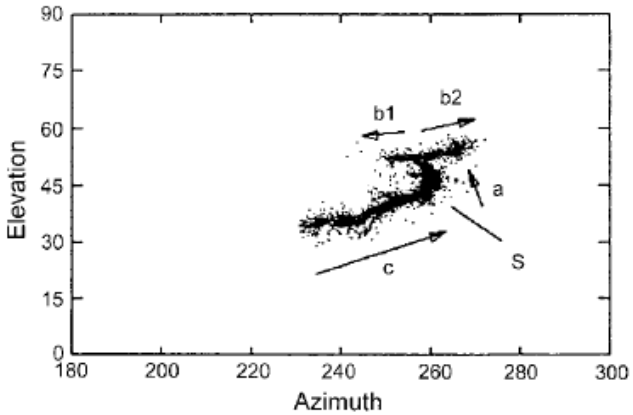
Overall characteristics of cloud discharges

Cloud discharge phenomenon inferred from VHF-UHF imaging system

Cloud discharge phenomenon inferred from VHF-UHF imaging system

The Bilevel flash concept (Shao and Krehbiel 1996**)**

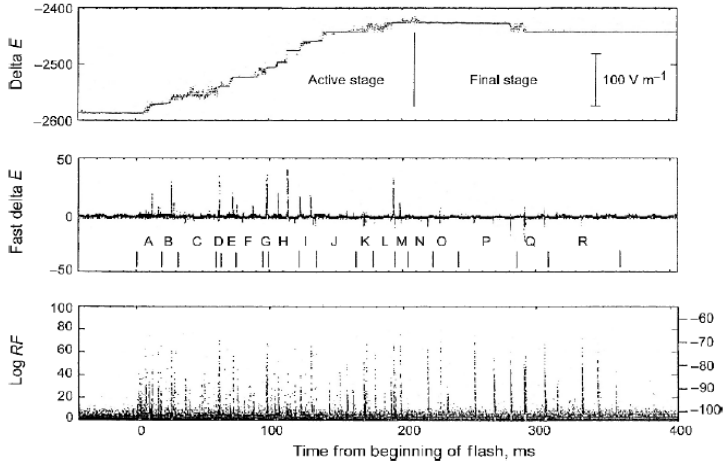
- Cloud discharge often exhibit **a single vertical channel** that **bridges both the lower and upper level charged region**
- The length of the channel is around **2-3km.**
- It **transport negative charges from the lower level to the upper level** through a steady-current processes

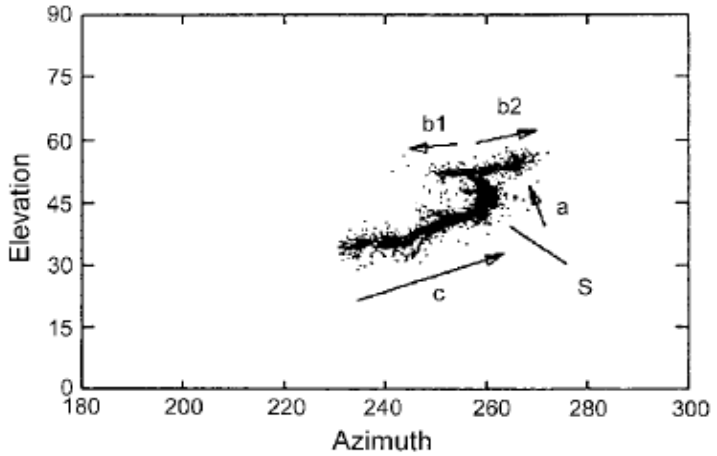


A two-dimensional 274MHz interferometric images of lightning channels (Shao and Krehbiel 1996)

Bilevel flash concept

Electric field waveform of bilevel lightning flash





Electrostatic field change (top graph), **Electric field changes** (middle graph), **RF radiation amplitude** (bottom graph) for an IC flash 01/09/1992 1941:54 UT (Shao and Krehbiel 1996)

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