Thunderstorm Observations at Langmuir Laboratory

Langmuir Laboratory for Atmospheric Research
New Mexico Institute of Mining and Technology
Socorro, New Mexico 87801
South Baldy Peak, New Mexico
3,088 meters
Thunderstorm over Langmuir Lab

3,088 M South Baldy Peak

-40°C

8 km

0°C

3,088 M South Baldy Peak
Graupel-Ice Charging

The diagram illustrates the process of graupel formation and ice crystal charging. It shows graupel nuclei (represented by crosses) attracting supercooled droplets (circles) and eventually forming ice crystals (stars). The temperature reversal from -10 to -20°C is indicated as a critical point for this process.
**Typical Thundercloud**

- **Charge**:
  - +35°C at 12 km
  - -40°C at 8 km
  - +5°C at 4 km

- **Temp**:
  - -20°C at 18 km
  - -10°C at 16 km
  - 0°C at 14 km
Volcano in Japan
Lightning on Jupiter
Aircraft Triggered Lightning
Lightning Channels
Downward Branching of Cloud-to-Ground Lightning Discharge

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Time of Arrival Lightning Mapping System

- Measure time RF pulse arrives at multiple stations
- Determine position and time of source
- Locate hundreds to thousands of sources per flash

\[ t_i = t + \sqrt{\frac{(x - x_i)^2 + (y - y_i)^2 + (z - z_i)^2}{c}} \]

Radiation occurs at time \( t \), at location \( (x, y, z) \)
Radiation arrives at station \( i \) at time \( t_i \), location \( (x_i, y_i, z_i) \)
Location of LMS Stations in New Mexico Summer and Fall, 1998
Layout of LMA Plots

Altitude vs. x

Plan View (x vs. y)

Altitude vs. Time (Color Coded for Time)

Number of LMA Points vs. Height

Altitude vs. y
LMA detects lightning over a 400-500 km diameter area.

Density of Points Plot Color-Coded by Log of Density of LMA Sources
LMA Image of an airplane avoiding thunderstorms

20 Minutes of Data
Plane Flying
400 MPH at
30,000 ft
Intra-Cloud Lightning

Normal IC

20 km
18 km
16 km
14 km
12 km
10 km
8 km
6 km
4 km
2 km

20000710

Altitude (km)

Time (UTC)

Altitude (km)

East-West distance (km)

Altitude (km)

North-South distance (km)

2338 pts
Cloud-to-Ground Lightning
Bolt from the Blue
Bolt from the Blue Animation
Large Positive CG
Lightning-Free Hole in Tornado-Producing Storm
A bilevel, inverted IC discharge. Positive charge appeared to be distributed horizontally at mid-to-low levels downwind of the core, and negative charge appeared to be in the upper part of the storm, 1-2 km below the cloud top.
A tortuous, downward-propagating intracloud discharge in an inverted-polarity storm near Bird City, Kansas. Also shown is the trajectory of an instrumented balloon that measured the electric field profile in the storm.
LMA source rate compared to Cloud-to-Ground Lightning Rate in Tornado-Producing Storm

Only one CG flash prior to formation of tornado
Lightning Channels
Downward Branching of Cloud-to-Ground Lightning Discharge
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RF Front End

RF Receiver

BiConical Antenna

Channel Filter

Pre-Amp

Broadband 30dB

Channel Filter

Selectable for TV Channel 2 -> 7

Log Detector

To Digitizer Card

Channel | 2 3 4 5 6 7

Freq
Impulsive 60 MHz RF Radiation from Lightning
VHF Power Received at LMS Stations

Time after 17:11:33 (ms)

Amplitude (dBm)
Cloud to Ground Lightning

A stepped leader is an electrical breakdown which starts in the cloud and propagates toward ground.

- Speed: $10^5$ m/s
- Current: 50 A
- Charge: 1 mC/m
Cloud to Ground Lightning

As the leader descends, fields on ground intensify
Cloud to Ground Lightning

When fields are strong enough, a breakdown (called a streamer) is induced on objects on the ground.

Speed: $10^5$ m/s
Current: 1 A
Cloud to Ground Lightning

If fields between object and leader are not strong enough, the streamer dies out
Cloud to Ground Lightning

When fields between leader and streamer are strong enough, streamer will propagate upward to meet leader.
Cloud to Ground Lightning

When a streamer meets the descending leader, the lightning strike point is fixed, and charge on the leader goes to ground.

Current: 30 kA

Speed: $10^8$ m/s
Experimental Setup At Langmuir Laboratory
Streamers from Lightning Rods

E-FIELD CHANGE AND CURRENT TO LIGHTNING RODS, June 17, 1999, 2209:47 UT

Down-conductor fuse blew

Successful Streamer from Blunt Rod

Black: Delta E (for kV/m: multiply by 20); Blue: 19-mm rod
Red: Radioactive "ESE" device; Green: Franklin rod

TIME RELATIVE TO TRIGGER SIGNAL (microseconds)
Sparks to van de Graff
Sparks to van de Graff
Rocket Triggered Lightning
Rocket Triggered Lightning

Streamer: $10^5$ m/s
Rocket Triggered Lightning

Positive Space Charge: $\approx 20 \text{ m/s}$
Rocket Triggered Lightning

Rocket: $\approx 100\text{m/s}$
Rocket Triggered Lightning
Rocket Triggered Lightning
Rocket Triggered Lightning
Rocket Triggered Lightning
Rocket Triggered Lightning
Rocket Triggered Lightning
Rocket Triggered Lightning
Rocket Triggered Lightning