

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







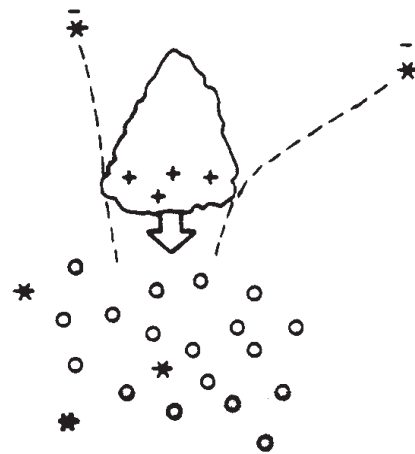
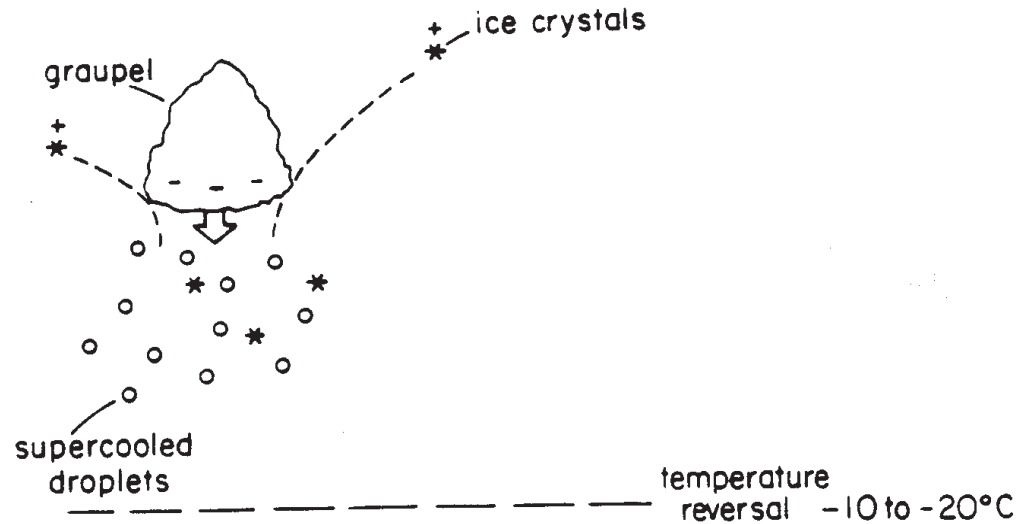
-40°C

~ 8 km

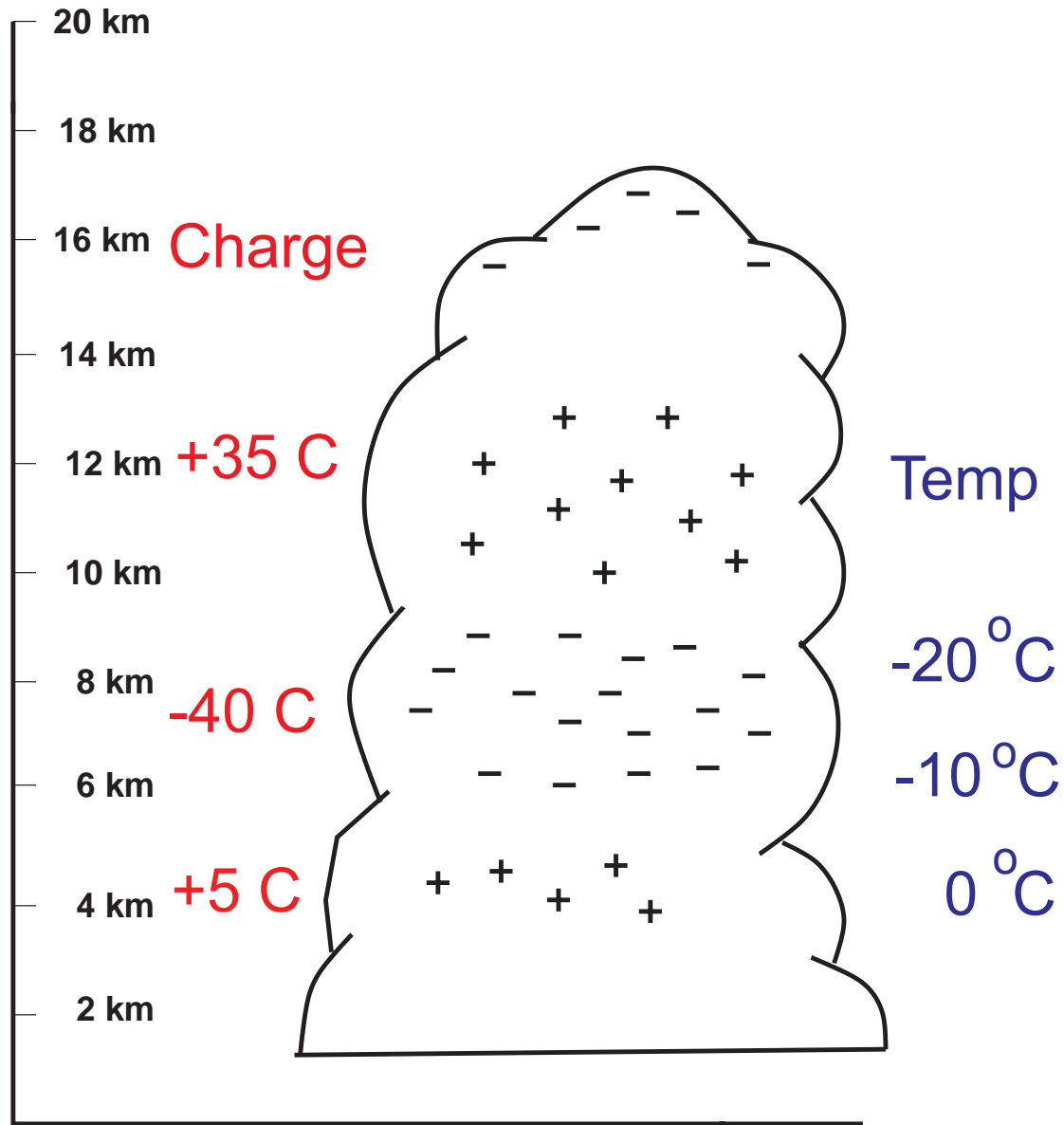
0°C

3,088 M South Baldy Peak

Graupel-Ice Charging



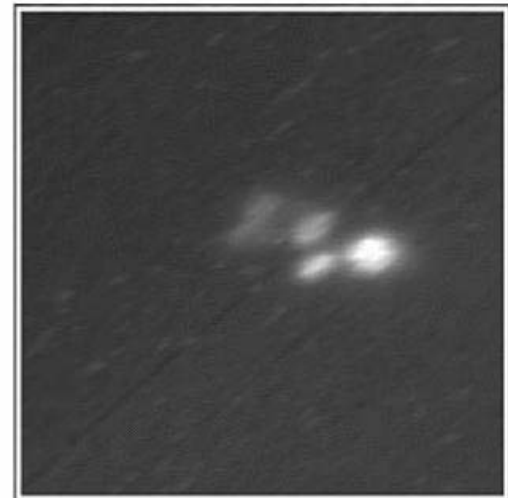
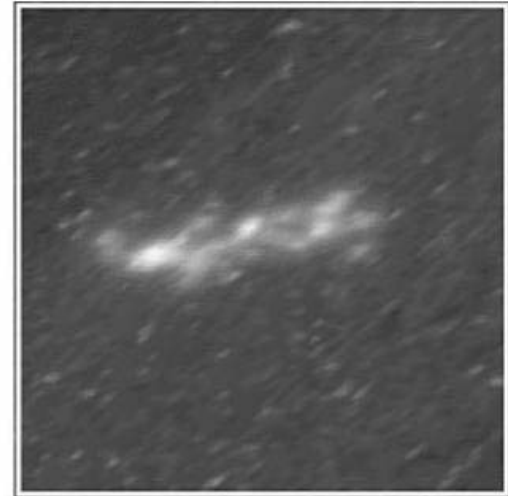
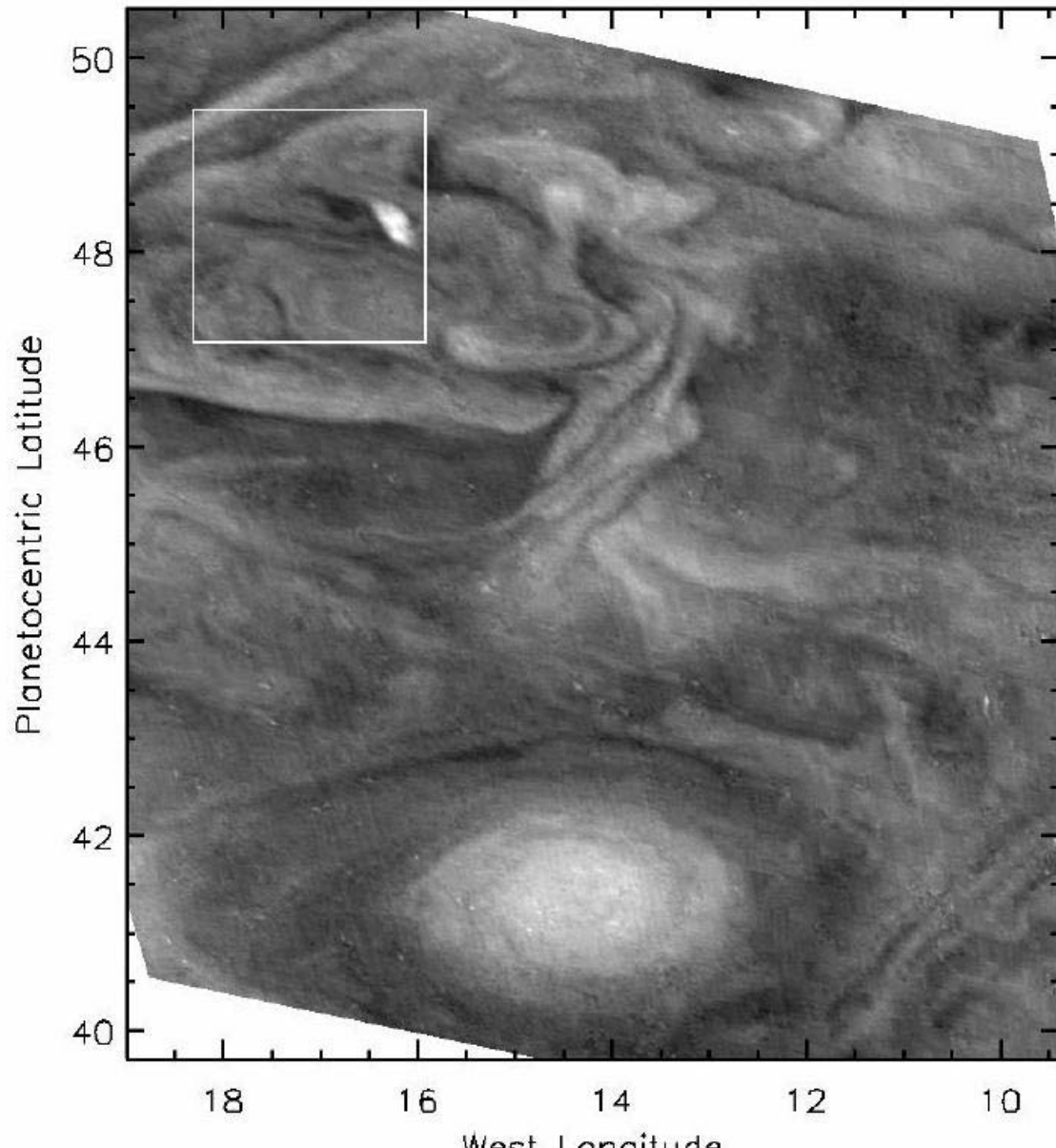
Typical Thundercloud



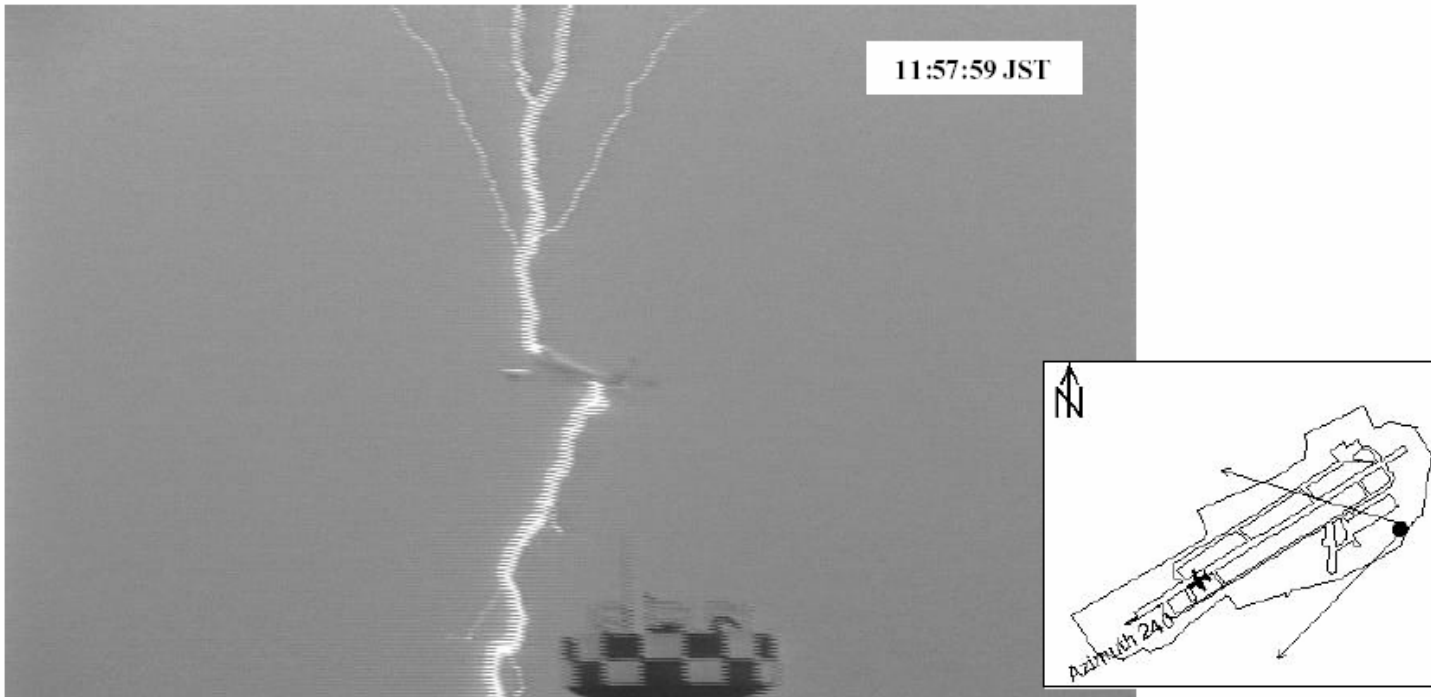
Volcano in Japan



Lightning on Jupiter



Aircraft Triggered Lightning



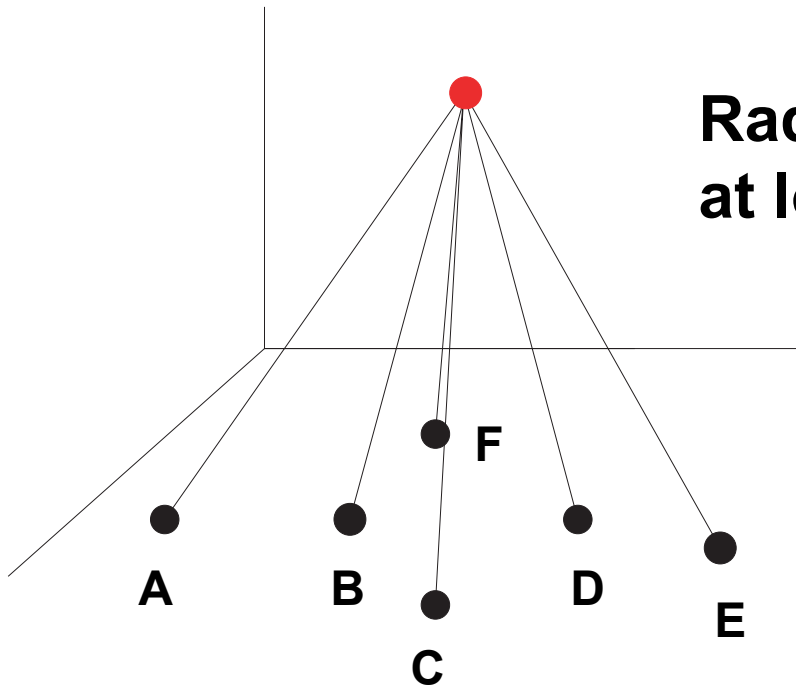
Lightning Channels

Downward Branching
of Cloud-to-Ground
Lightning Discharge



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



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)

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

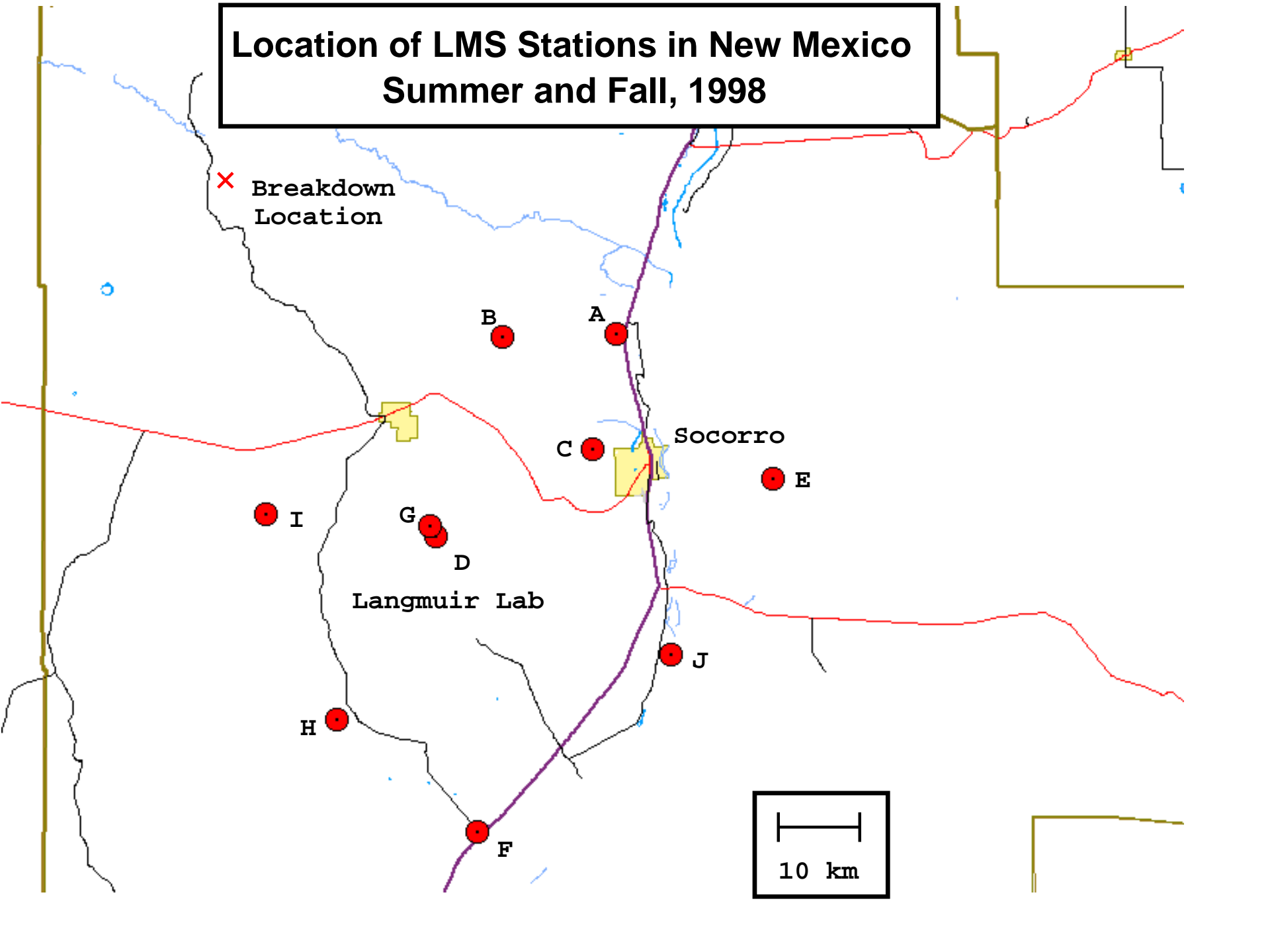


Communications
Antennas

VHF Antenna

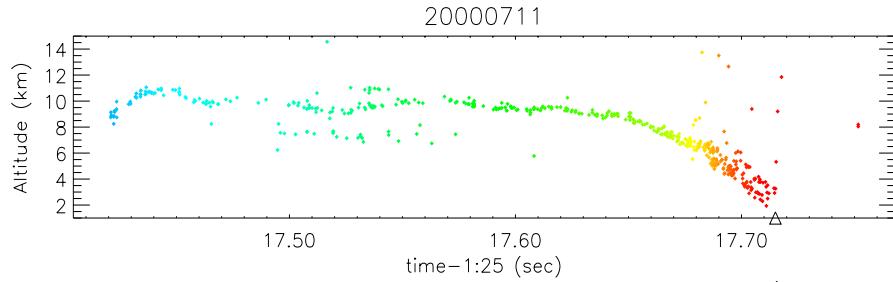
LMA Station

Location of LMS Stations in New Mexico Summer and Fall, 1998

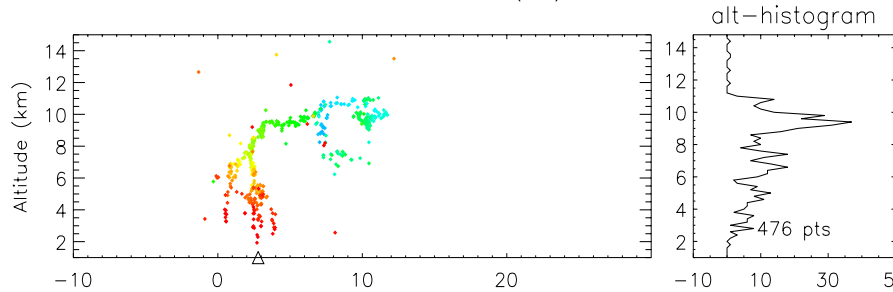


Layout of LMA Plots

Altitude vs. x

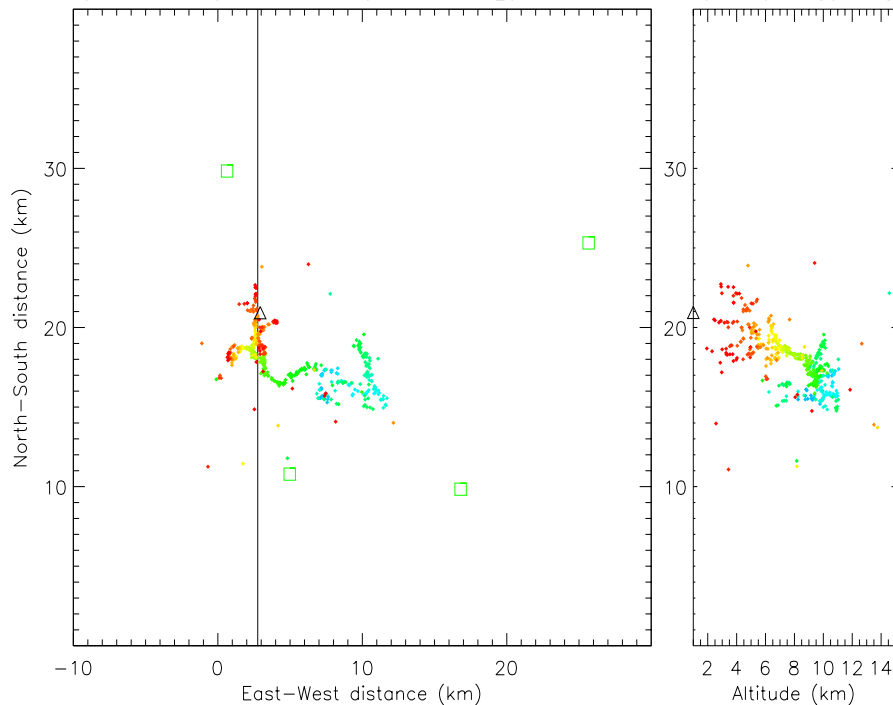


Altitude vs. Time
(Color Coded
for Time)

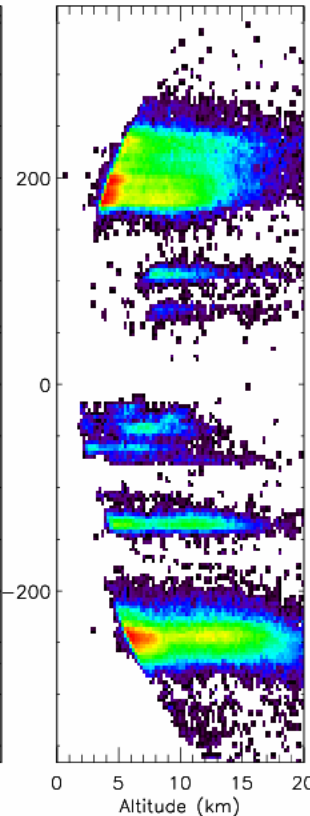
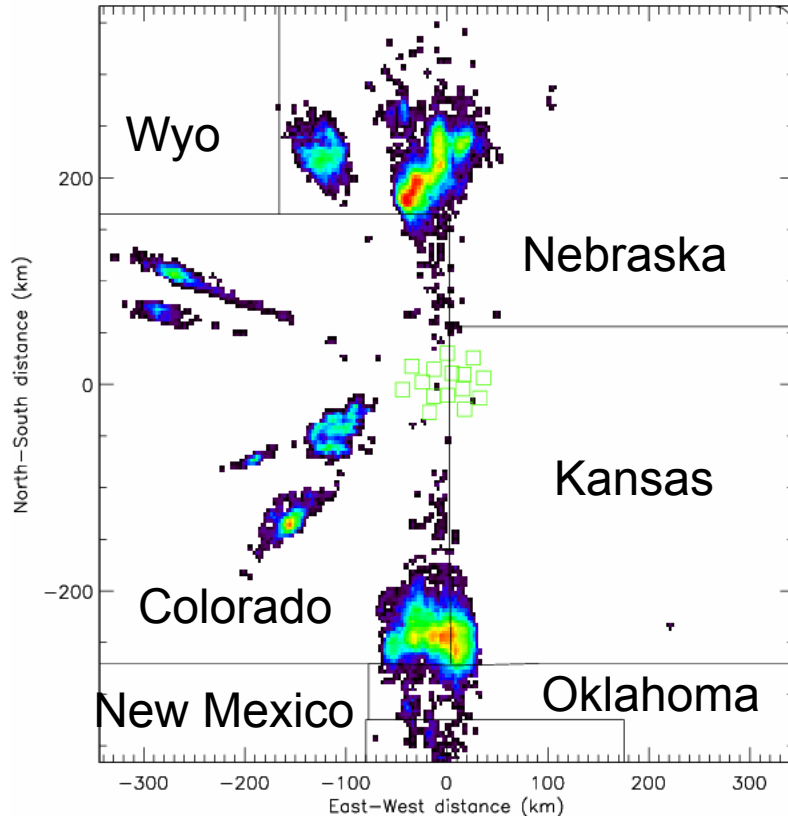
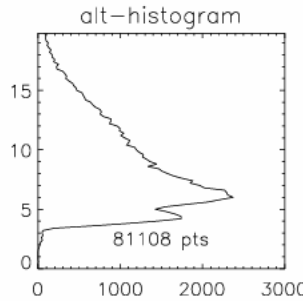
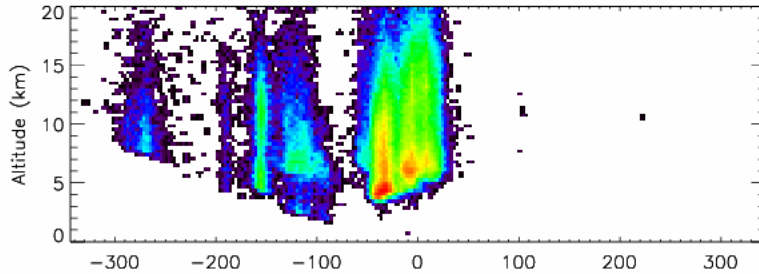
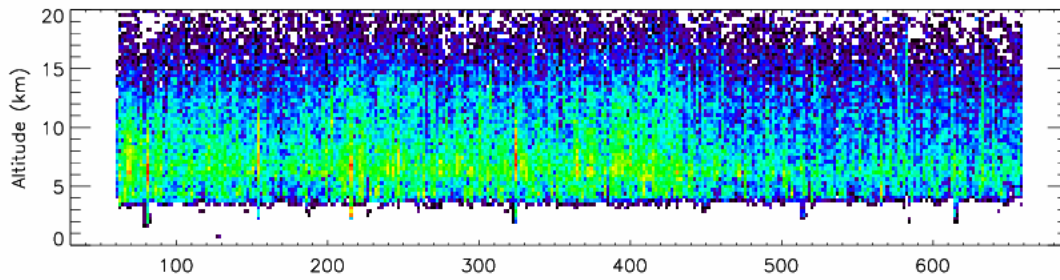


Number of LMA
Points vs.
Height

Plan View
(x vs. y)



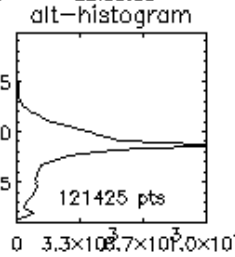
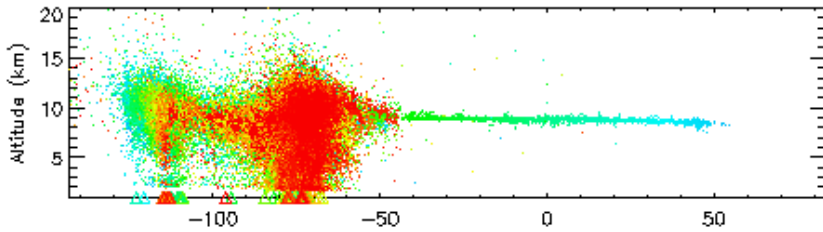
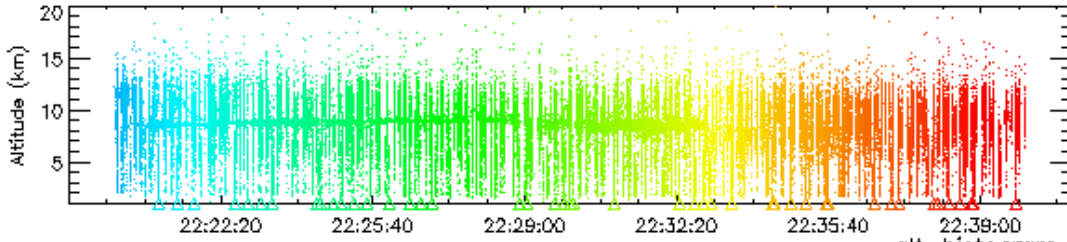
Altitude vs. y



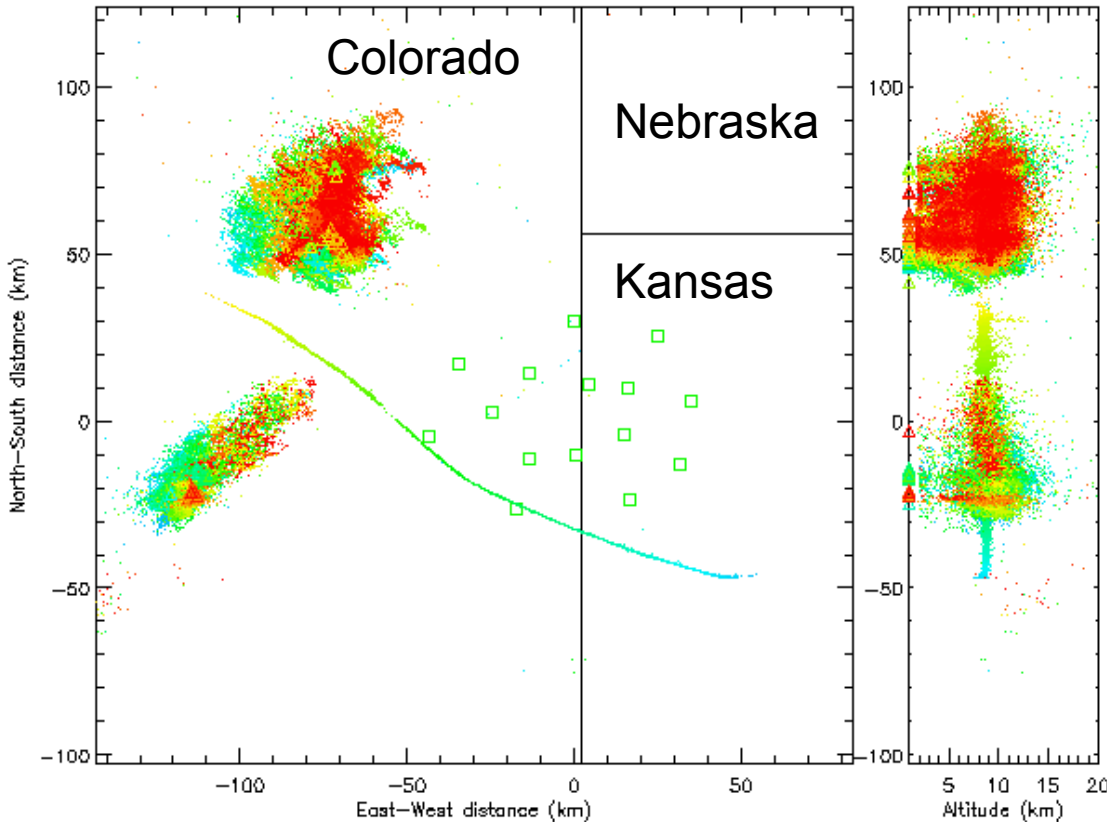
LMA detects lightning over a 400-500 km diameter area.

Density of Points Plot Color-Coded by Log of Density of LMA Souces

20000525

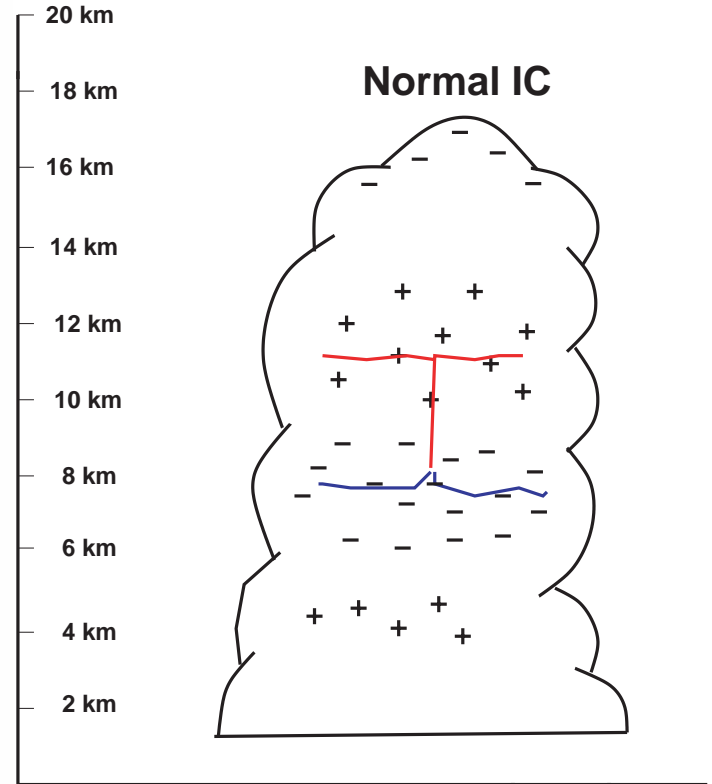
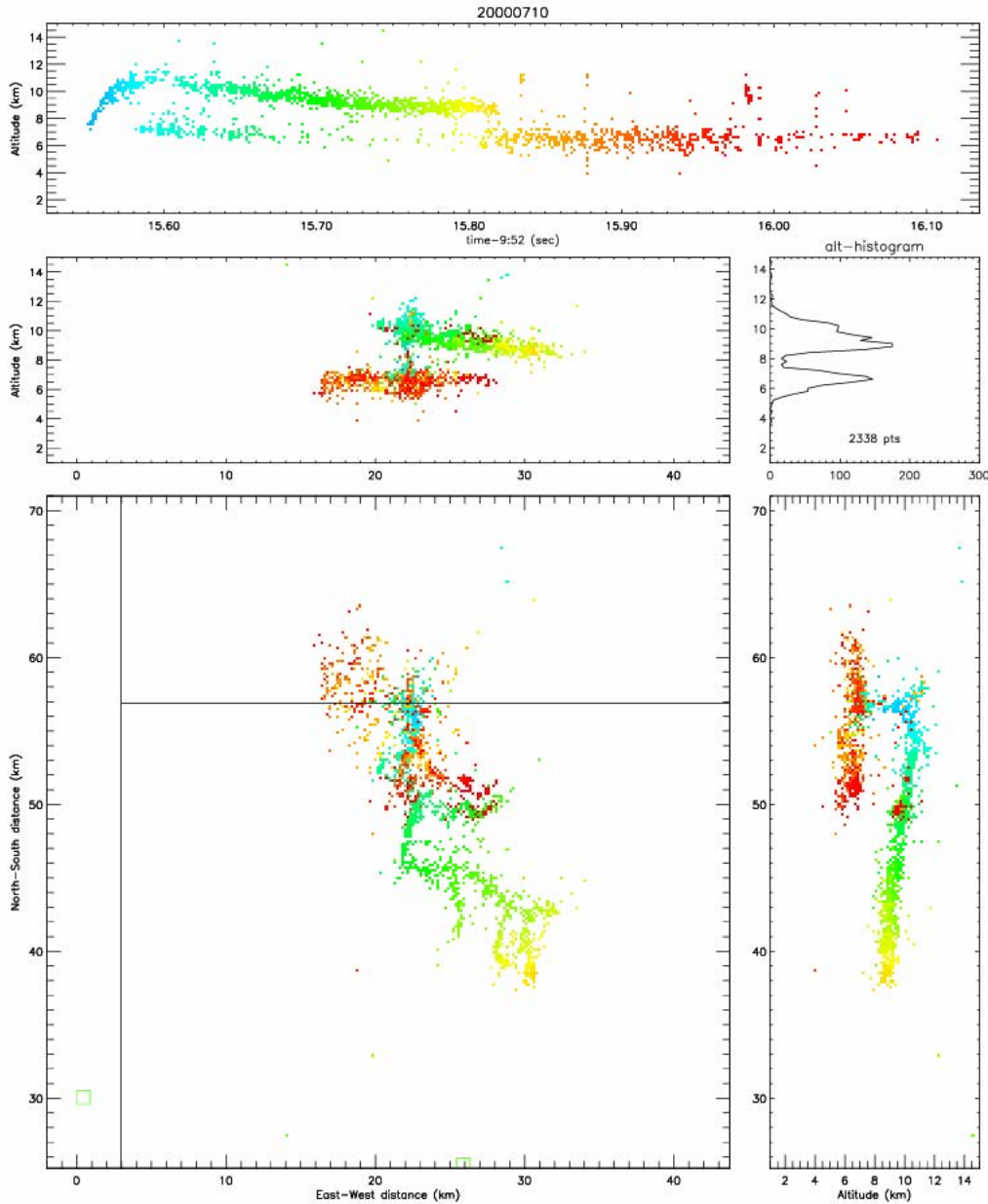


LMA Image of an airplane avoiding thunderstorms

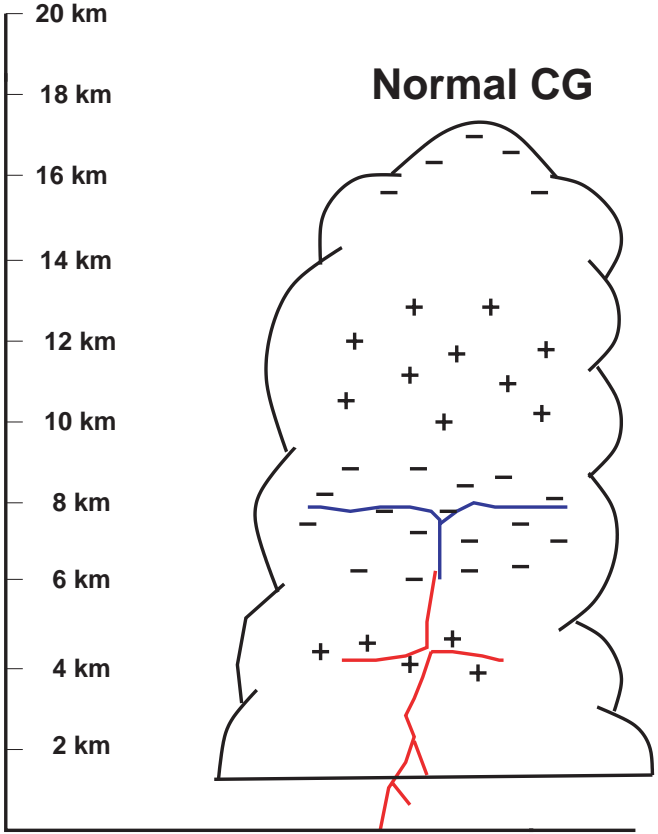
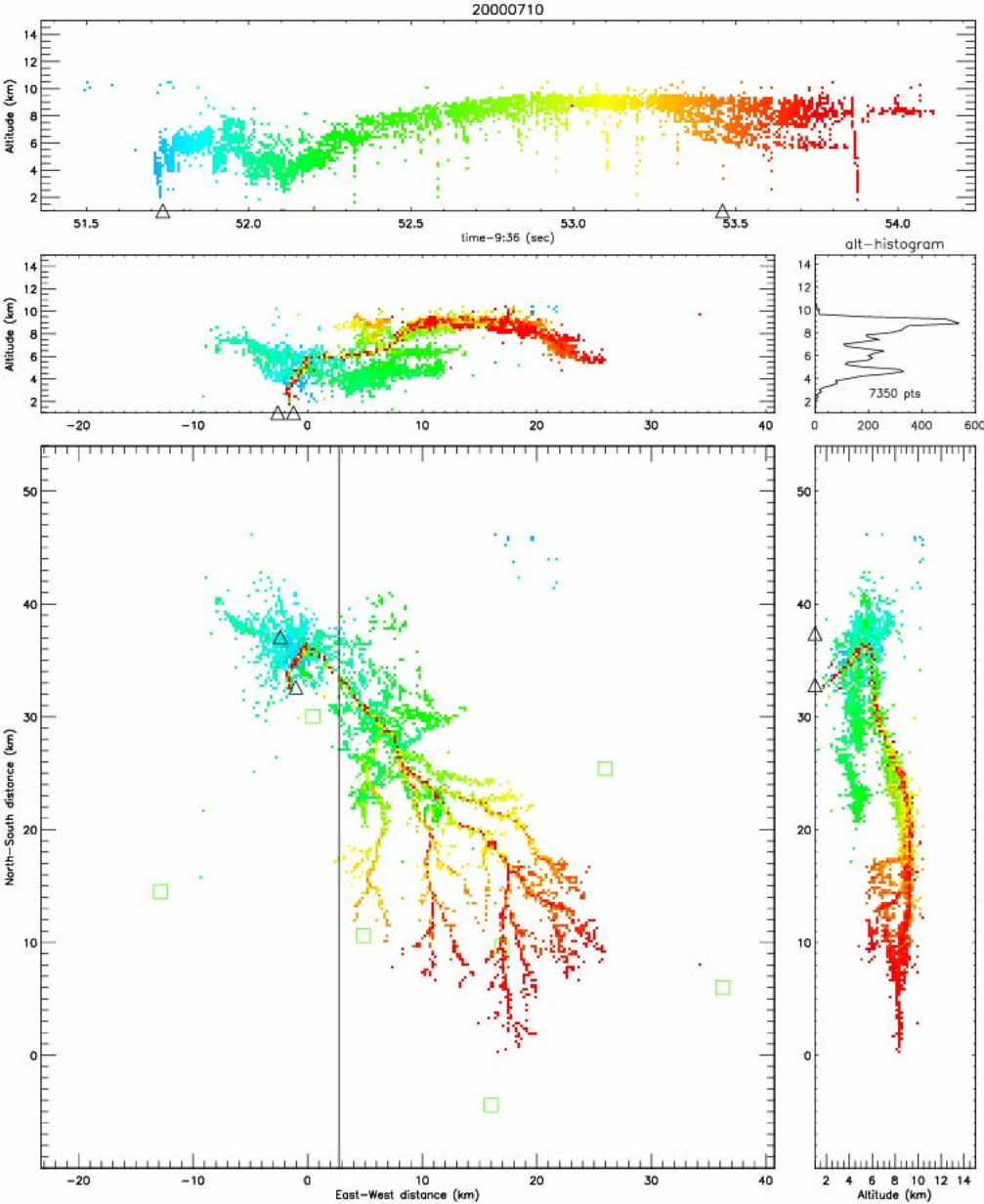


20 Minutes of Data
Plane Flying
400 MPH at
30,000 ft

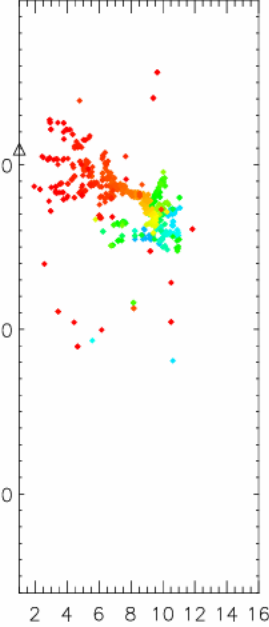
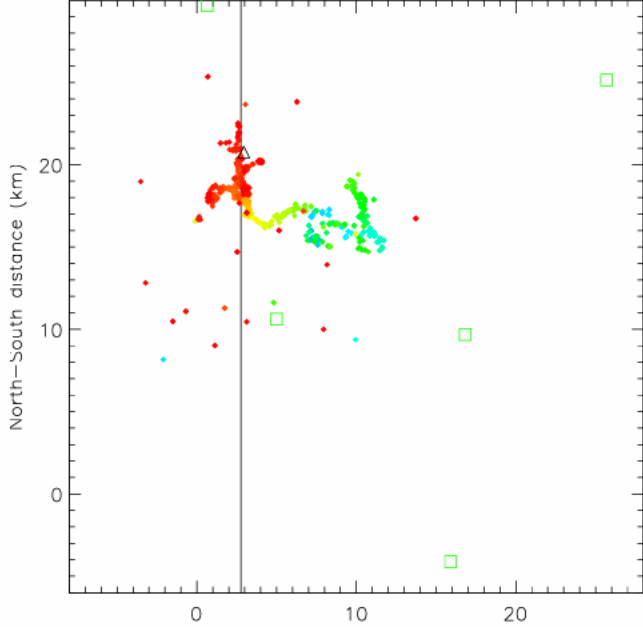
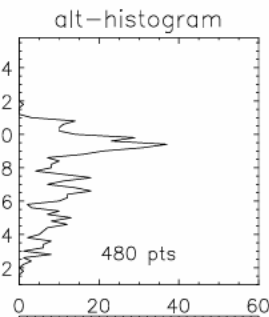
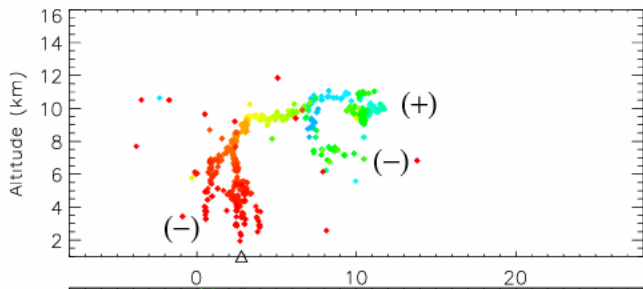
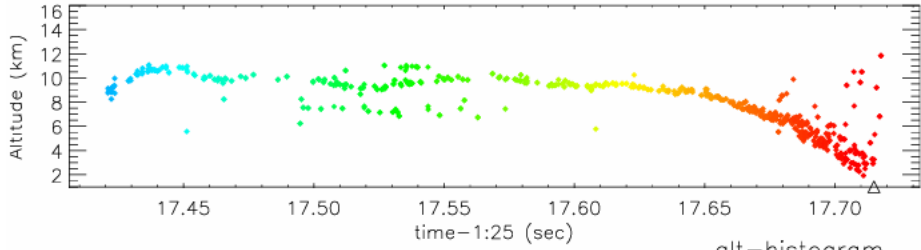
Intra-Cloud Lightning



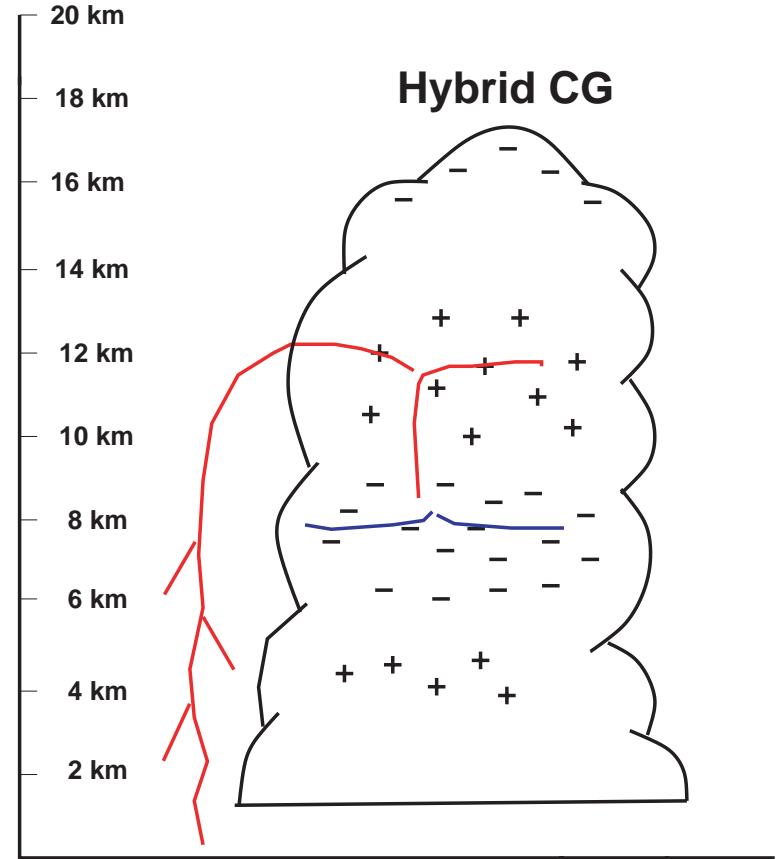
Cloud-to-Ground Lightning



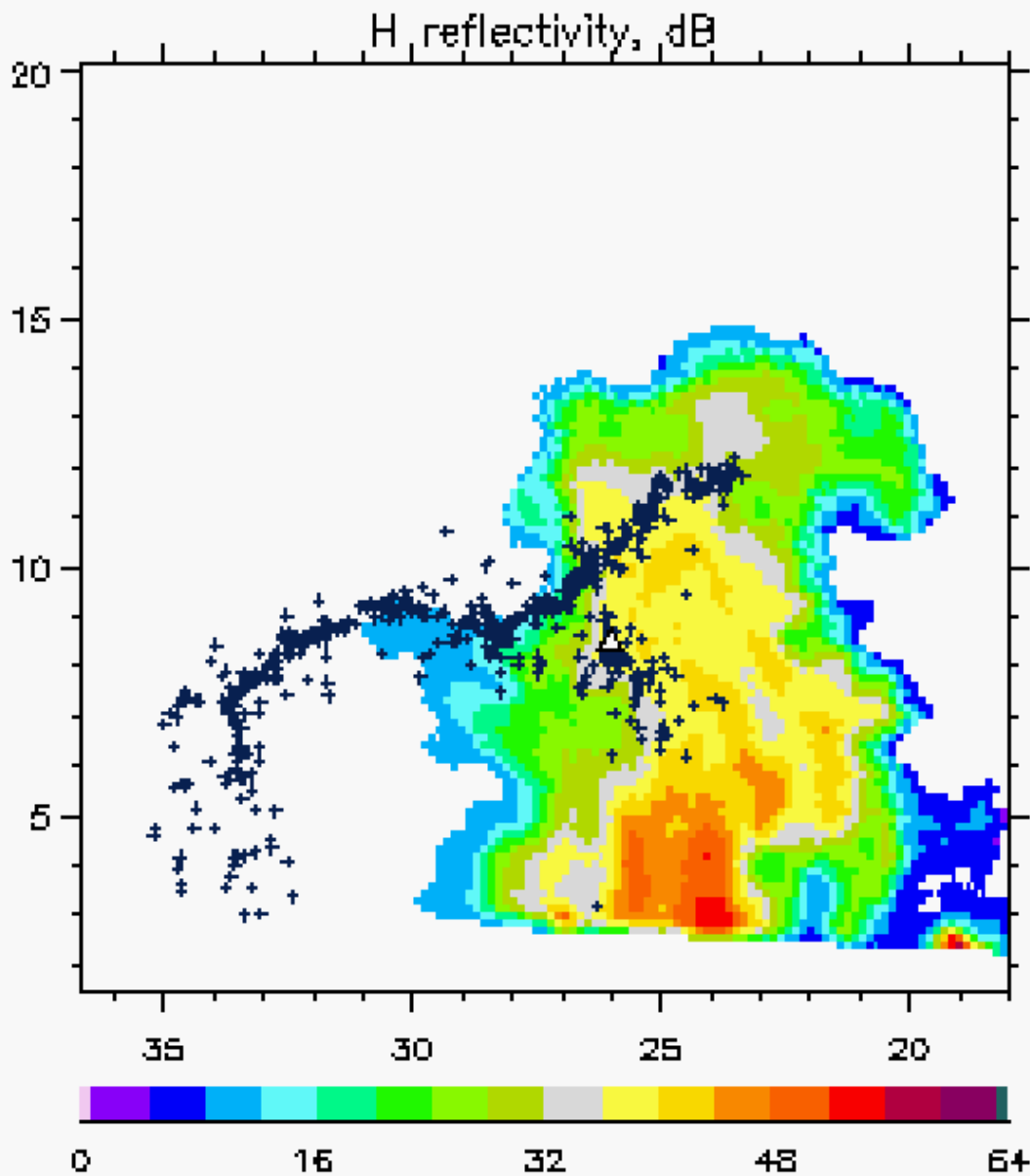
20000711



Bolt from the Blue

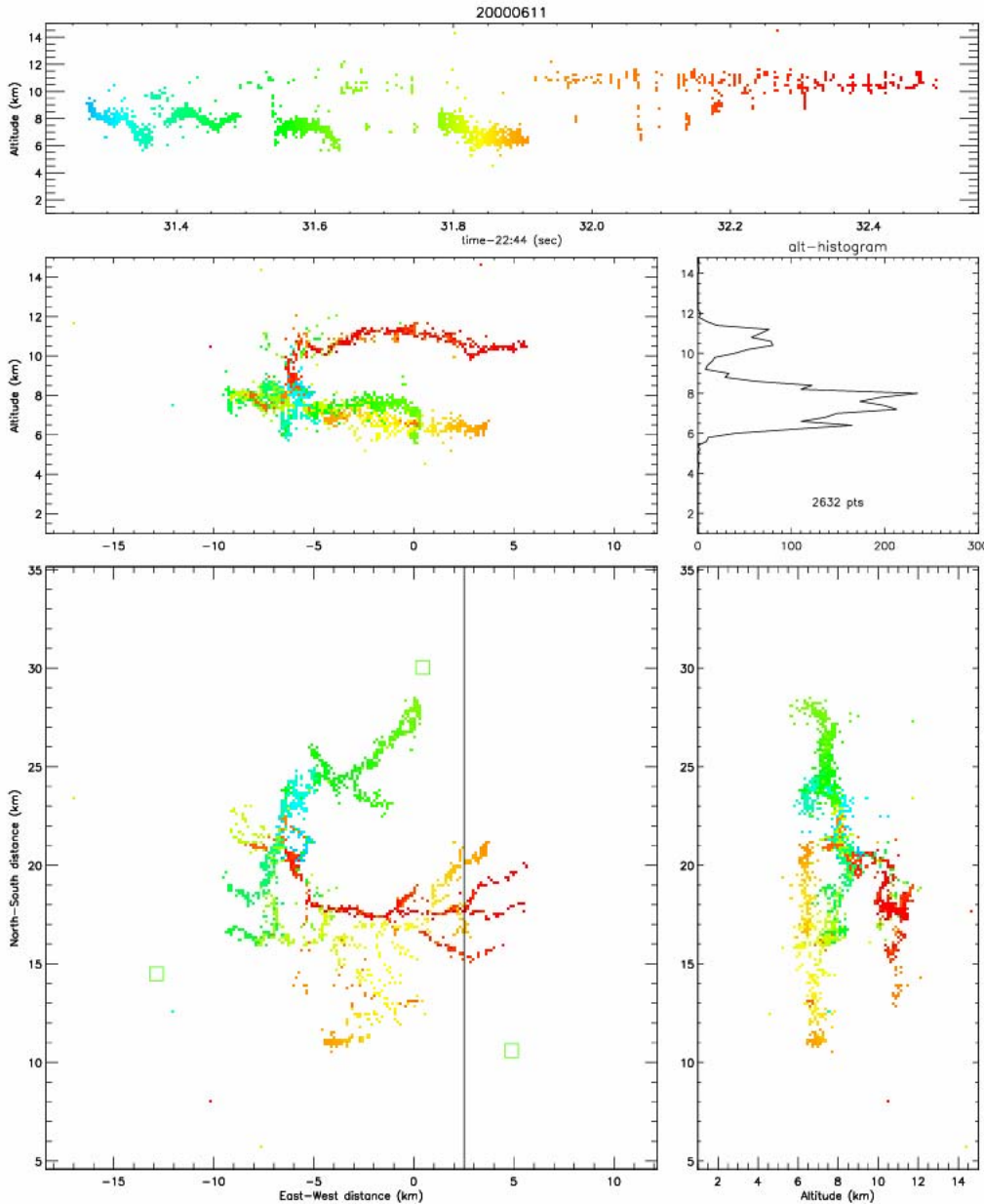




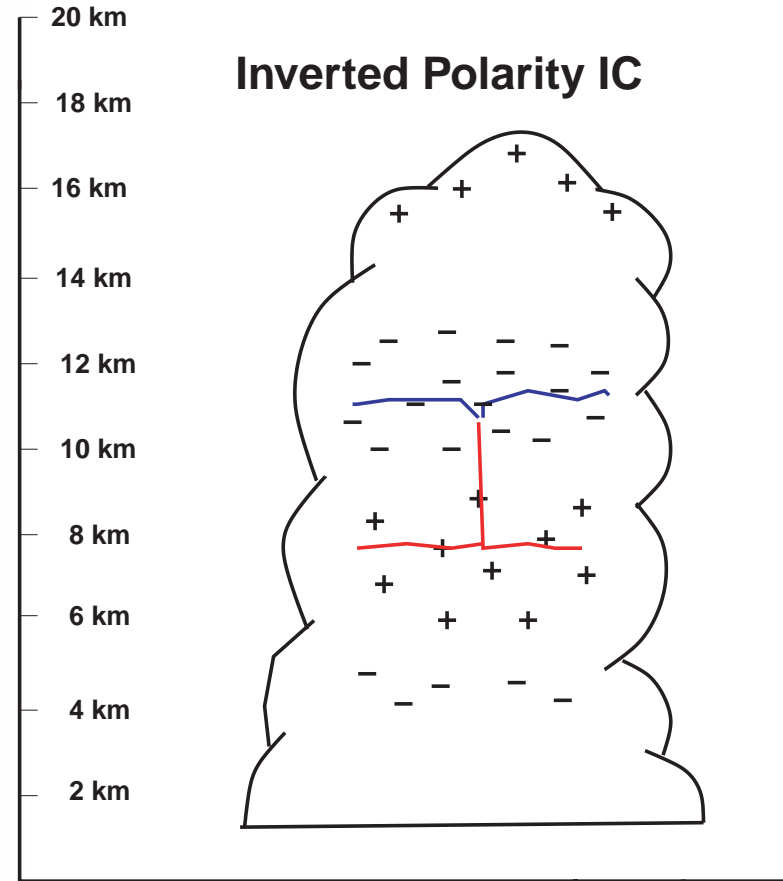


**Bolt from
the Blue
Animation**

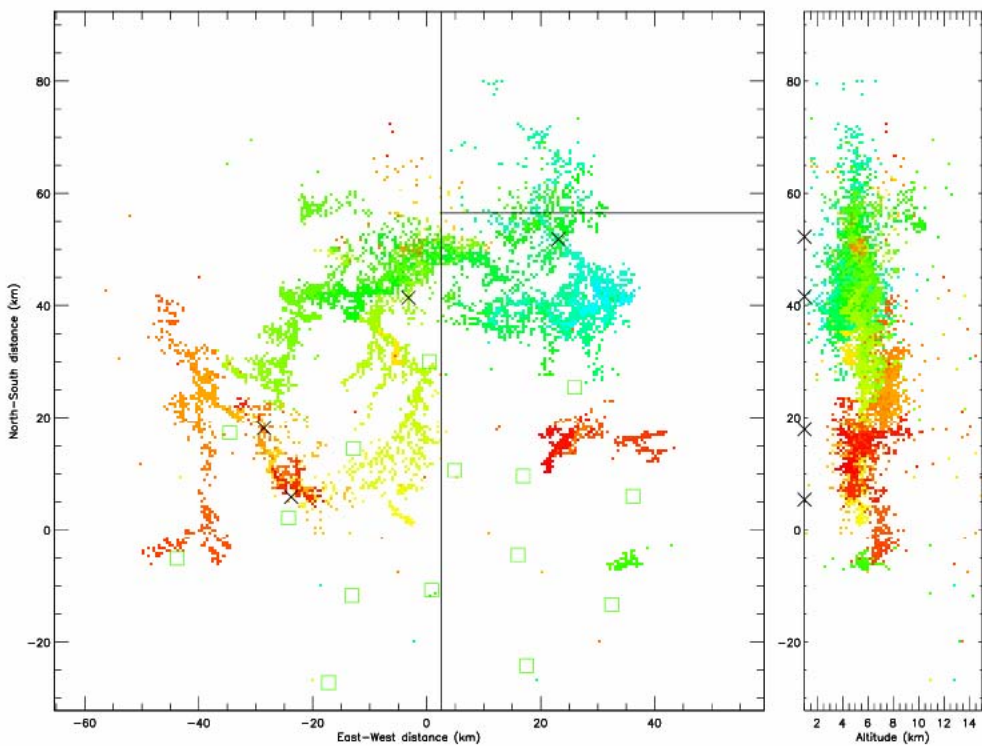
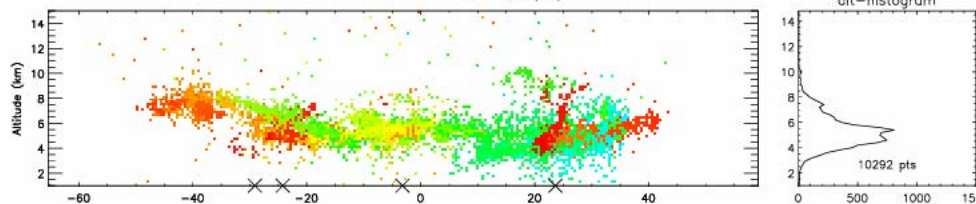
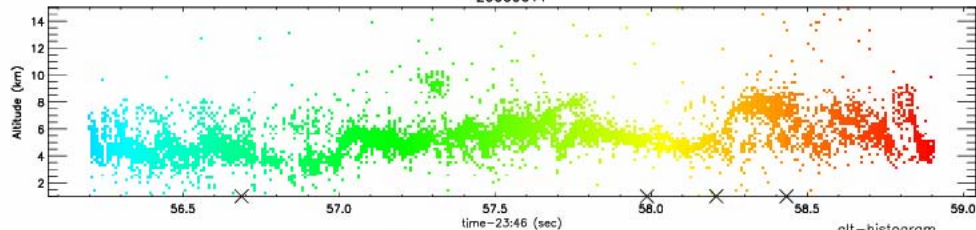
Inverted Polarity IC



Inverted Polarity IC

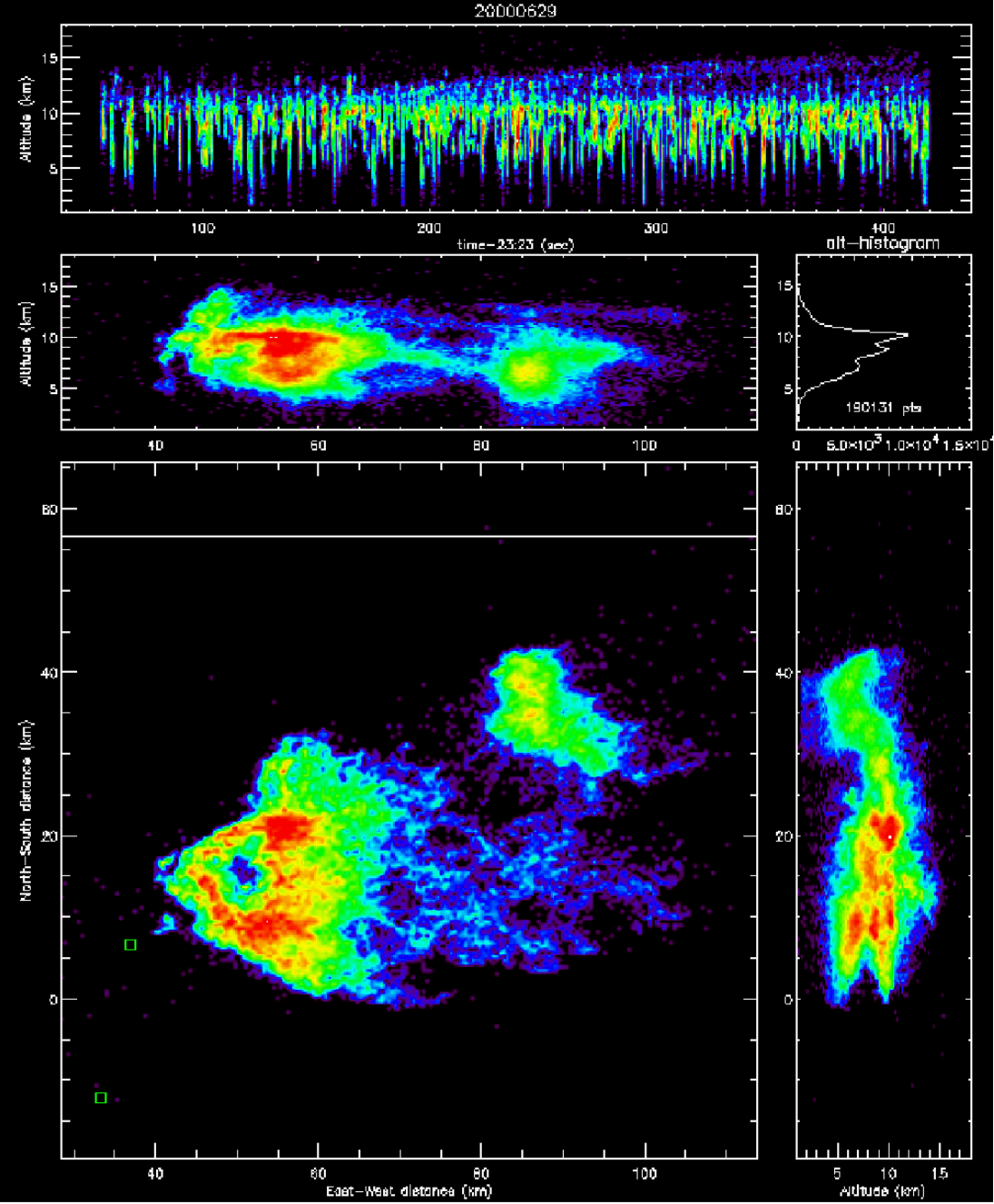


20000611



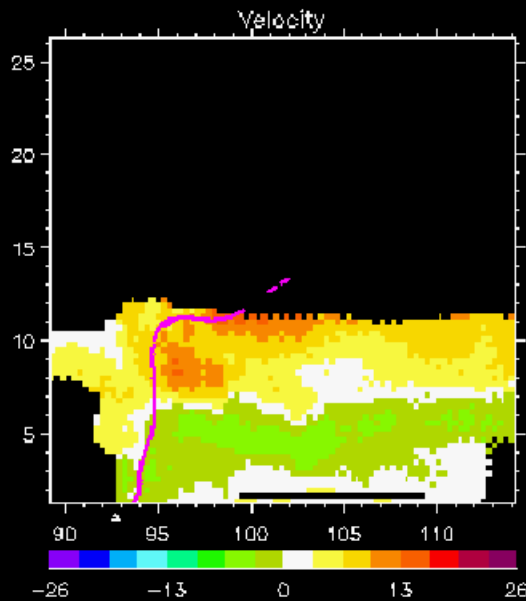
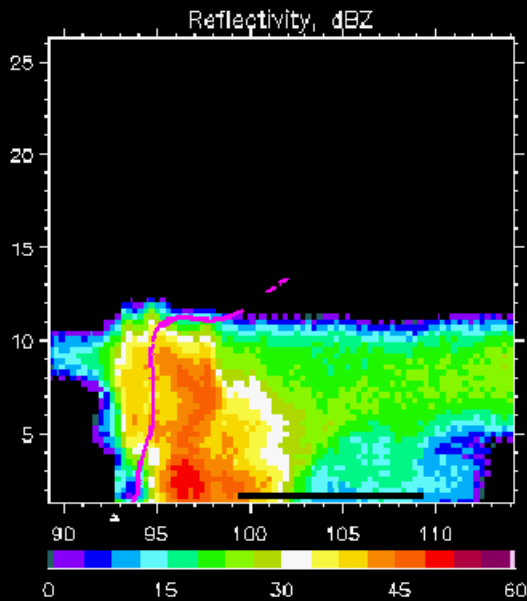
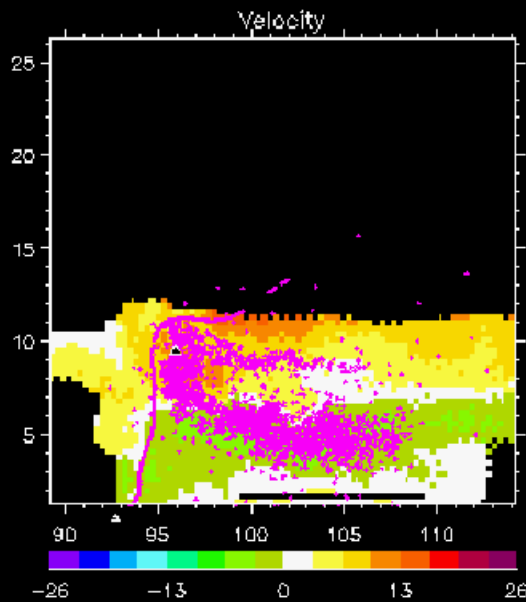
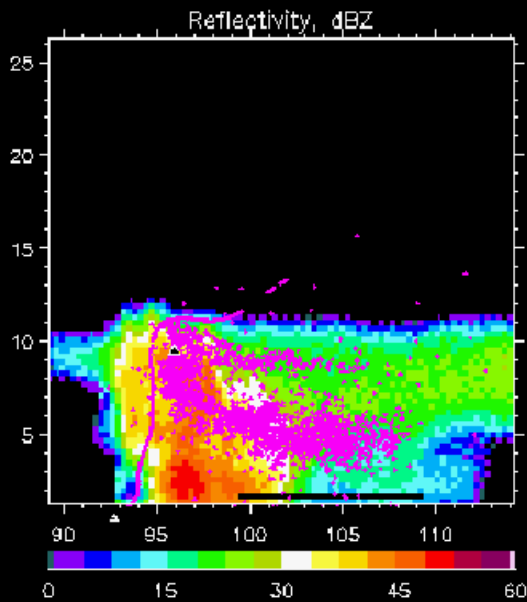
Large Positive CG

Lightning-Free Hole in Tornado-Producing Storm



Inverted IC and Radar Image

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.



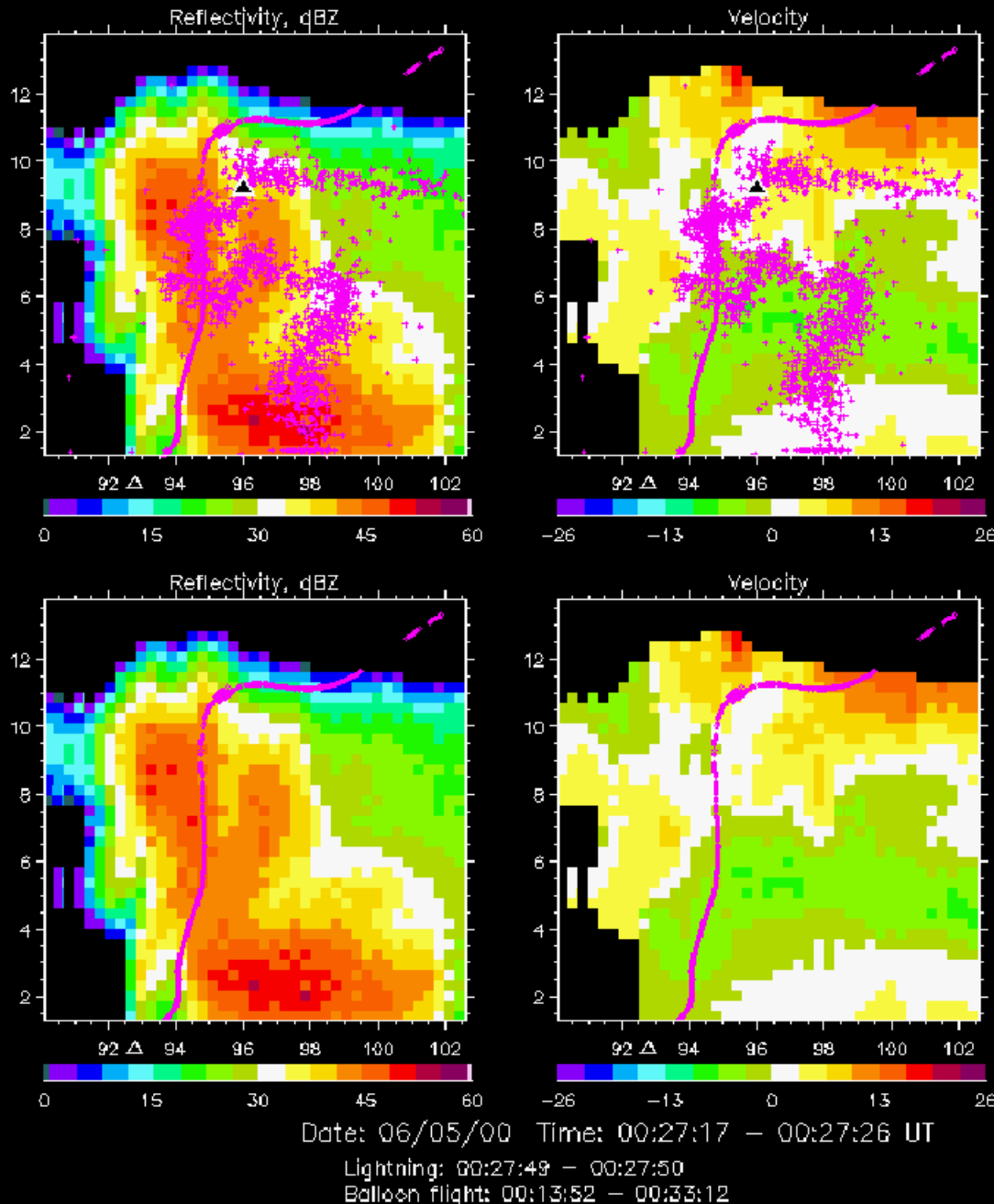
Date: 06/05/00 Time: 00:27:26 - 00:27:35 UT

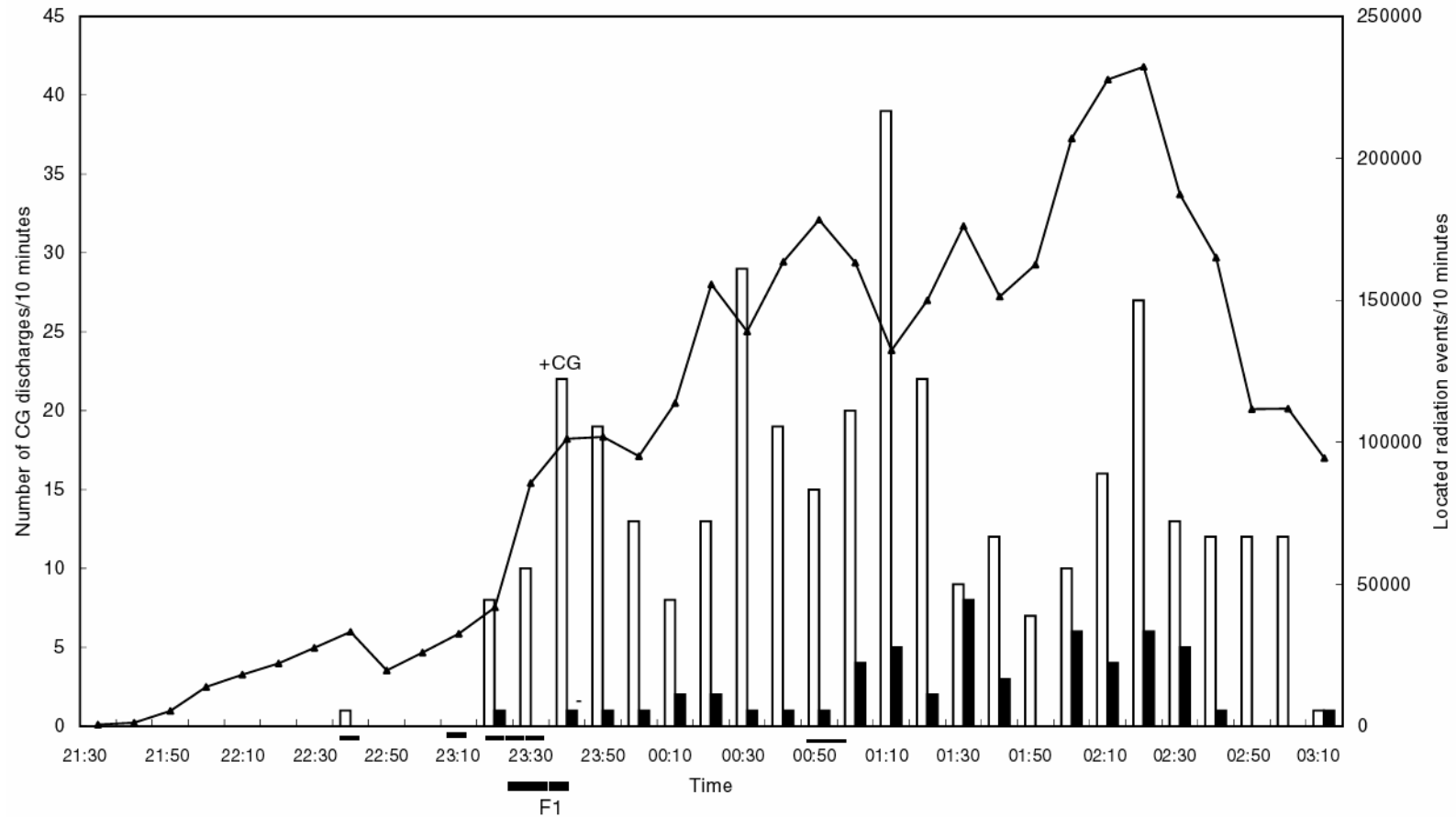
Lightning: 00:27:07 - 00:27:07

Balloon flight: 00:13:52 - 00:33:12

Inverted IC with Radar Image

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

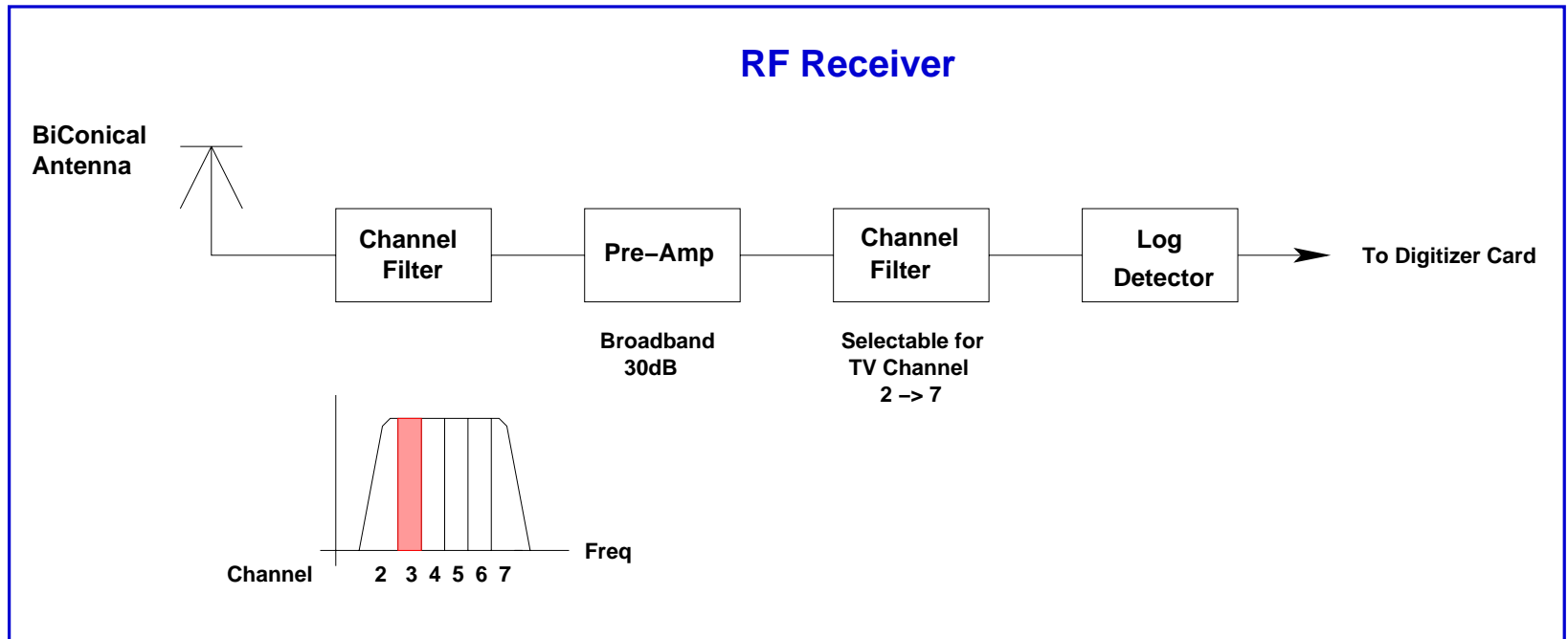
Only one CG flash prior to formation of tornado

Lightning Channels

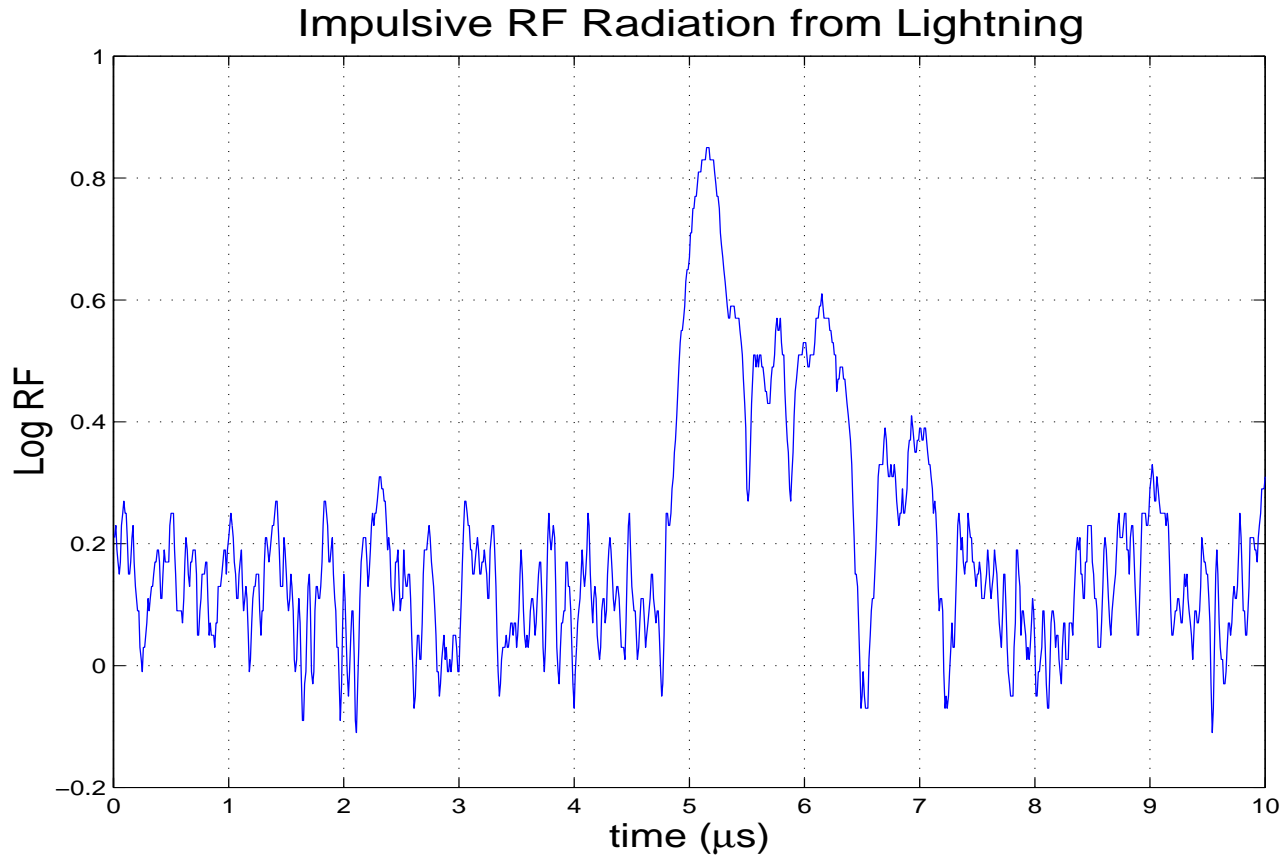
Downward Branching
of Cloud-to-Ground
Lightning Discharge



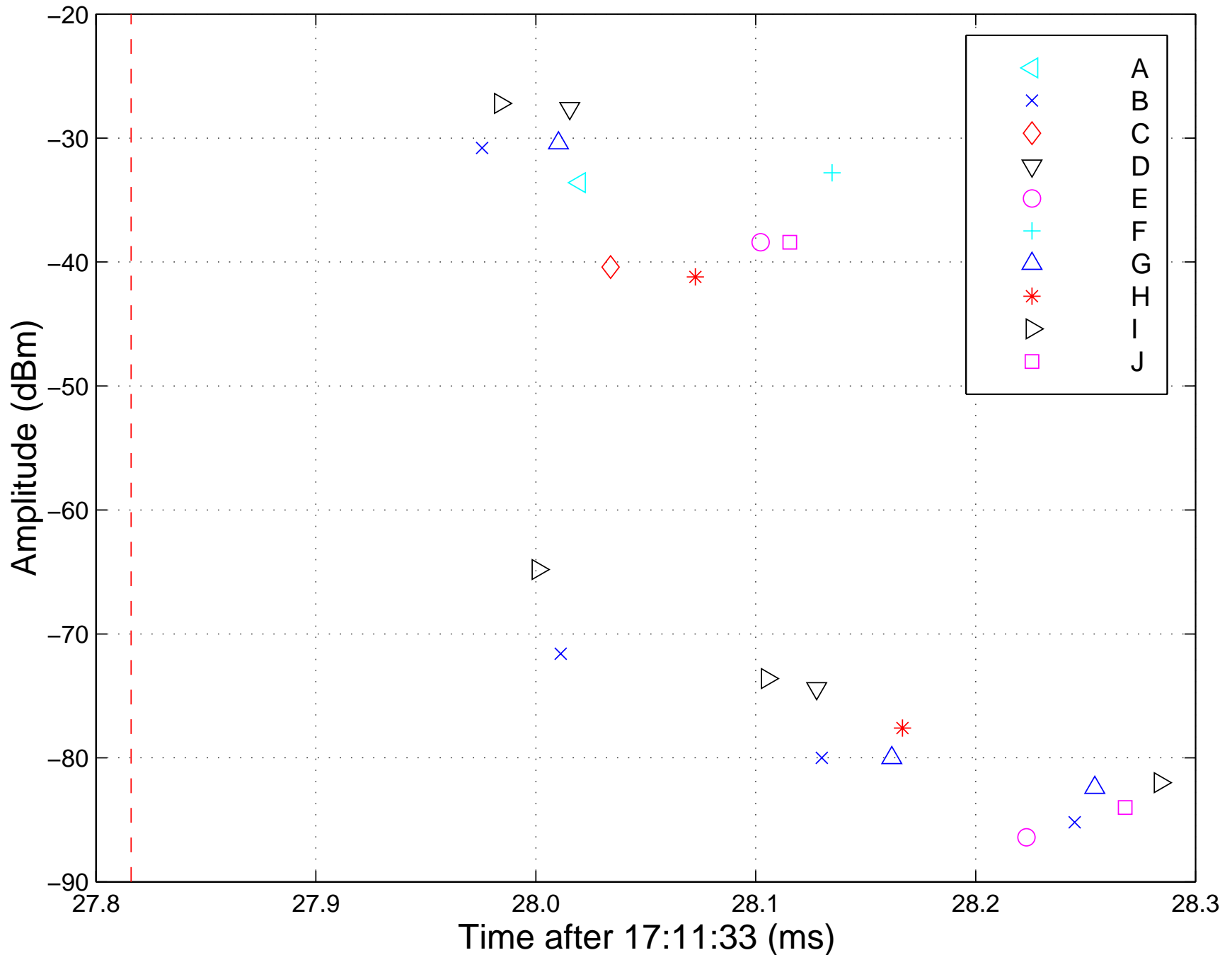
RF Front End



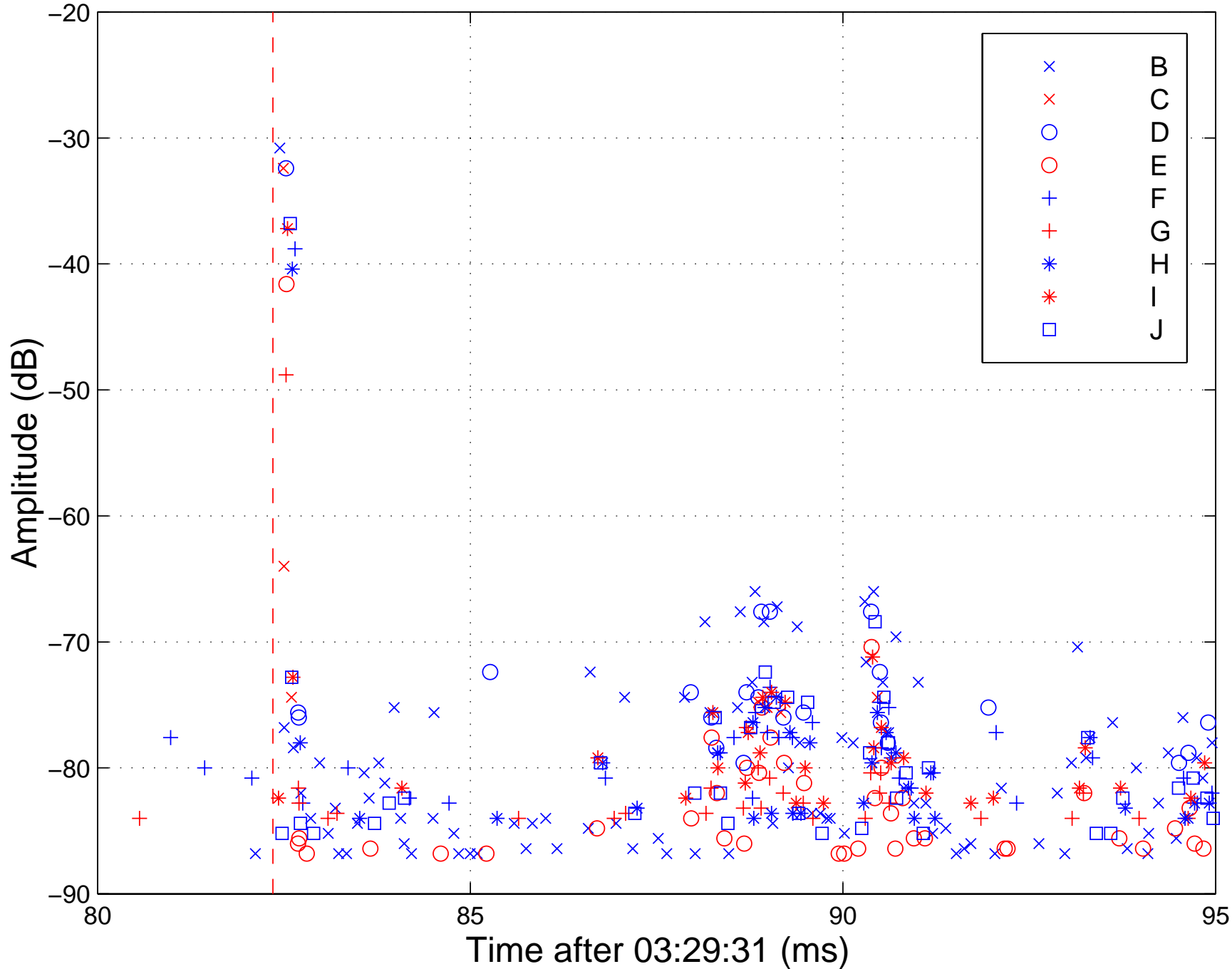
Impulsive 60 MHz RF Radiation from Lightning



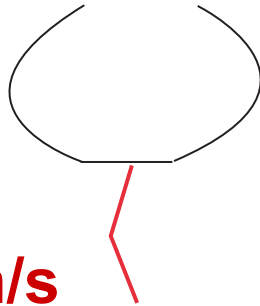
VHF Power Received at LMS Stations



+BP at time 03:29:31.082353



Cloud to Ground Lightning

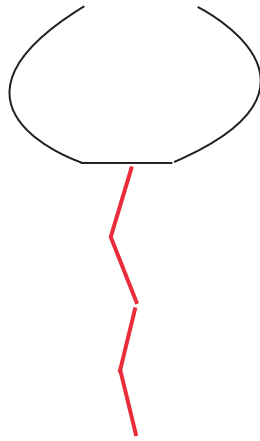


Speed: 10^5 m/s
Current: 50 A
Charge: 1 mC/m

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

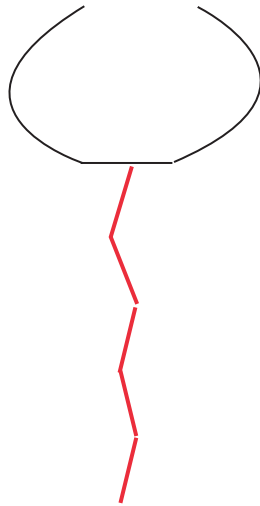


Cloud to Ground Lightning



**As the leader descends,
fields on ground
intensify**

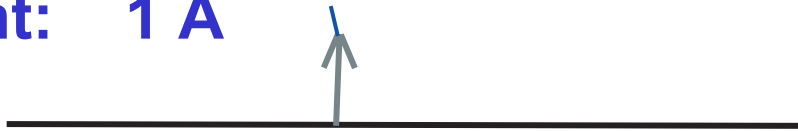
Cloud to Ground Lightning



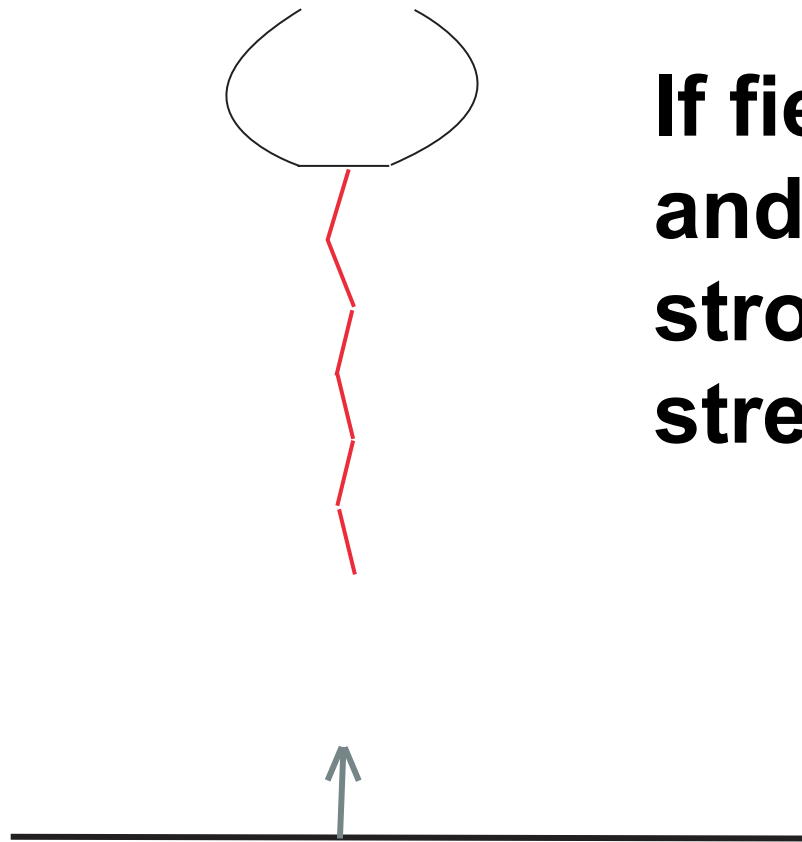
When fields are strong enough, a breakdown (called a streamer) is induced on objects on the ground

Speed: 10^5 m/s

Current: 1 A

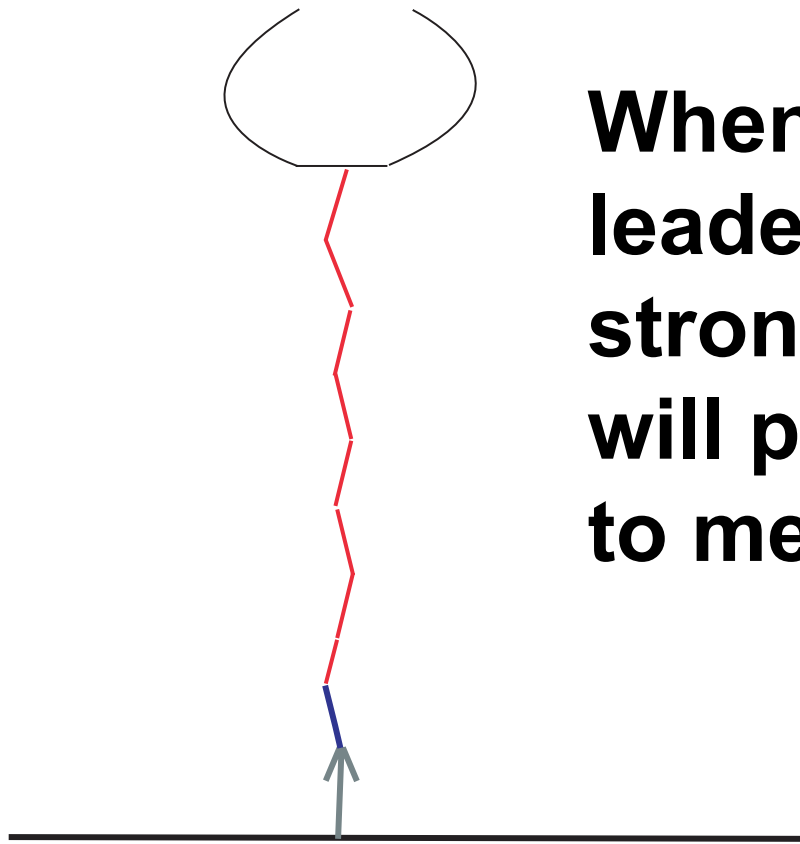


Cloud to Ground Lightning



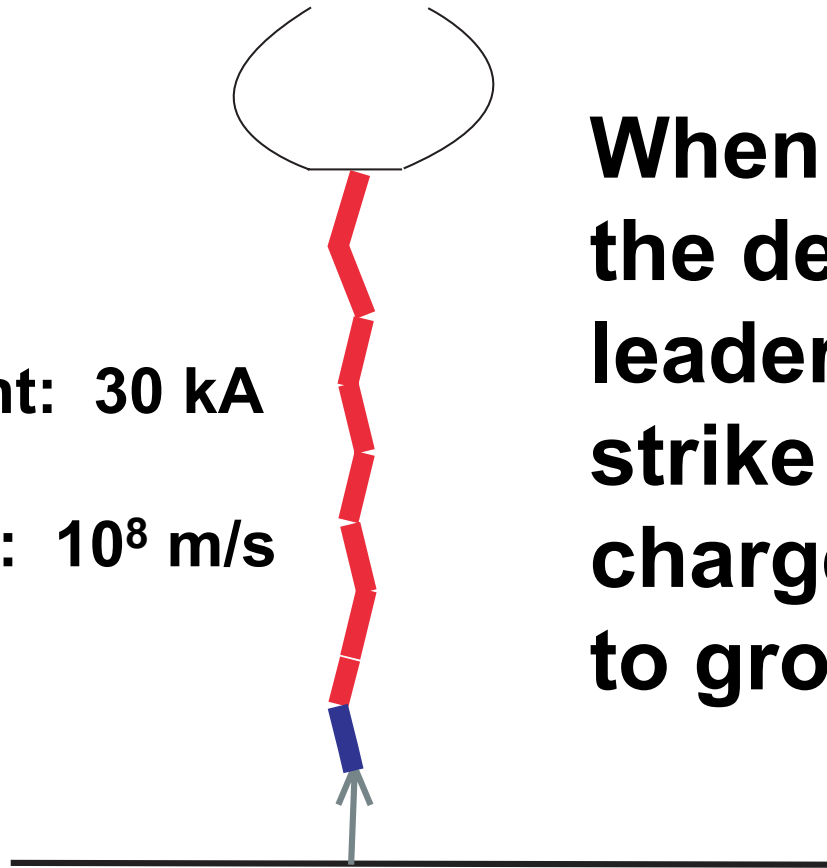
If fields between object and leader are not strong enough, the streamer dies out

Cloud to Ground Lightning



When fields between leader and streamer are strong enough, streamer will propagate upward to meet leader

Cloud to Ground Lightning



Current: 30 kA

Speed: 10^8 m/s

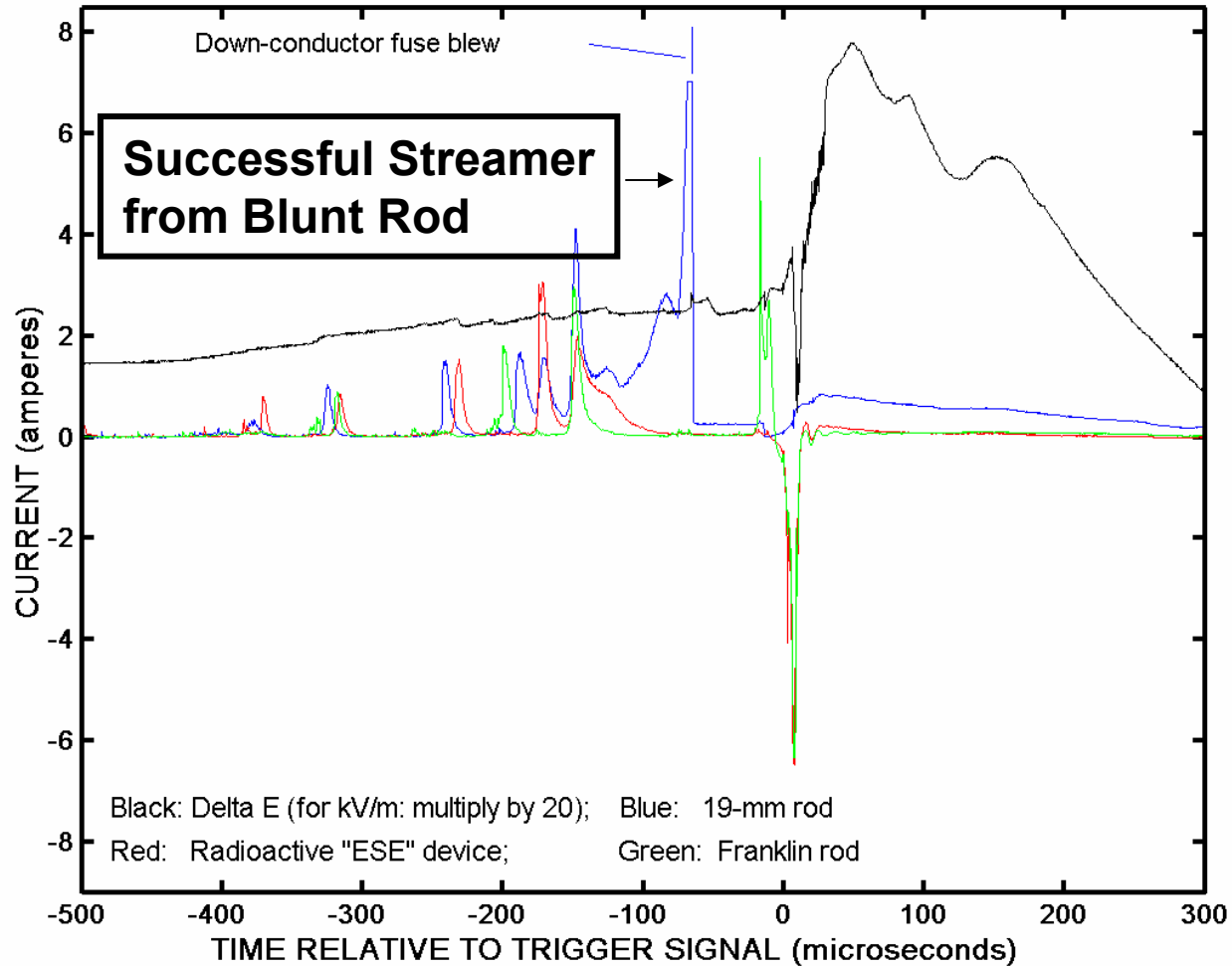
When a streamer meets the descending leader, the lightning strike point is fixed, and charge on the leader goes to ground

Experimental Setup At Langmuir Laboratory



Streamers from Lightning Rods

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



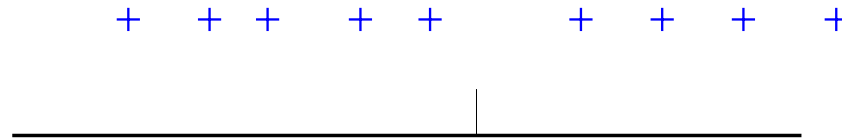
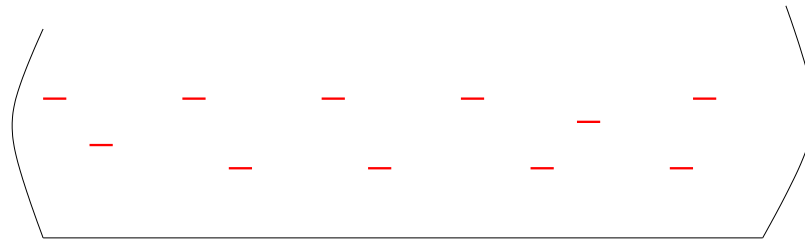
Sparks to van de Graaff



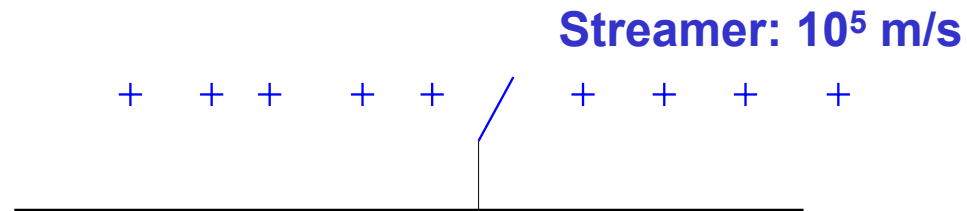
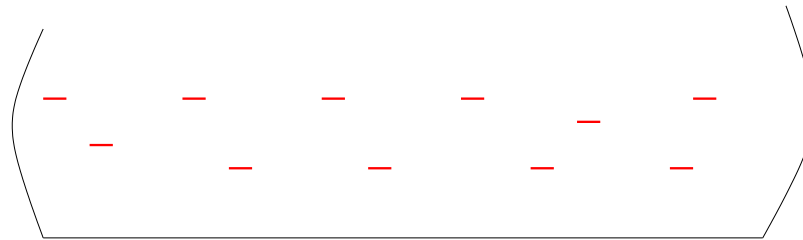
Sparks to van de Graff



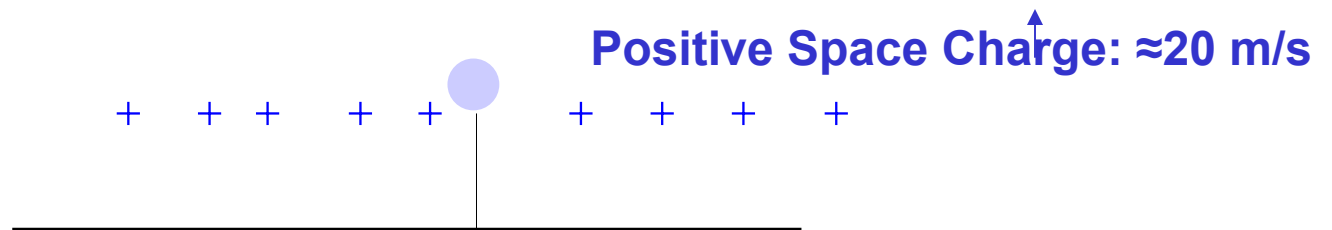
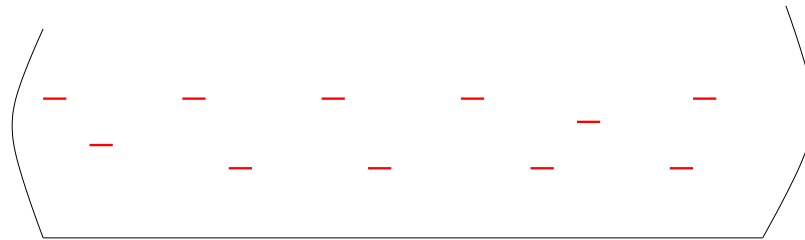
Rocket Triggered Lightning



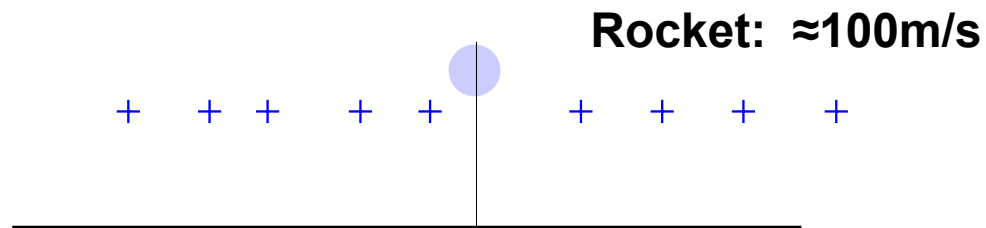
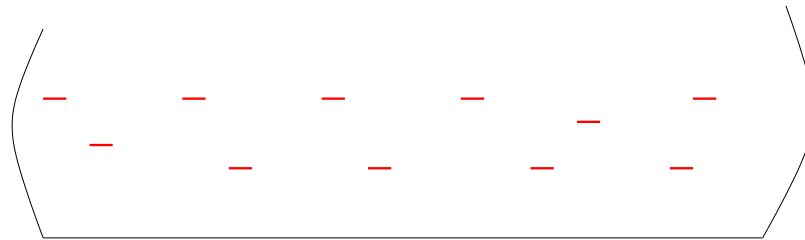
Rocket Triggered Lightning



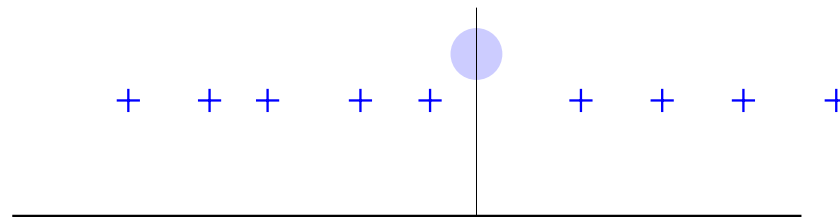
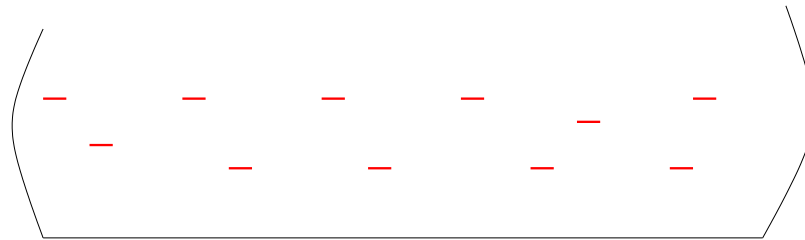
Rocket Triggered Lightning



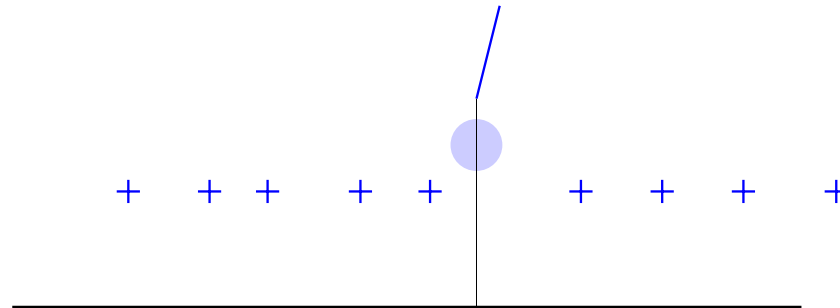
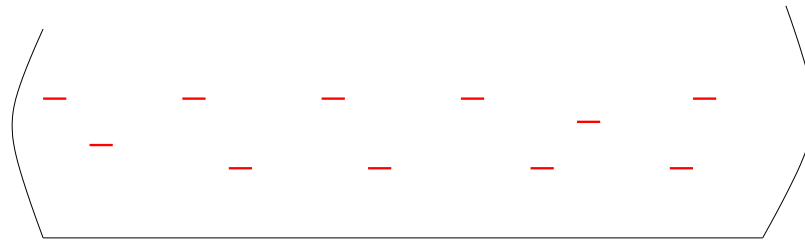
Rocket Triggered Lightning



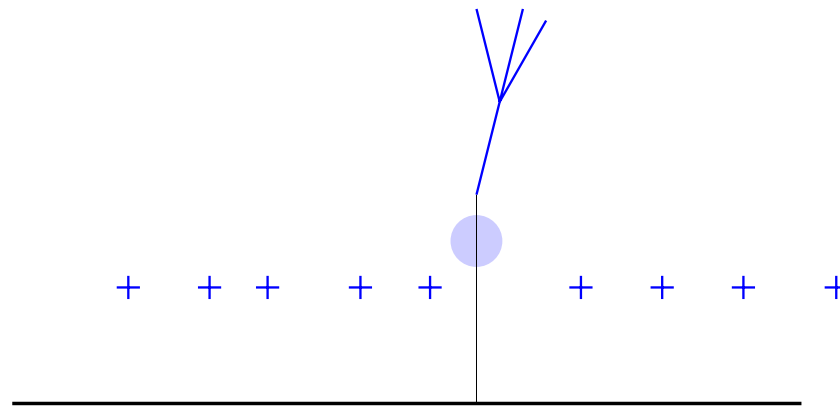
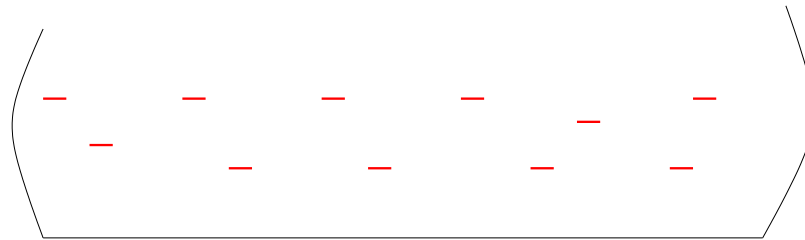
Rocket Triggered Lightning



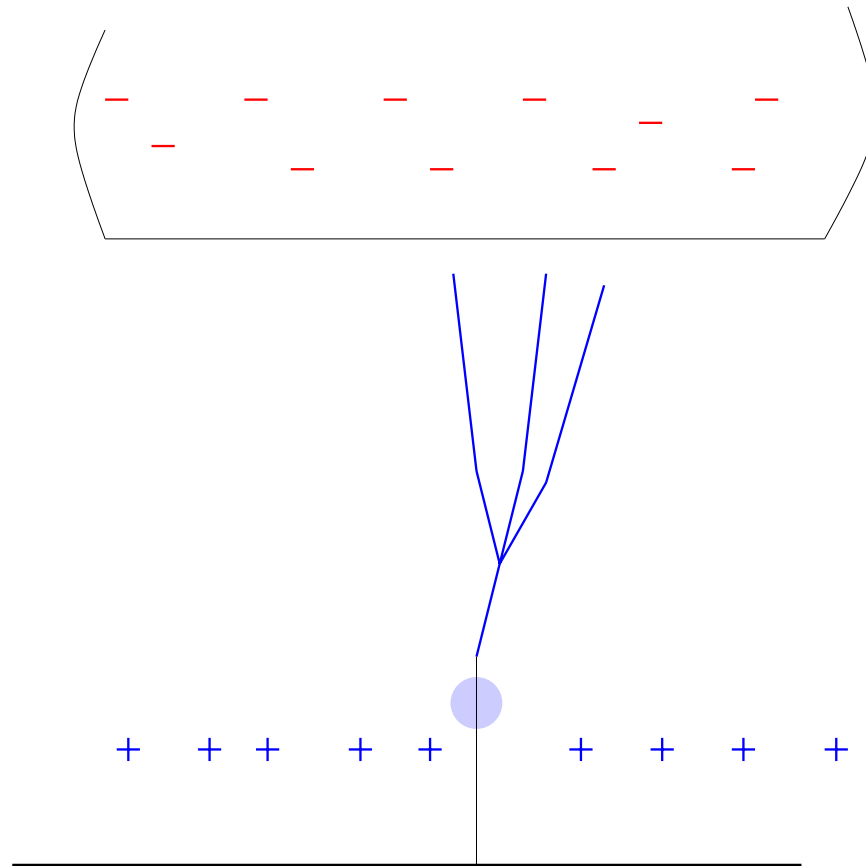
Rocket Triggered Lightning



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Rocket Triggered Lightning



Rocket Triggered Lightning



Rocket Triggered Lightning



Rocket Triggered Lightning

