

# Effect of Lightning Charge Deposition on Storm Electrical Structure



# Effect of Lightning Charge Deposition on Storm Electrical Structure

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# **Collaborators on this work**

**At the University of Mississippi:**

**Drs. Lee Coleman** and **Chris Maggio**  
former Ph. D. graduate students

**At New Mexico Tech:**

**Drs. Paul Krehbiel, Ron Thomas, Bill Rison, Bill Winn**  
provide radar data, two types of lightning data, and  
surface electric field data

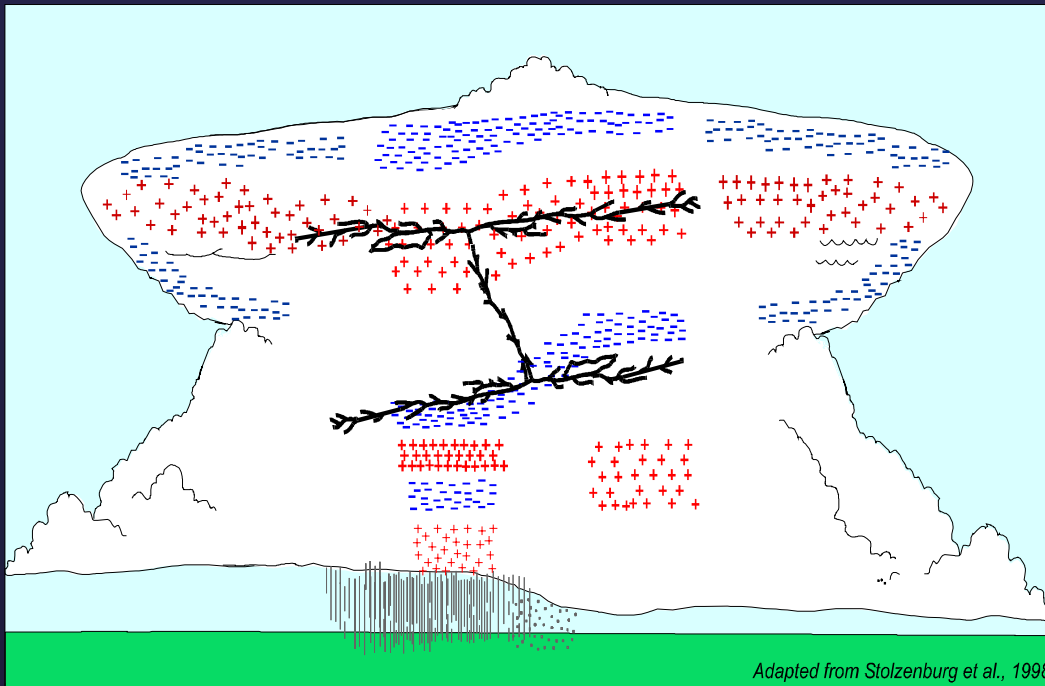
**Funding from the National Science Foundation**

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Our measurements aimed at determining the electrical conditions inside thunderstorms.

Lightning data → tripolar charge structure.

Balloon E data → 4 to 6 charges.



*Adapted from Stolzenburg et al., 1998*

One goal:  
Resolve  
These  
Differences

## Outline of Talk:

1. **Measurements and calculations**
2. Lightning charge polarity
3. Charge deposition hypothesis
4. Examples
5. Conclusions

# What we measure

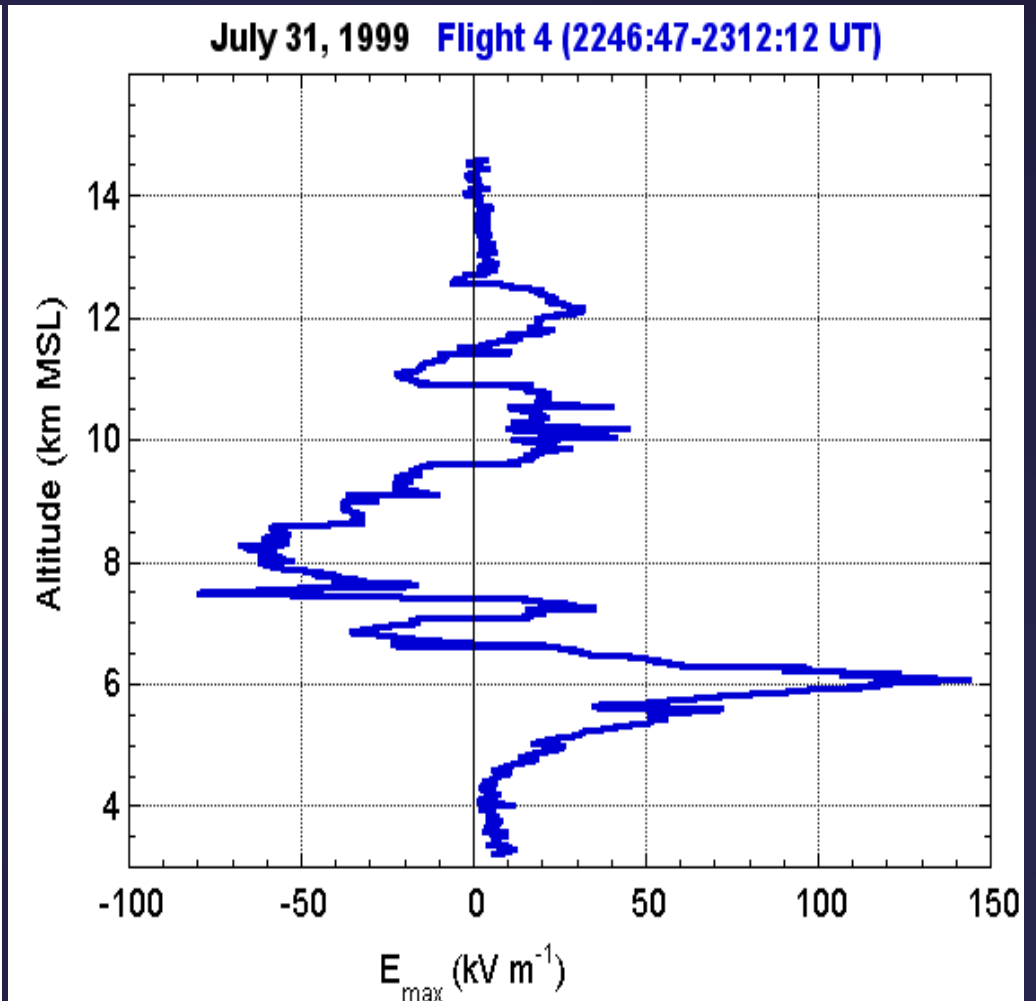
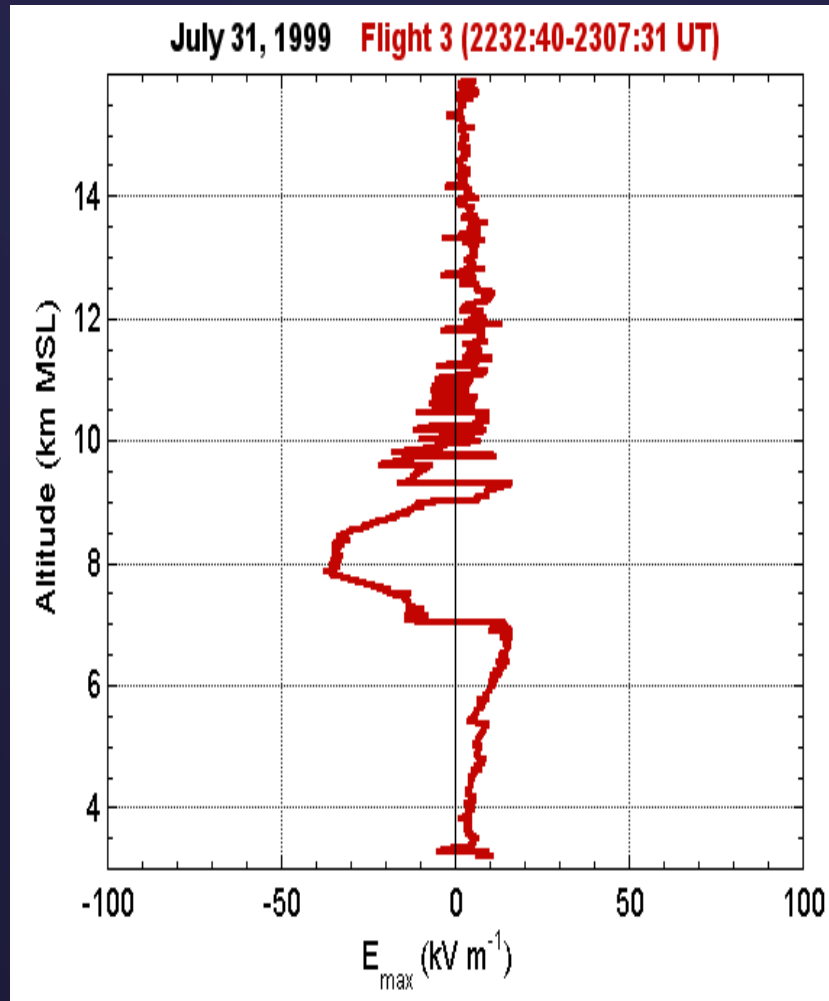
## → Electric field inside thunderstorms

- Instrumented balloons are launched at intervals during storms
- Each balloon travels along an approximately vertical path
- Each balloon also measures pressure, temperature, humidity, and GPS position

# Simple and Complex Soundings

Early, pre-lightning sounding

Mature storm sounding ~ 15 min later



# Charge Structure

We deduce the storm charge structure from Gauss's Law.

➤  $\rho = \epsilon_0 \vec{\nabla} \cdot \vec{E}$  Gauss's Law

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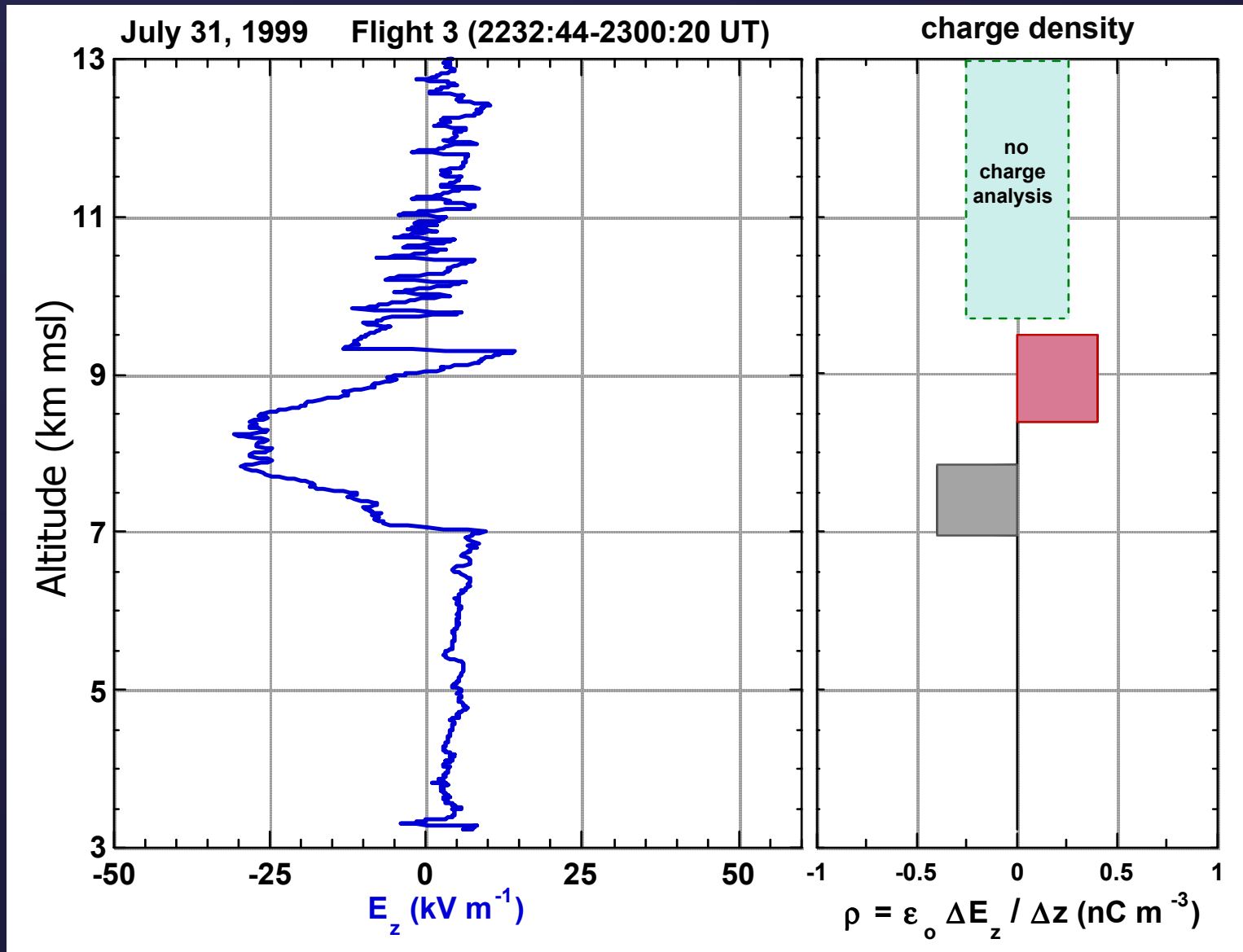
➤  $\rho = \epsilon_0 \vec{\nabla} \cdot \vec{E}$  Gauss's Law

➤  $\rho \simeq \epsilon_0 \frac{\Delta E_z}{\Delta z}$  **One-dimensional approximation to Gauss's Law**

from sounding

➔ **charge density is proportional to the vertical slope of the vertical electric field component**

# Charge Structure



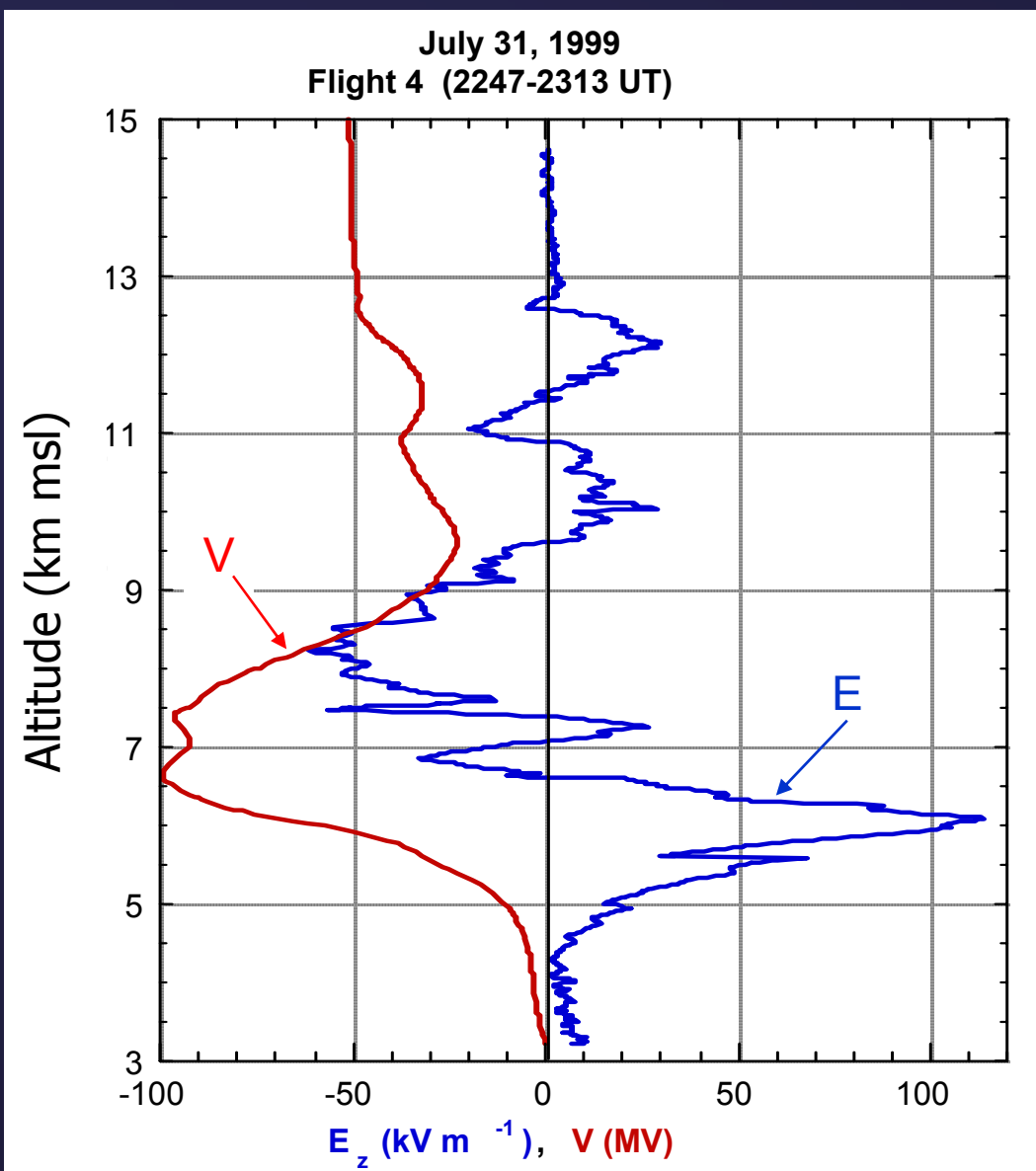
# Electric Potential (Voltage) Profile

→ Voltage profile inside thunderstorms

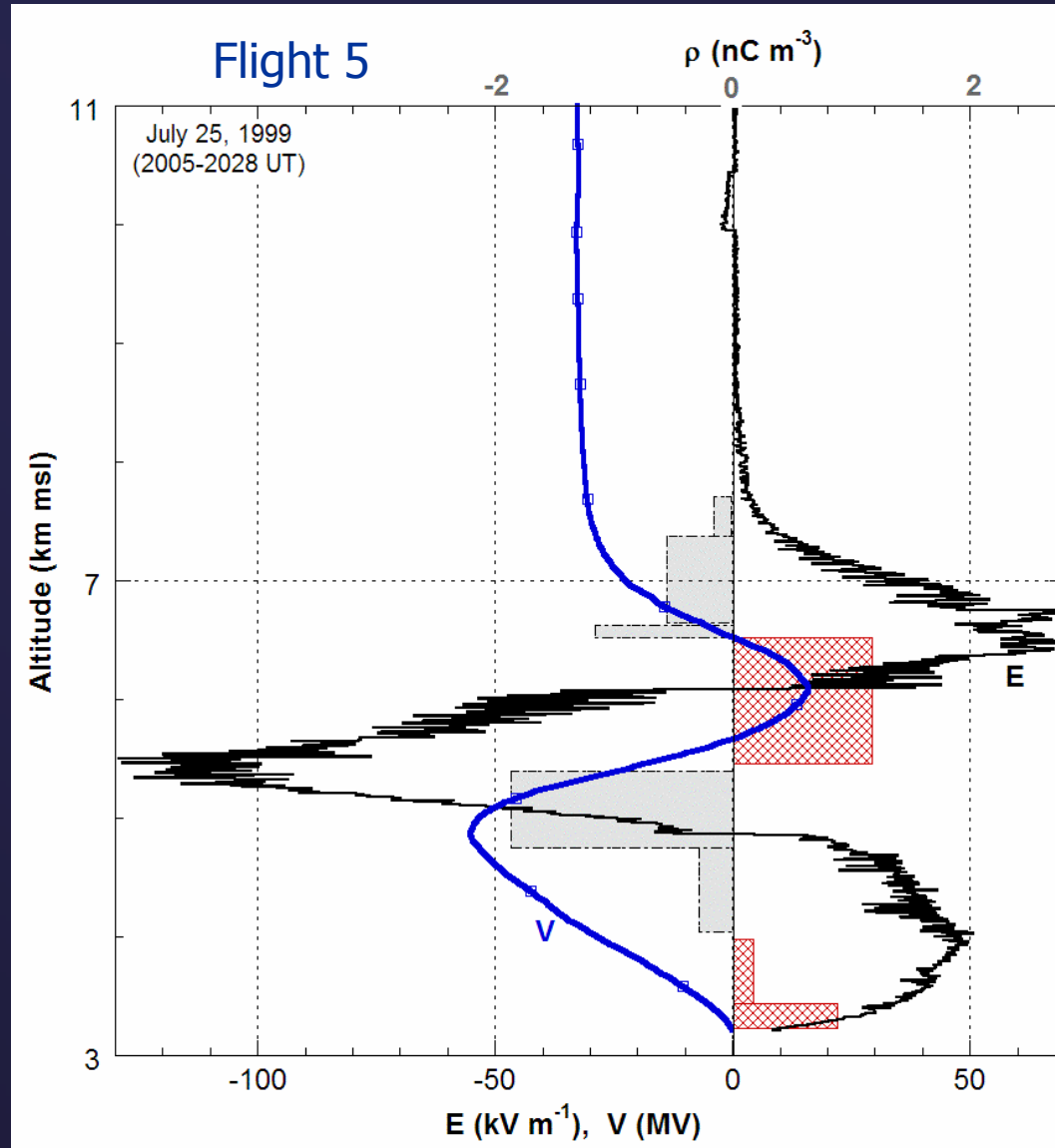
$$\text{➤ } V - 0 = - \int_{\text{sfc}}^z E_z \cdot dz$$

from sounding

# Voltage Profile



The main potential extrema (potential wells) are associated with the largest charge regions.



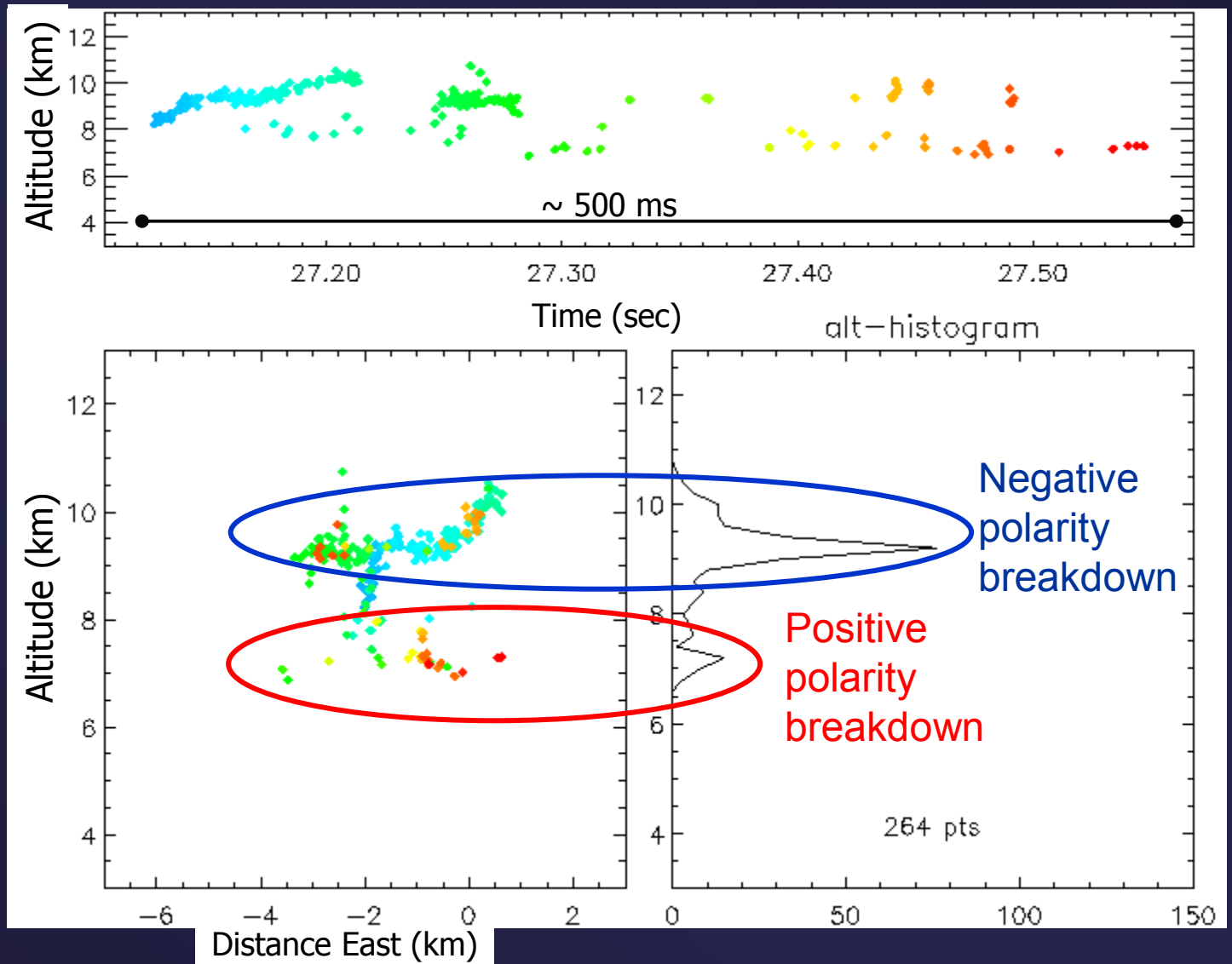
To find where lightning deposits charge,  
we need to know the lightning path.

Use Lightning Mapping Array (LMA).

# LMA data: VHF Radiation of an IC Flash

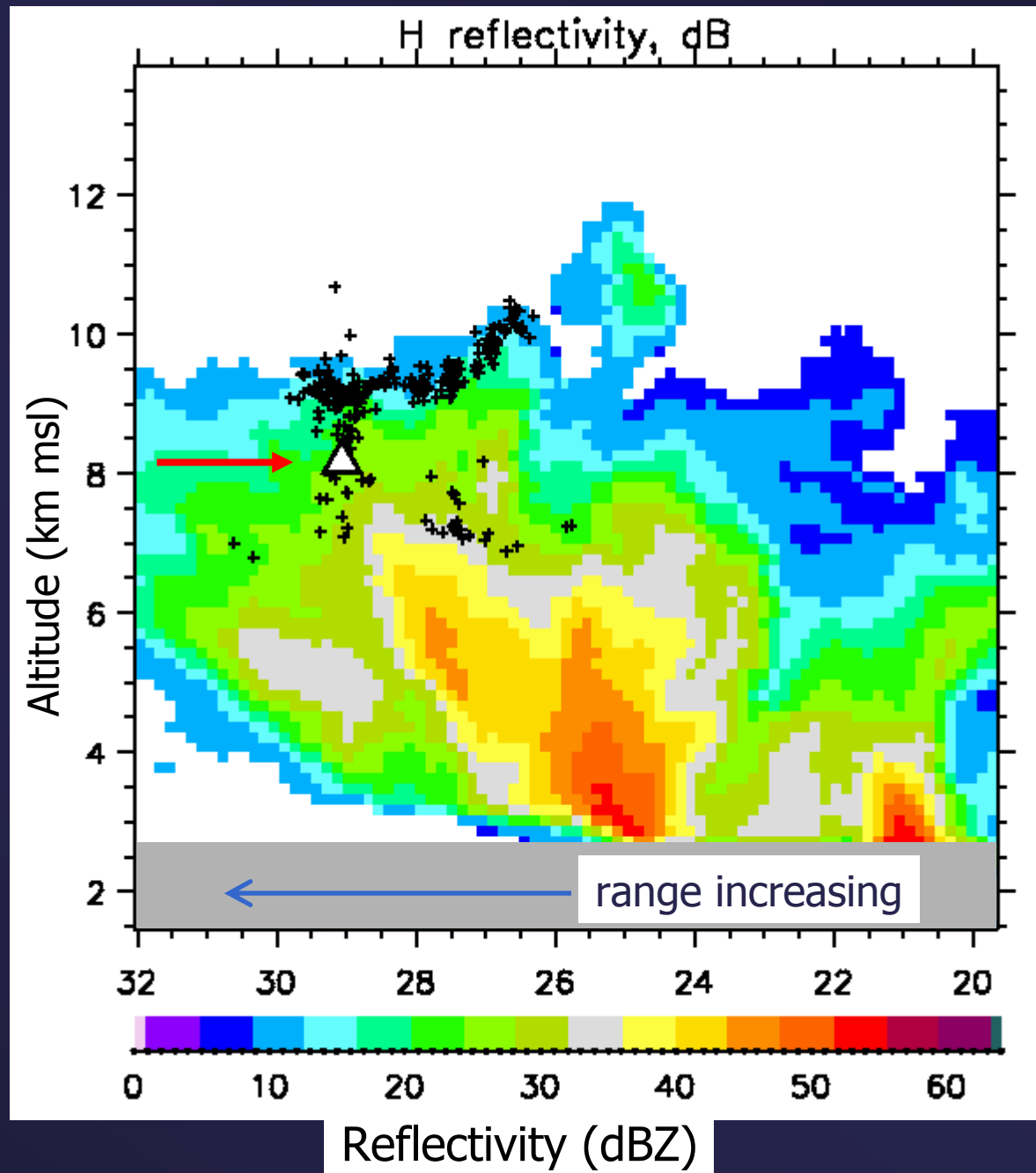
IC Flash:  
Points are  
locations of  
VHF radiation  
from a single  
lightning flash  
(color coded  
by **time**).

Note:  
the main  
lightning  
channels are  
horizontal.



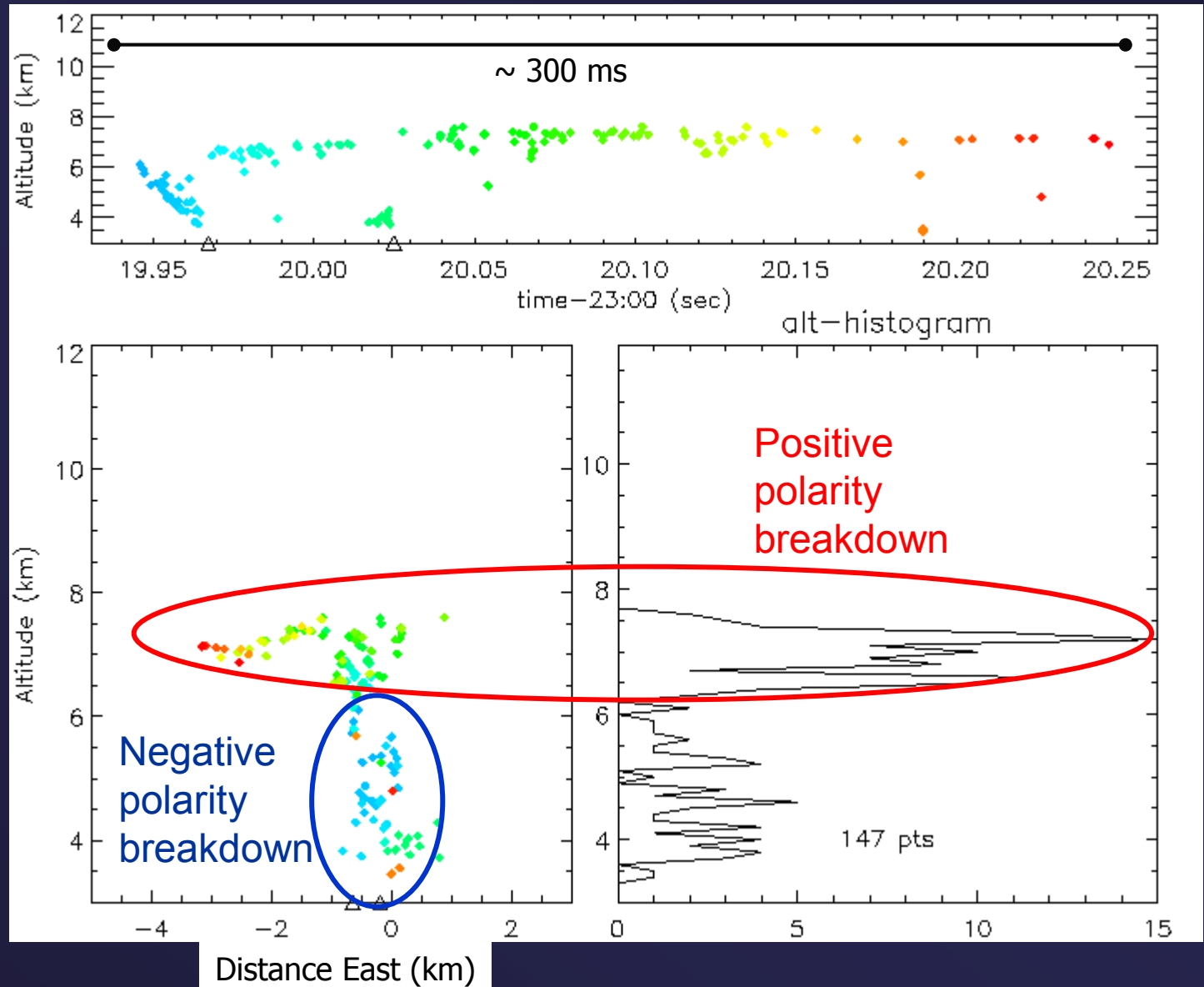
# IC Flash on a Radar RHI (Range-Height Indicator view)

IC flashes  
usually occur in  
the upper part  
of the cloud.



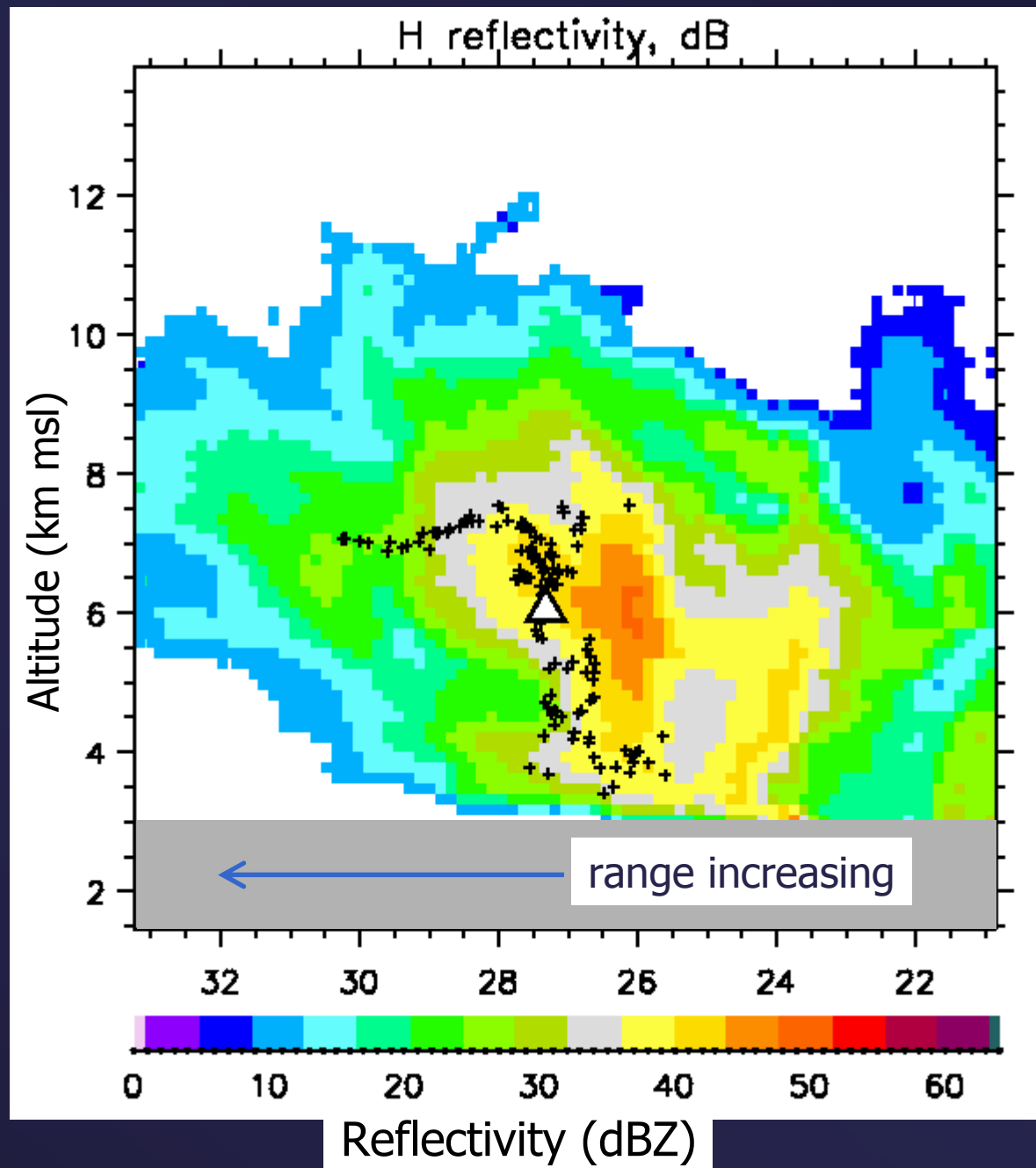
# LMA data for a 2-stroke CG Flash

CG Flash:  
vertical  
channel to  
ground &  
horizontal  
channels  
inside the  
cloud.



# CG Flash on a Radar RHI

CG flashes usually occur at and below middle levels in the cloud.



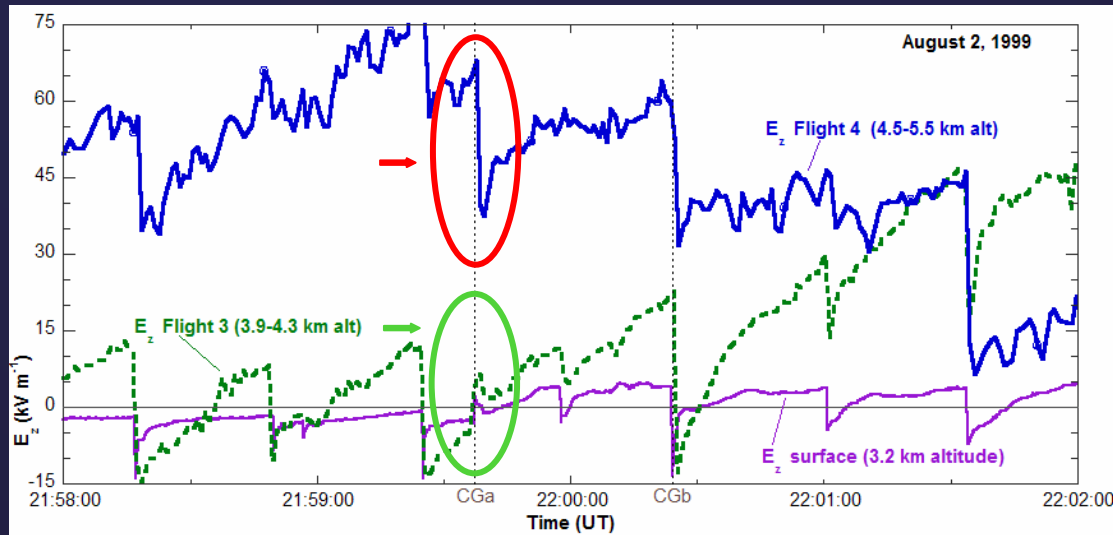
## Outline of Talk:

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Testing LMA charge polarity assignment:

If a horizontal lightning branch passes between two balloons, then the charge polarity of the branch can be determined.

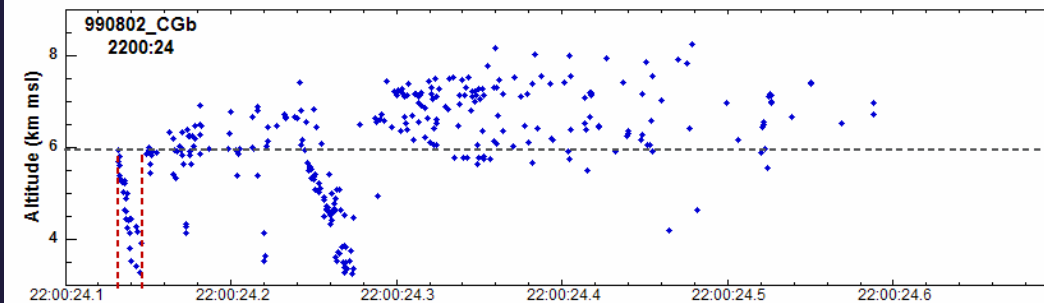
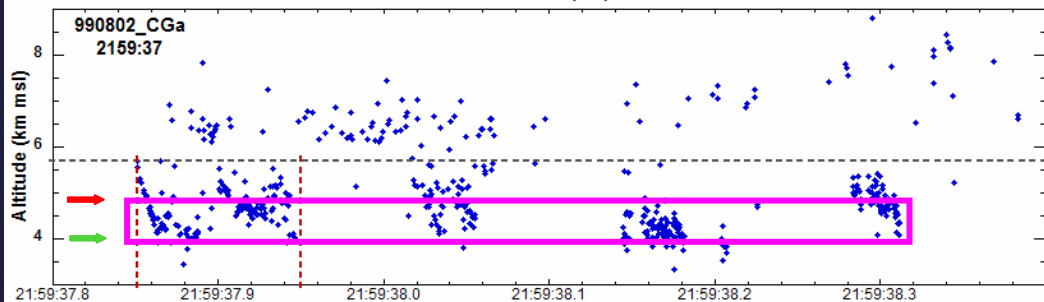
# LMA-inferred negative polarity breakdown passed between two balloons.



Upper balloon at 4.8 km  
and has  $\Delta E$  negative.

Lower balloon at 4.0 km  
and has  $\Delta E$  positive.

Hence, Lightning charge  
is *negative* as inferred.

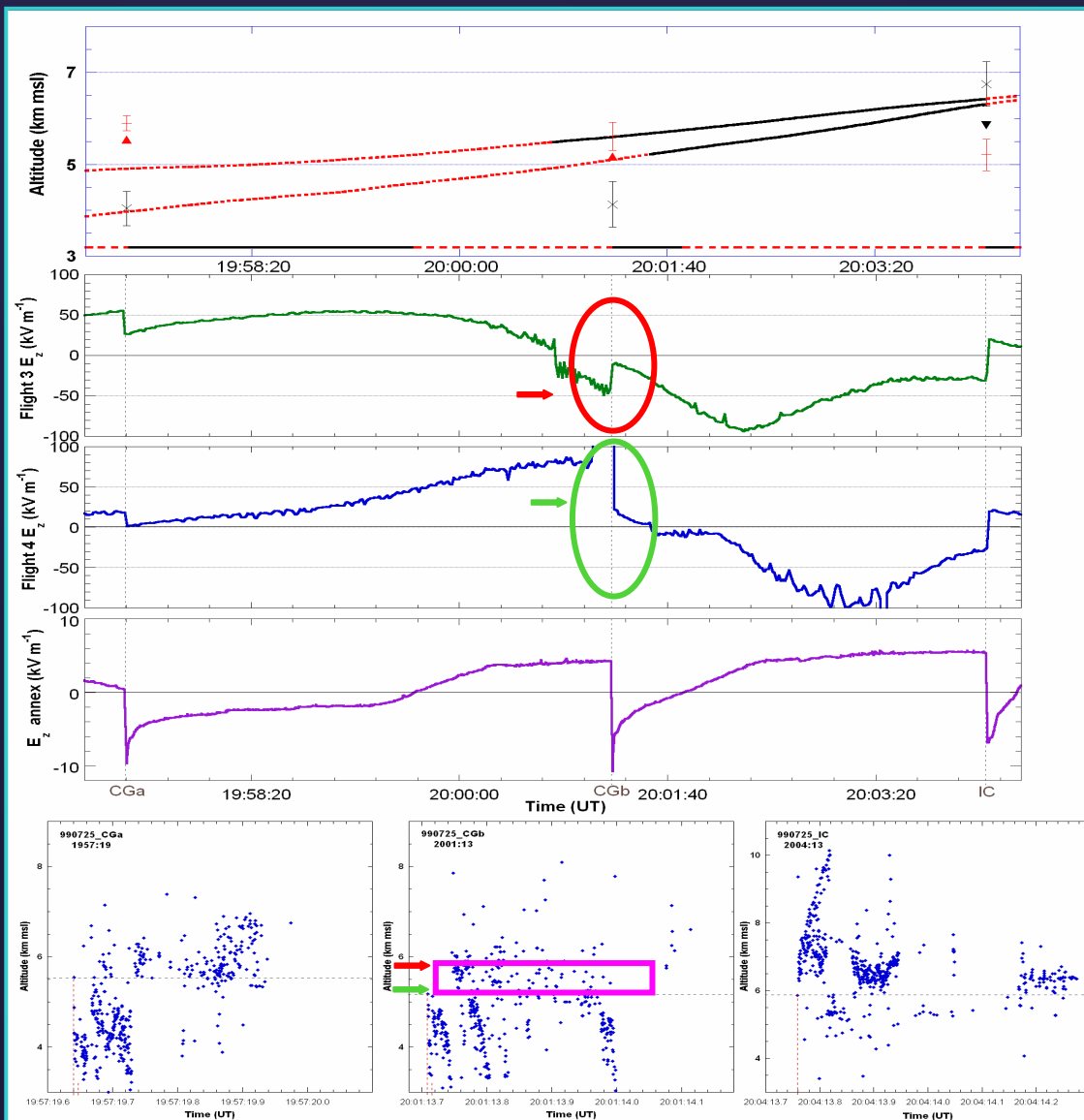


# LMA-inferred positive polarity breakdown passed between two balloons, mean altitude of LMA sources was 5.6 km.

Upper balloon at 5.7 km and has  $\Delta E$  positive.

Lower balloon at 5.2 km and has  $\Delta E$  negative.

Hence, Lightning charge is *positive* as inferred.



▪

To date, we have four sets of data (with balloons in the right place) to test the charge polarity of lightning channels.

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Hypothesis:

Horizontal lightning branches  
deposit charge in the cloud.

Why?

The deposited charge gives the flash *energy* for dielectric breakdown.

How?

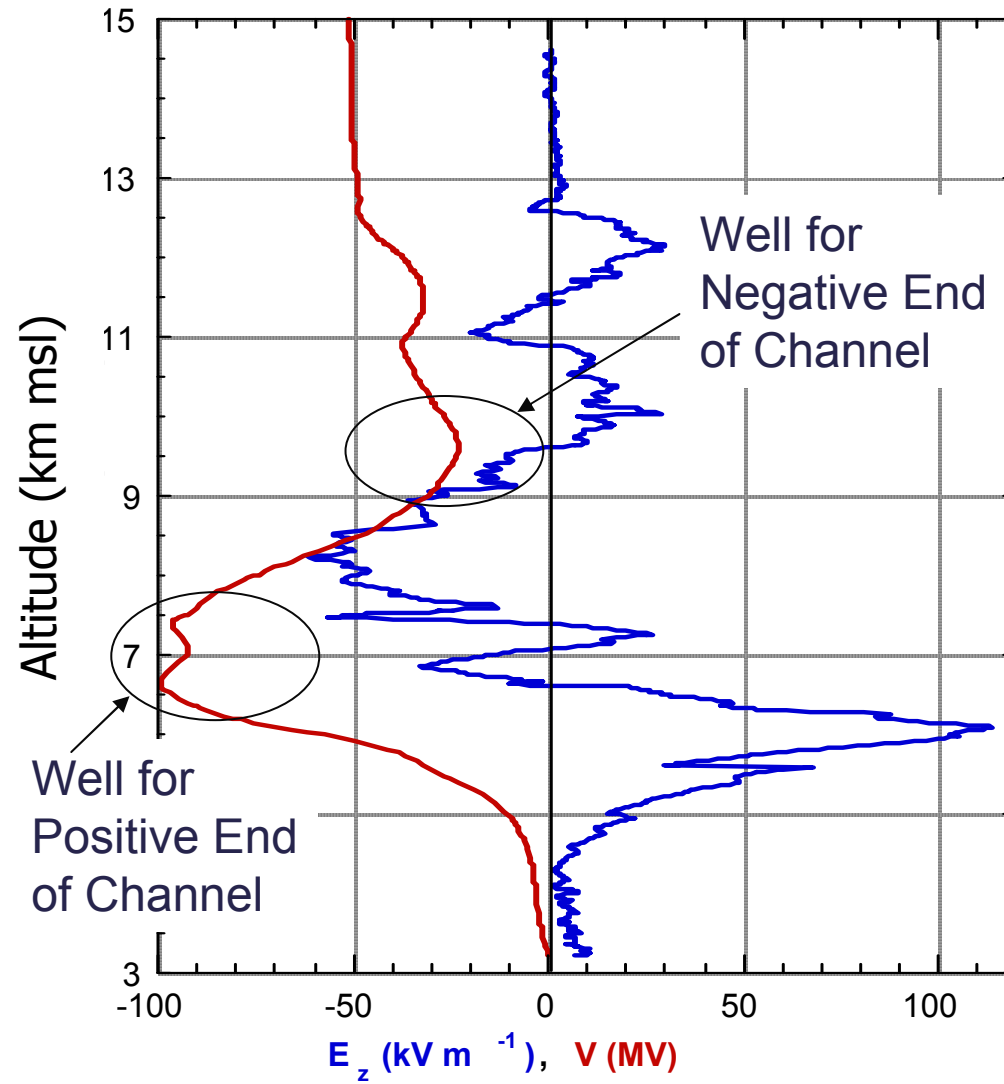
The flash deposits charge into  
*low potential energy* locations in  
the cloud. [Coleman et al., 2003]

In other words:  
The flash deposits charge into  
*potential wells*  
in the voltage profile.

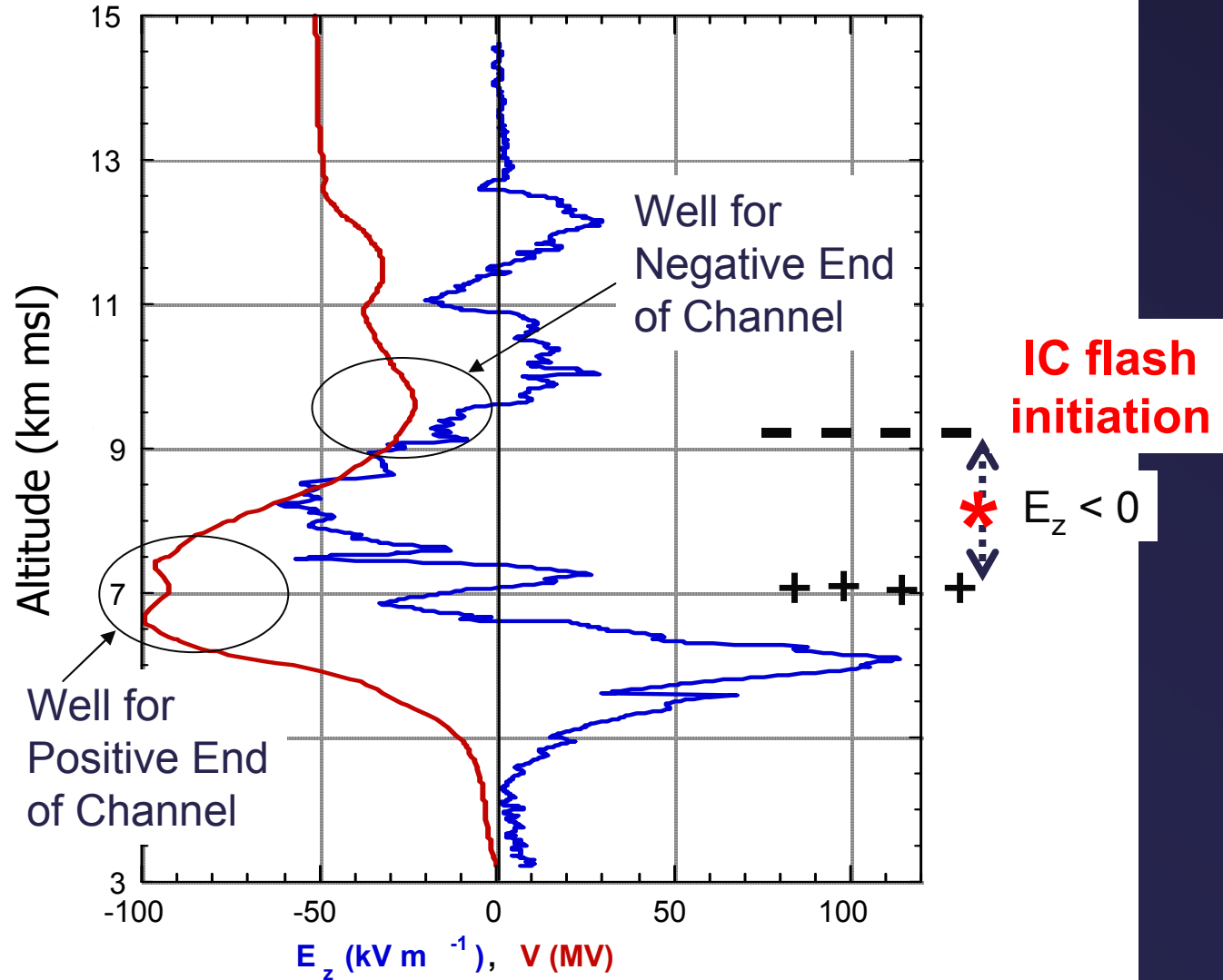
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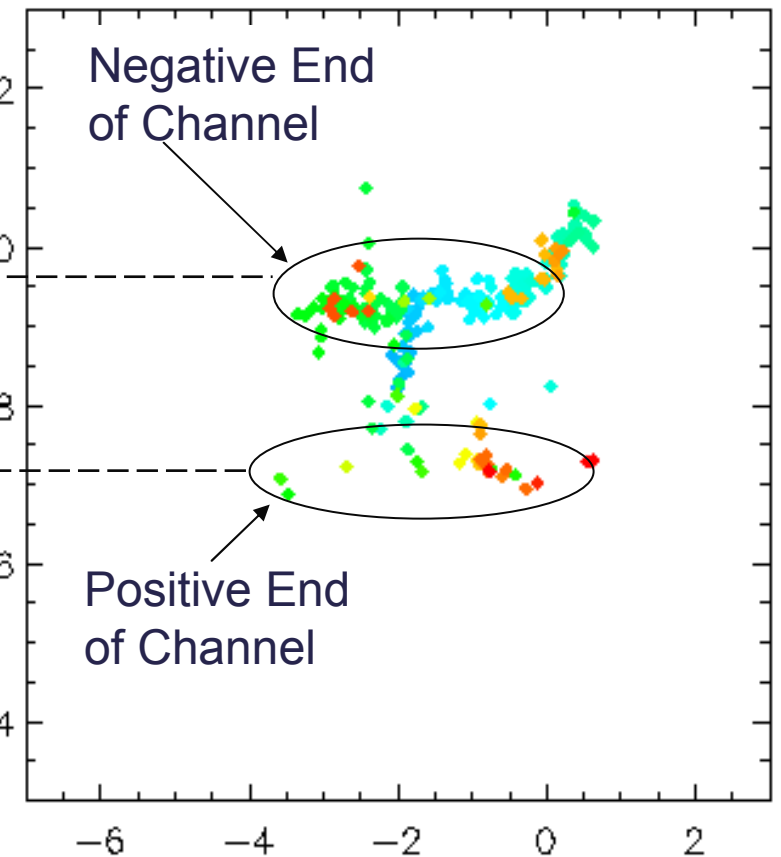
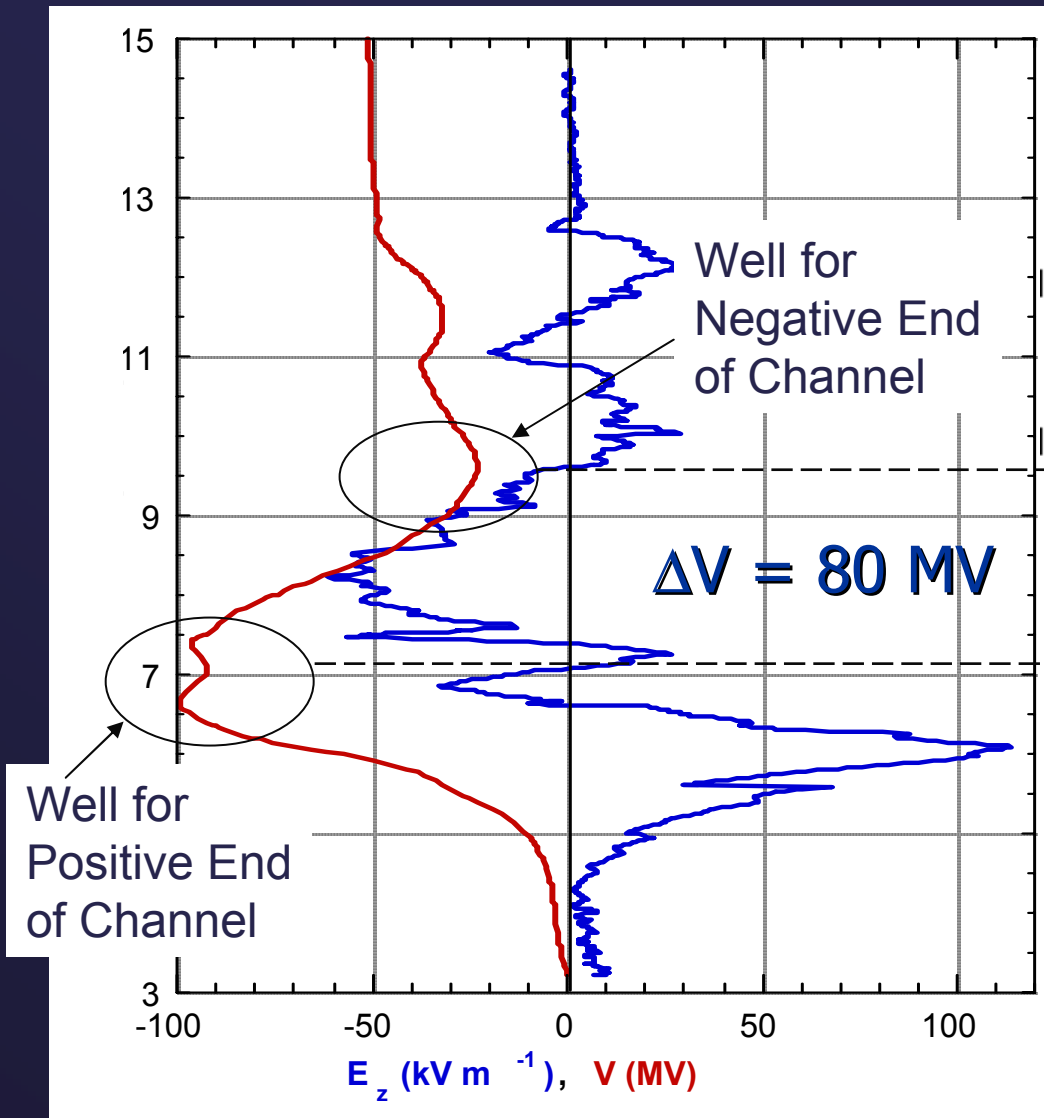
July 31, 1999  
Flight 4 (2247-2313 UT)



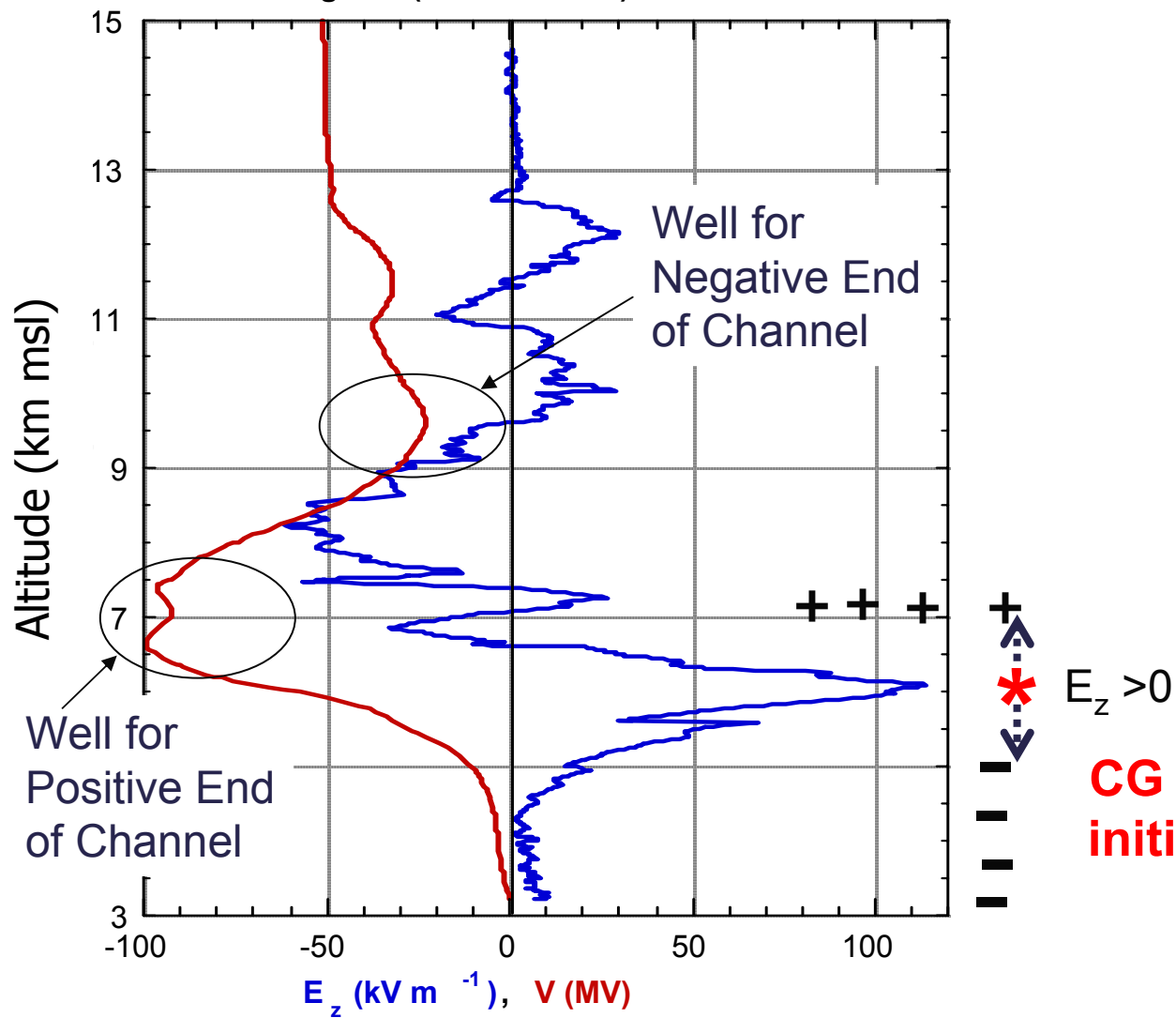
July 31, 1999  
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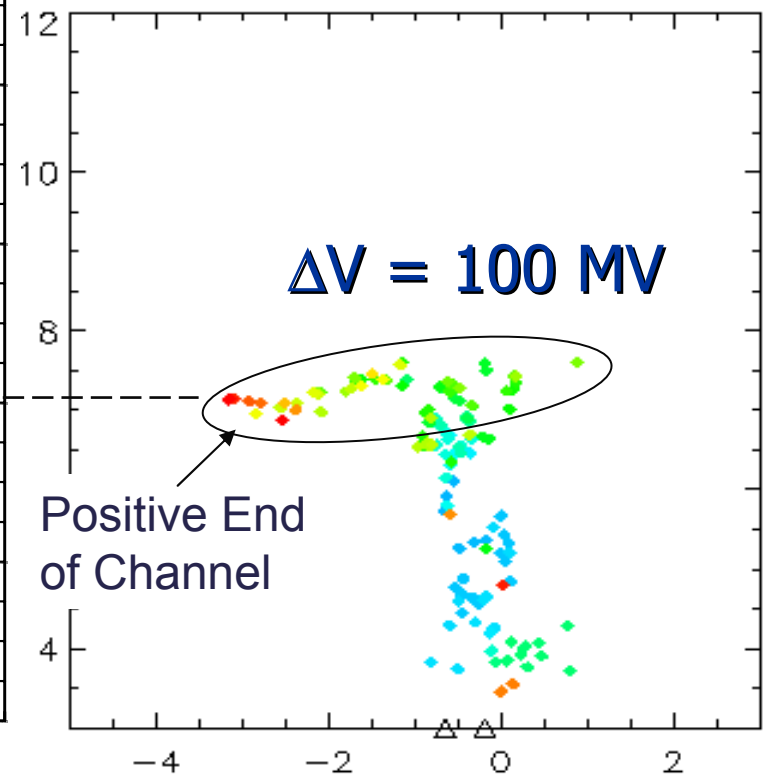
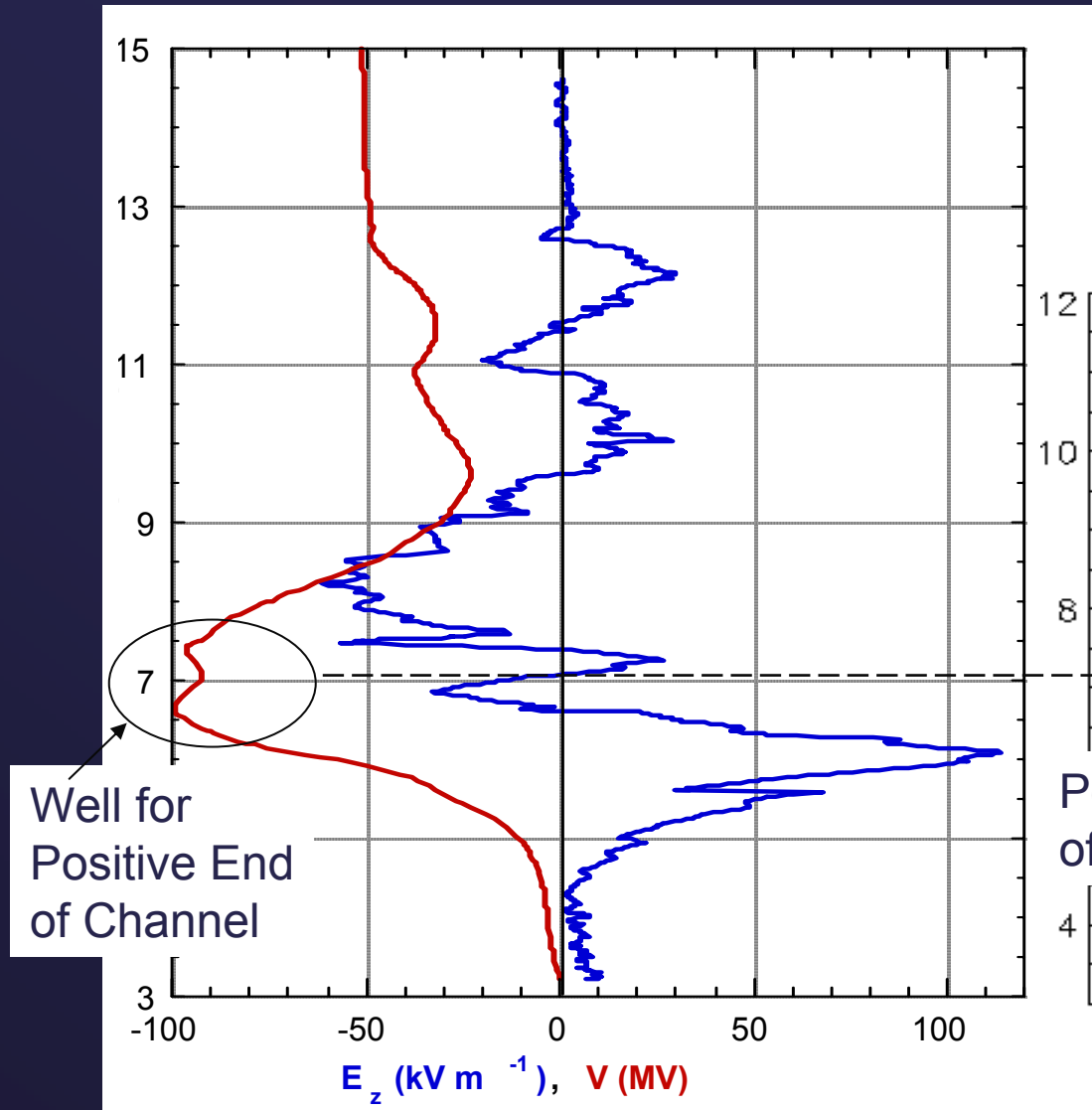
# IC Flash & Potential Wells



July 31, 1999  
Flight 4 (2247-2313 UT)

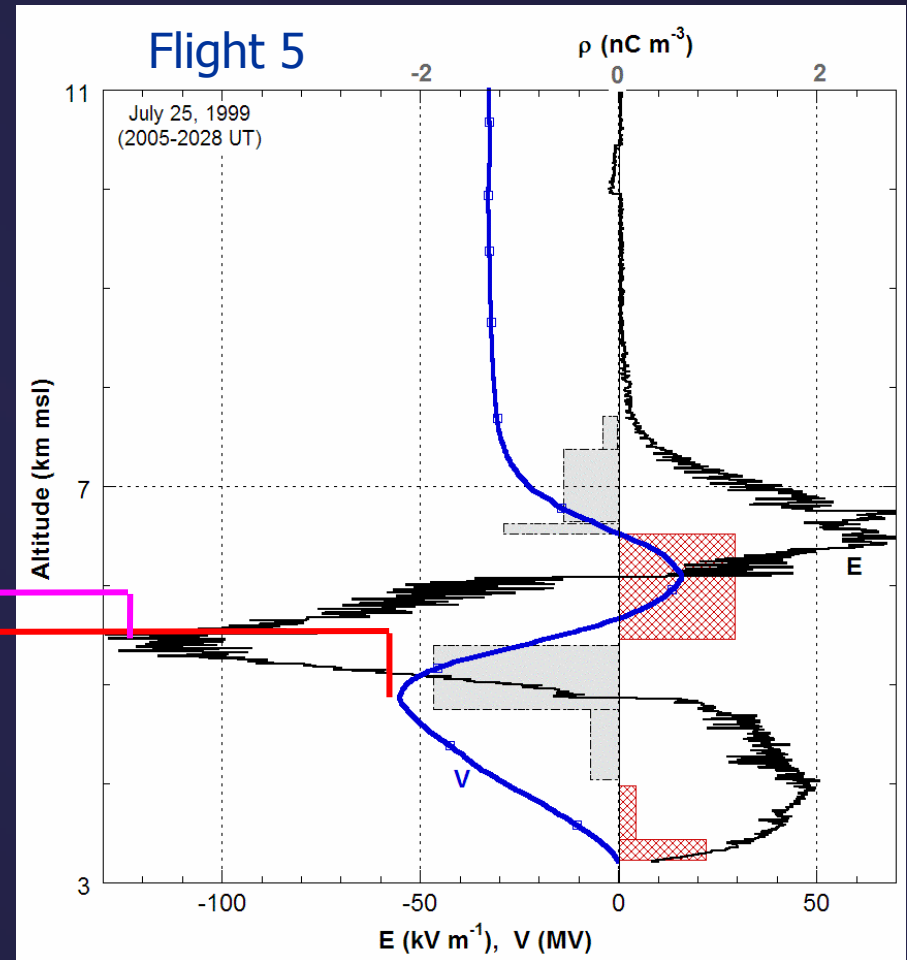
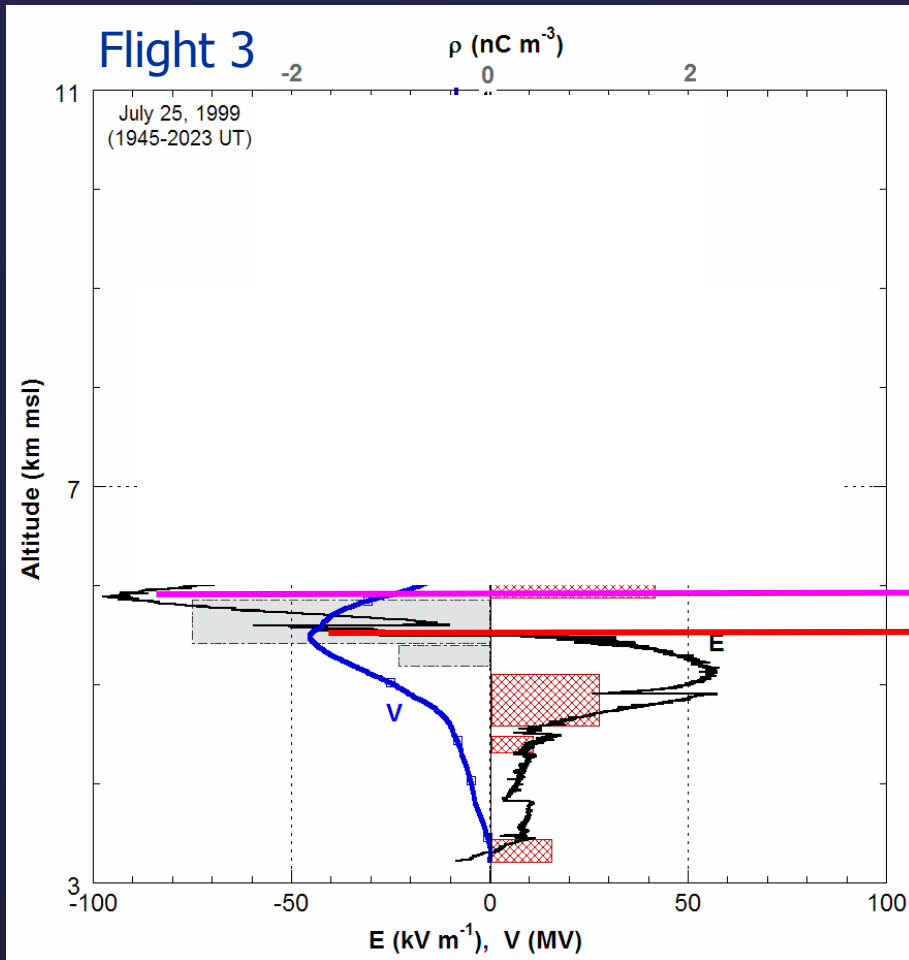


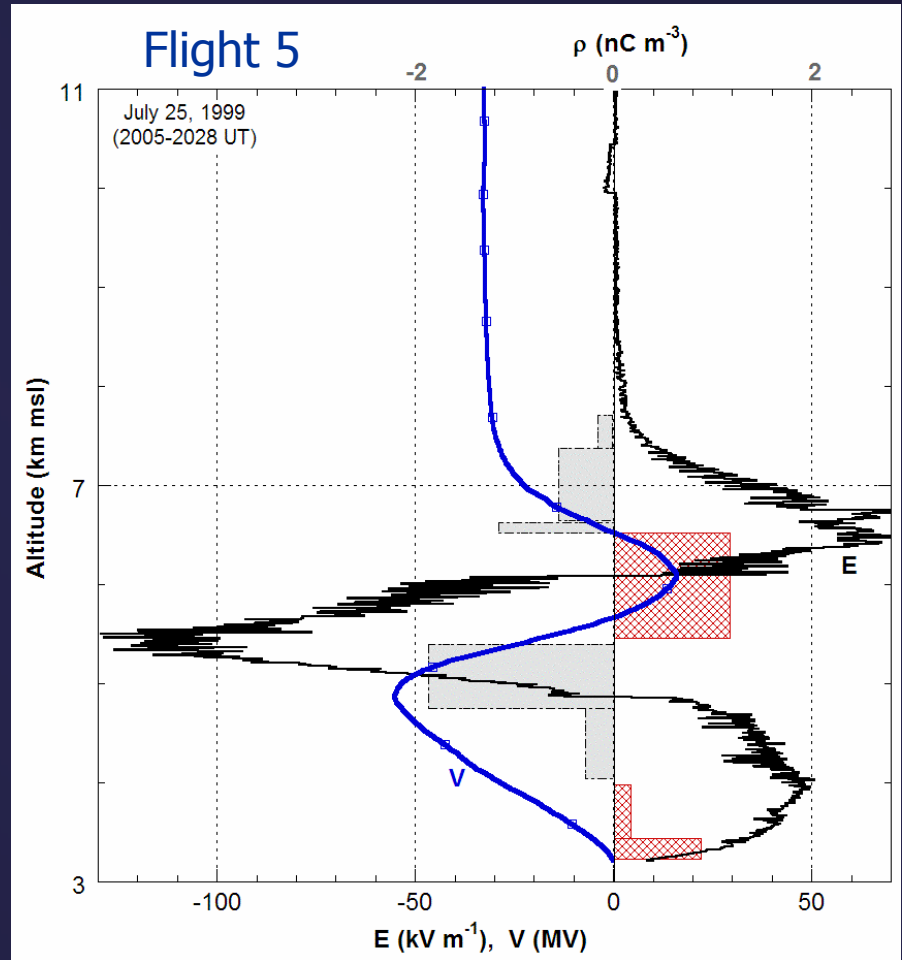
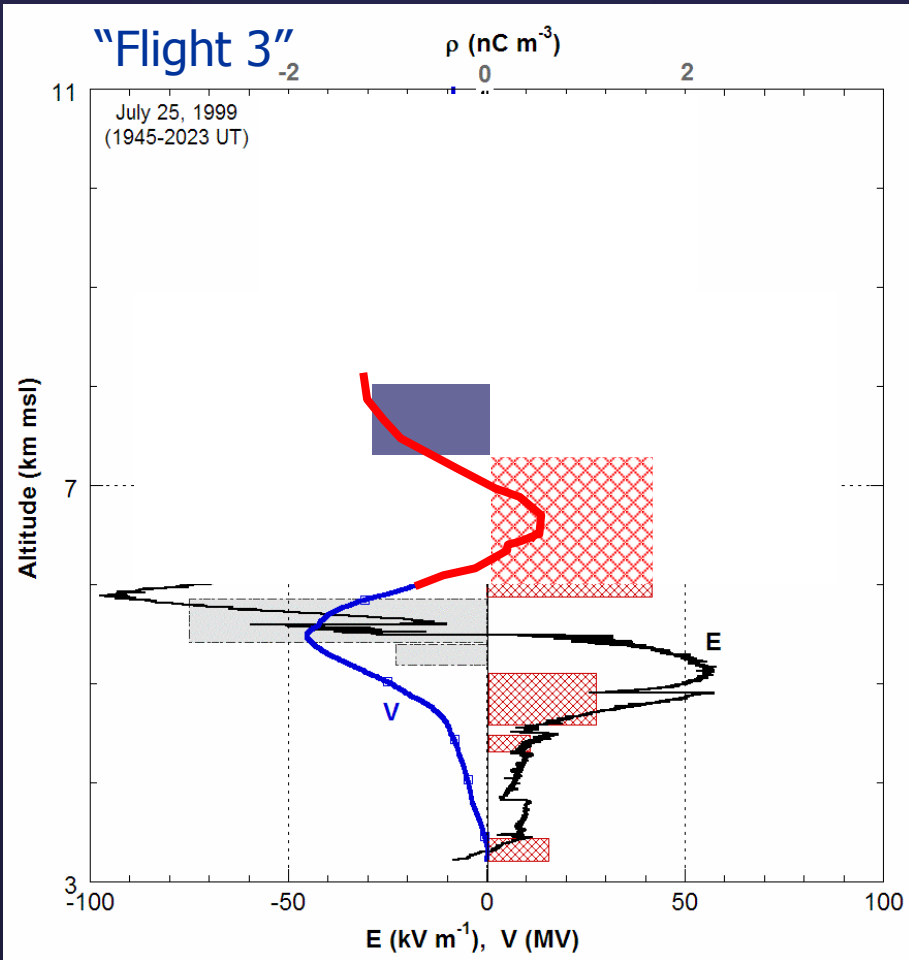
# CG Flash & Potential Wells

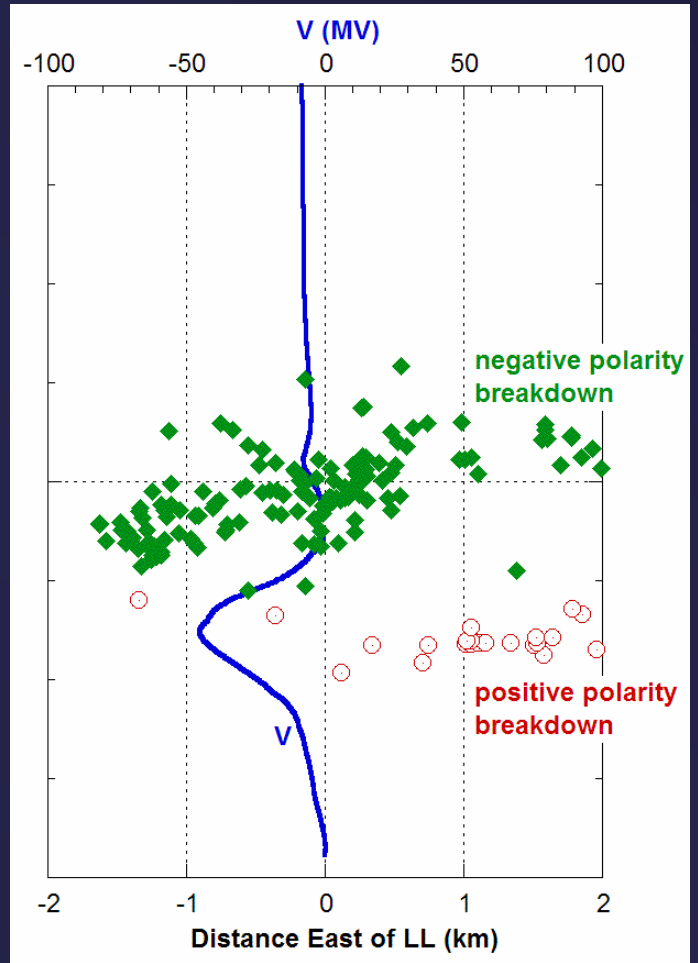
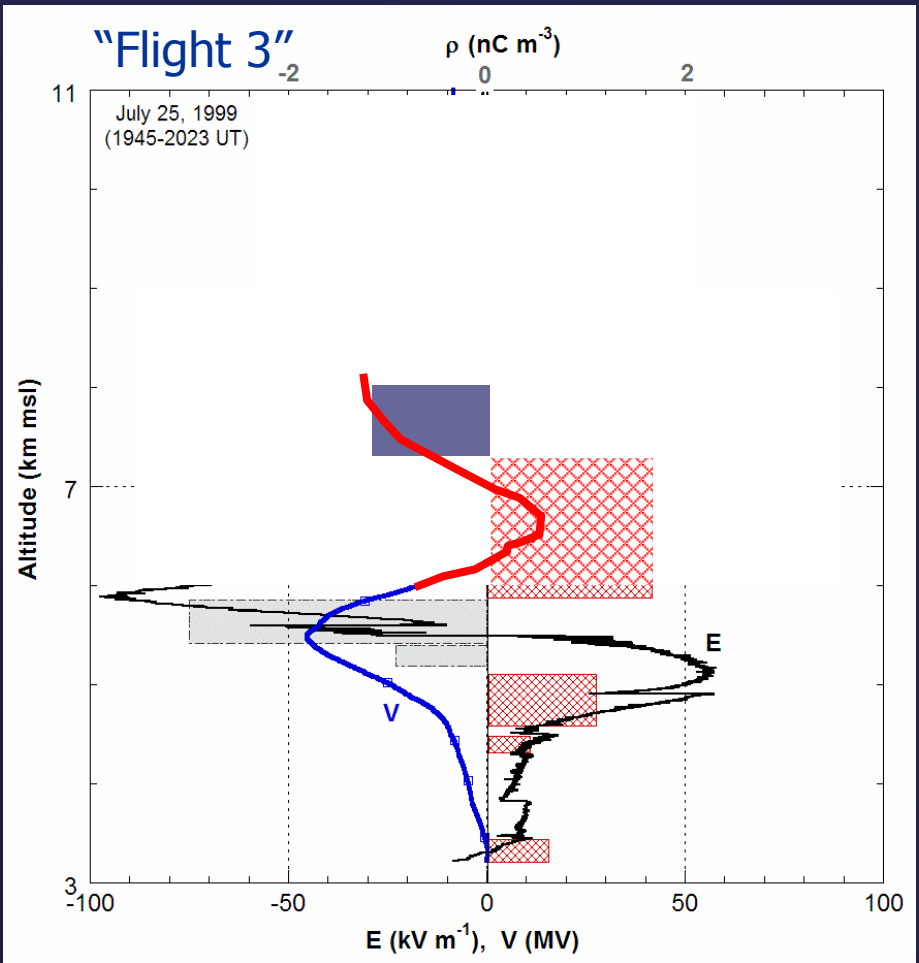




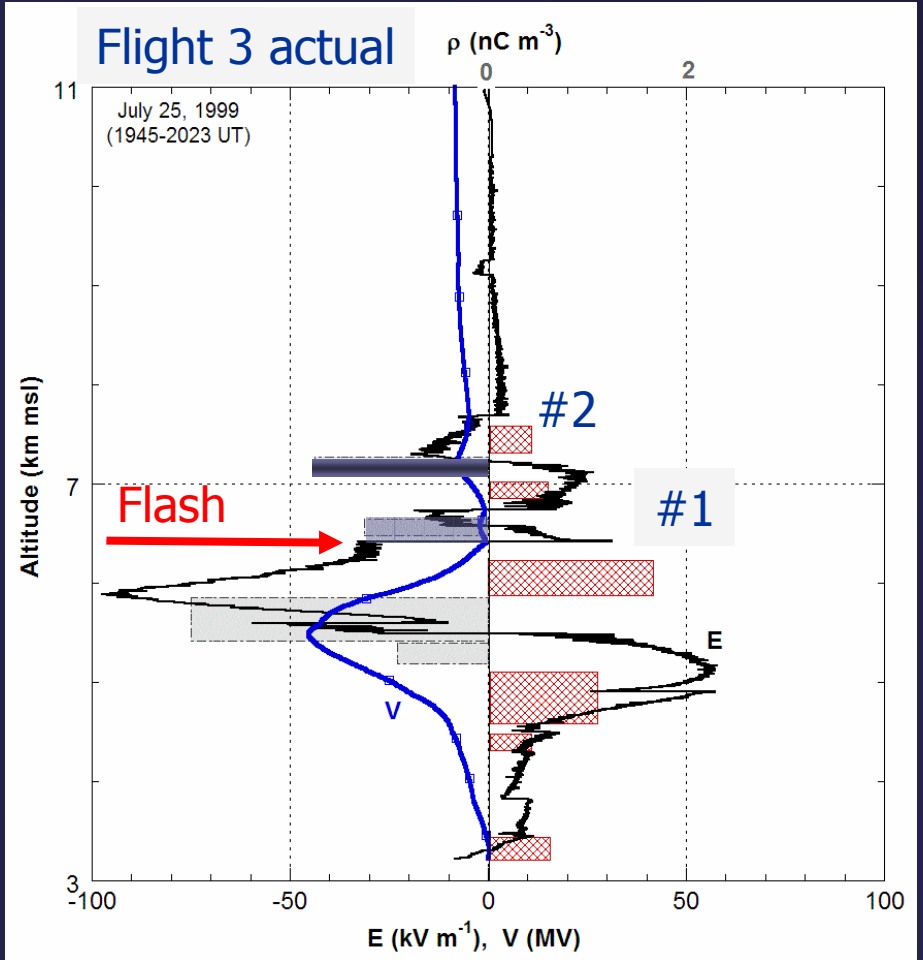
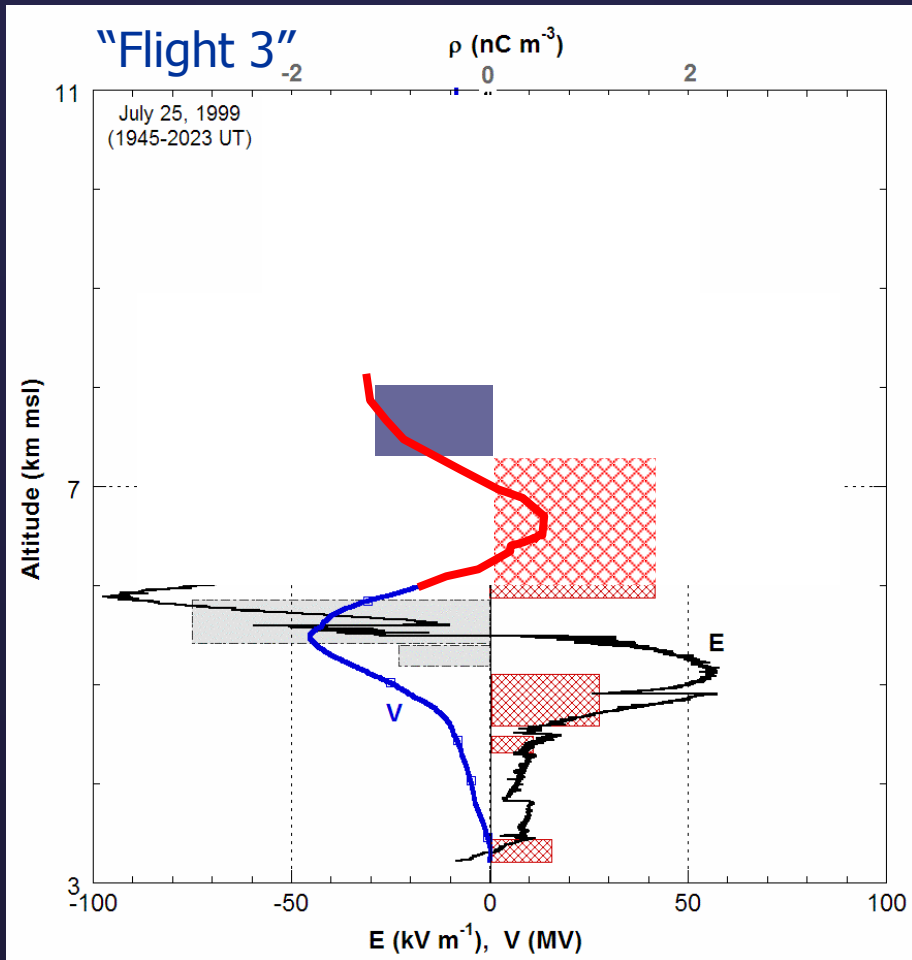
Similar voltage and charge regions, except they are *higher in the earlier flight.*



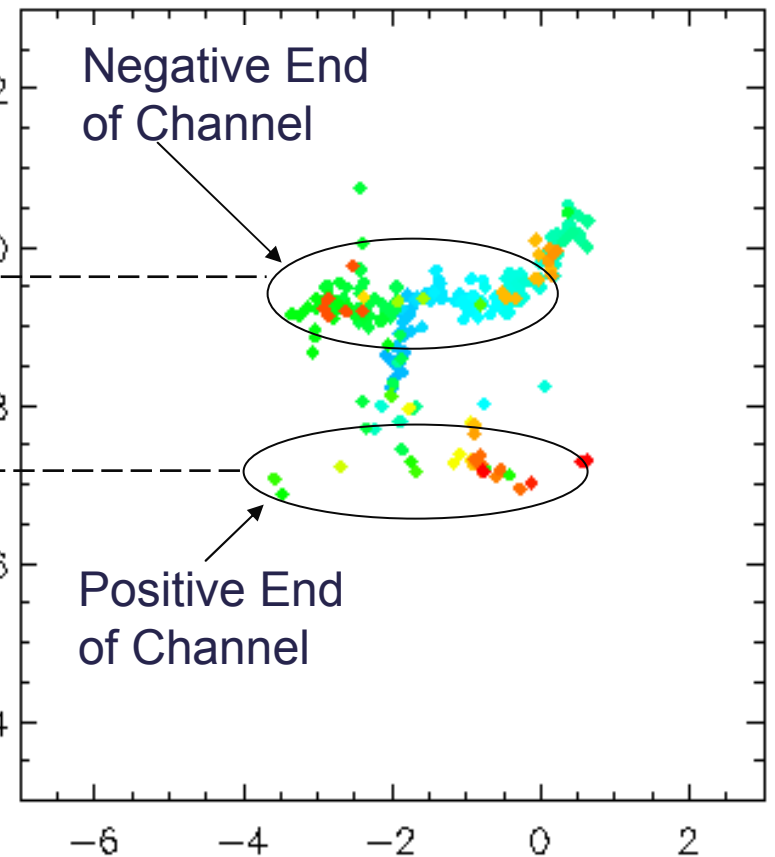
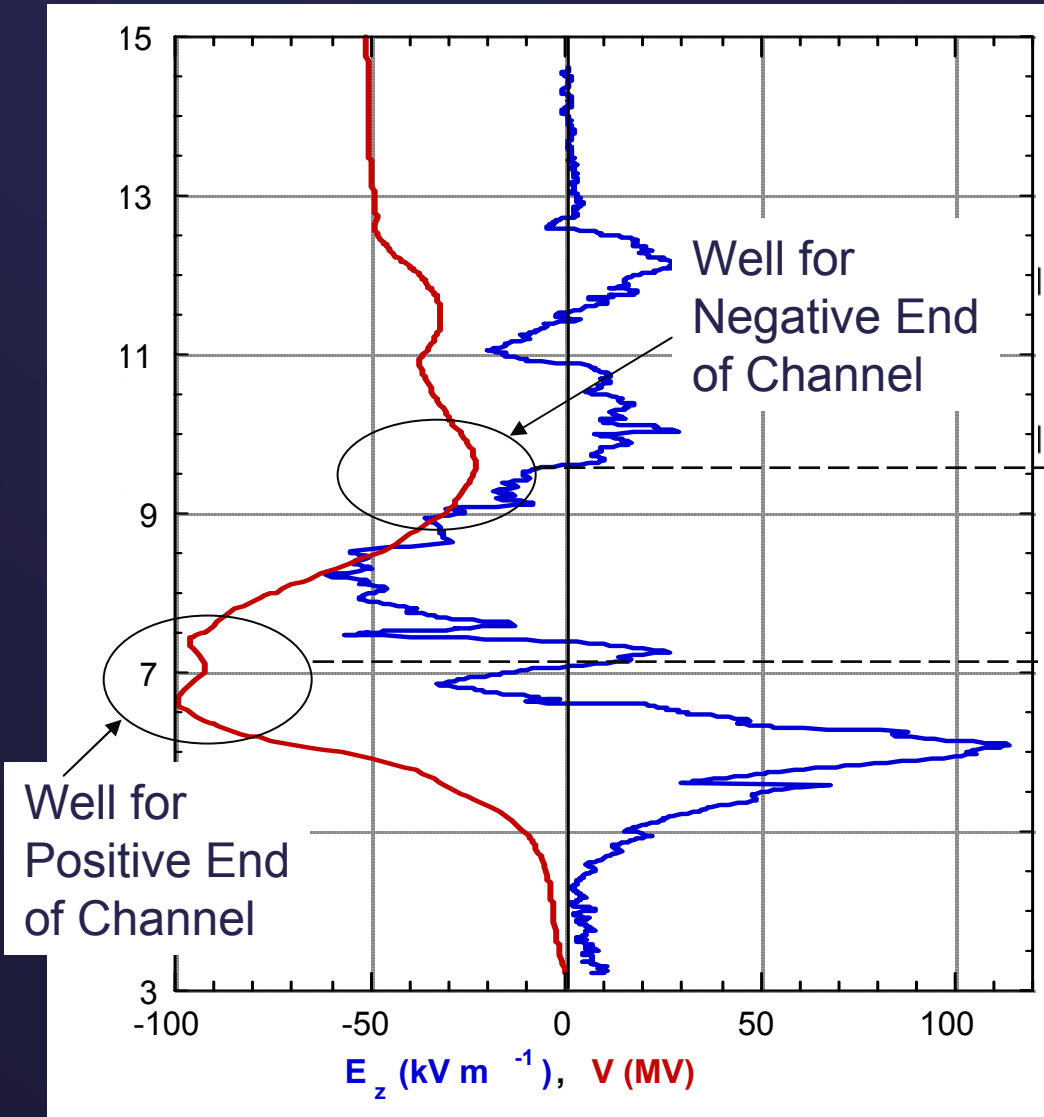




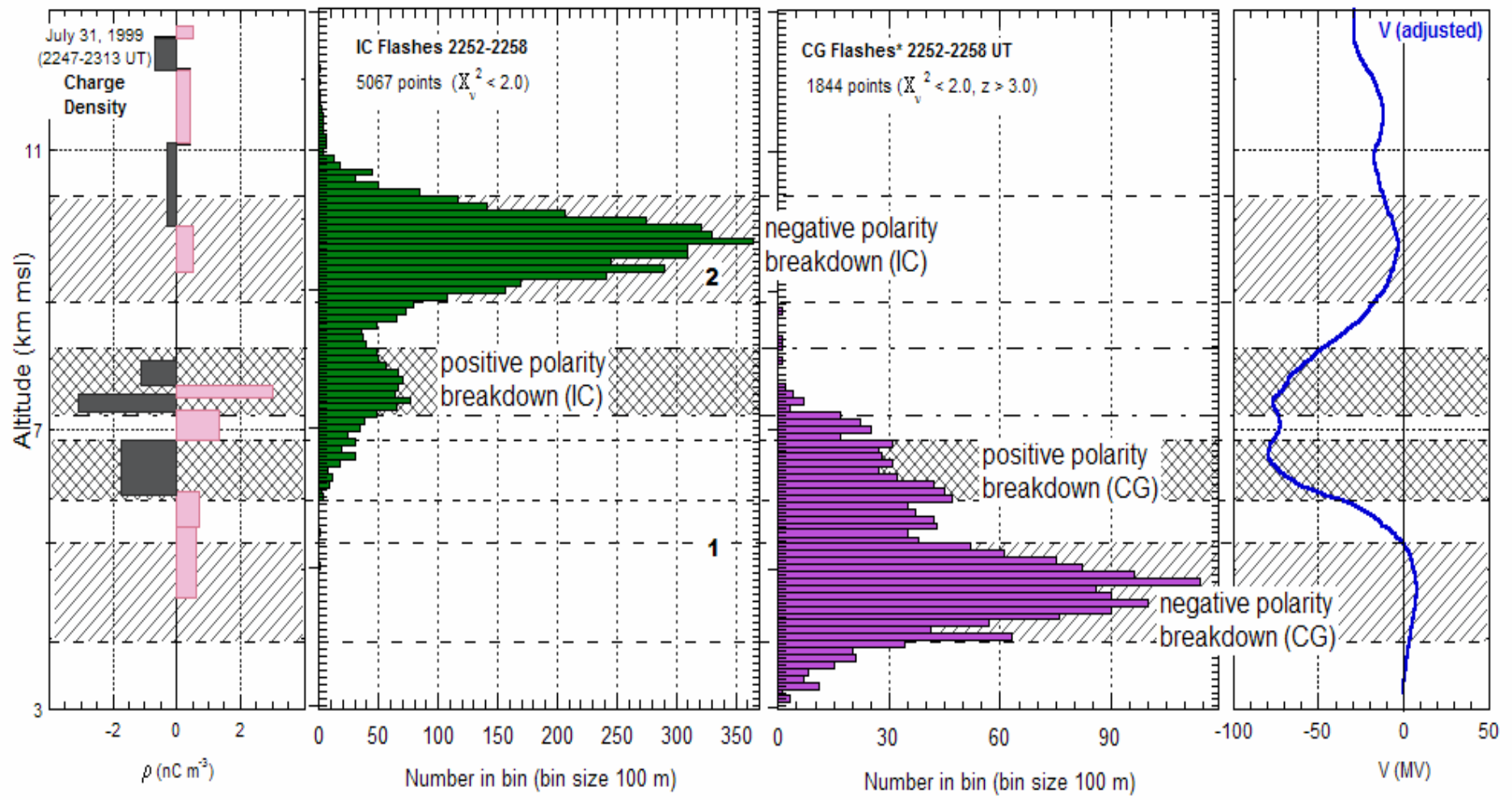
# The deposited charge altered the charge structure in two ways.



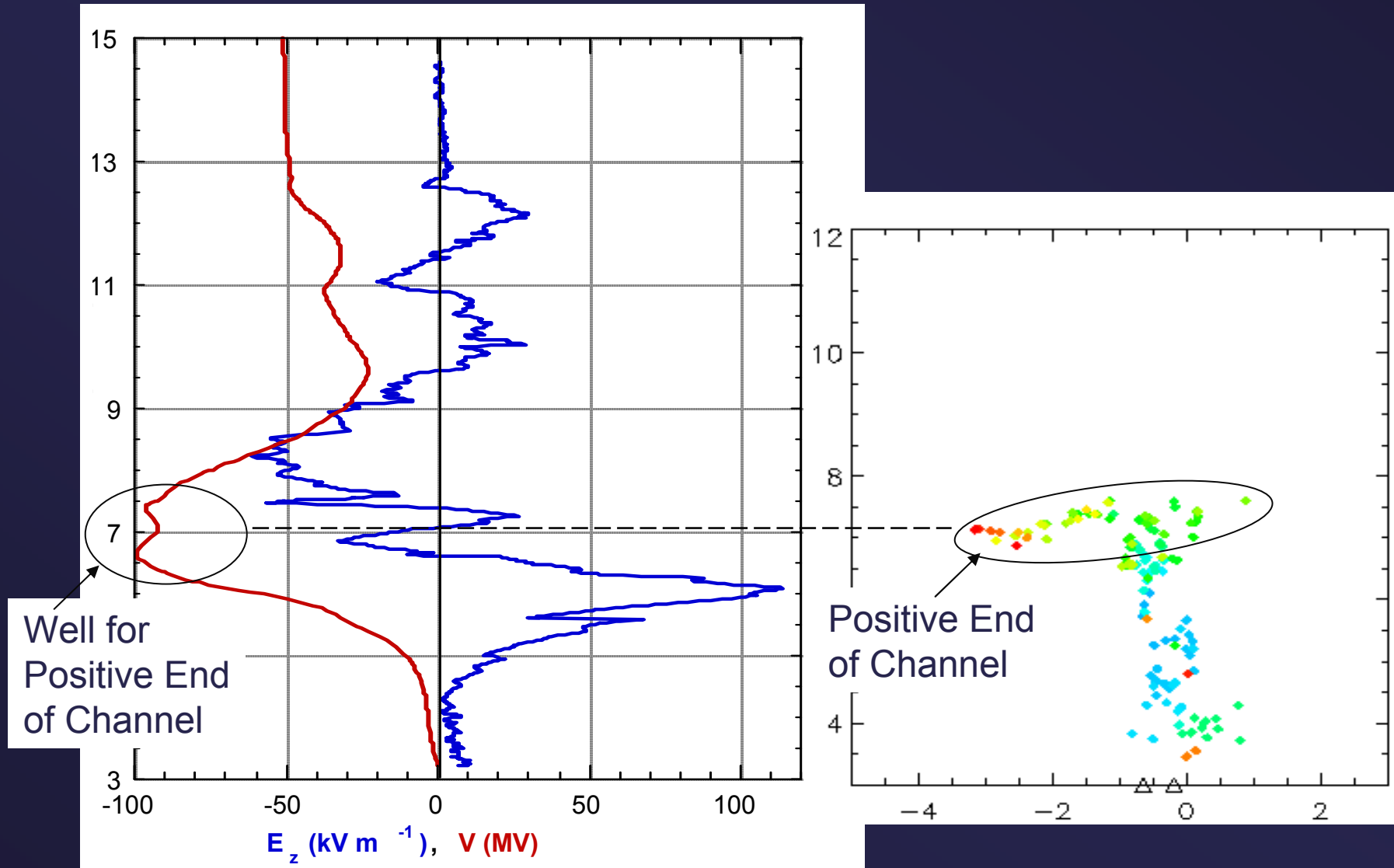
# IC Flash



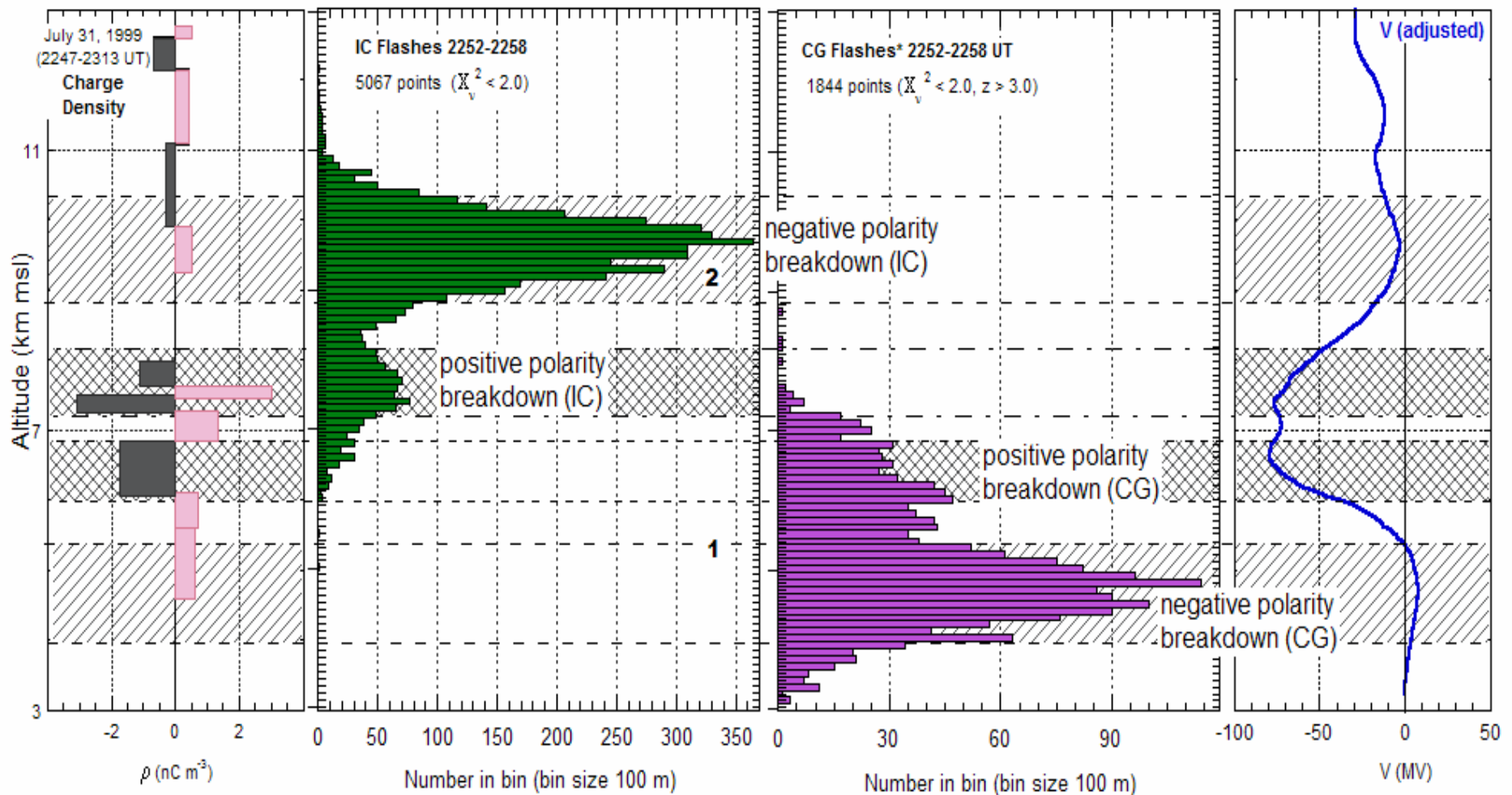
# Lightning charge deposition from 6 minutes of flashes (27 IC and 9 CG flashes)



# CG Flash



# Lightning charge deposition from 6 minutes of flashes (27 IC and 9 CG flashes)



## Conclusions

- Lightning deposits charge along horizontal branches.
- The horizontal branches travel at the altitudes of potential wells, and within the substantial, opposite polarity, cloud charge regions.
- Lightning charge deposition tends to make the charge structure in the cloud more complex in at least two ways.
- Overall, the findings suggest that lightning charge deposition should be greatest for horizontal branches in potential wells because these depositions are favored by energy considerations.