Integrating Multistation Radio and Electric Field Measurements to Understand Lightning

APS 4Corners 10/15/2010

Abstract D4.00003 (3:54 pm)

Richard Sonnenfeld

Physics Department &
Langmuir Laboratory for Atmospheric Physics
New Mexico Institute of Mining and Technology

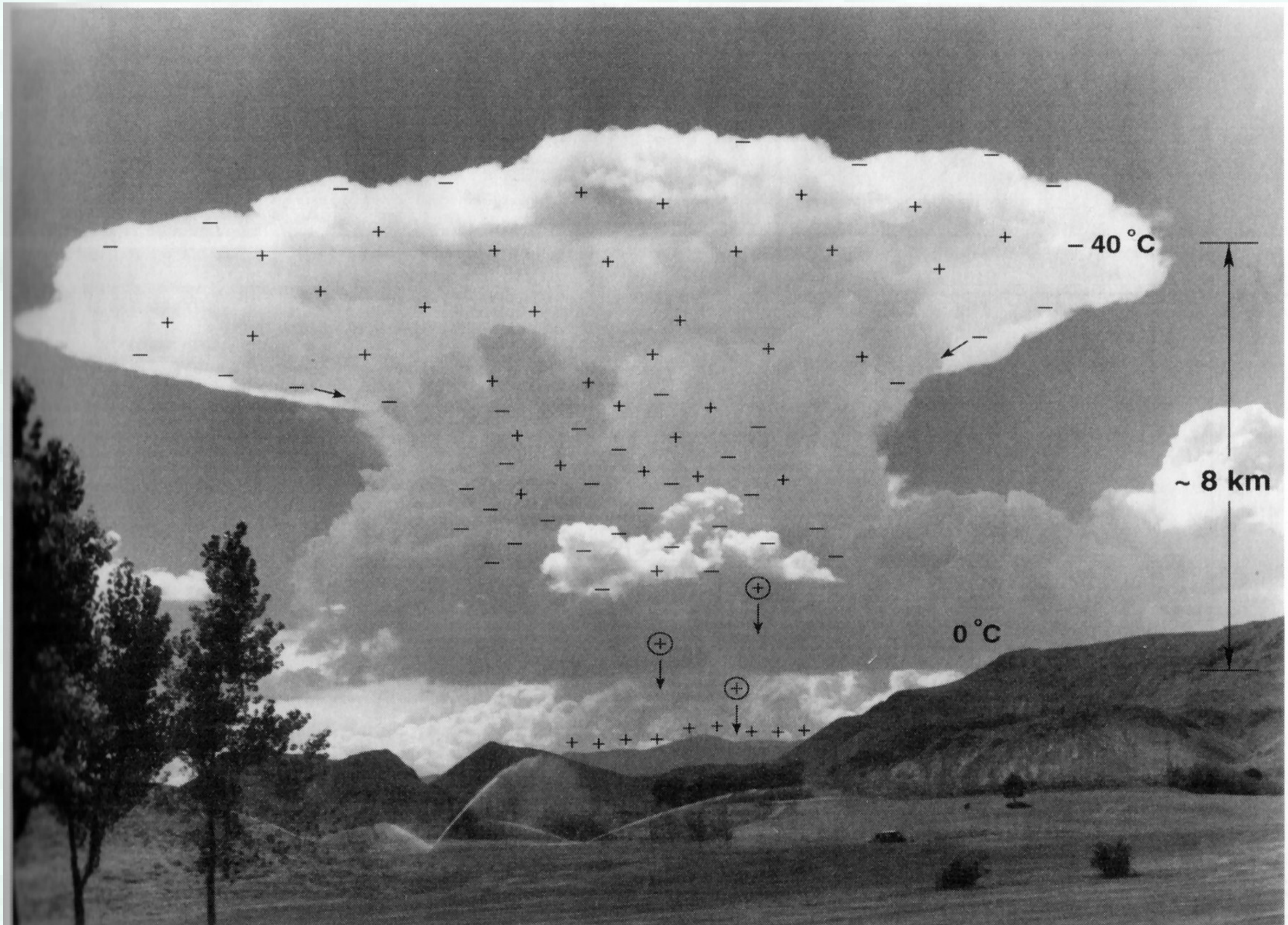
(Photo courtesy of Harald Edens)

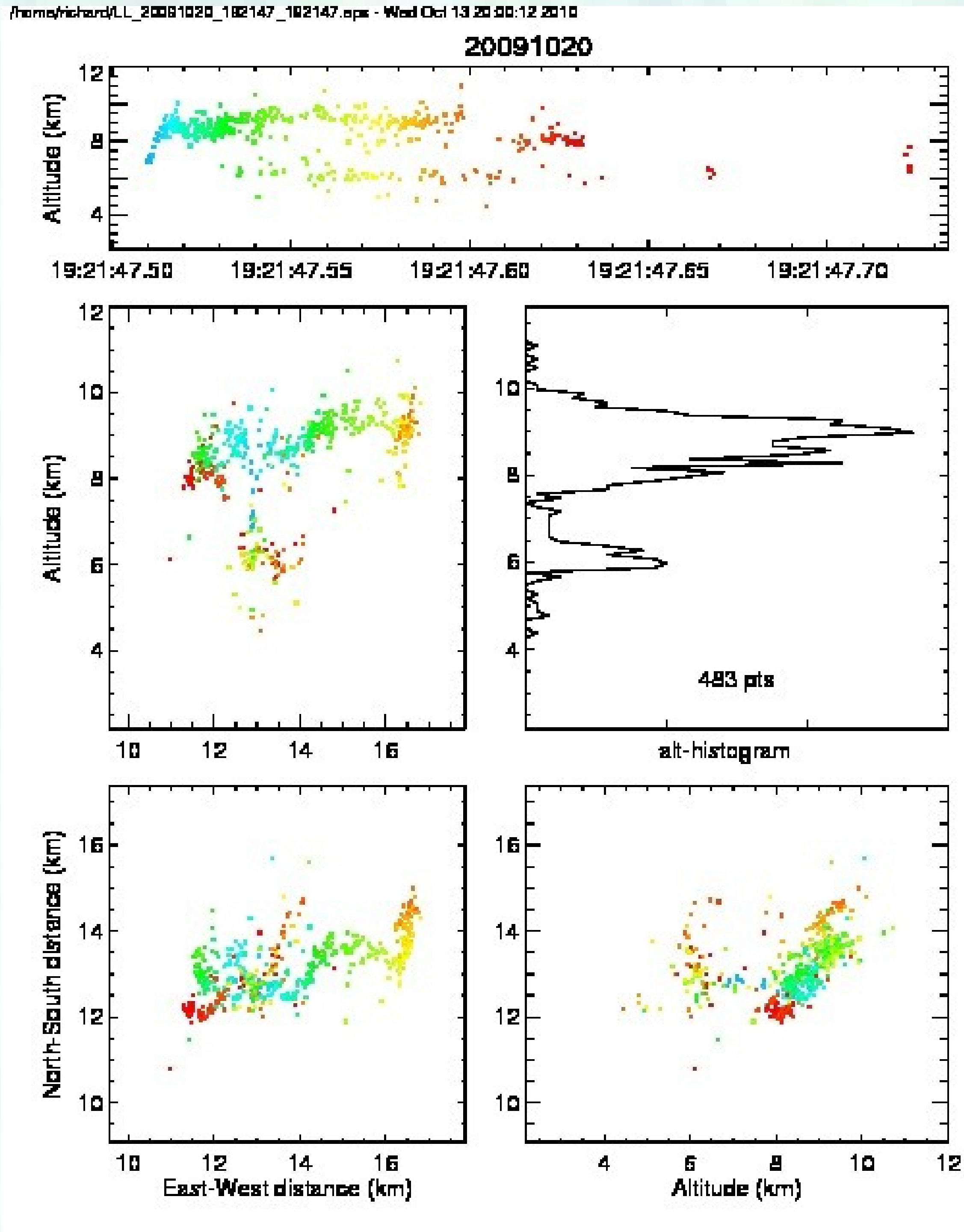
Understanding lightning

- Lightning moves coulombs across kilometers
  - causing electric field-changes of tens of kilovolts/meter
  - and rich (but complex) electric field structure
- The breakdown of air by negative leaders results in radio pulses which can be located by time of arrival techniques.
- Charge moves mostly AFTER the air breaks down.
  - Use RF emissions to see where the channel is. Use E-field measurements to see where the charge goes.

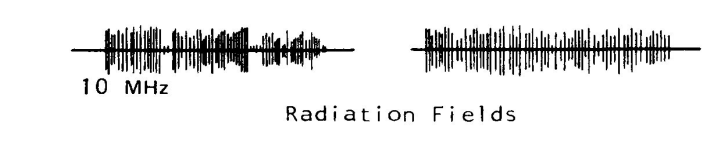
Charging is caused by freezing

-Q at 5-7 km   +Q at 8-10 km





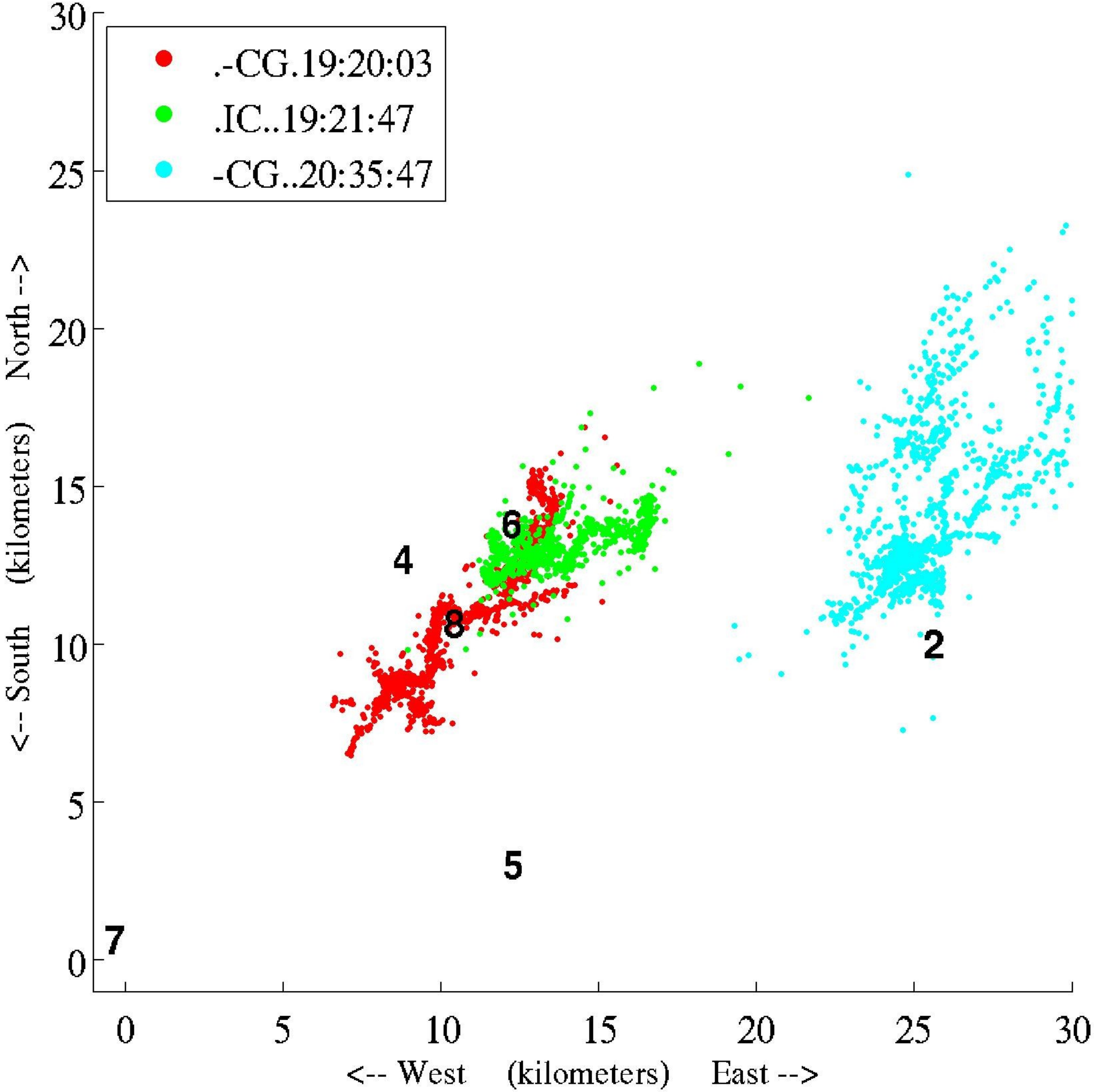
New Mexico Tech Lightning Mapping Array (LMA)

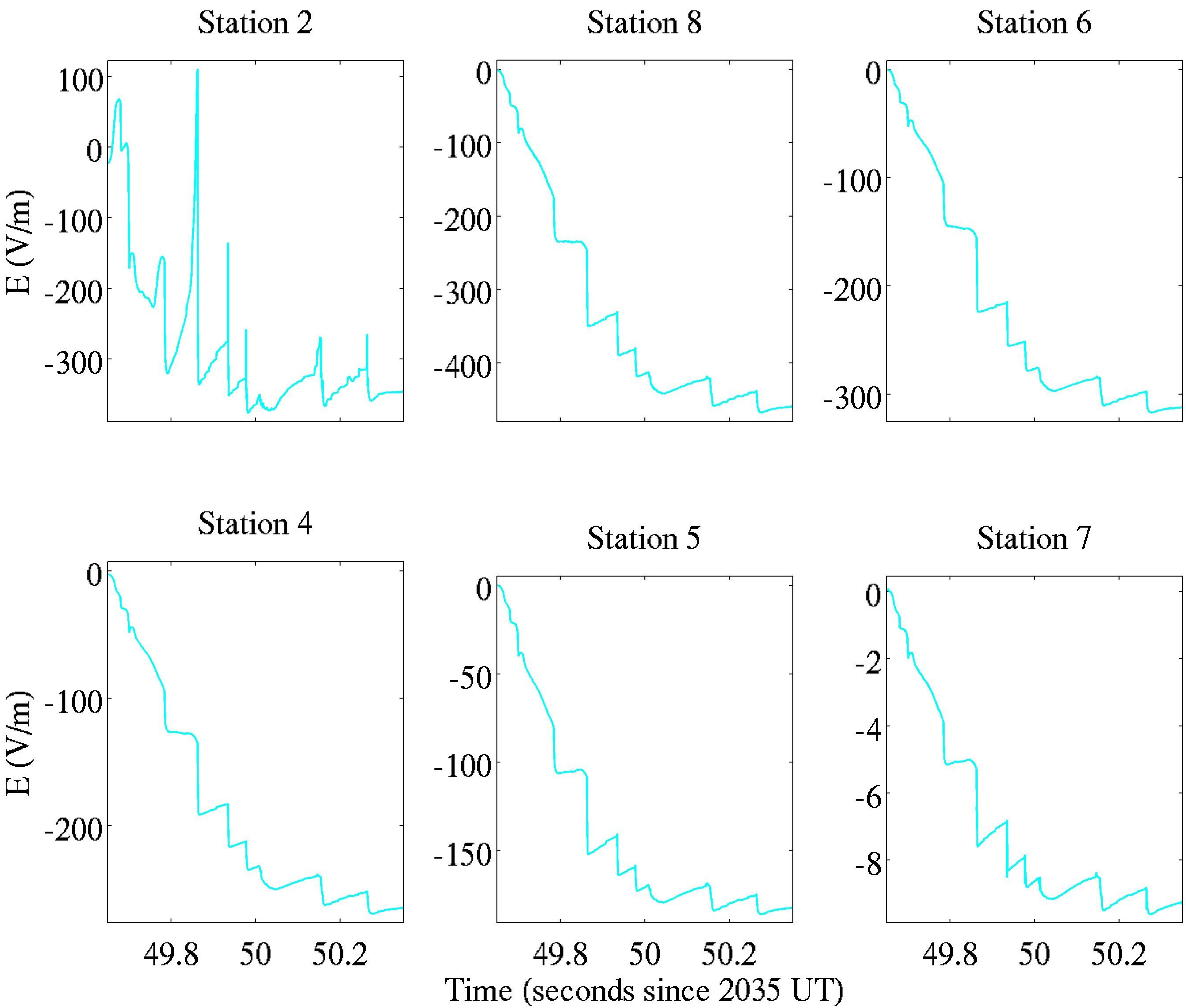


- Uses a network of 12 television receivers tuned to 66 MHz.

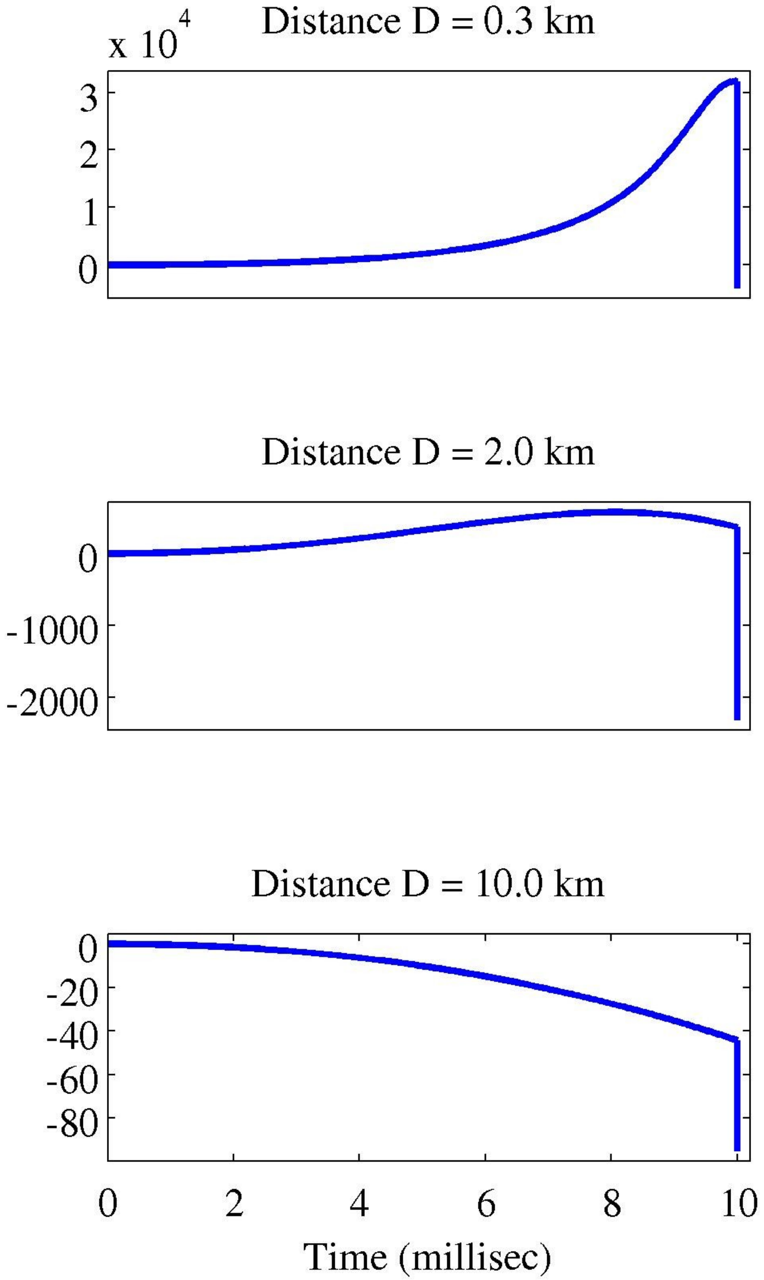
- Shows the charge layers

Flashes and Station Locations

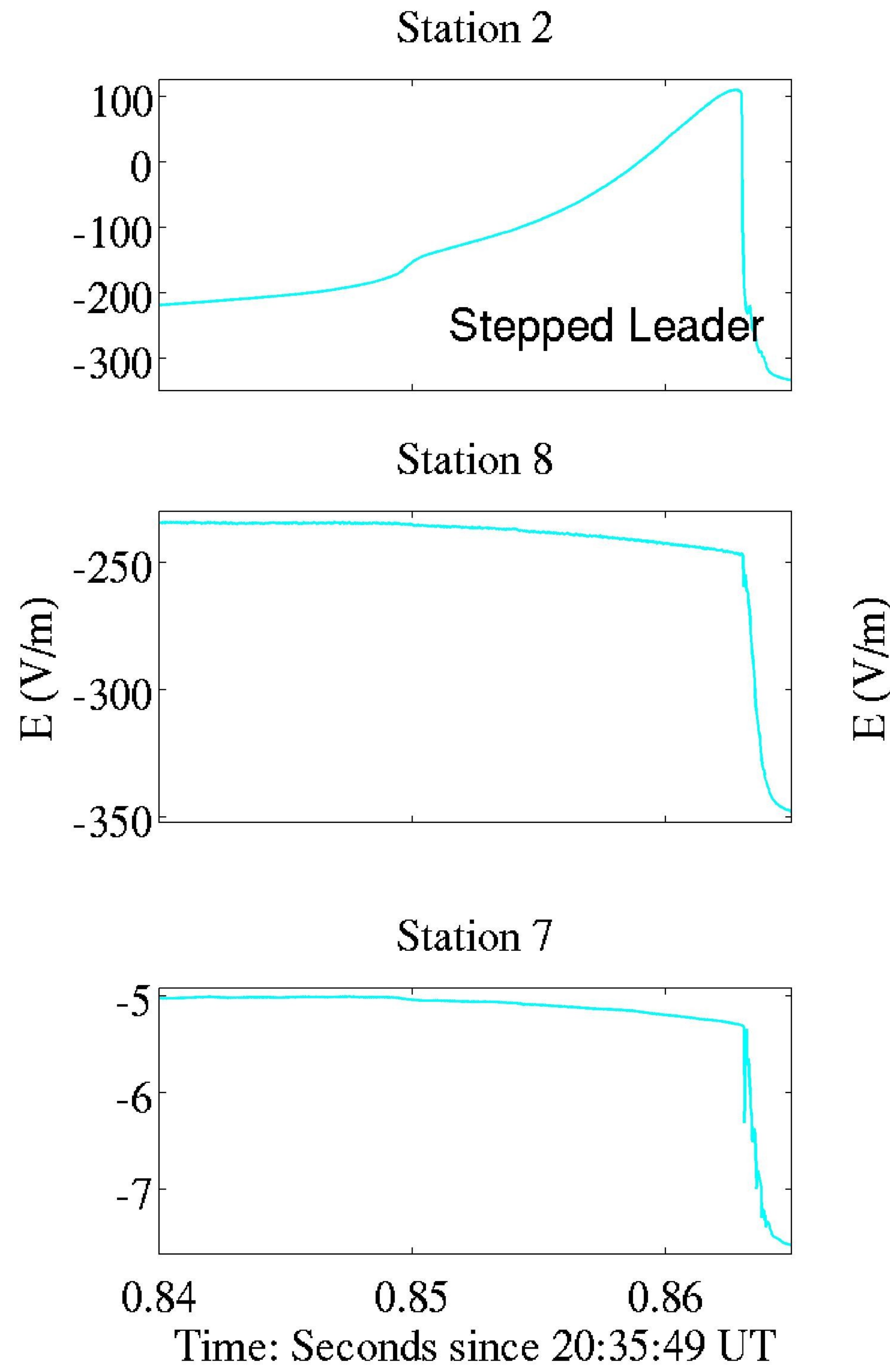



Station 2
Station 8
Station 6
Station 4
Station 5
Station 7
E (V/m)
E (V/m)
100
0
-100
-200
-300
-400
-50
-150
-2
-4
-6
-8
49.8
50
50.2
Time (seconds since 2035 UT)

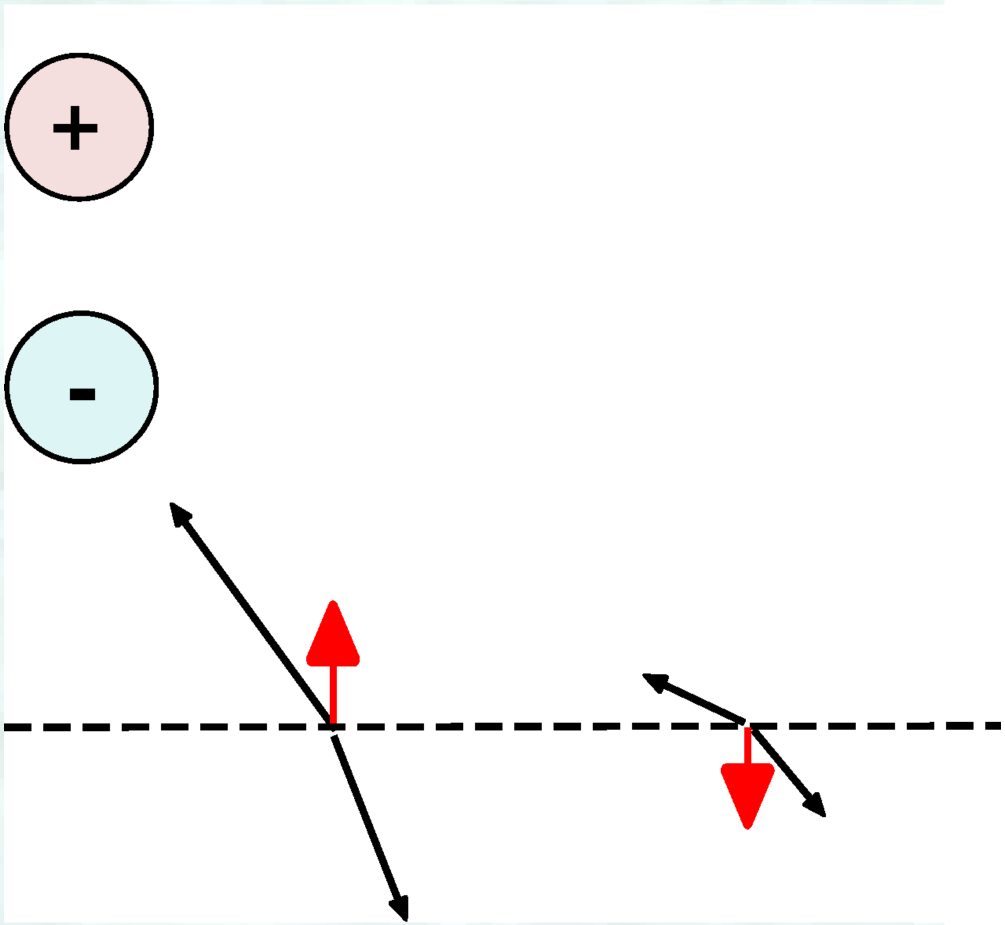
C

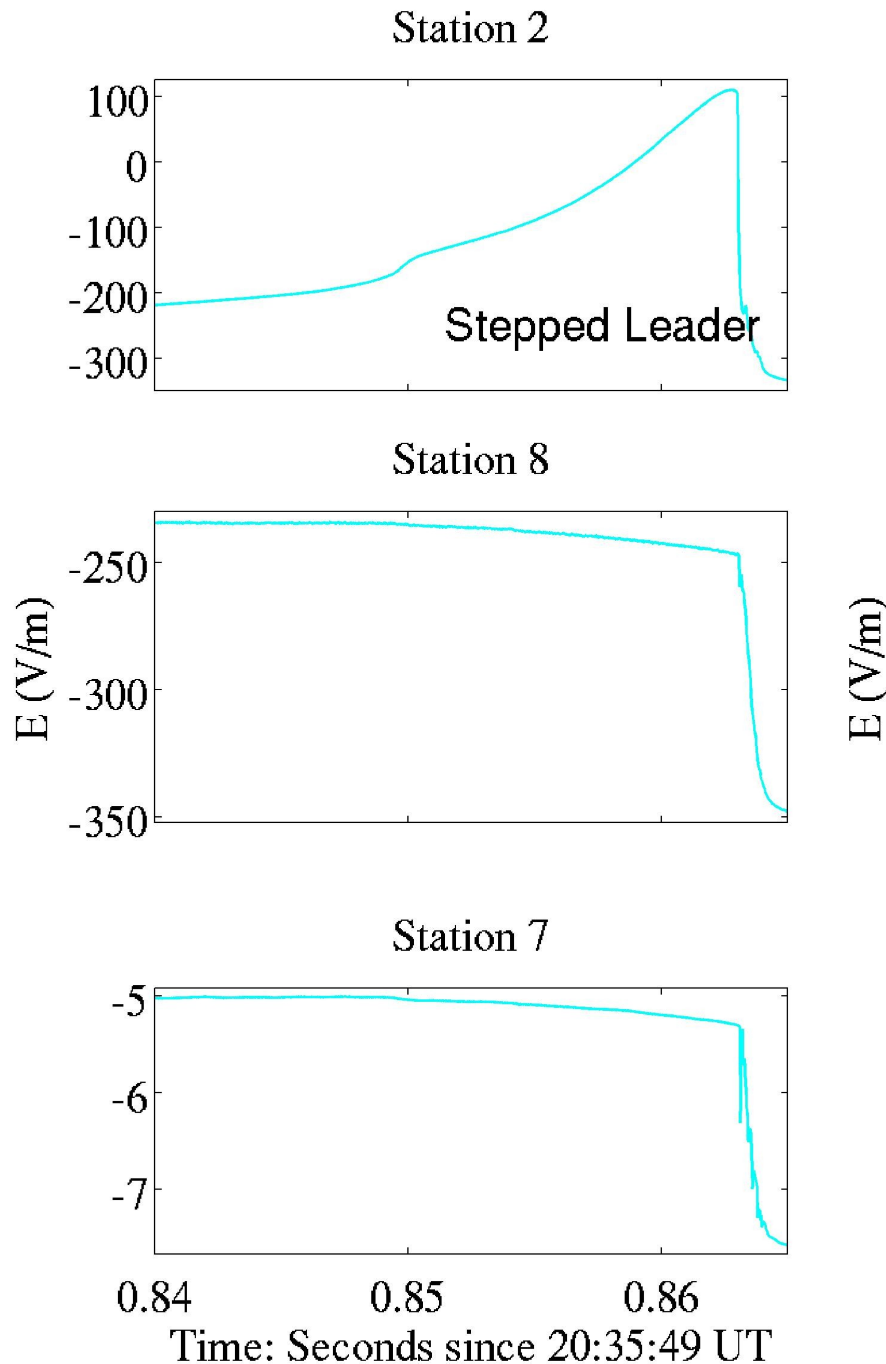


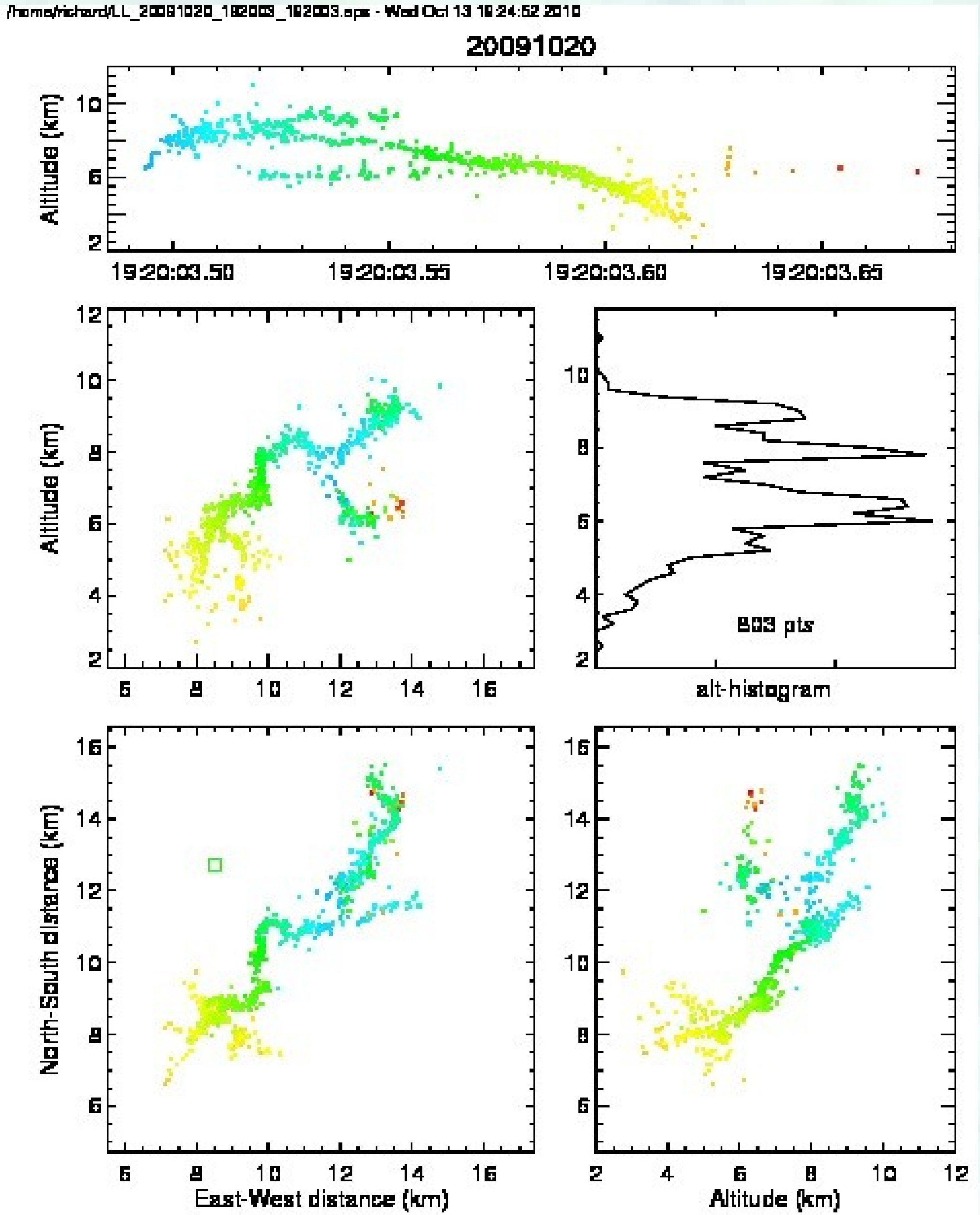
Distance D = 0.3 km
x 10^4
3
2
1
0
Distance D = 2.0 km
0
-1000
-2000
Distance D = 10.0 km
0
-20
-40
-60
-80
0
2
4
6
8
10
Time (millisec)



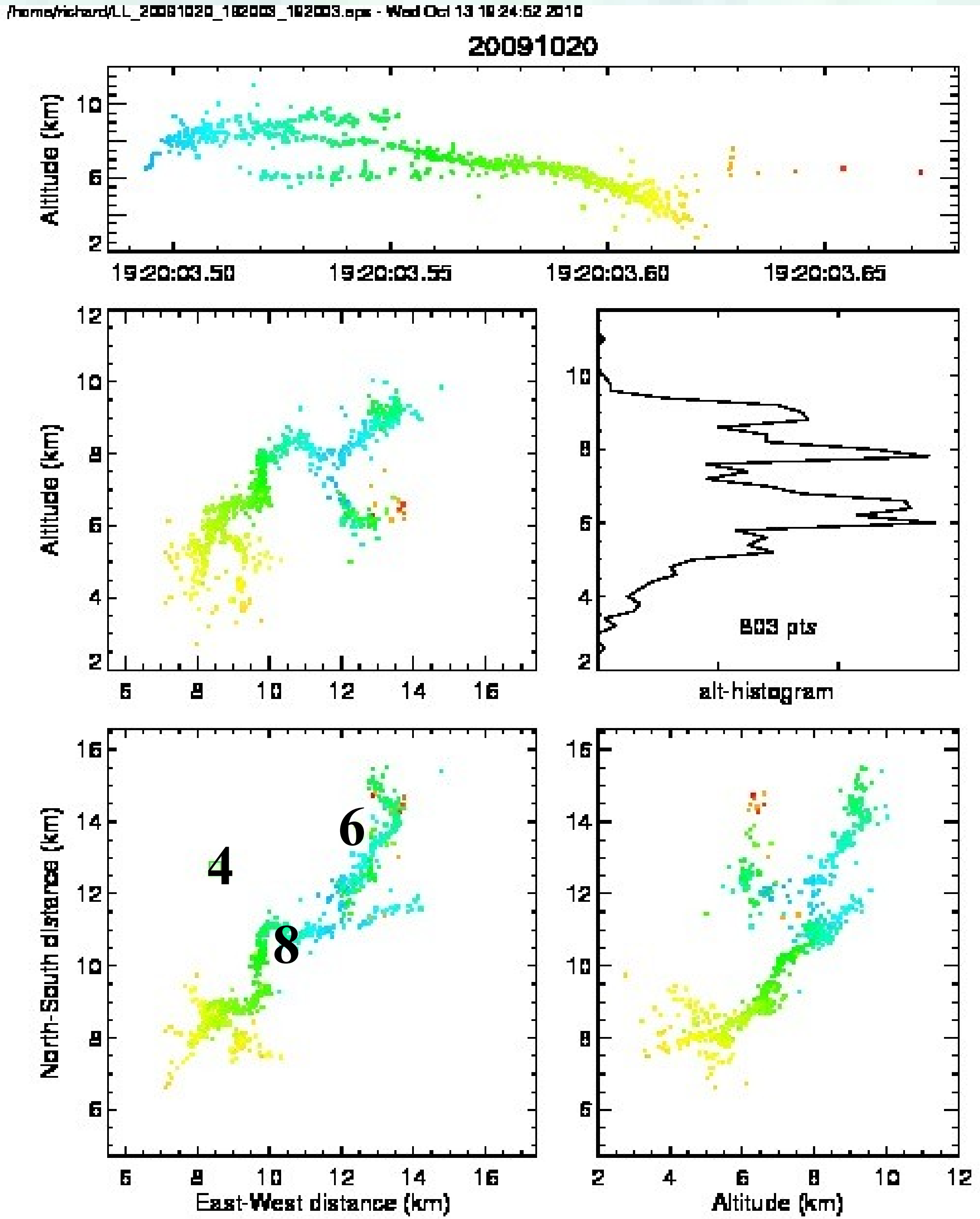
Station 2
100
0
-100
-200
-300
Stepped Leader
Station 8
-250
-300
-350
E (V/m)
Station 7
-5
-6
-7
0.84
0.85
0.86
Time: Seconds since 20:35:49 UT
E (V/m)


+
-


Station 2
100
0
-100
-200
-300
Stepped Leader
Station 8
-250
-300
-350
E (V/m)
Station 7
-5
-6
-7
E (V/m)
0.84
0.85
0.86
Time: Seconds since 20:35:49 UT

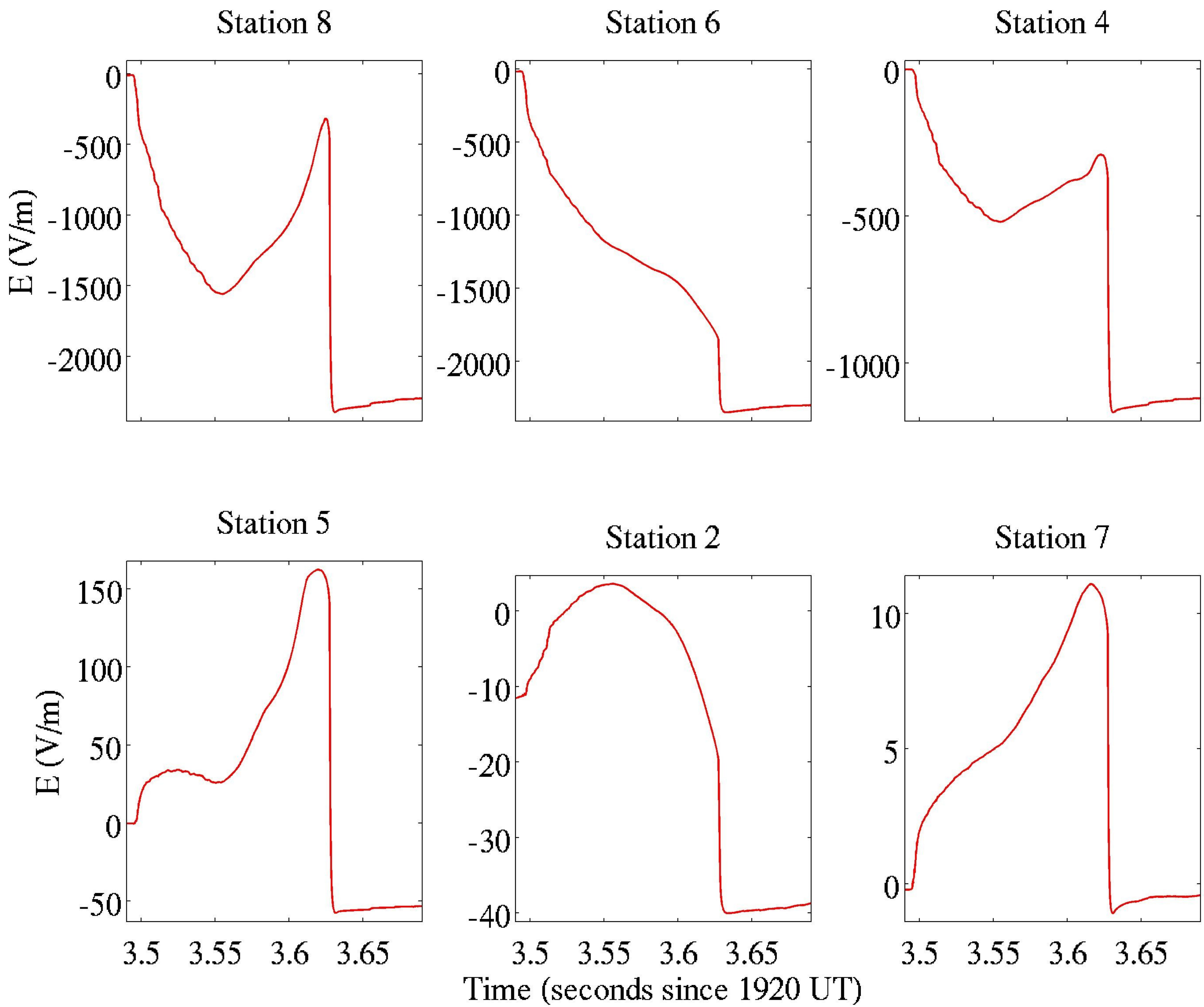


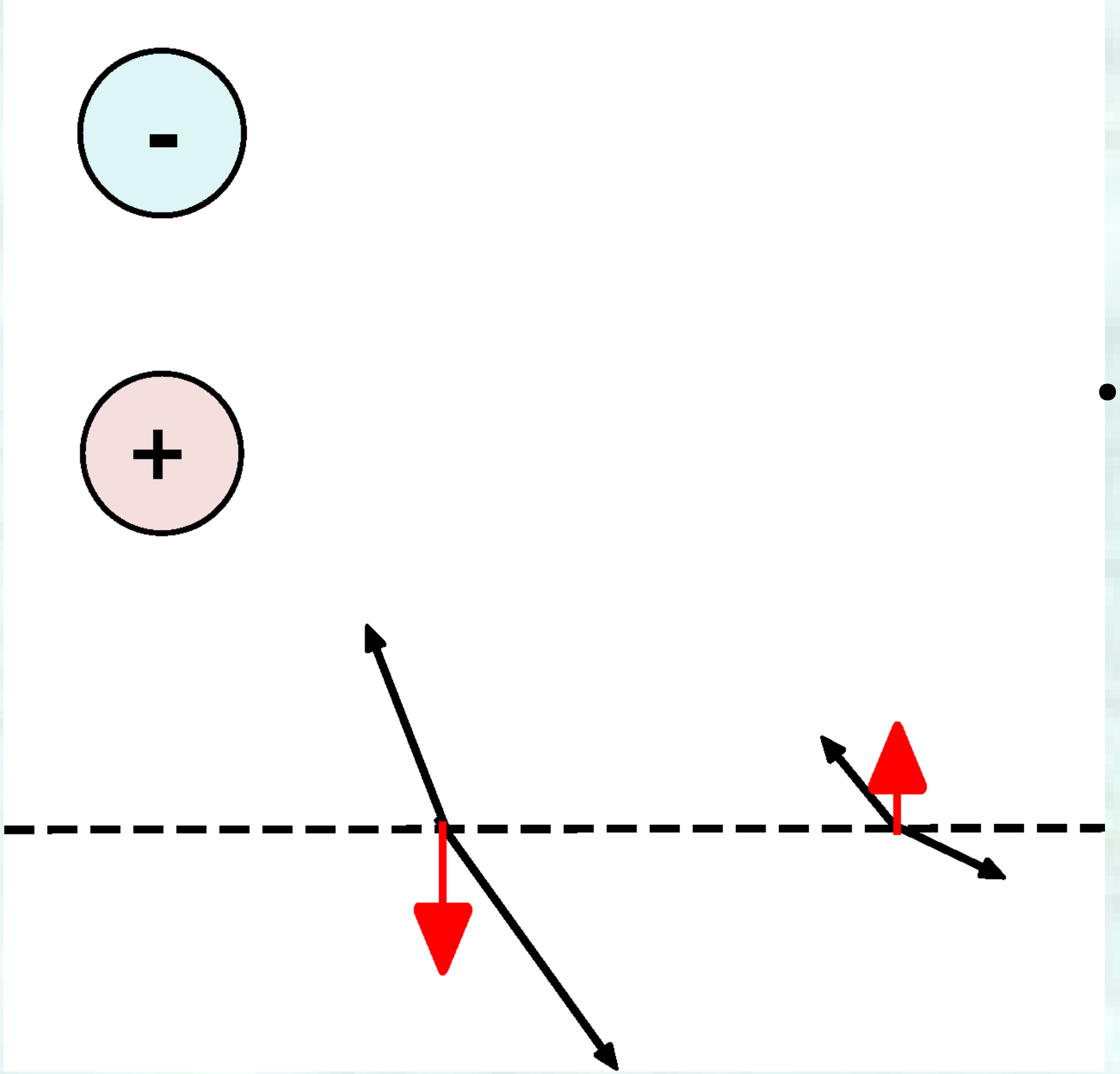
/home/richard/LL_20091020_192003_192003.eps - Wed Oct 13 19:24:52 2010
20091020
Altitude (km)
19:20:03.50
19:20:03.55
19:20:03.60
19:20:03.65
Altitude (km)
803 pts
alt-histogram
North-South distance (km)
East-West distance (km)
Altitude (km)



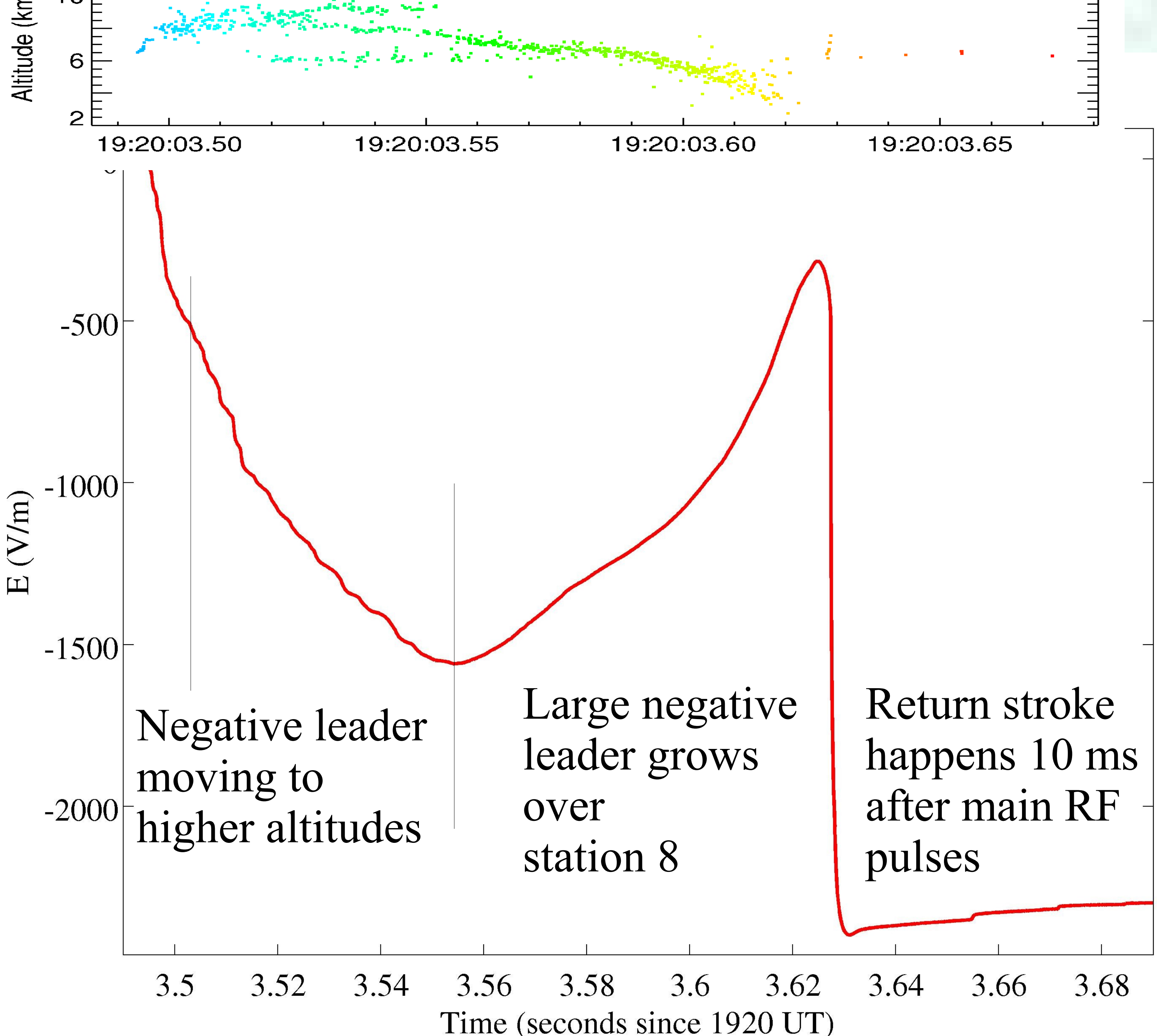
/home/richard/LL_20091020_192003_192003.eps - Wed Oct 13 19:24:52 2010
20091020
Altitude (km)
19:20:03.50
19:20:03.55
19:20:03.60
19:20:03.65
Altitude (km)
803 pts
alt-histogram
North-South distance (km)
4
6
8
East-West distance (km)
Altitude (km)

Animation

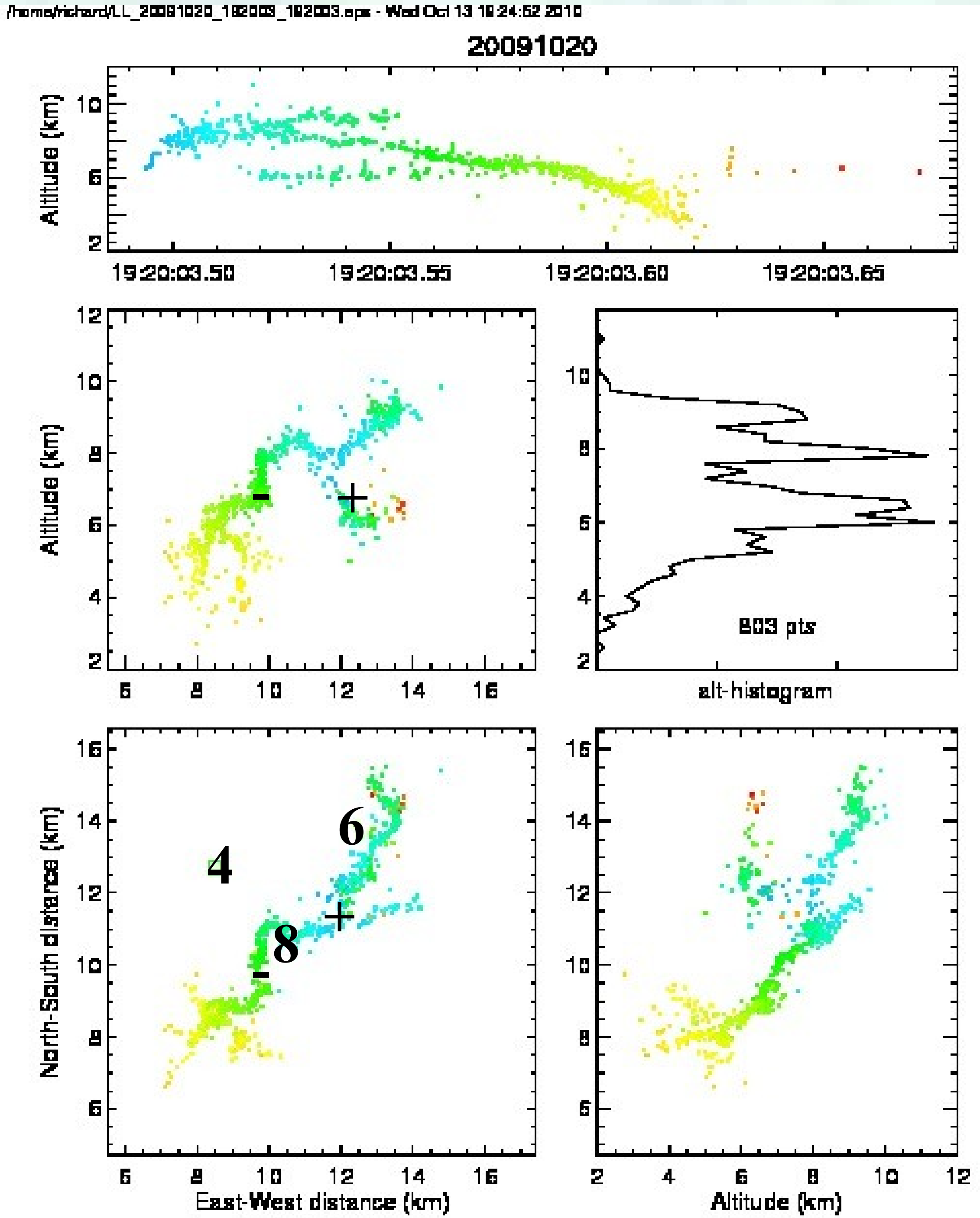

Station 8
Station 6
Station 4
Station 5
Station 2
Station 7
E (V/m)
E (V/m)
0
-500
-1000
-1500
-2000
0
-500
-1000
-1500
-2000
0
-500
-1000
150
100
50
0
-50
0
-10
-20
-30
-40
10
5
0
3.5
3.55
3.6
3.65
Time (seconds since 1920 UT)



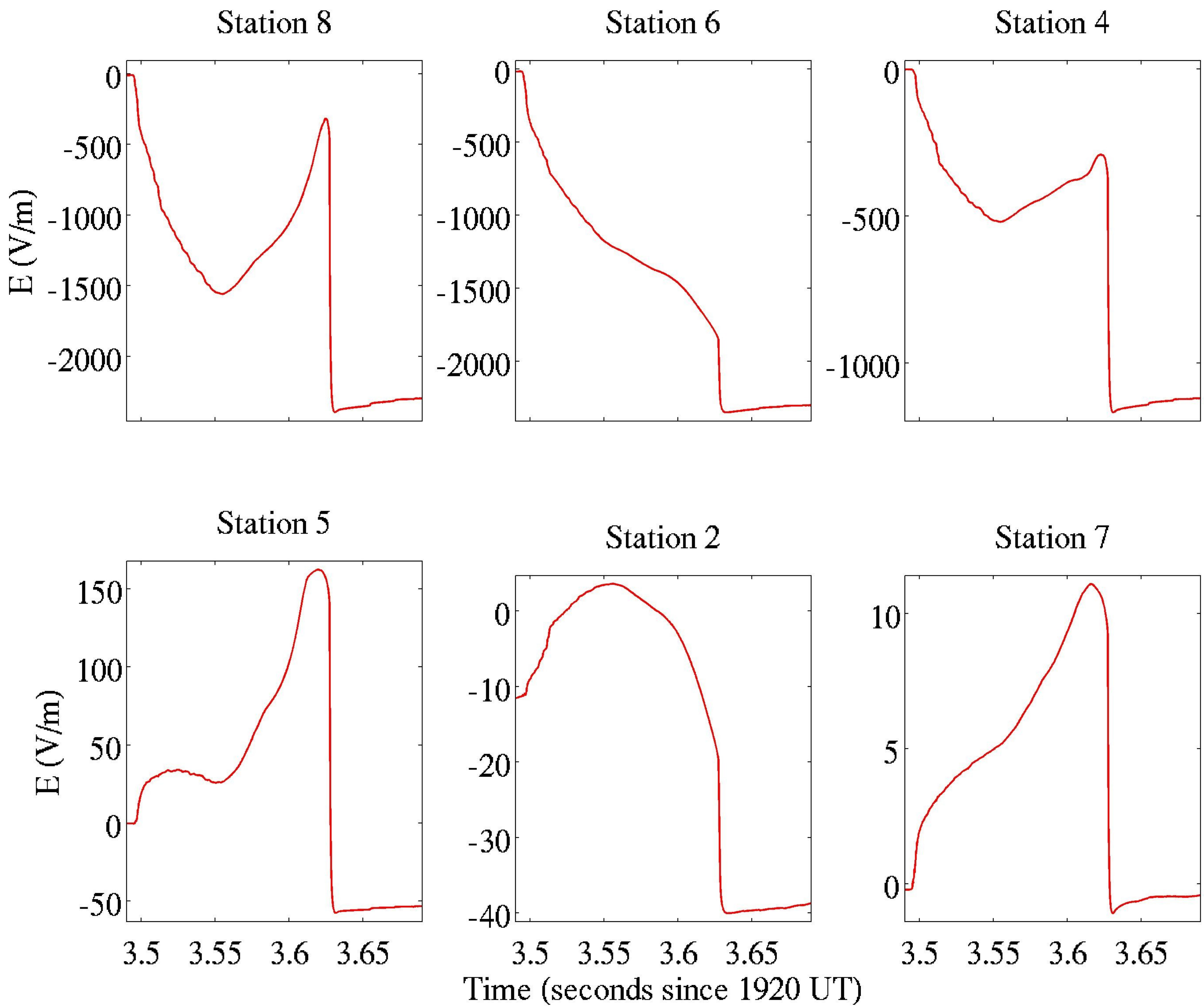
- Negative charge is moved into the positive charge layer from 3.5 to 3.52 seconds. The resulting field change is from an upward dipole.



Altitude (km
6
2
19:20:03.50
19:20:03.55
19:20:03.60
19:20:03.65
E (V/m)
-500
-1000
-1500
-2000
Negative leader moving to higher altitudes
Large negative leader grows over station 8
Return stroke happens 10 ms after main RF pulses
3.5
3.52
3.54
3.56
3.58
3.6
3.62
3.64
3.66
3.68
Time (seconds since 1920 UT)



- 3.50-3.55 s .. Negative charge moves from z=6 to z=10 km. Nearby stations see effective + overhead. Distant stations see – overhead.
- 3.55-3.62 s. Negative charge moves horizontally. Stations toward which is moves see + field-change. Others see - field-change.
- 3.62 s. Return stroke. All stations see new positive charge overhead.


Station 8
Station 6
Station 4
Station 5
Station 2
Station 7
E (V/m)
E (V/m)
0
-500
-1000
-1500
-2000
-1000
150
100
50
-50
-10
-20
-30
-40
10
5
3.5
3.55
3.6
3.65
Time (seconds since 1920 UT)

Summary and Conclusions

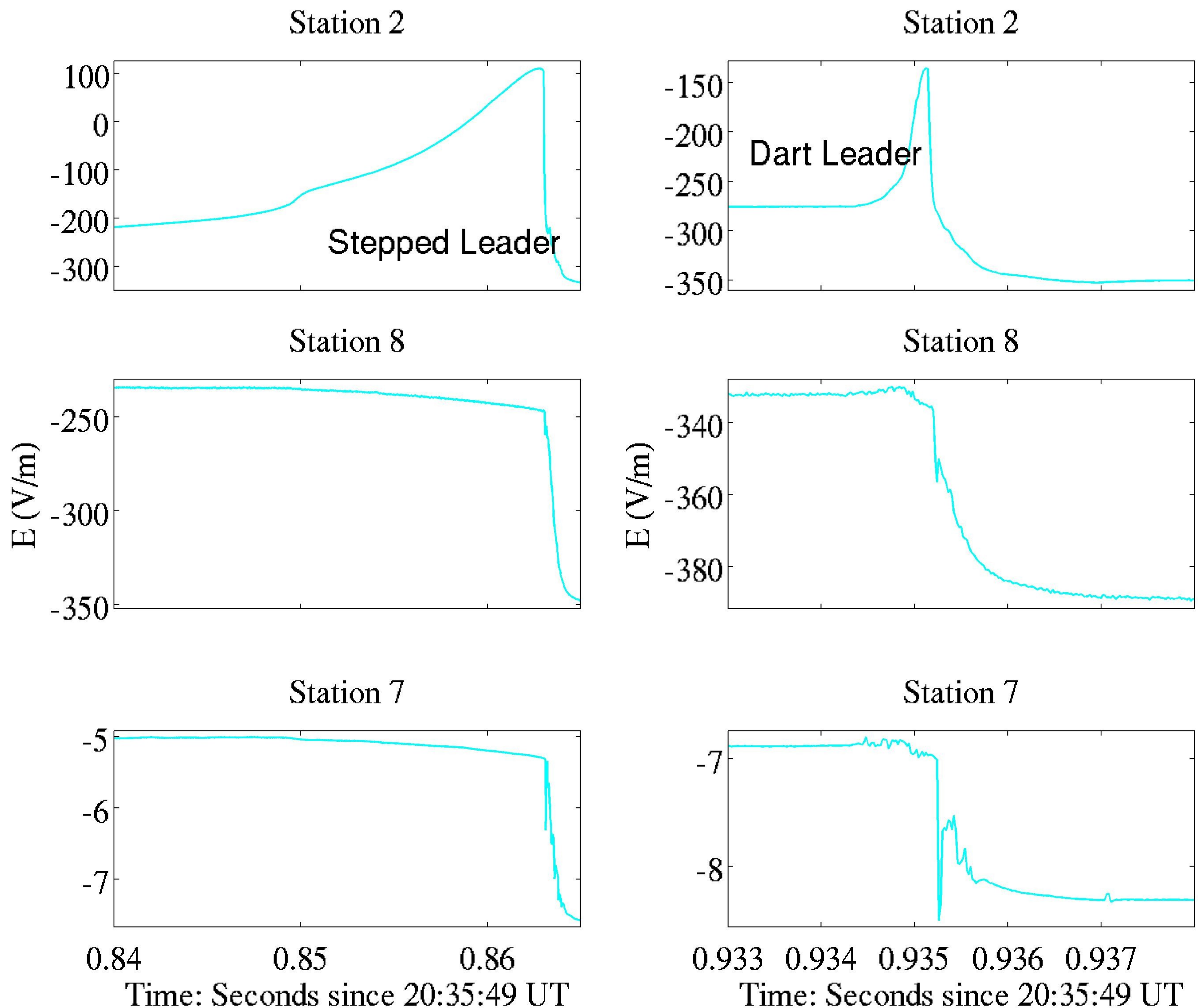
- Electric field records in parallel with radio emission records are confirming our understanding that charge transfer occurs largely during radio quiet periods.

- Arrays of electric field sensors can independently locate the charge centers accessed by a lightning flash.

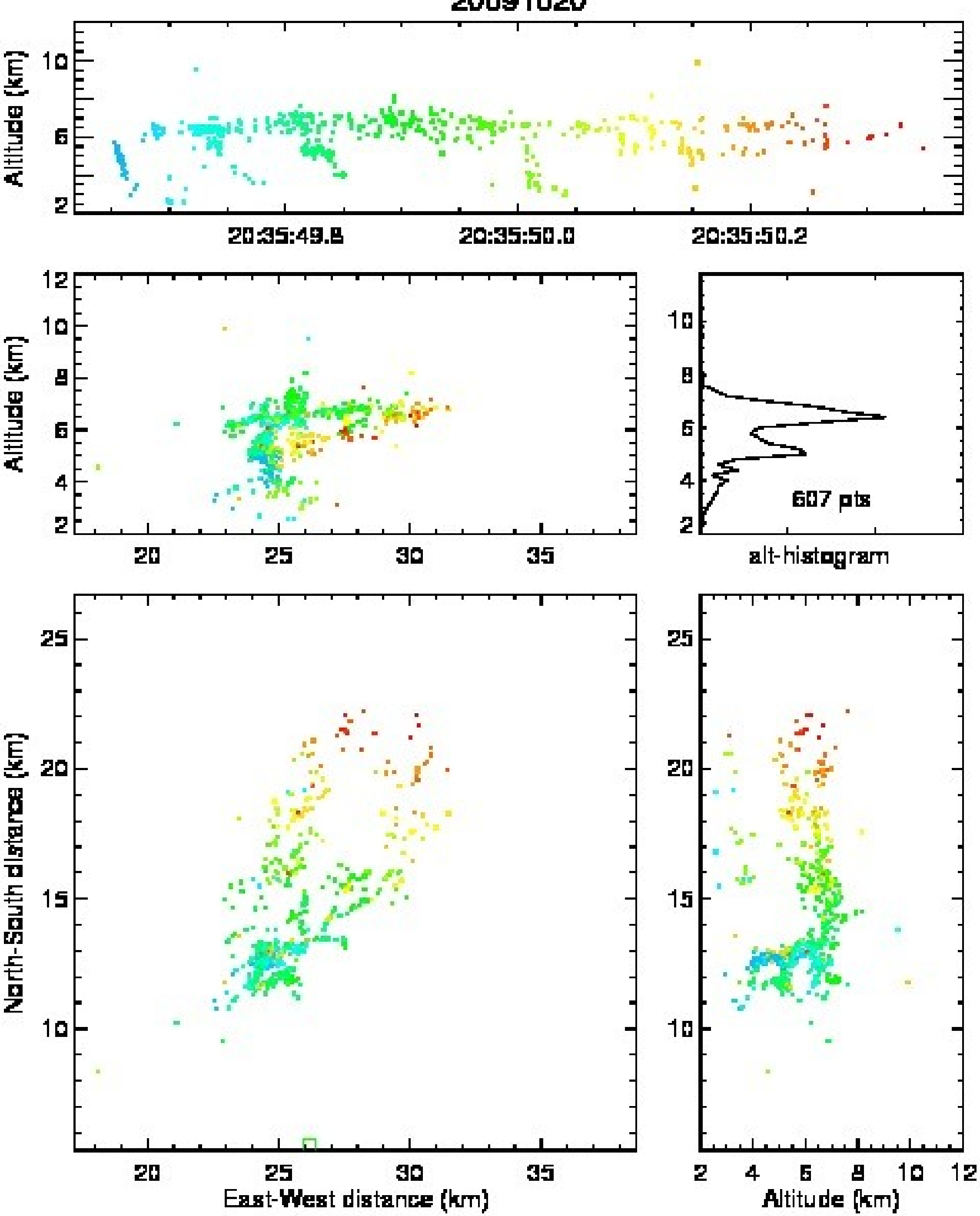
- The wonderful complexity of natural lightning is beginning to yield to study by coordinated techniques.

Applications

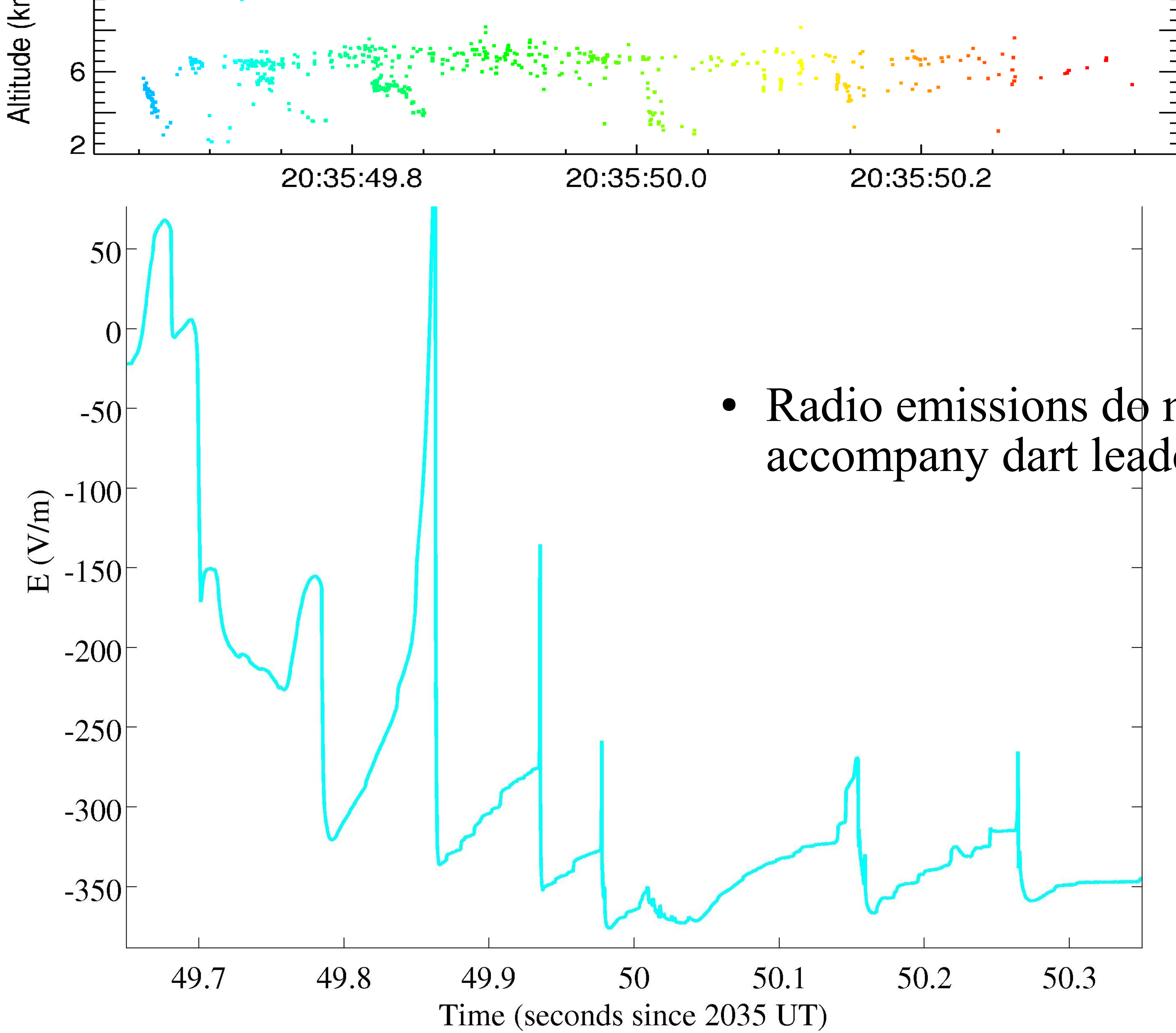
- Knowing detailed charge transfer during a flash allows knowing currents and temperatures, which are important for atmospheric chemistry (e.g. NOx production)



Station 2
100
0
-100
-200
-300
Stepped Leader
Station 2
-150
-200
-250
-300
-350
Dart Leader
Station 8
-250
-300
-350
E (V/m)
Station 8
-340
-360
-380
E (V/m)
Station 7
-5
-6
-7
Station 7
-7
-8
0.84
0.85
0.86
Time: Seconds since 20:35:49 UT
0.933
0.934
0.935
0.936
0.937
Time: Seconds since 20:35:49 UT



Altitude (km)
20:35:49.8
20:35:50.0
20:35:50.2
Altitude (km)
607 pts
alt-histogram
North-South distance (km)
East-West distance (km)
Altitude (km)



- Radio emissions do not accompany dart leaders