

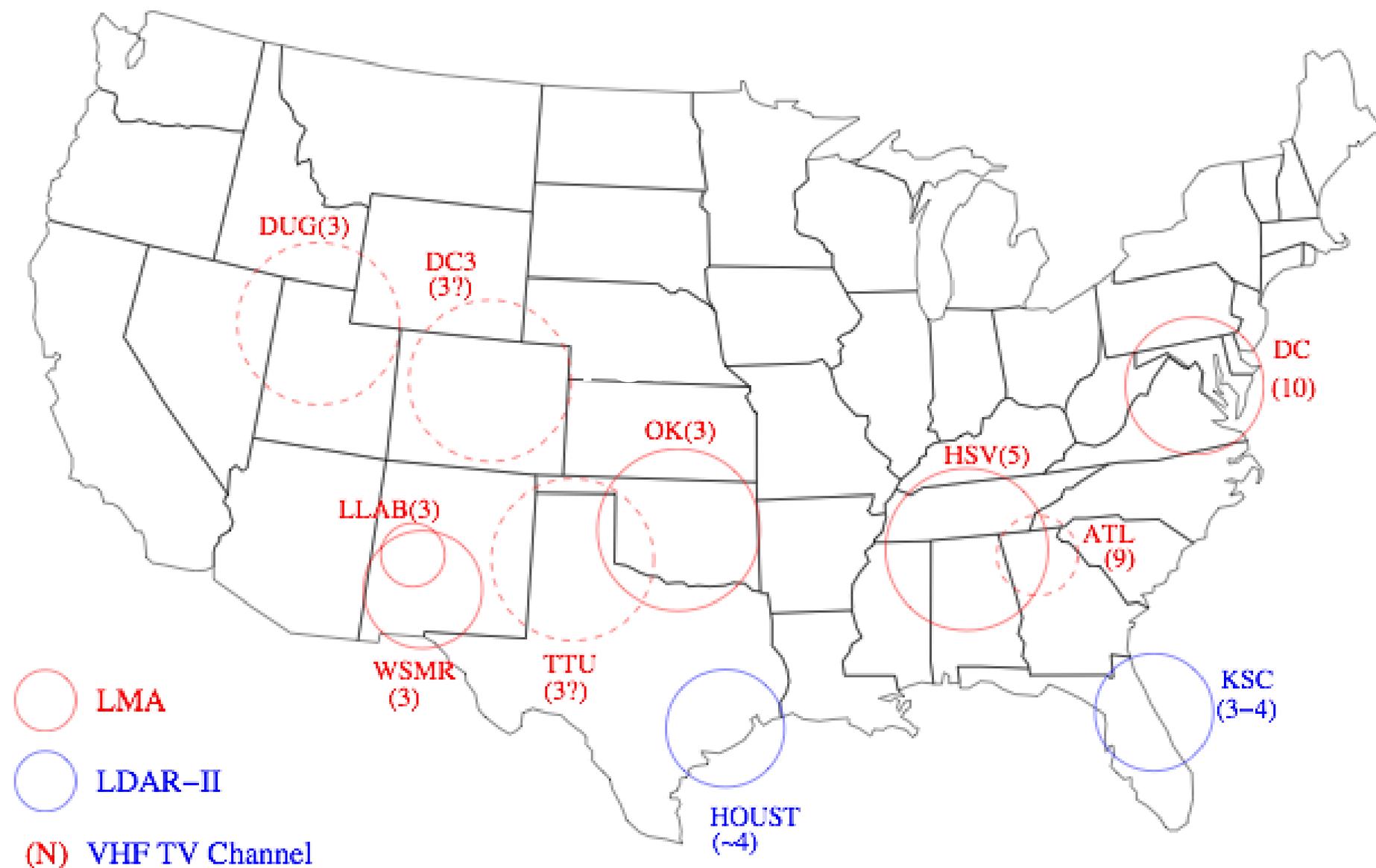
The Lightning Mapping Array

12 years of evolution and growth

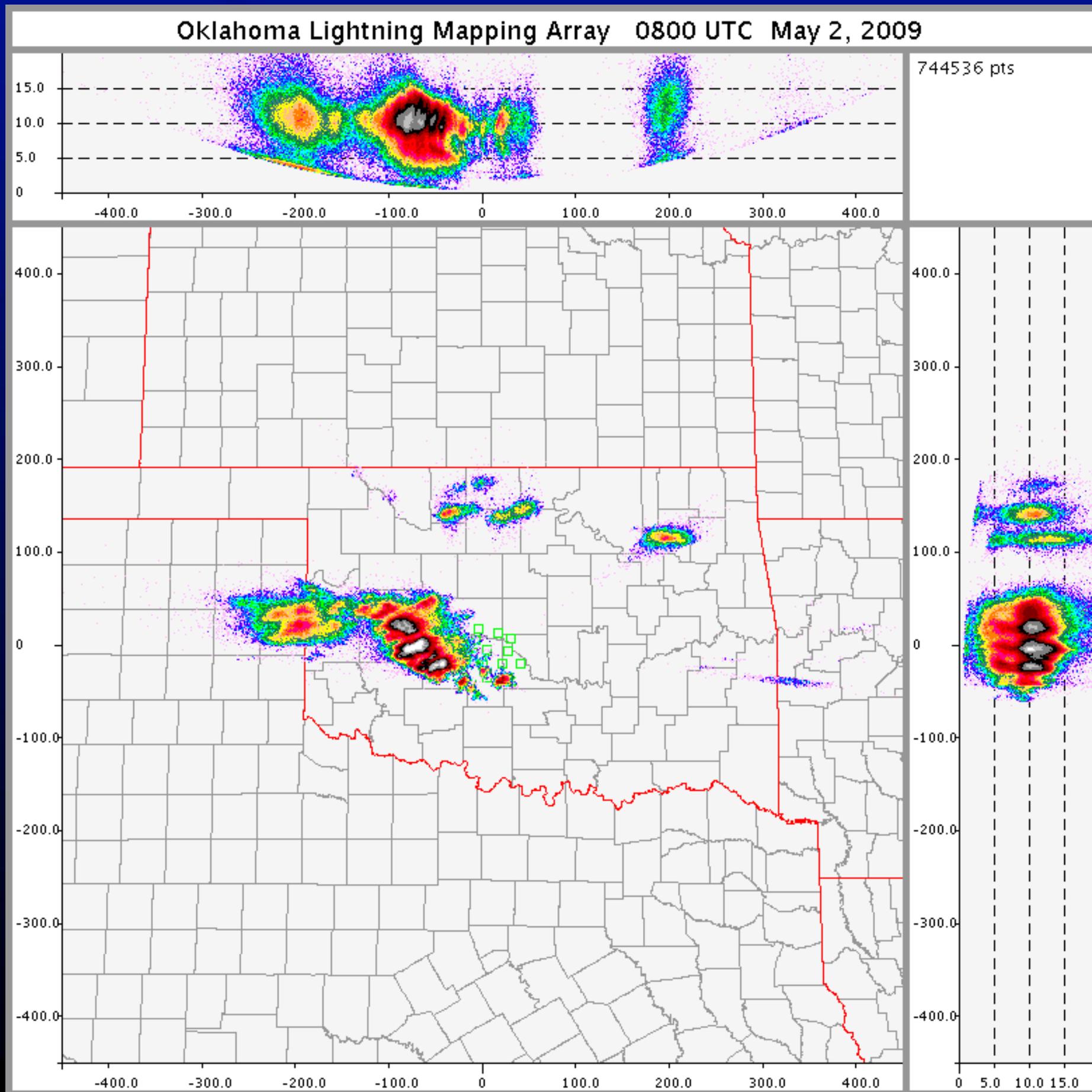
Ronald Thomas, Paul Krehbiel, Bill Rison
New Mexico Tech

Lightning Mapping arrays

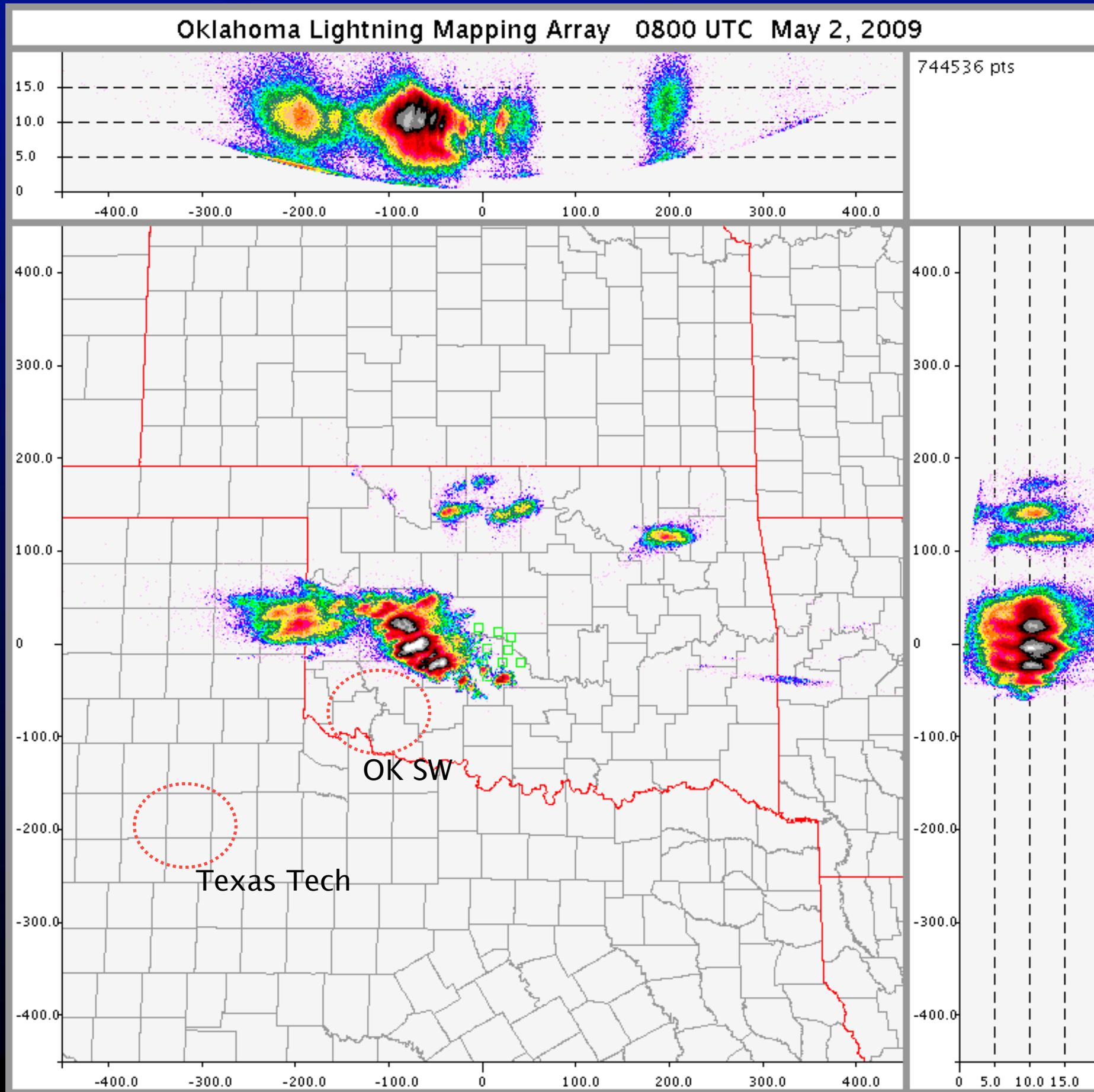
7 now 3 more in the next 2 years



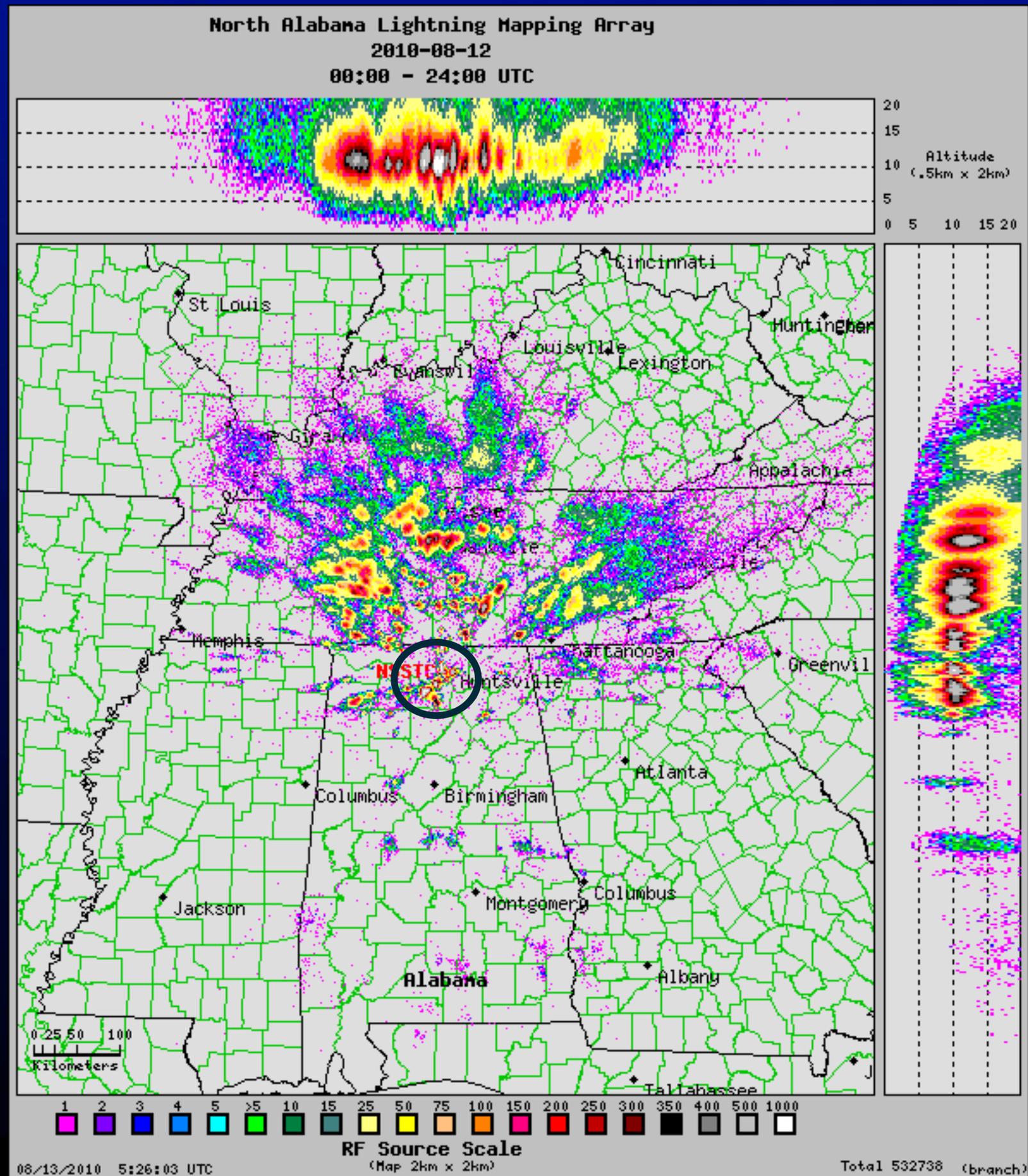
An example of Storm Detection



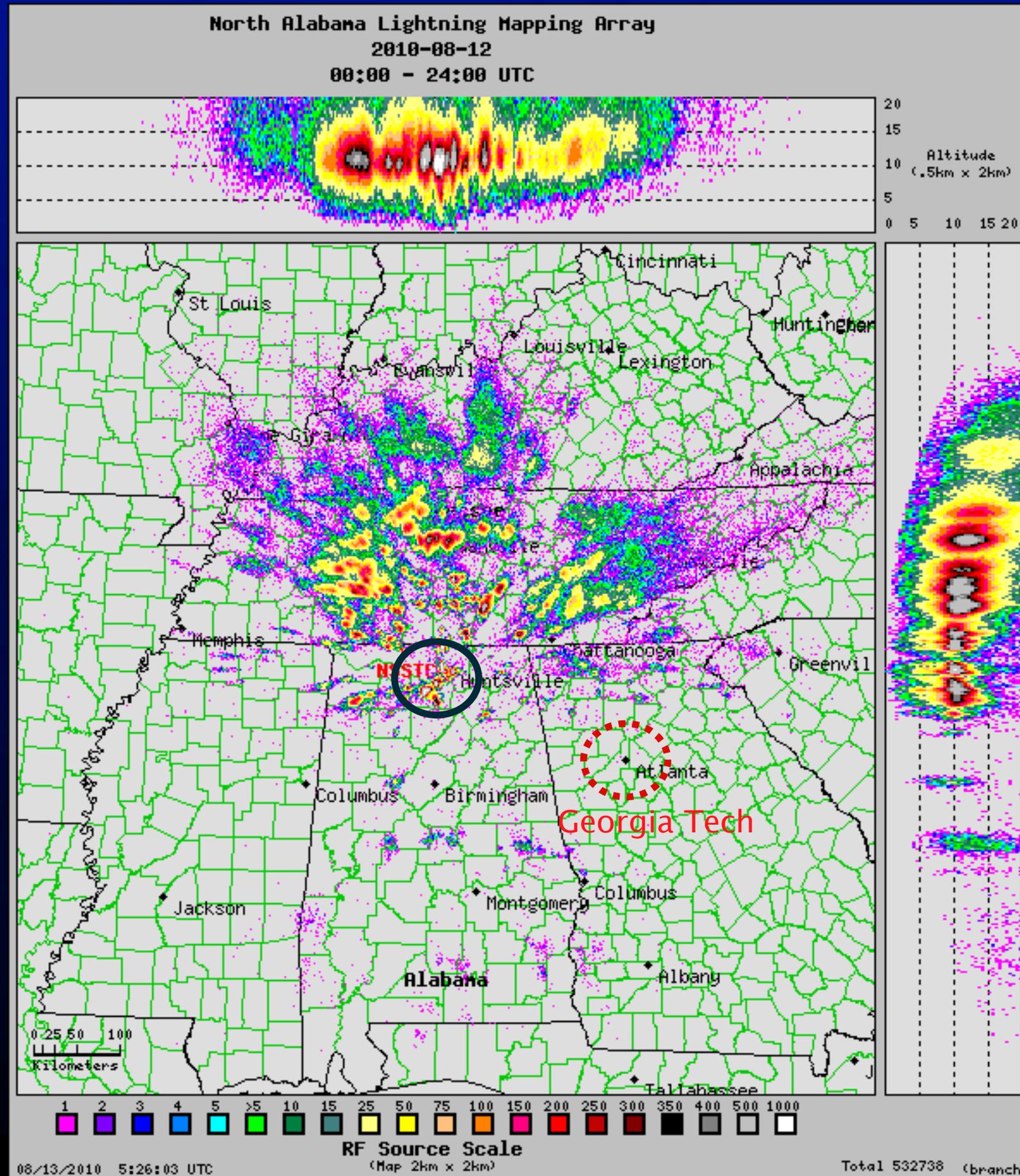
Additional and Expanded Networks



NA real time



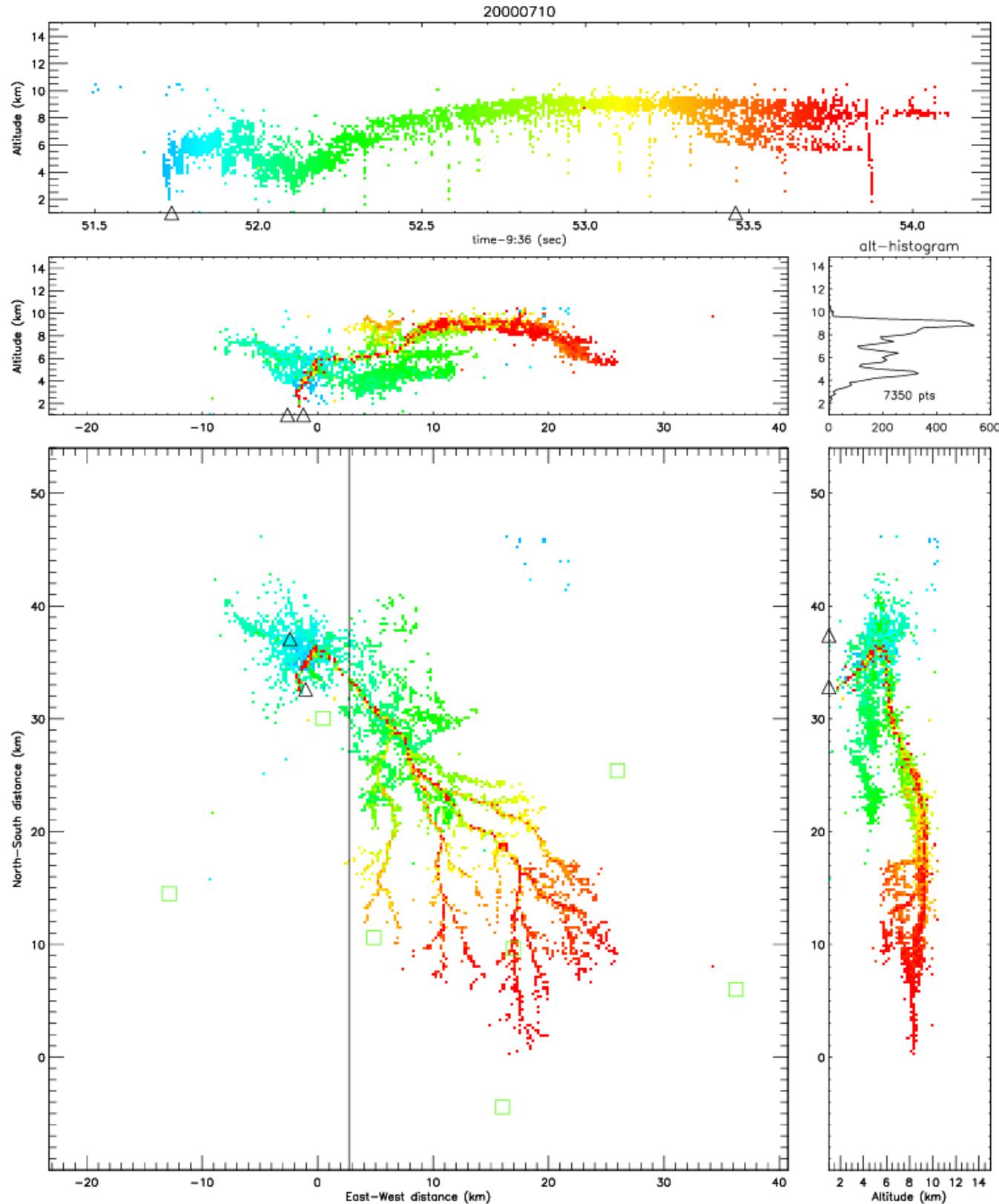
Additional and Expanded Networks



2 minute
updates to
NWS

An example of imaging of a single lightning flash

Example of Highly Dendritic Negative CG flash STEPS 2000, Kansas, Colorado



Height vs Time

Height vs E-W

Plan View

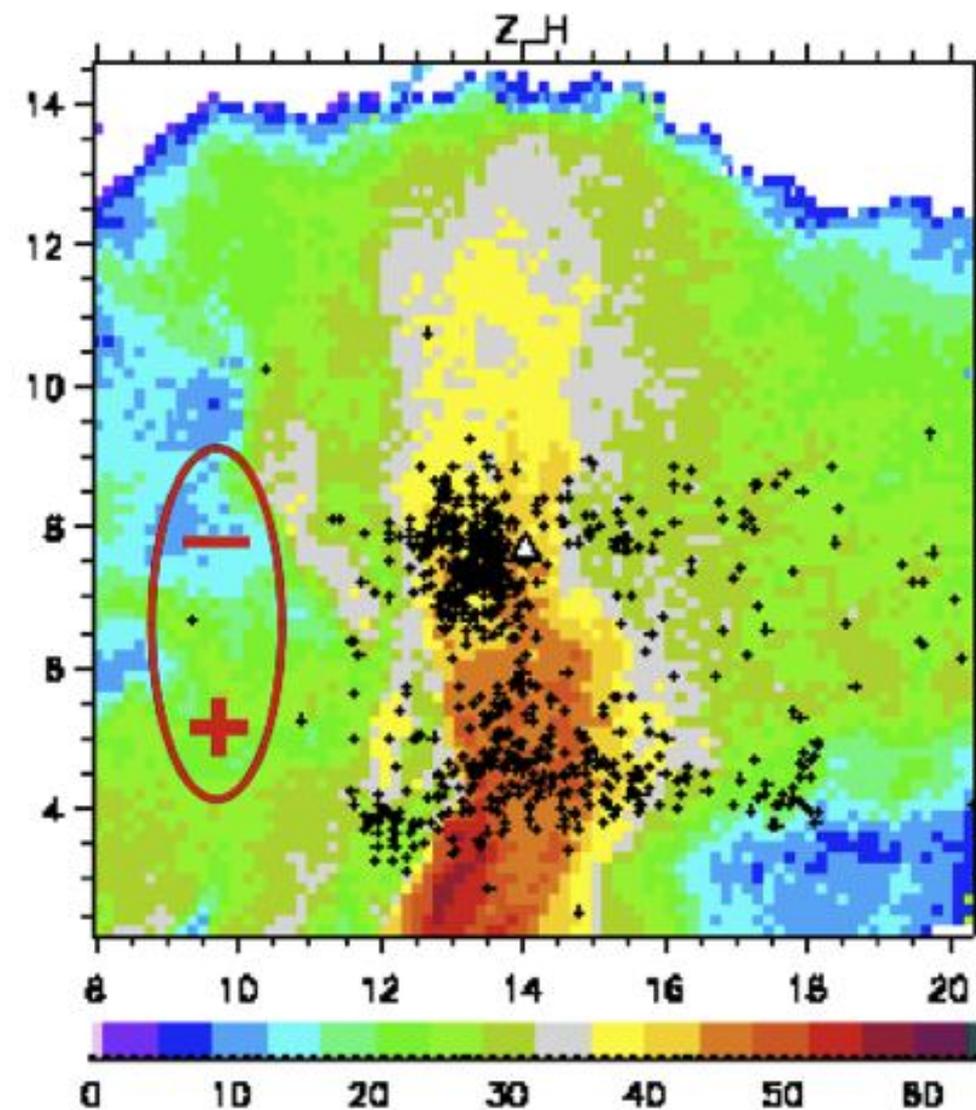
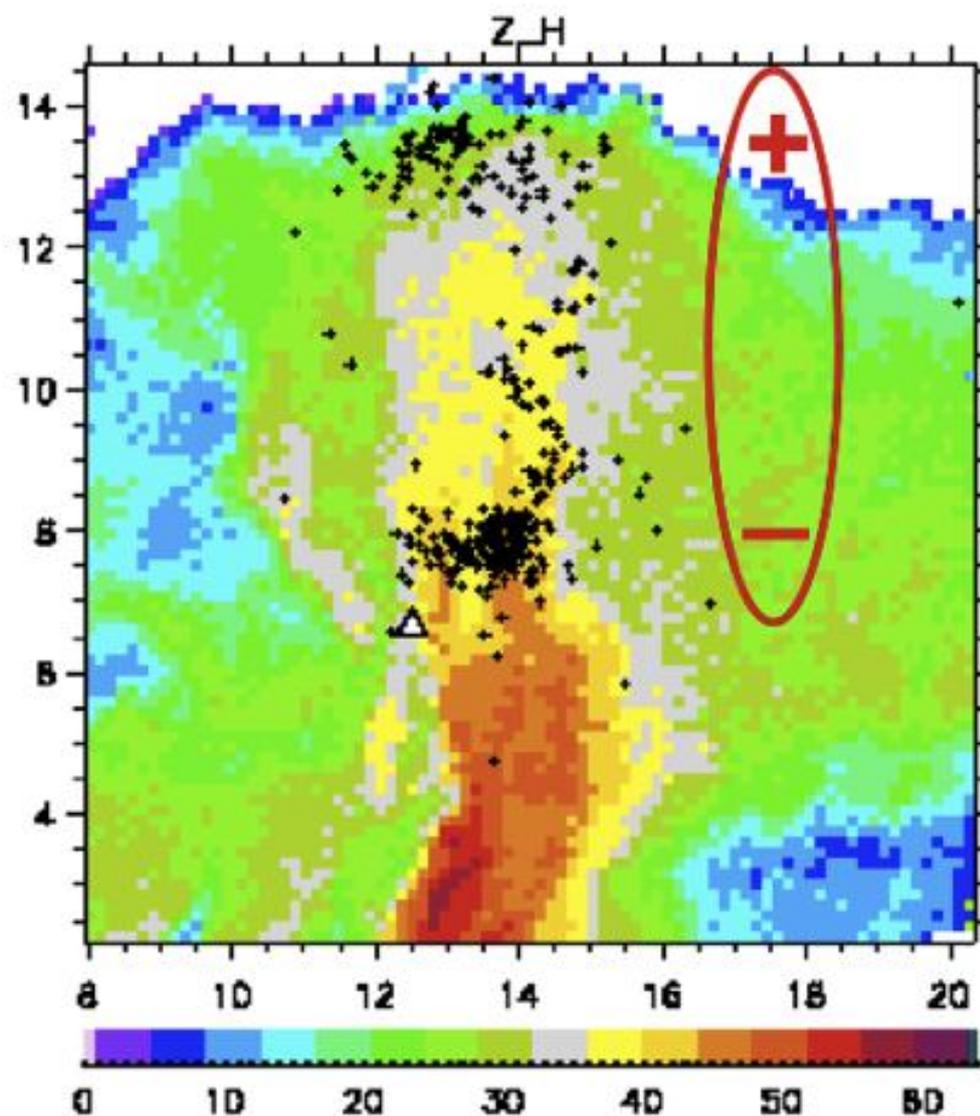
Height vs N-S

Comparison with radar

Lightning mapping (LMA) observations in a normally-electrified convective storm (Thomas et al., 2001)

Intracloud (IC) flash

Cloud-to-ground (CG) flash

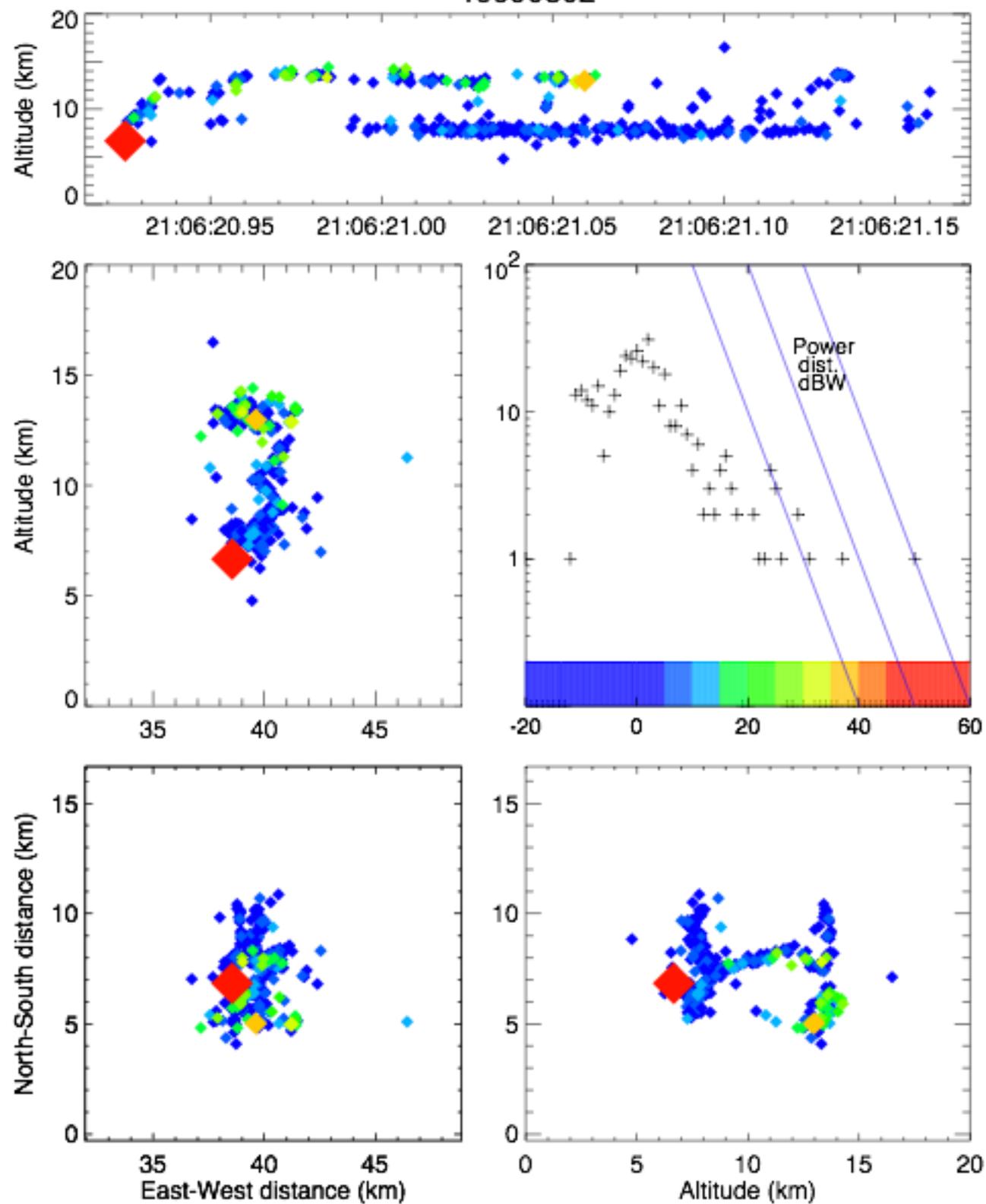


Classic tripolar interior charge structure, showing the negative charge well-correlated with precipitation (graupel/small hail) at storm mid-levels.

LMA source power

/home/thomas/NM_19990802_210620_210621-power.ps - Fri Nov 19 14:33:34 2010

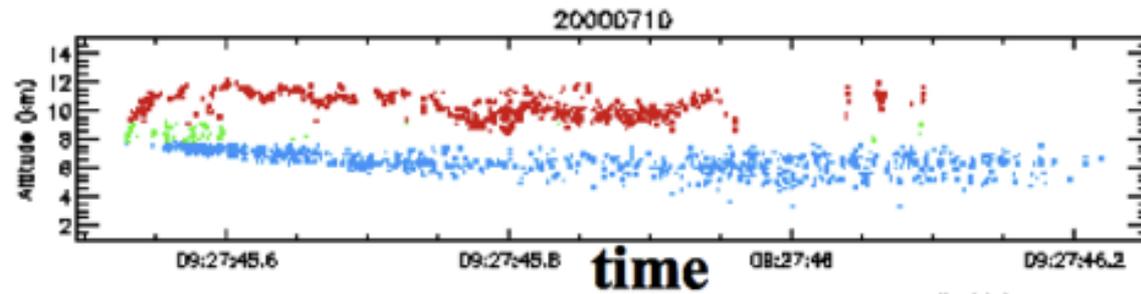
19990802



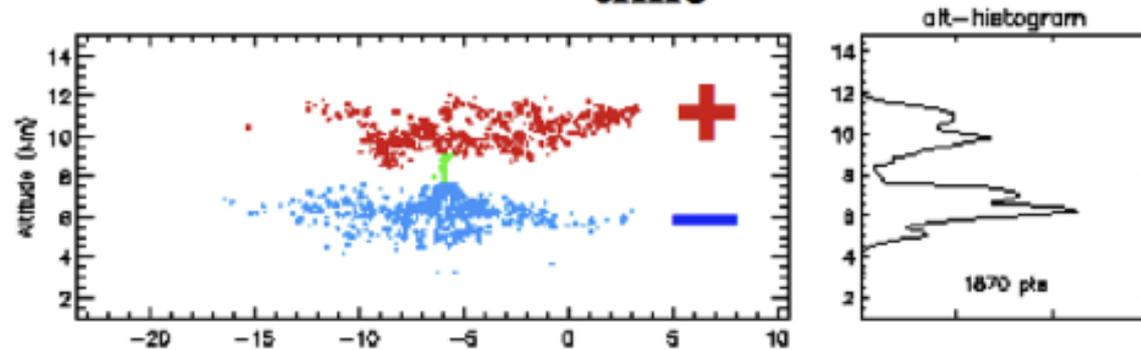
Determination of charge polarity for IC lightning flashes

- From asymmetries in the flash development (e.g. Shao and Krehbiel, 1996).

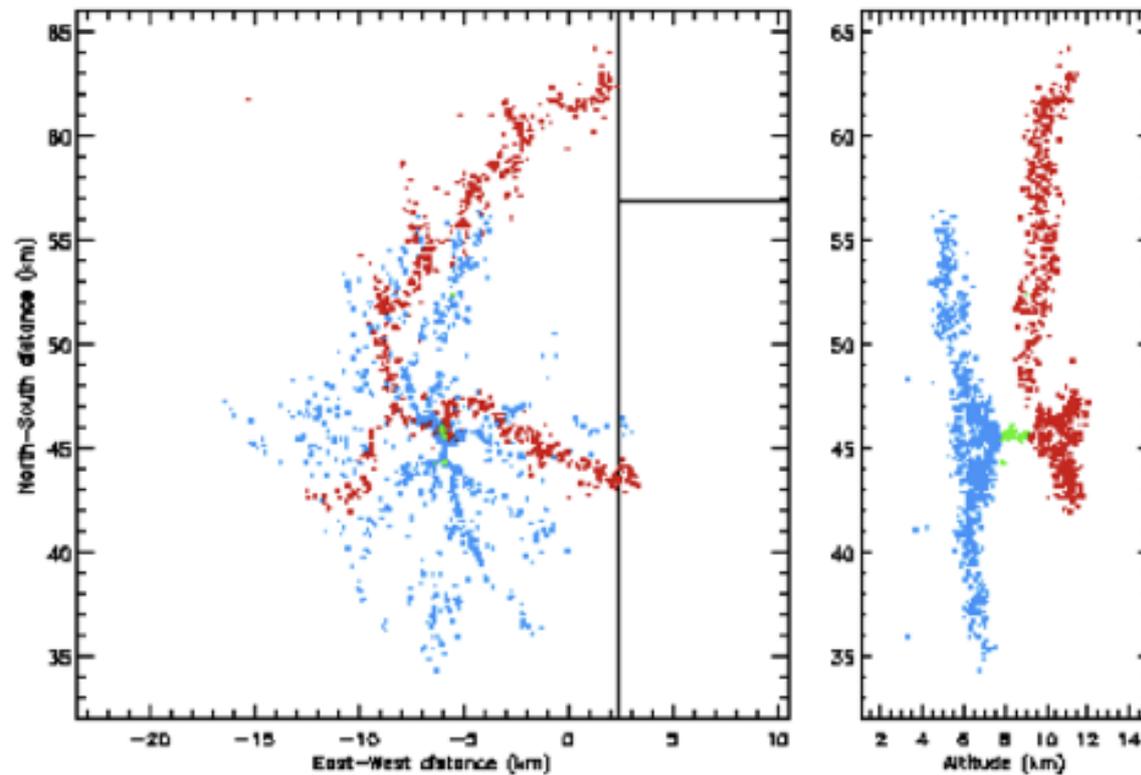
Z



Z



Y



X

Z

- Initial VHF sources develop **upward** with time into positive charge (i.e., **away** from negative charge).
- Delayed onset of sources in negative charge region.
- K-leaders at end of flash propagate from (-) to (+) charge regions

(Normal polarity intracloud flash)

Enables charge structure of storm to be inferred from lightning activity

- 24 min of complete lightning activity in storm over Langmuir Lab, 1999

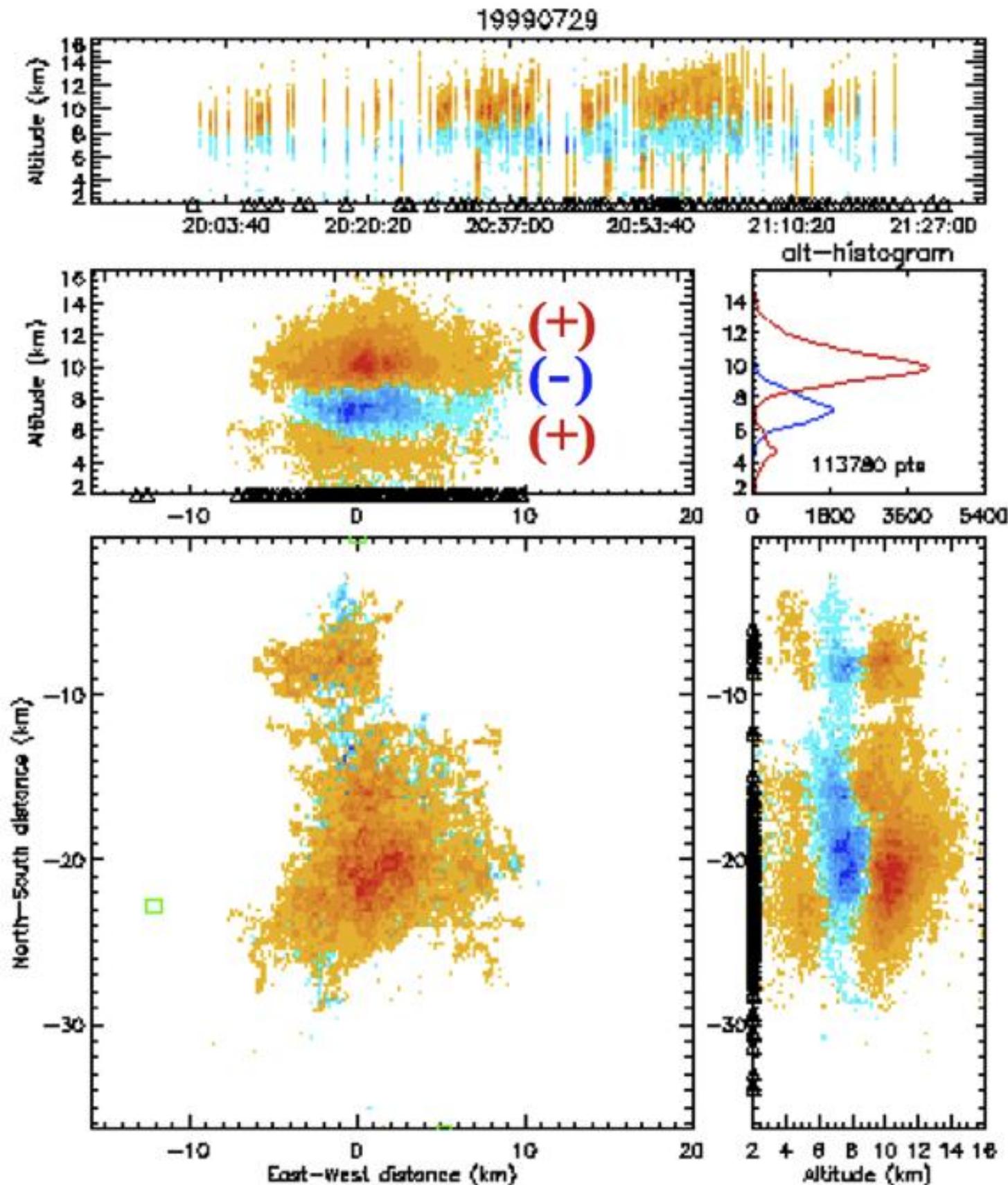
- Classic tri-polar charge structure

- Dominant mid-level negative charge (blue)

- Upper and lower positive charge regions (orange)

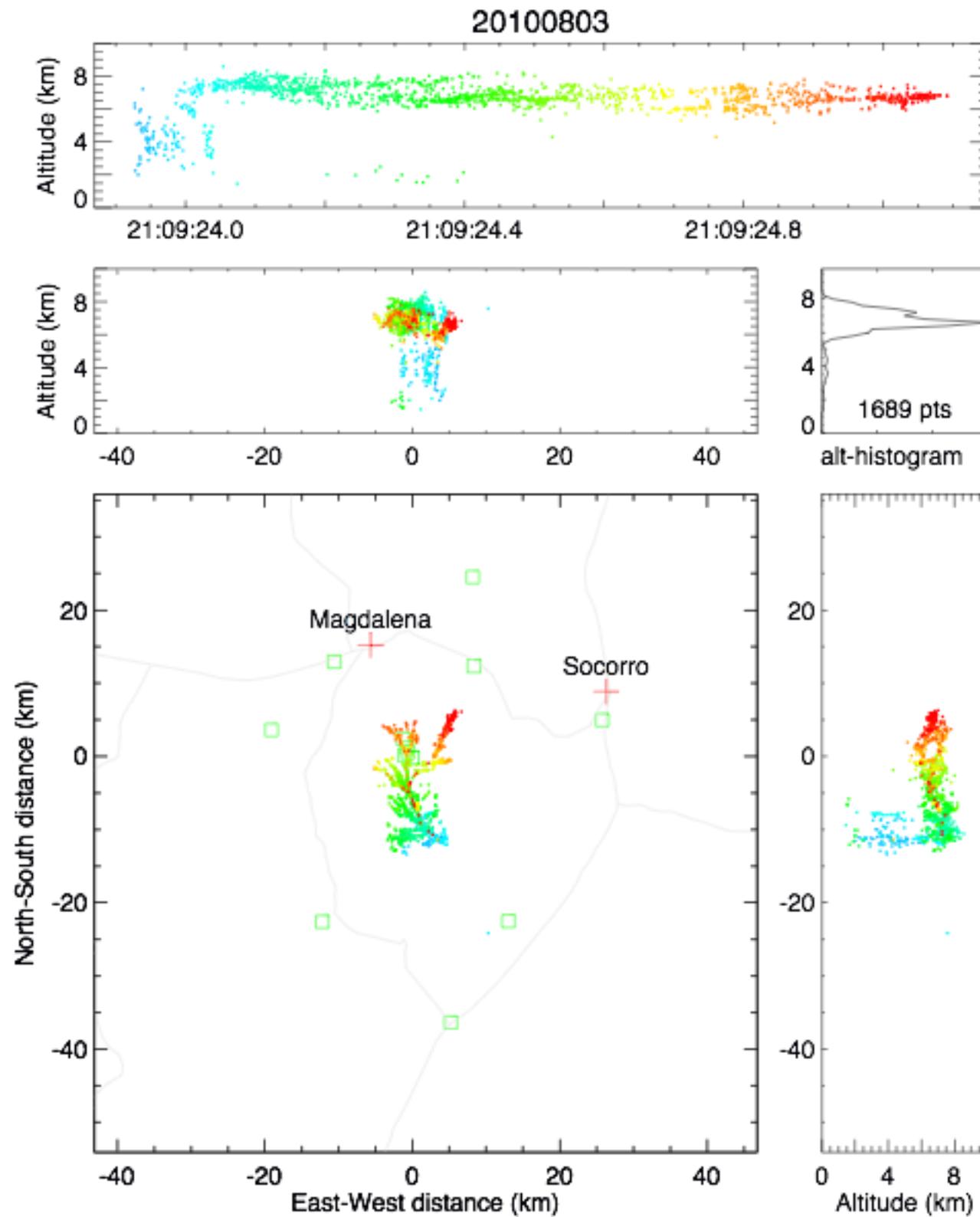
- Parallel plate-like charge structure (horizontally extensive)

(Not seen: Screening charges at upper and lateral cloud boundaries)



Langmuir Laboratory LMA with 16 stations

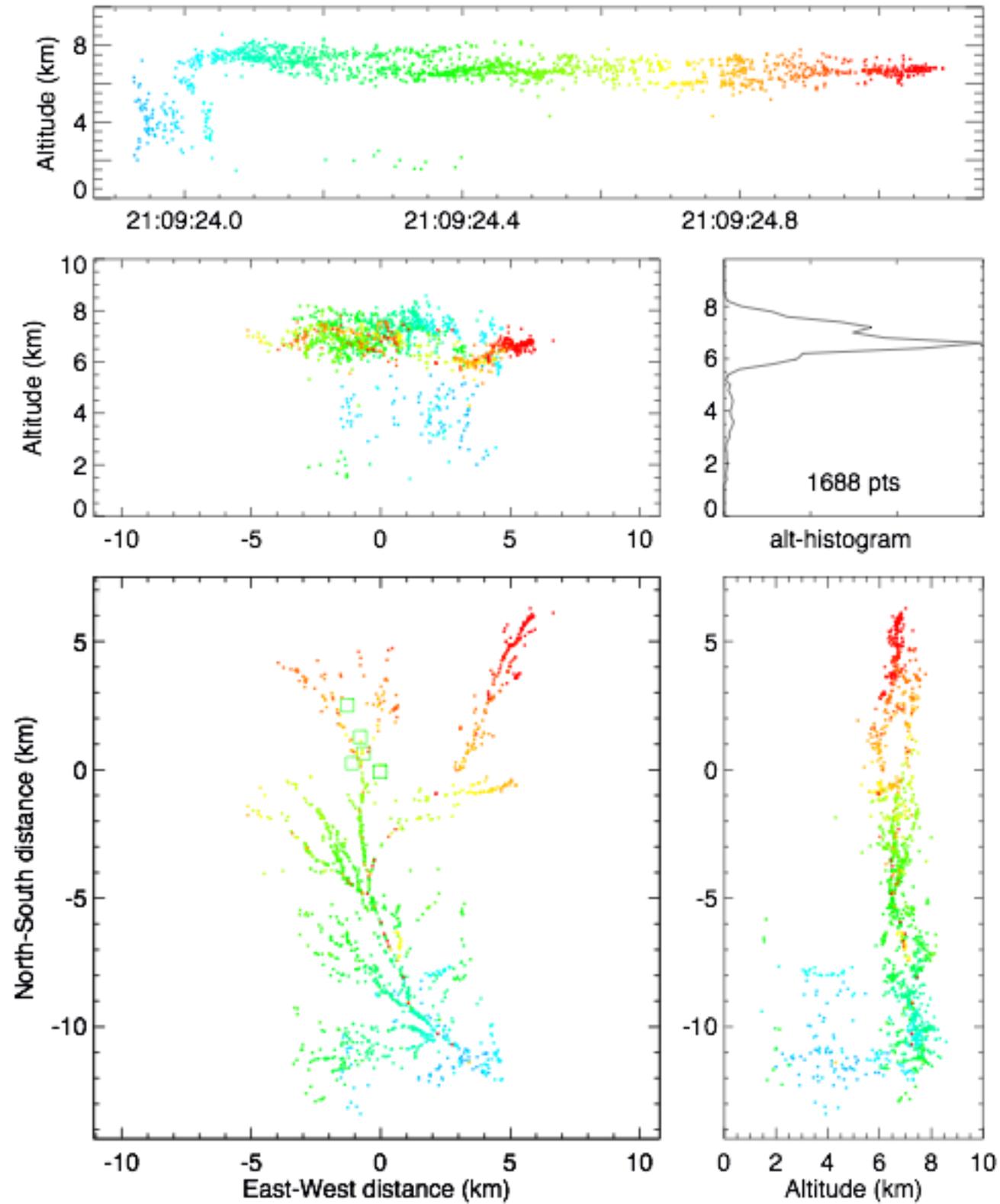
/Users/thomas/lma/volcano/iceland/Langmuir_2010_20100803_210923_210925.ps - Thu Nov 18 08:56:34 2010



Langmuir Laboratory LMA with 16 stations

/Users/thomas/lma/volcano/iceland/Langmuir_2010_20100803_210923_210925z.ps - Thu Nov 18 06:58:30 2010

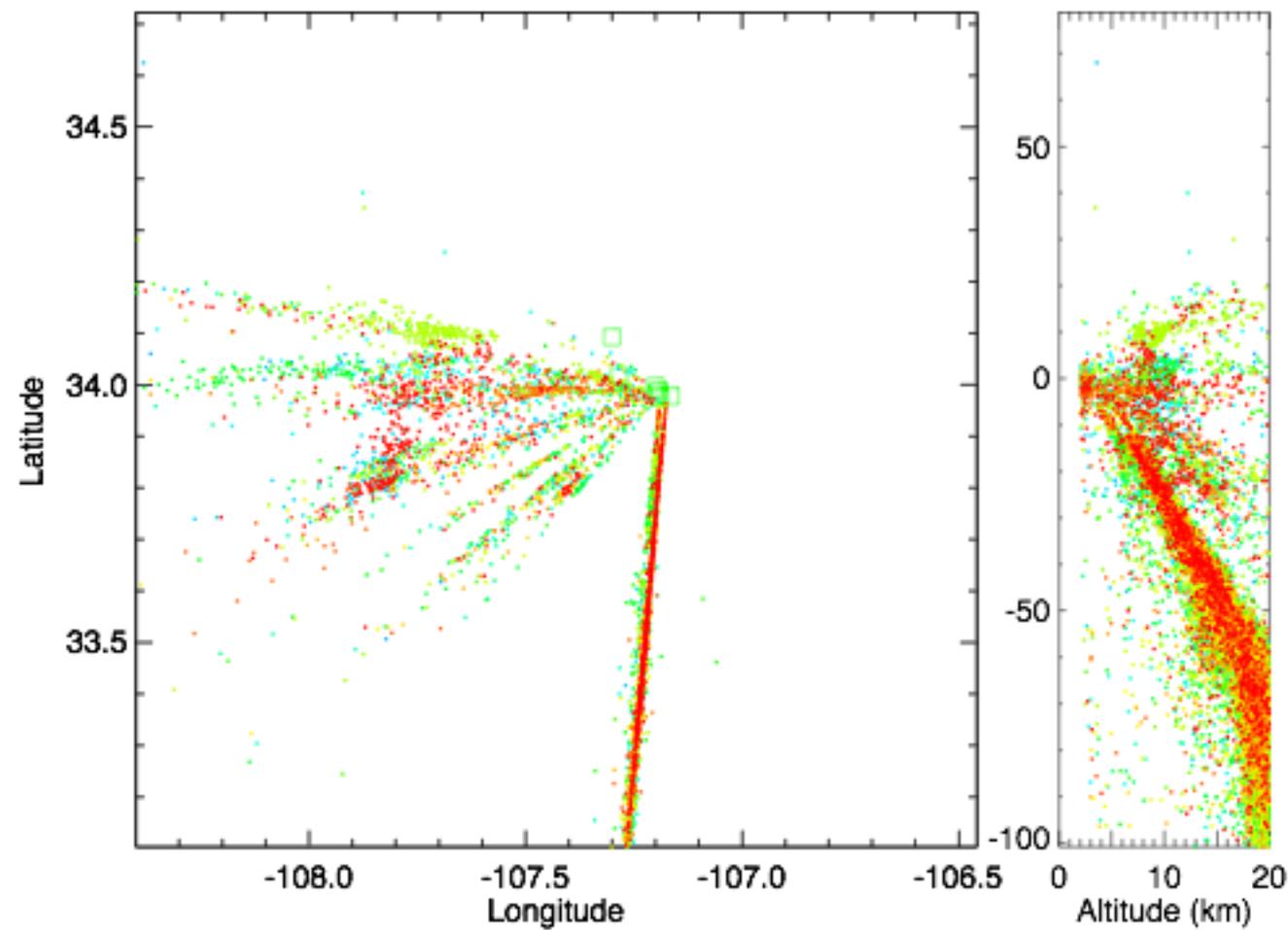
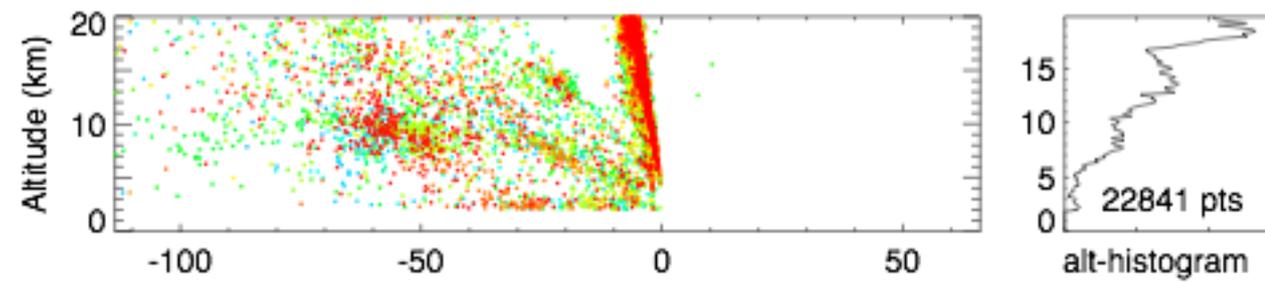
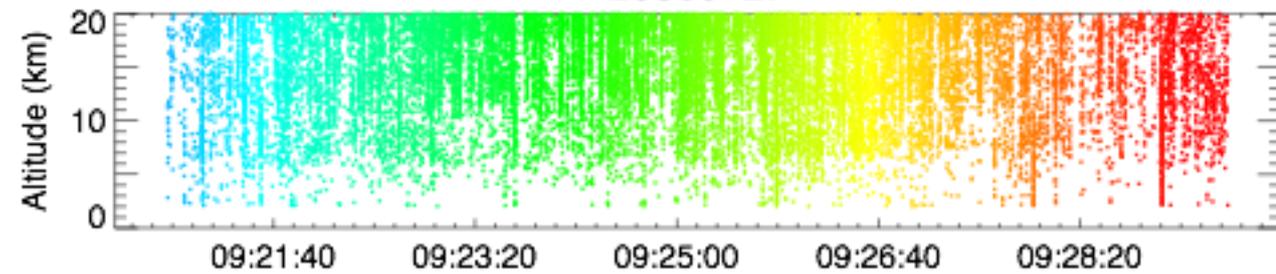
20100803



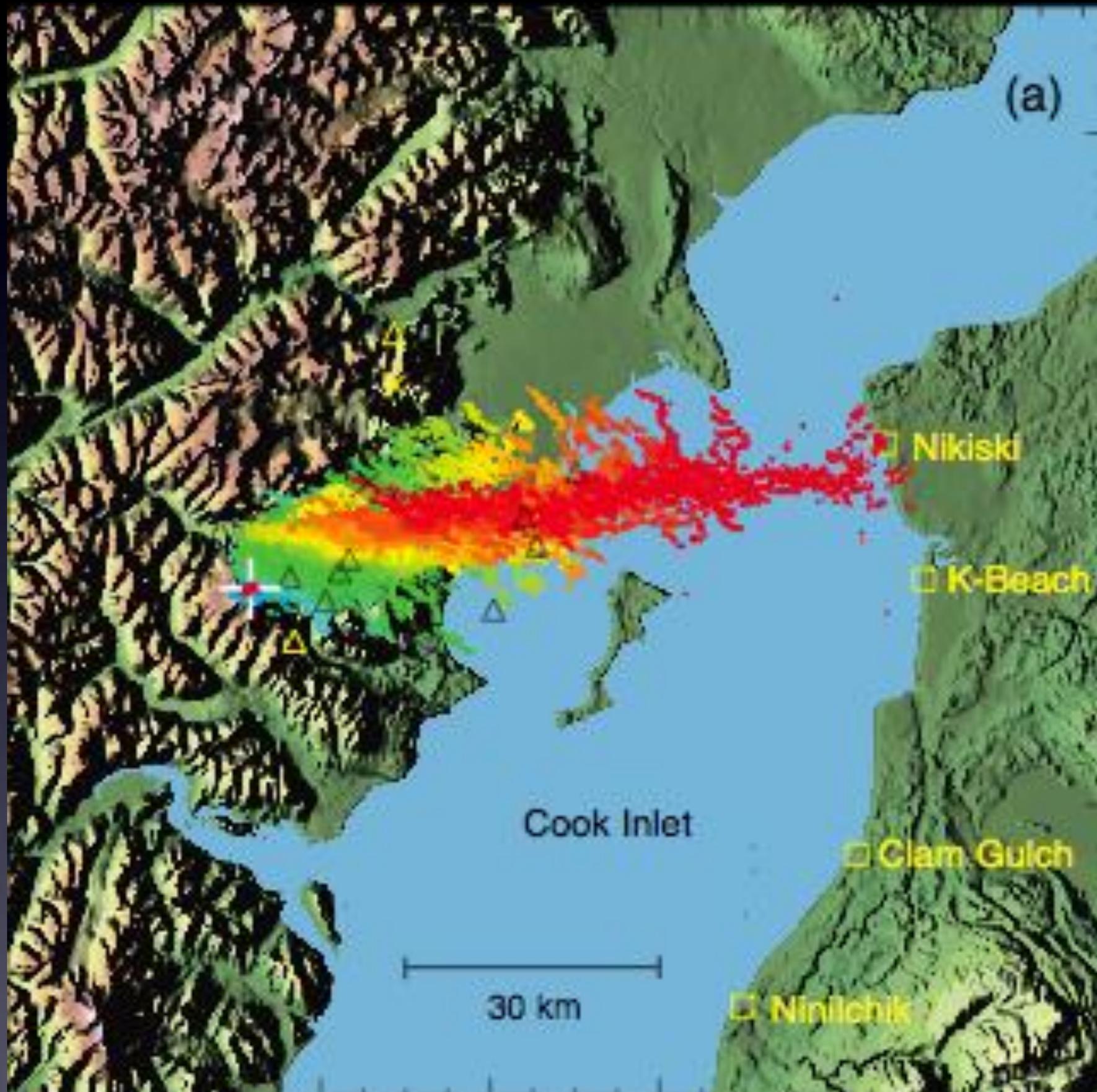
Langmuir Laboratory with Analog TV interference

/Users/thomas/NM_20060727_092047_092933.ps - Thu Nov 18 21:11:18 2010

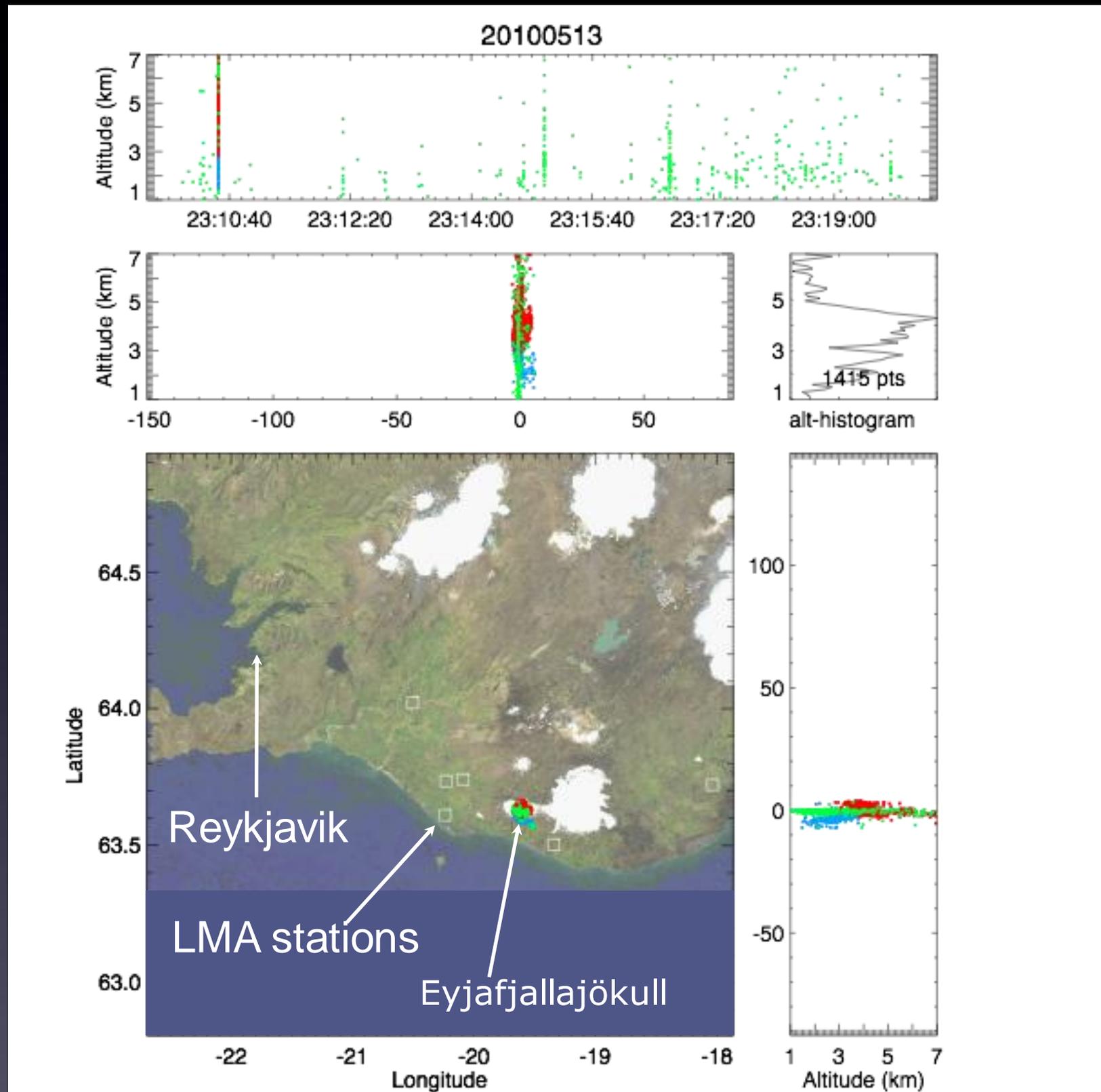
20060727



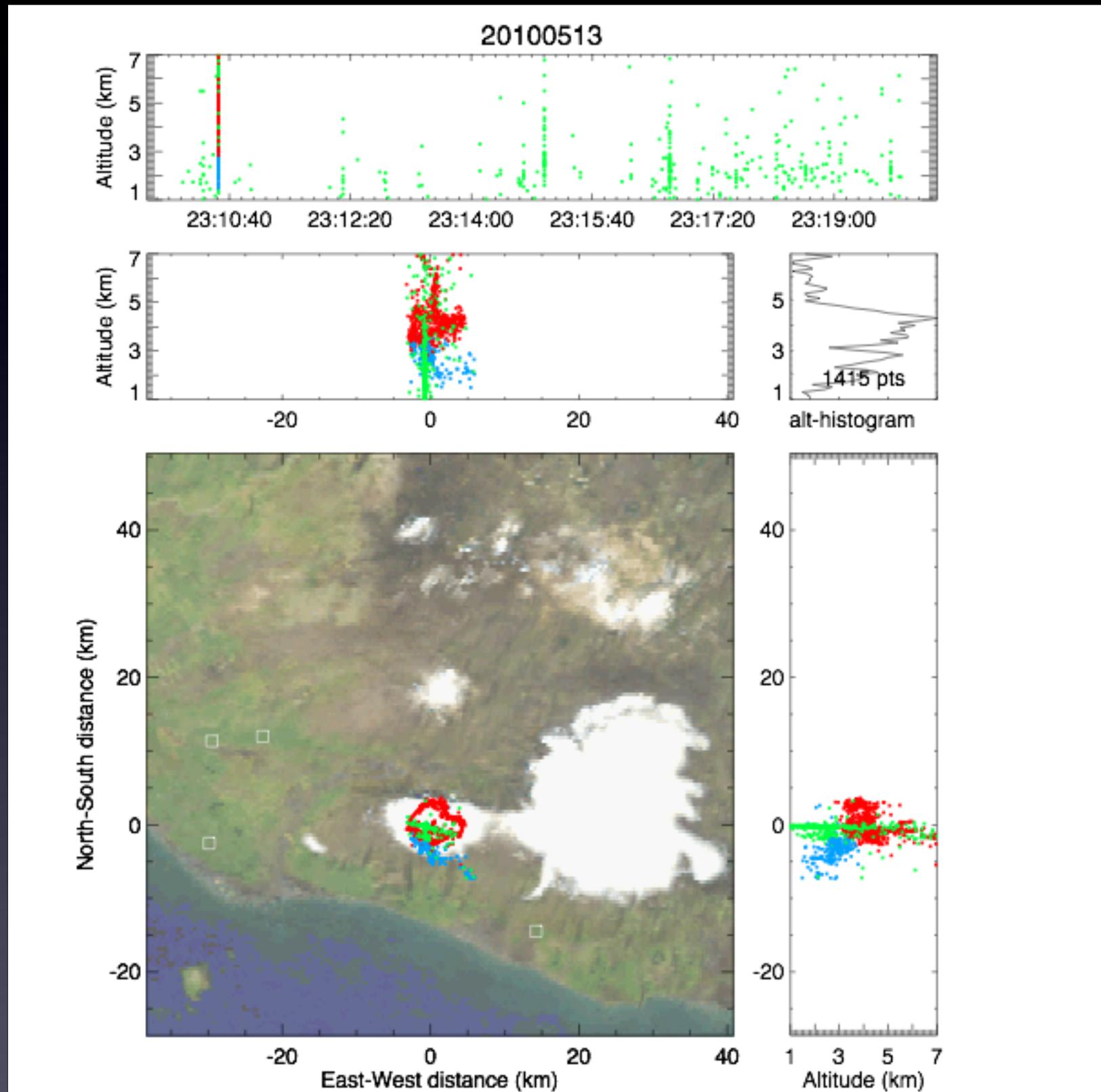
Eruption of Redoubt Volcano



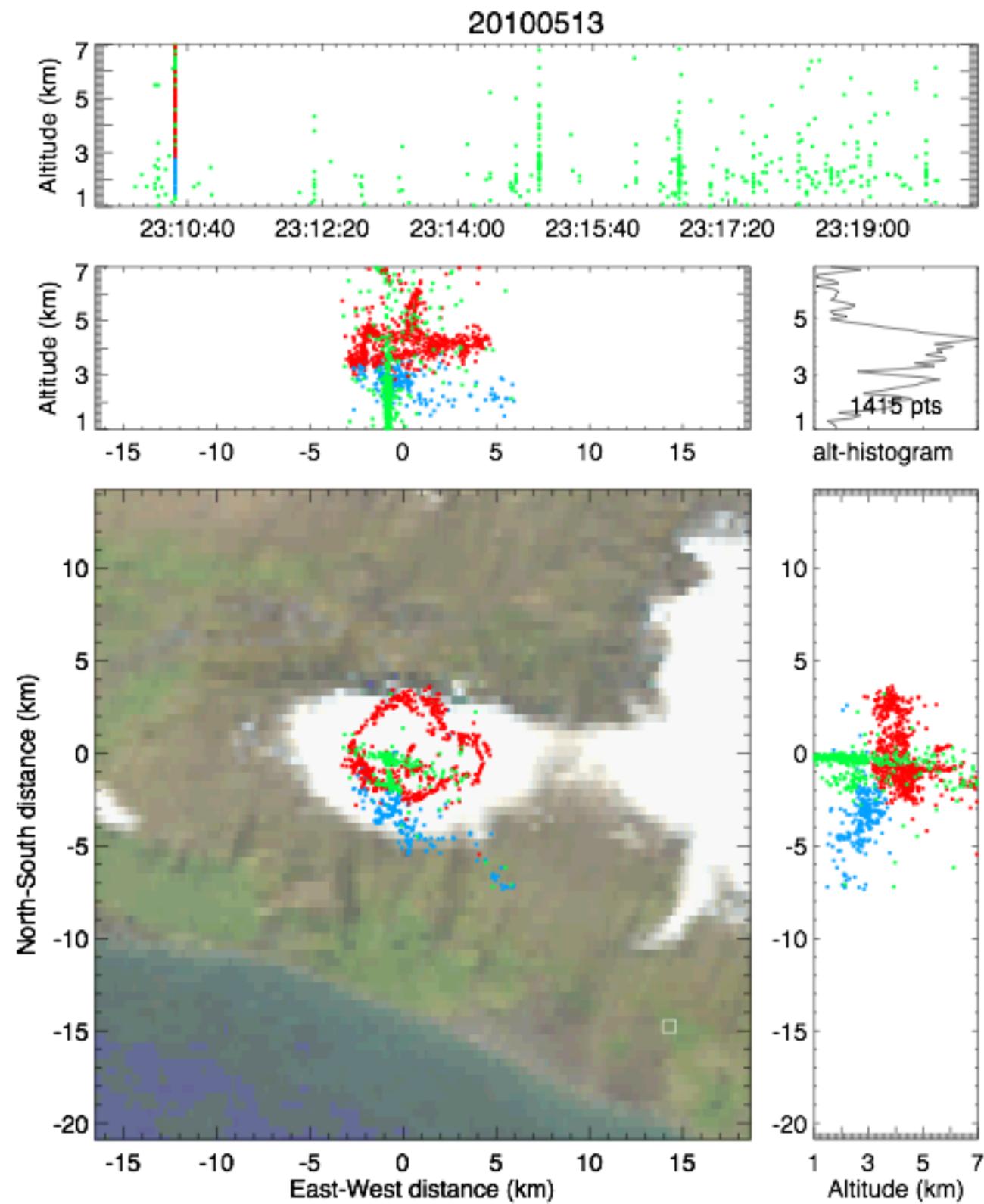
Eyjafjallajökull Eruption, Iceland 2010



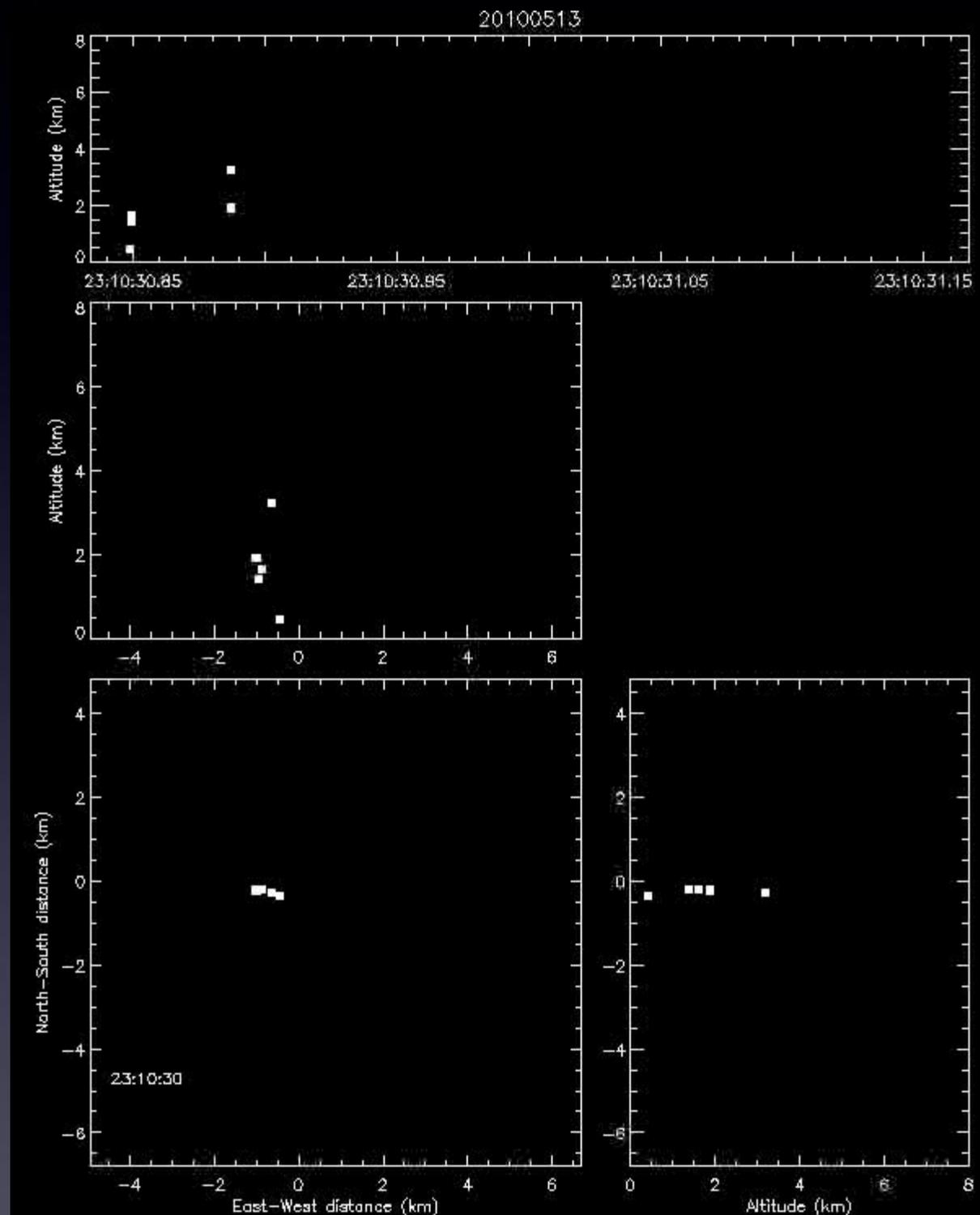
Eyjafjallajökull Eruption, Iceland 2010



Eyjafjallajökull Eruption, Iceland 2010



Eyjafjallajökull Eruption, Iceland 2010

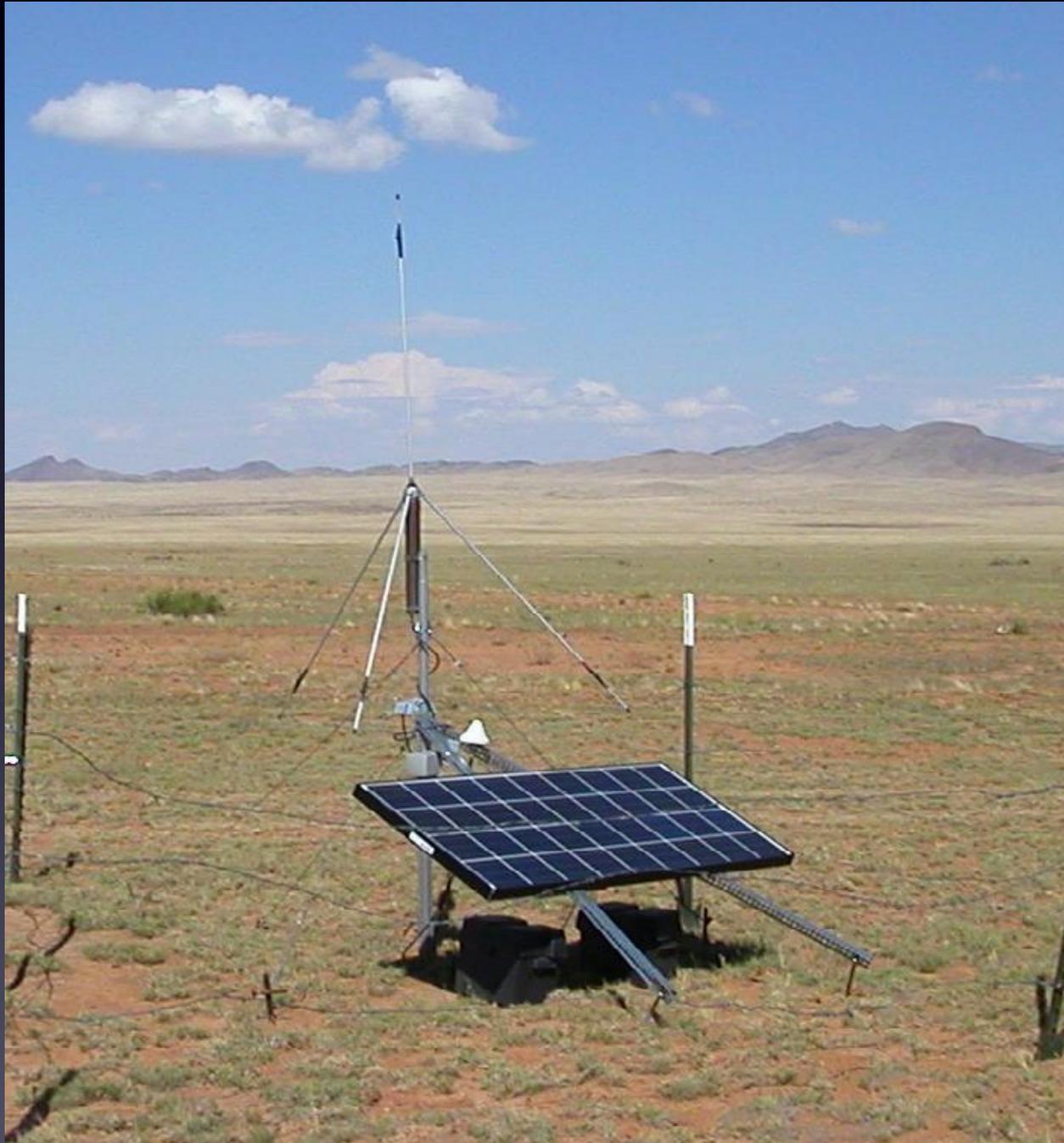


Animation of one flash
lasting about 300 ms

Charge identified
Red - positive
Blue - negative
Green - undetermined

Solar LMA - Langmuir Lab 2010

Solar power moves system away from infrastructure to quieter RF environments, reduces noise and improves sensitivity

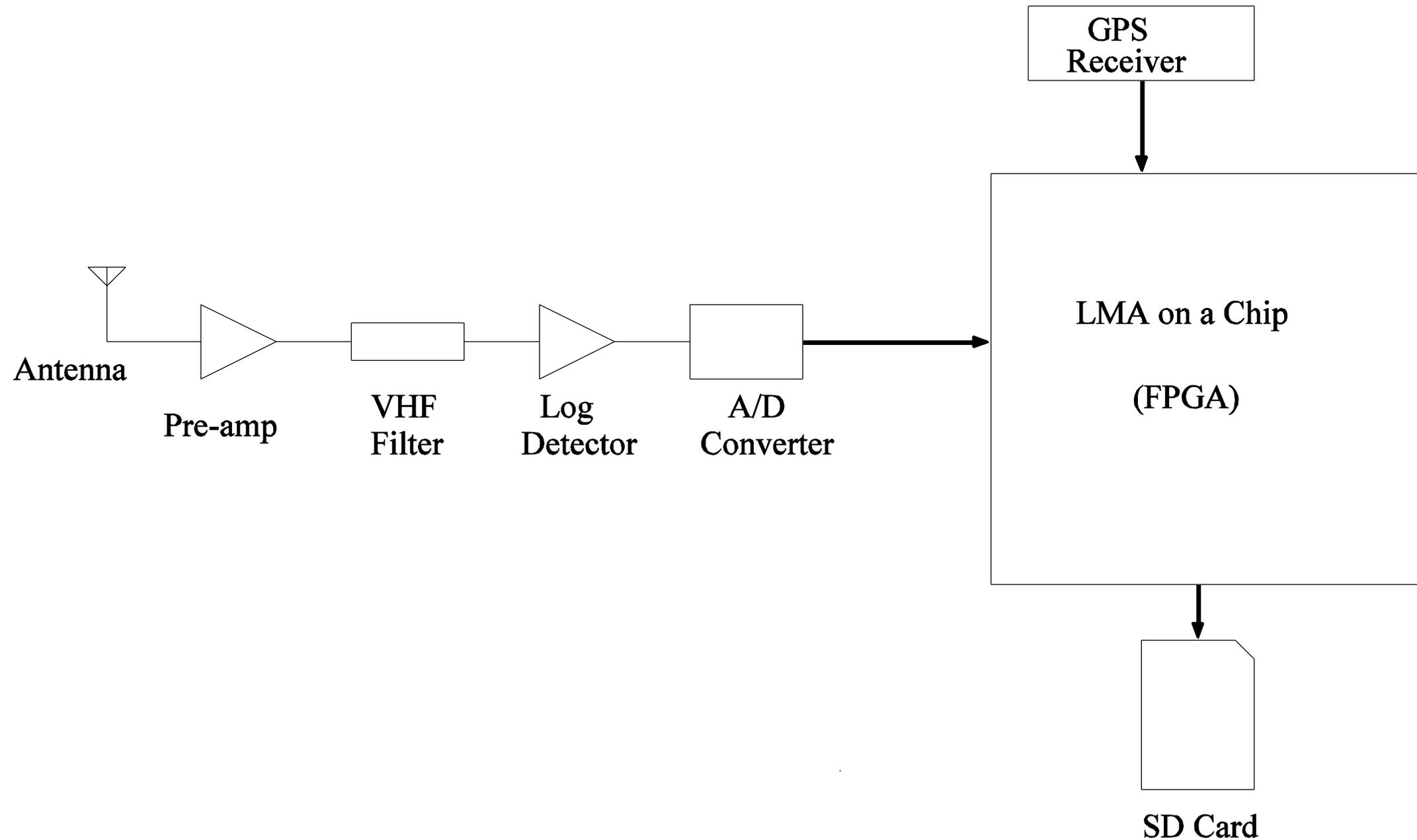


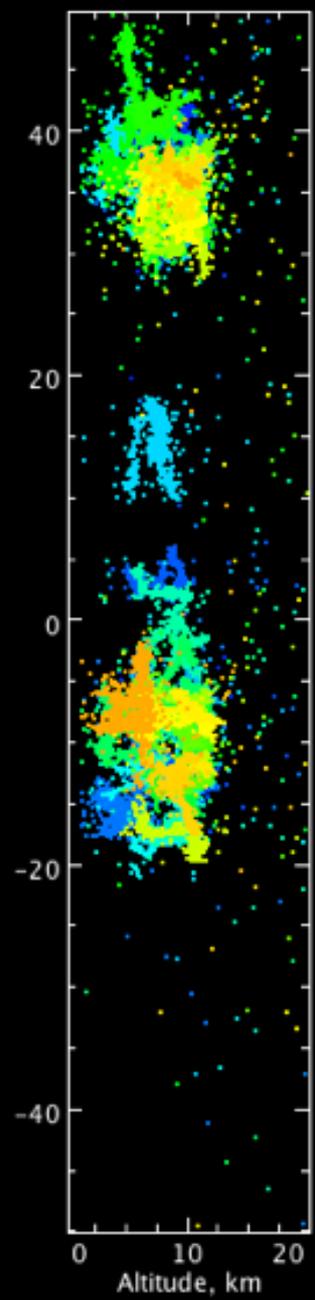
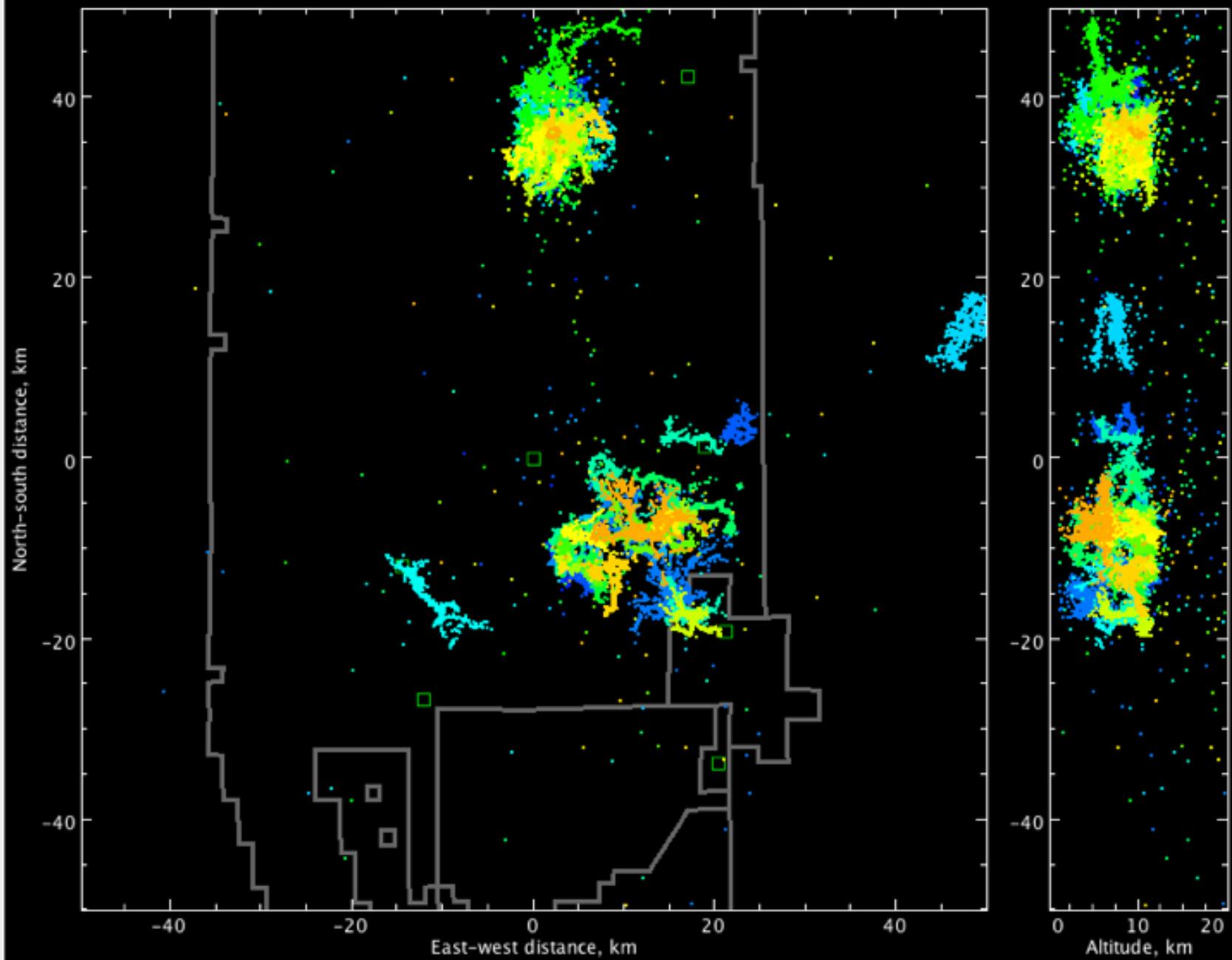
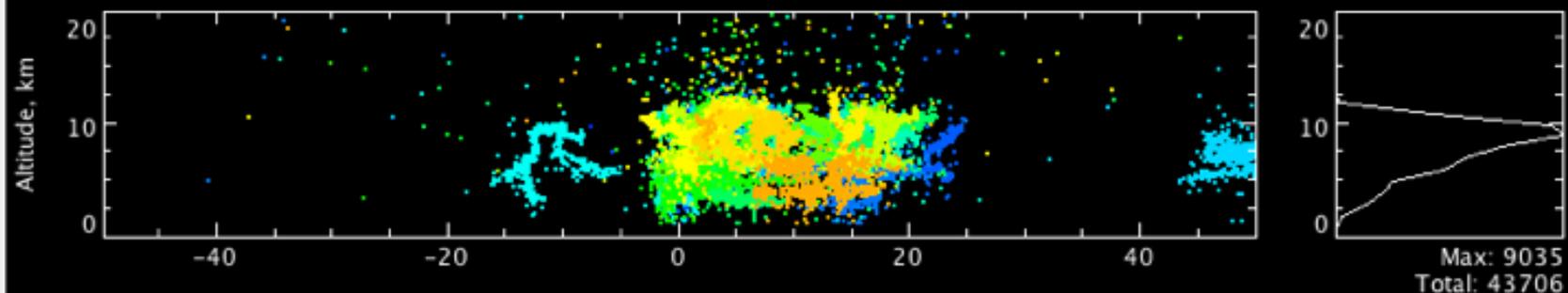
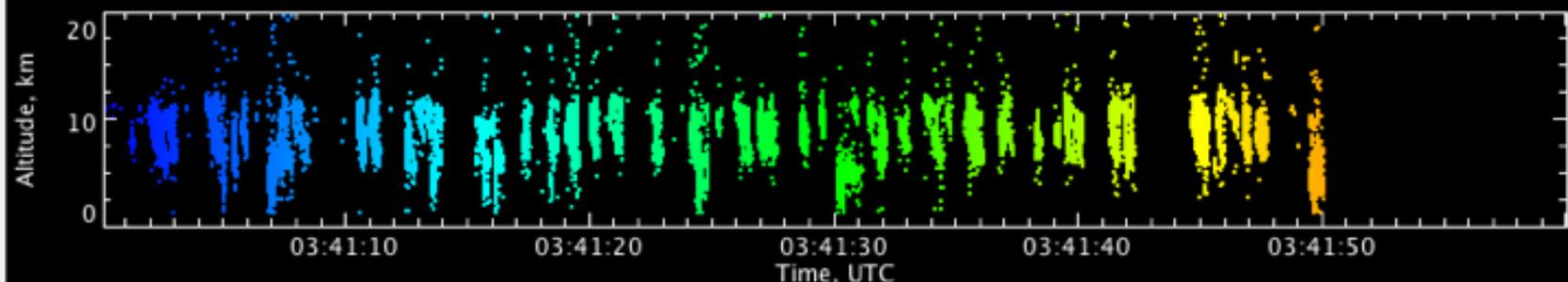
Sealed electronics enclosure for weather proofing and RF isolation



-95 dBm internally generated noise

LMA on a Chip





Server 127.0.0.1
 Processing time 11/21/2010 03:41:49
 VHF sources 92
 Data passes 0
 Stations contr. 9 (min. 0)
 Max. chi-sq. 5.0
 Decimation (us) 0

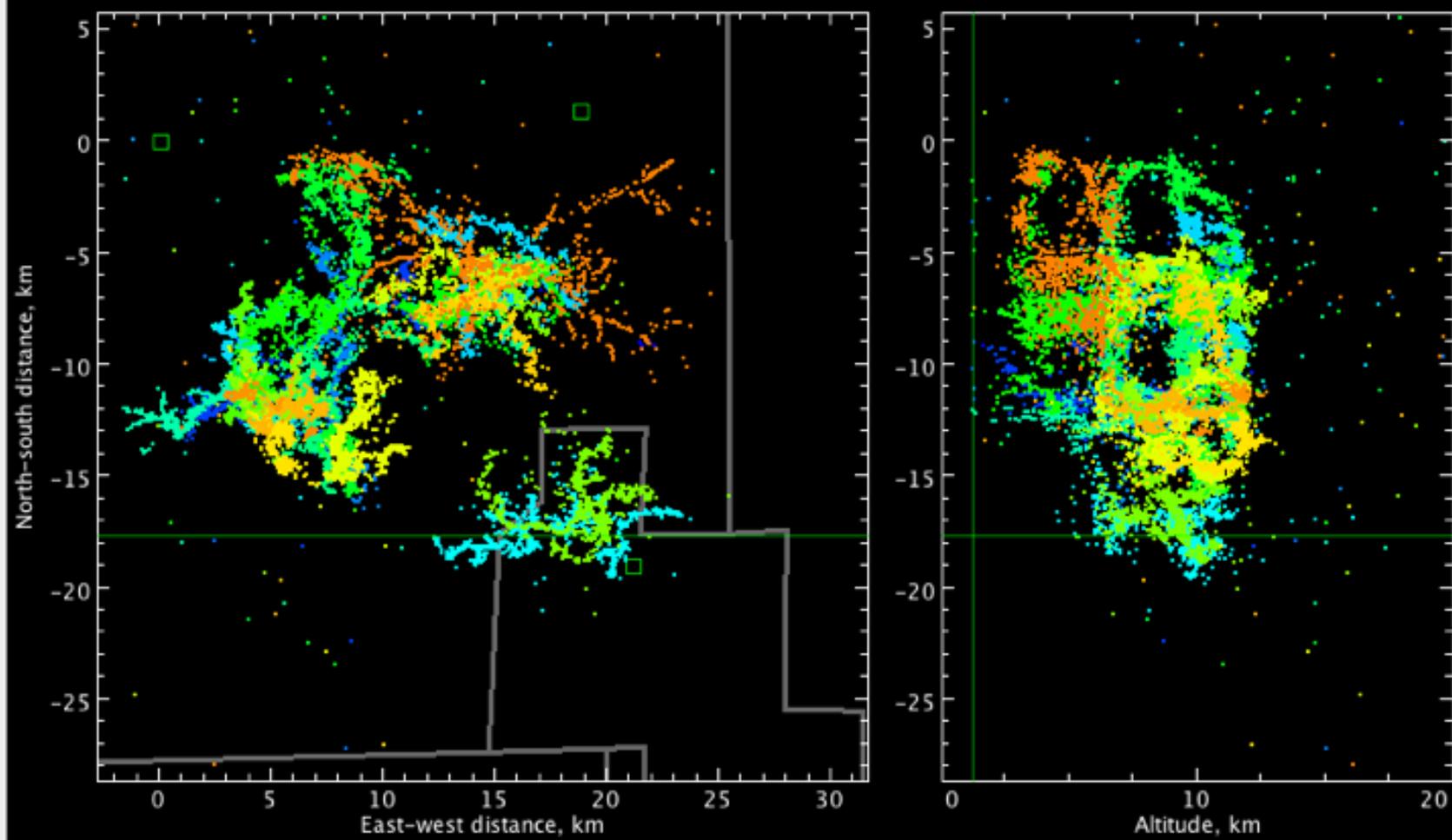
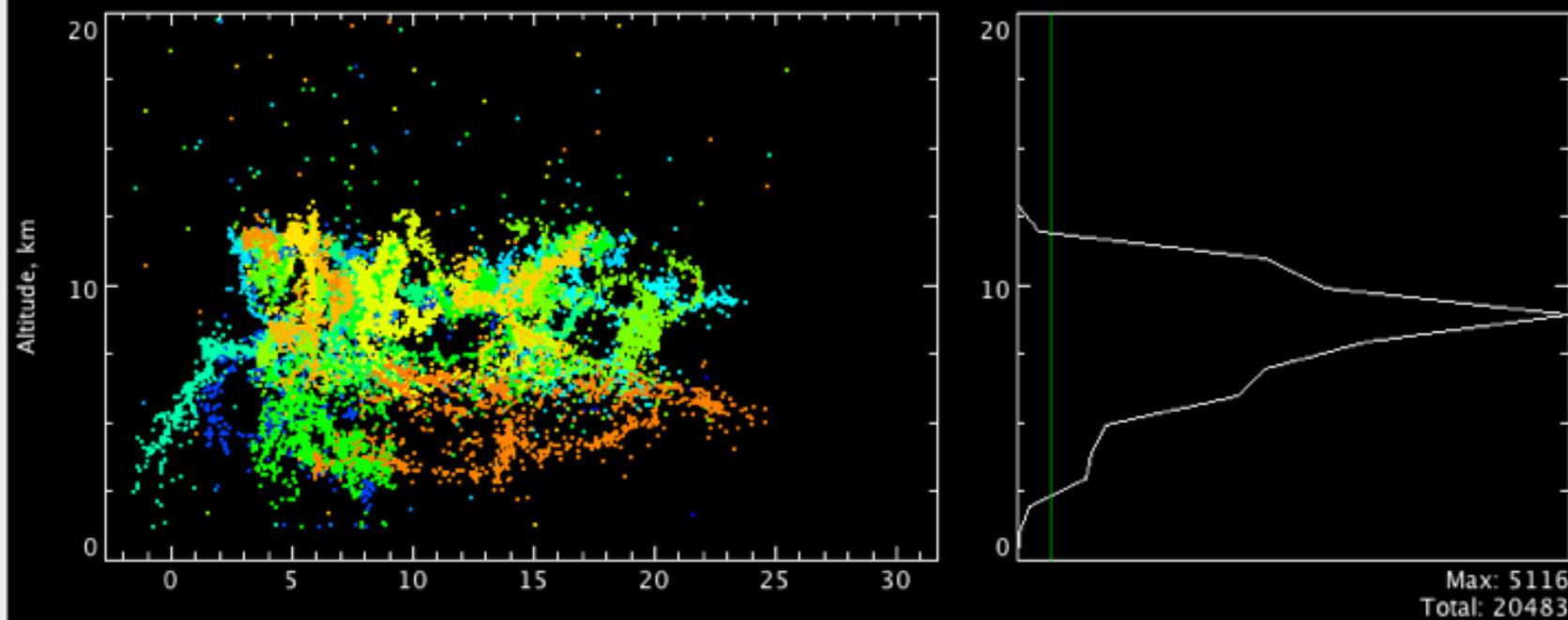
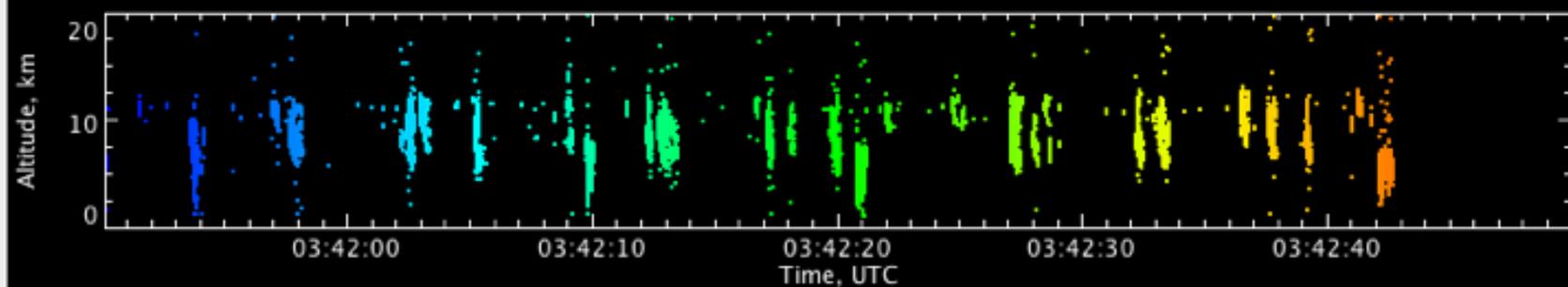
Time interval
 Time base
 Real-time mode On Off

Source size
 Color coding
 Background White Black
 Terrain On Off

Range
 Selection cursor On Off

| | Min | Max |
|----------------|------------------------------------|-----------------------------------|
| Latitude (km) | <input type="text" value="-50.0"/> | <input type="text" value="50.0"/> |
| Longitude (km) | <input type="text" value="-50.0"/> | <input type="text" value="50.0"/> |
| Altitude (km) | <input type="text" value="0.0"/> | <input type="text" value="20.0"/> |
| Stations | <input type="text" value="6"/> | <input type="text" value="12"/> |
| Chi-squared | <input type="text" value="0.0"/> | <input type="text" value="5.0"/> |

LiveLMA
 Updates each 1 second
 2 second delay
 Time-height as a 'strip-chart'
 zoom and pan



Server 127.0.0.1
 Processing time 11/21/2010 03:42:42
 VHF sources 47
 Data passes 0
 Stations contr. 9 (min. 0)
 Max. chi-sq. 5.0
 Decimation (us) 0

Time interval 1 minute
 Time base UTC
 Real-time mode On Off

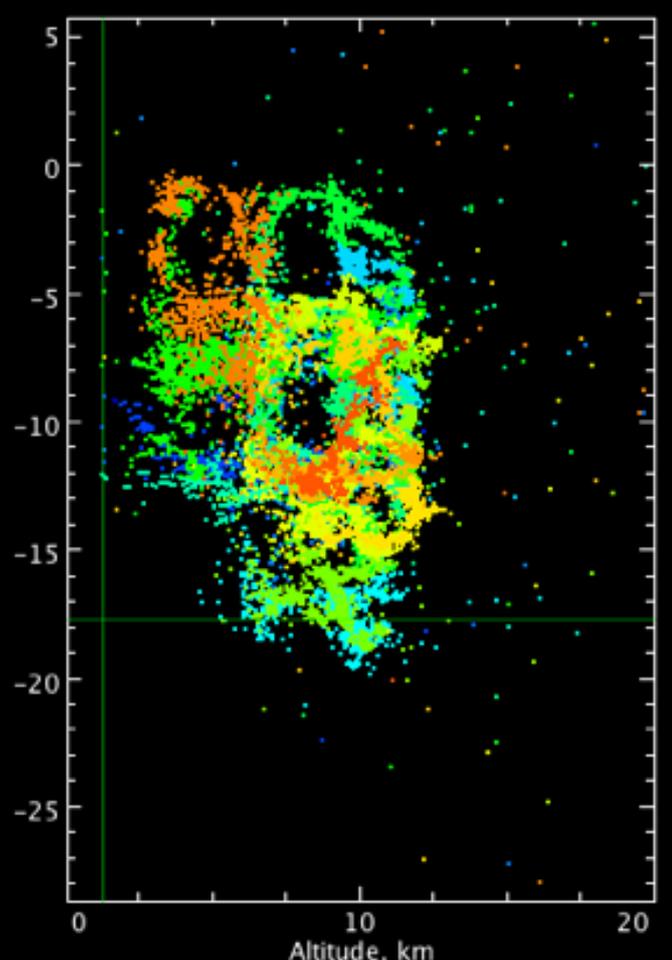
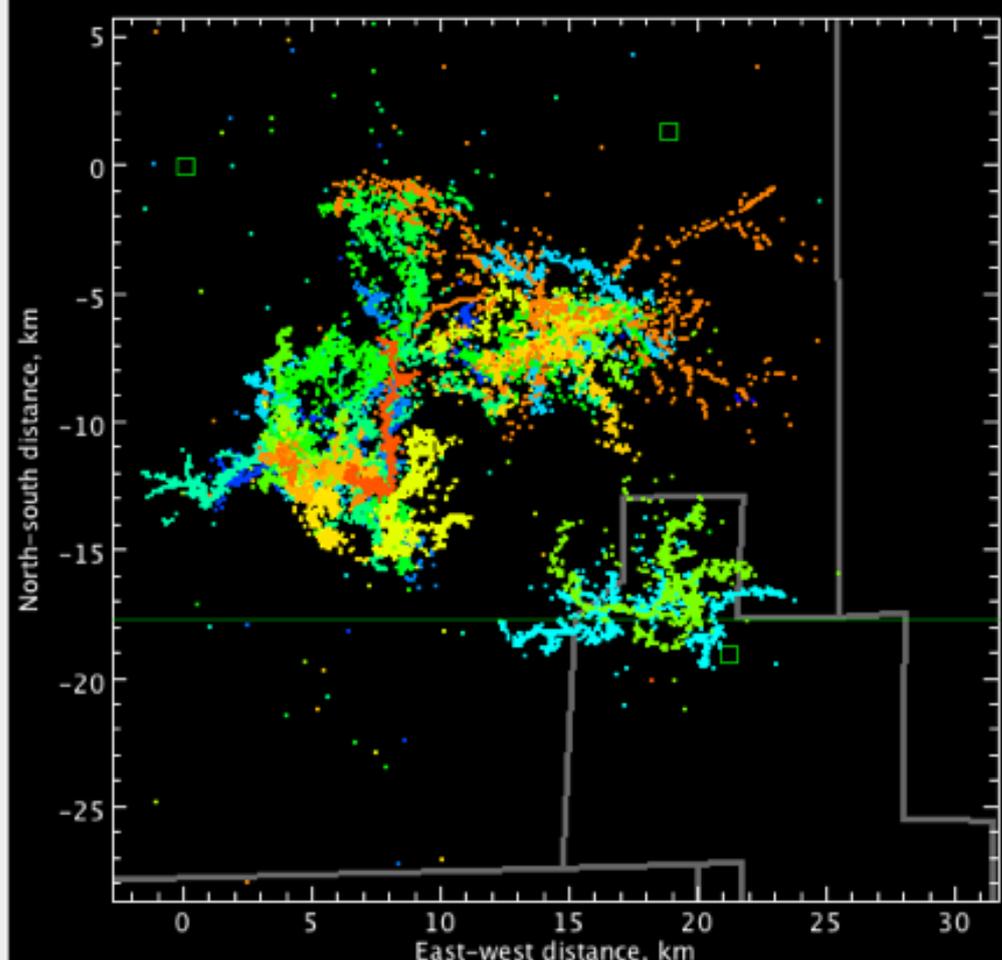
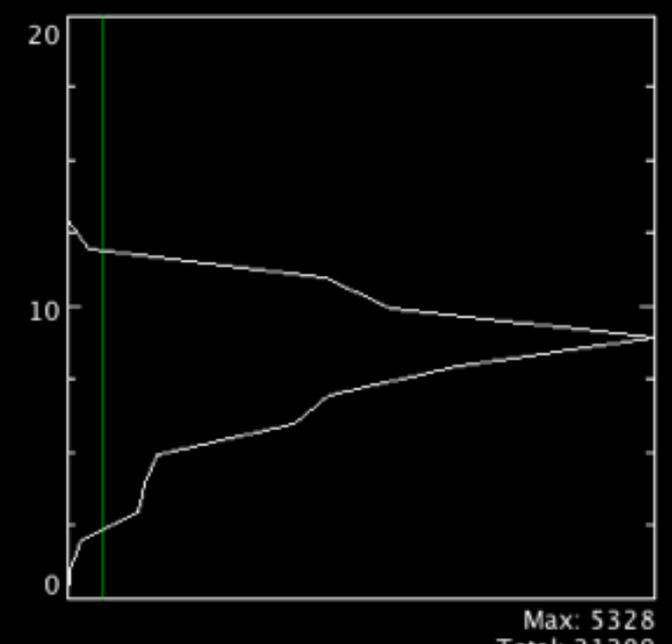
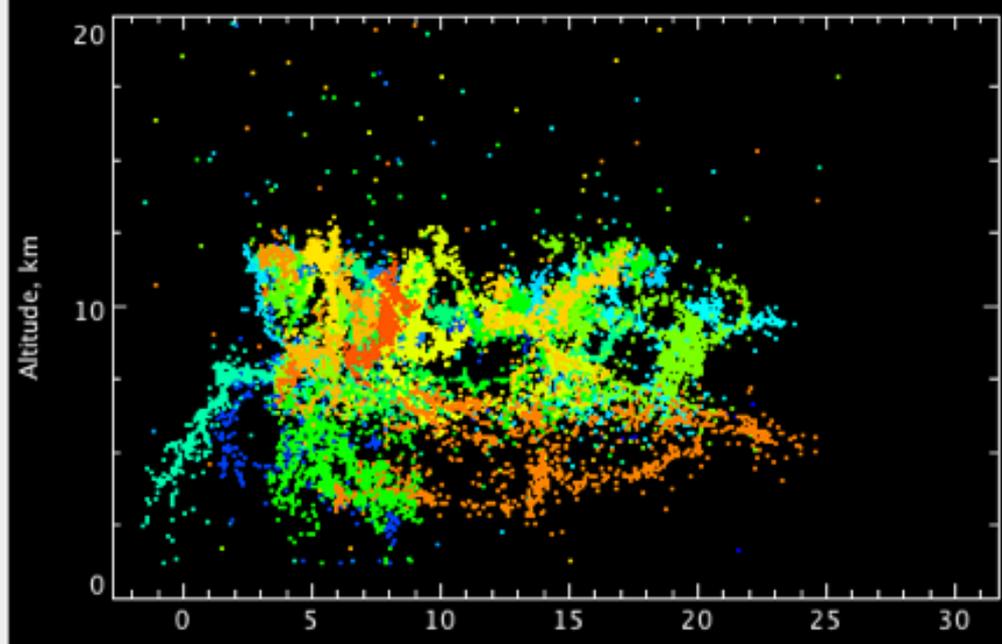
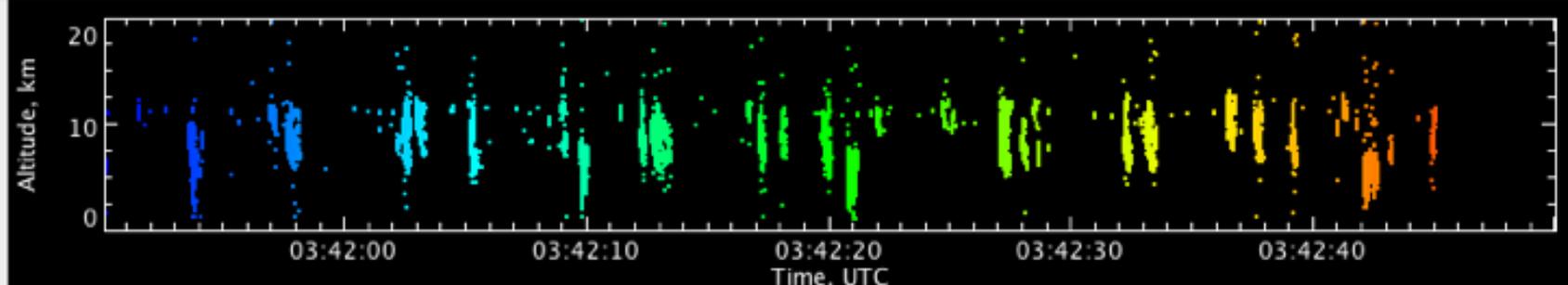
Source size Medium (2 pix...
 Color coding Color by time
 Background White Black
 Terrain On Off

Range Custom
 Selection cursor On Off

| | Min | Max |
|----------------|-------|------|
| Latitude (km) | -28.7 | 5.8 |
| Longitude (km) | -2.9 | 31.6 |
| Altitude (km) | 0.0 | 20.0 |
| Stations | 6 | 12 |
| Chi-squared | 0.0 | 5.0 |

<< Station mask

Redraw



Server 127.0.0.1
 Processing time 11/21/2010 03:42:44
 VHF sources 25
 Data passes 0
 Stations contr. 9 (min. 0)
 Max. chi-sq. 5.0
 Decimation (us) 0

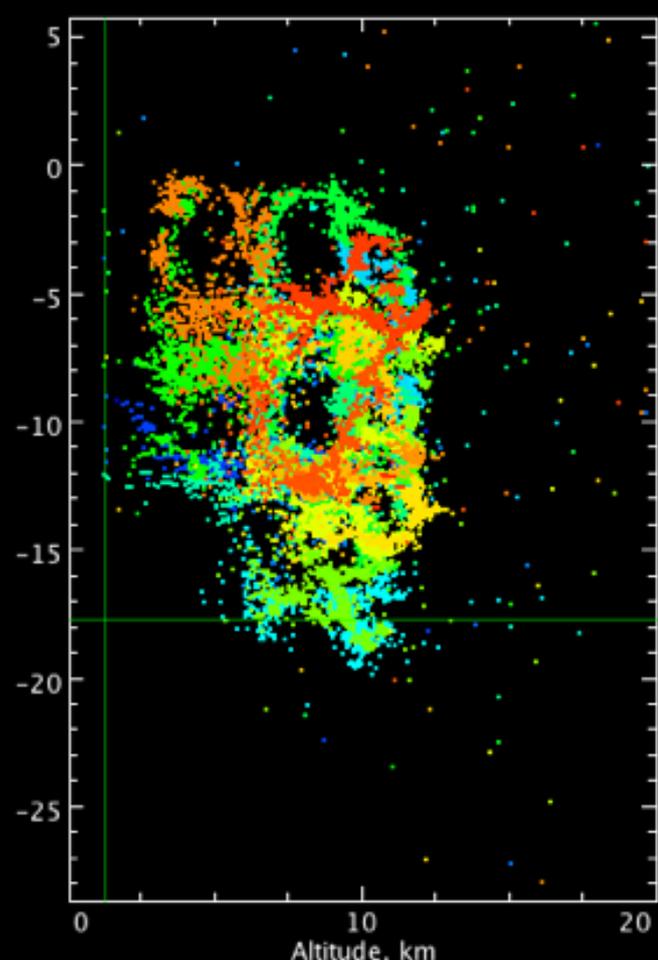
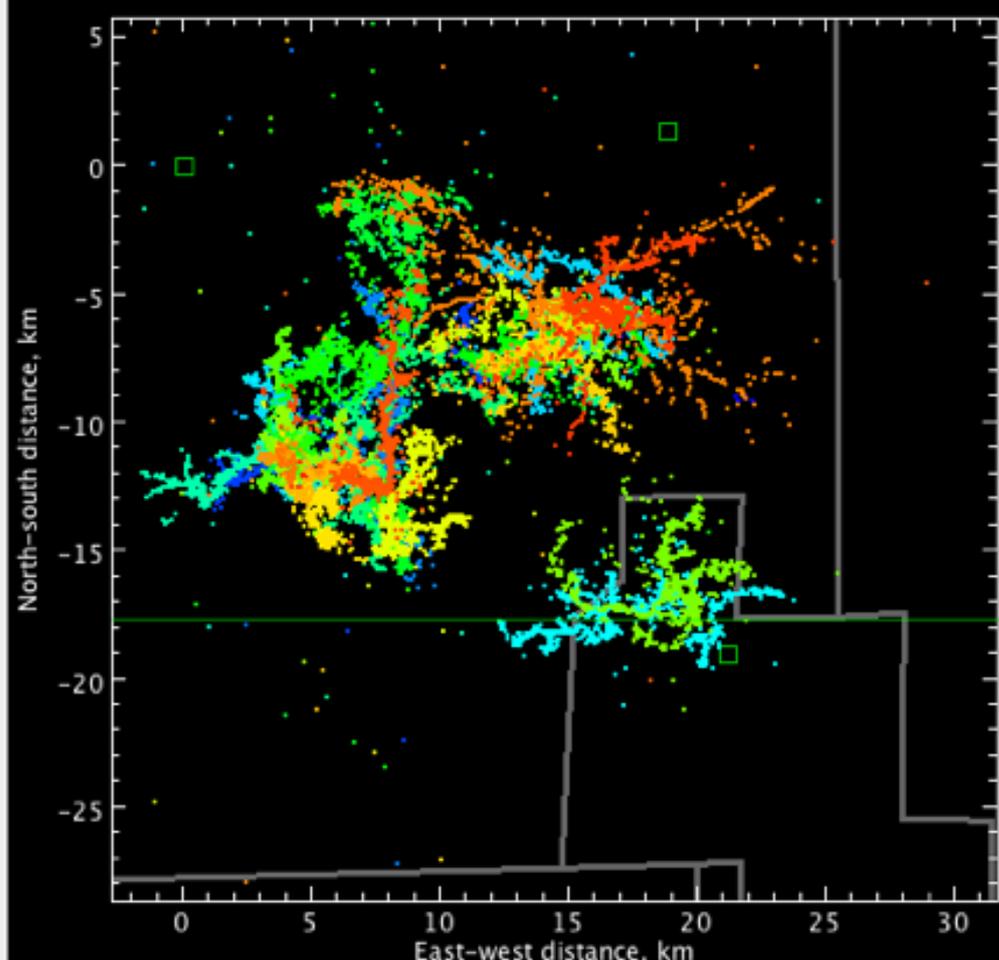
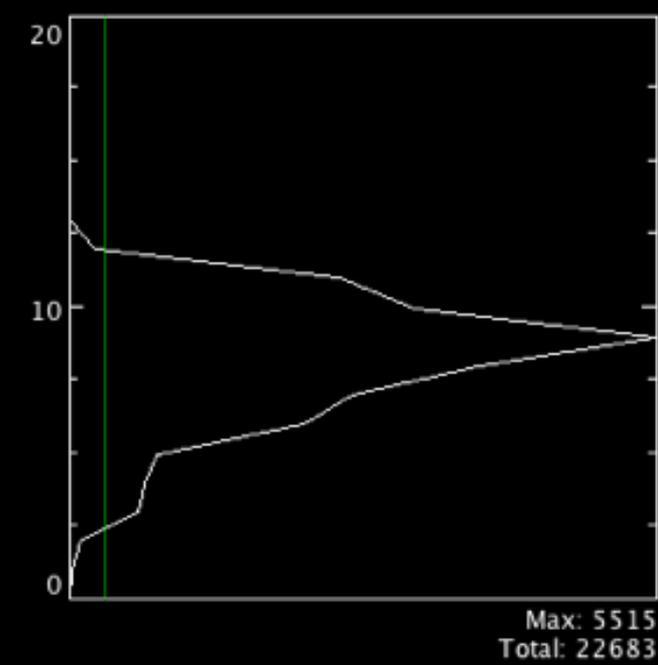
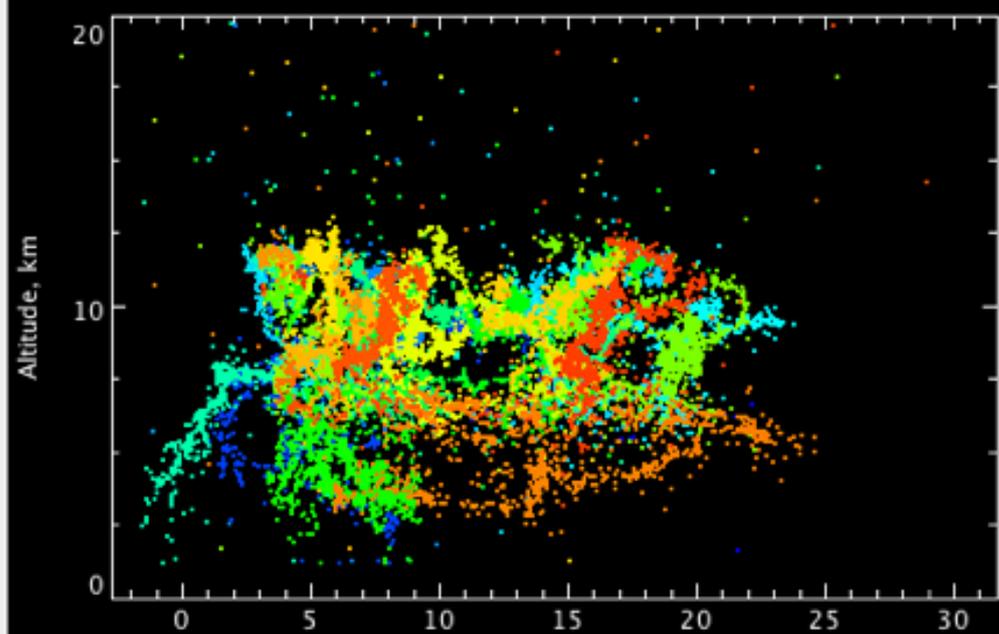
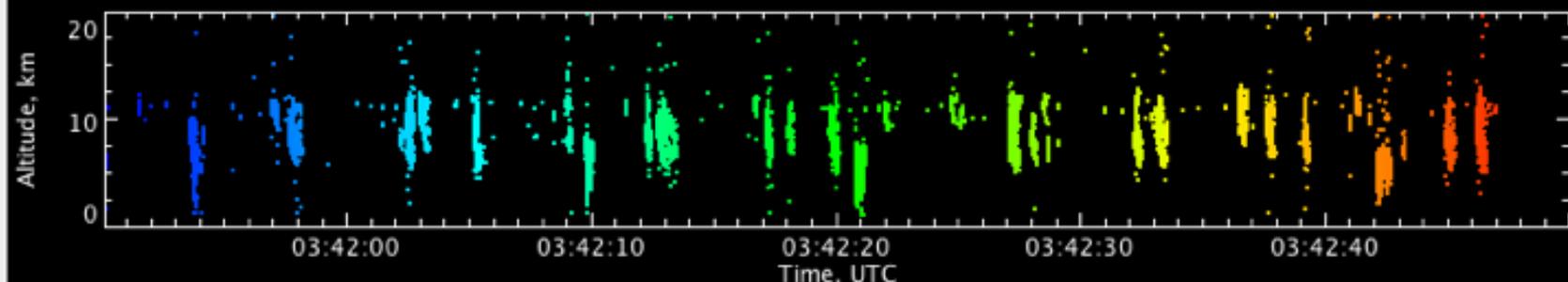
Time interval
 Time base
 Real-time mode On Off

Source size
 Color coding
 Background White Black
 Terrain On Off

Range
 Selection cursor On Off

| | Min | Max |
|----------------|-------|------|
| Latitude (km) | -28.7 | 5.8 |
| Longitude (km) | -2.9 | 31.6 |
| Altitude (km) | 0.0 | 20.0 |
| Stations | 6 | 12 |
| Chi-squared | 0.0 | 5.0 |

<< Station mask
 Redraw



Server 127.0.0.1
 Processing time 11/21/2010 03:42:46
 VHF sources 48
 Data passes 0
 Stations contr. 9 (min. 0)
 Max. chi-sq. 5.0
 Decimation (us) 0

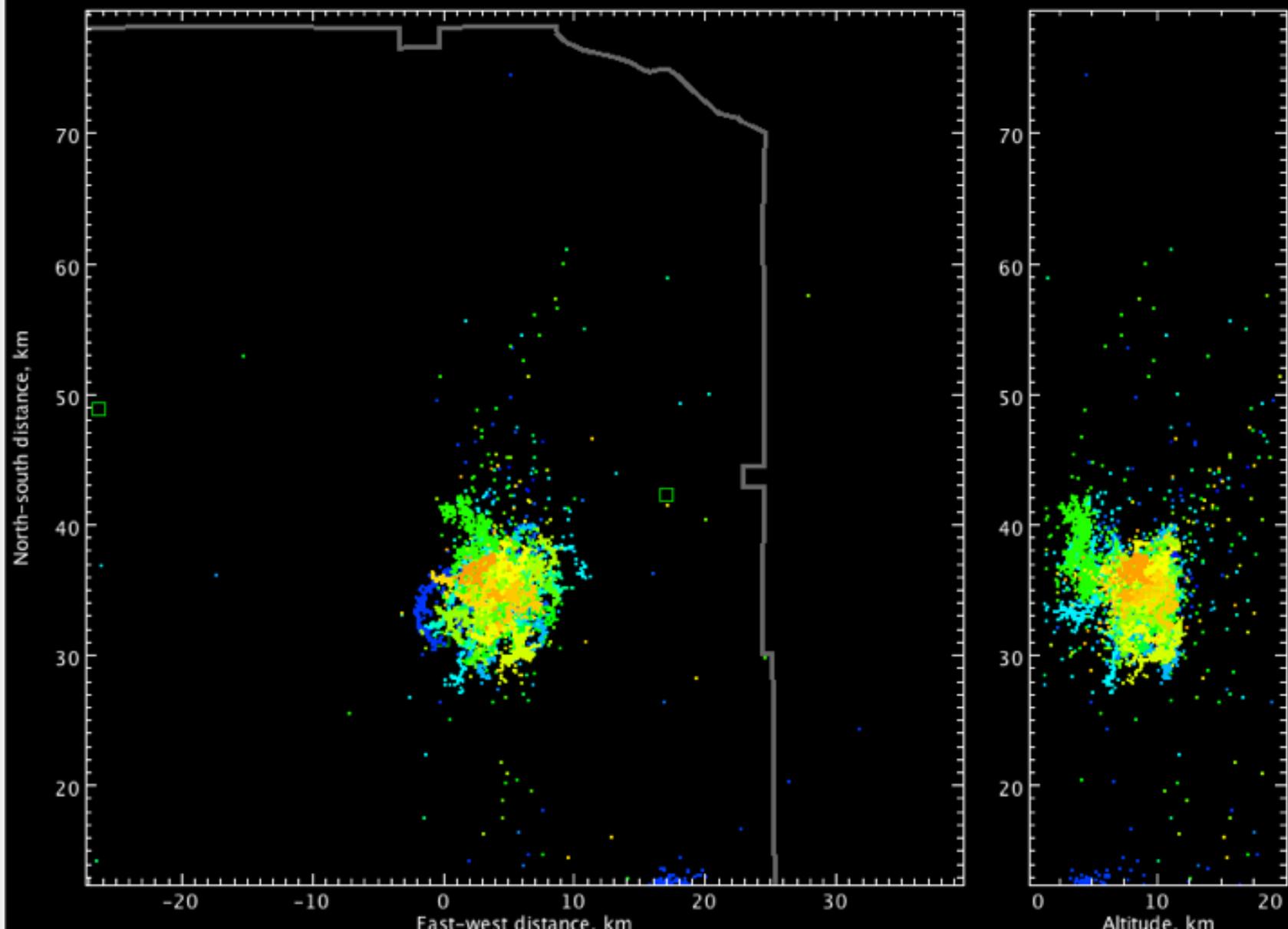
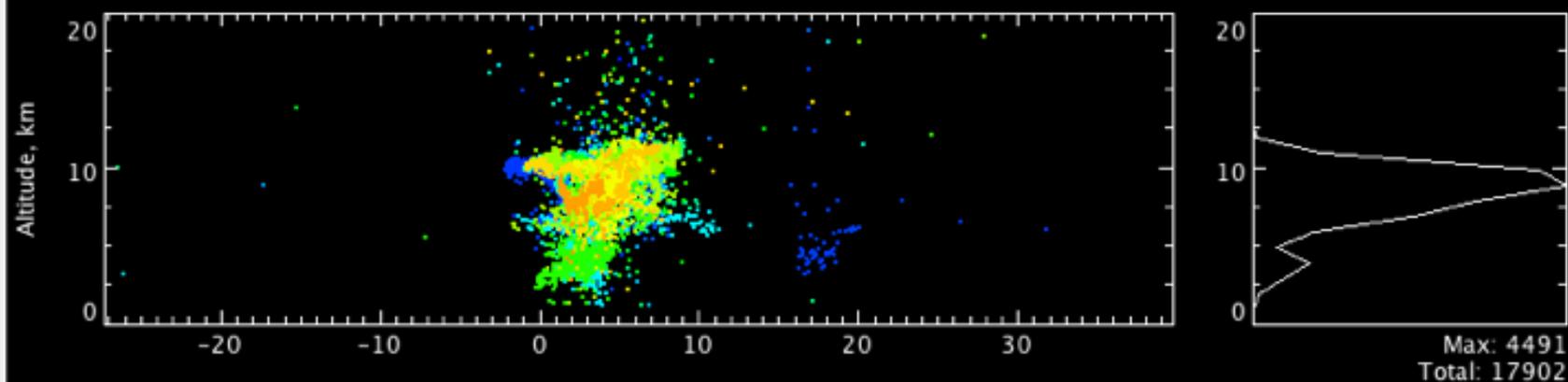
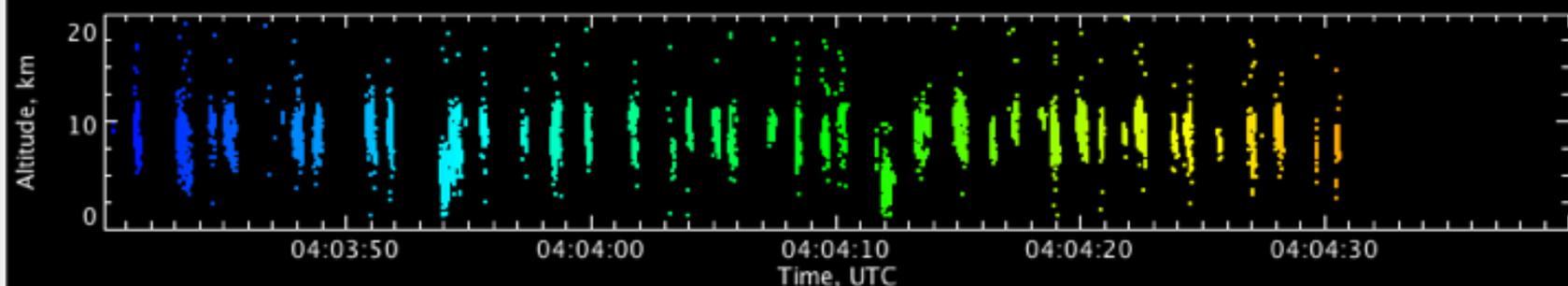
Time interval 1 minute
 Time base UTC
 Real-time mode On Off

Source size Medium (2 pix...
 Color coding Color by time
 Background White Black
 Terrain On Off

Range Custom
 Selection cursor On Off

| | Min | Max |
|----------------|-------|------|
| Latitude (km) | -28.7 | 5.8 |
| Longitude (km) | -2.9 | 31.6 |
| Altitude (km) | 0.0 | 20.0 |
| Stations | 6 | 12 |
| Chi-squared | 0.0 | 5.0 |

<< Station mask
 Redraw



Server 127.0.0.1
 Processing time 11/21/2010 04:04:30
 VHF sources 37
 Data passes 0
 Stations contr. 9 (min. 0)
 Max. chi-sq. 5.0
 Decimation (us) 0

Time interval 1 minute
 Time base UTC
 Real-time mode On Off

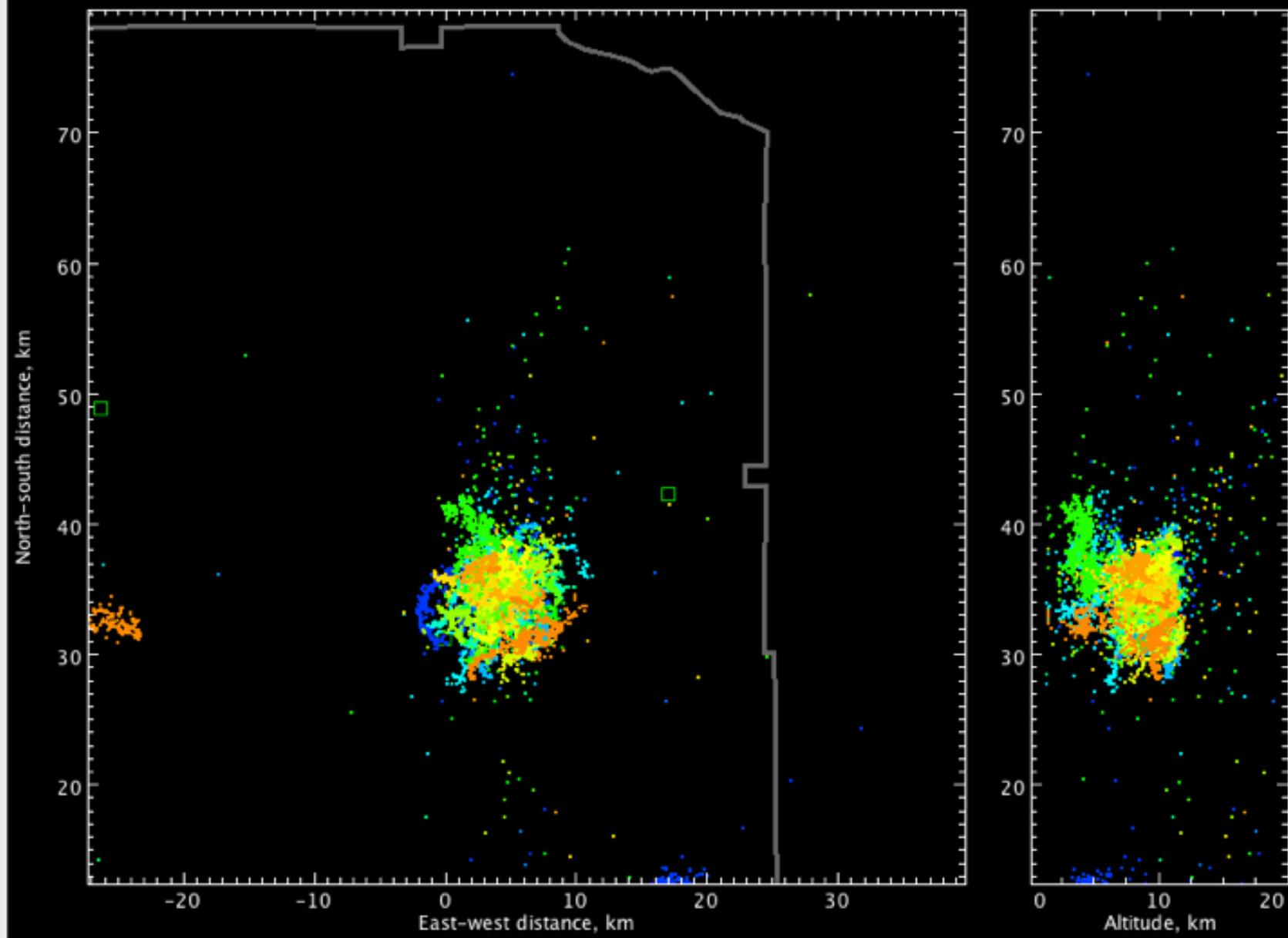
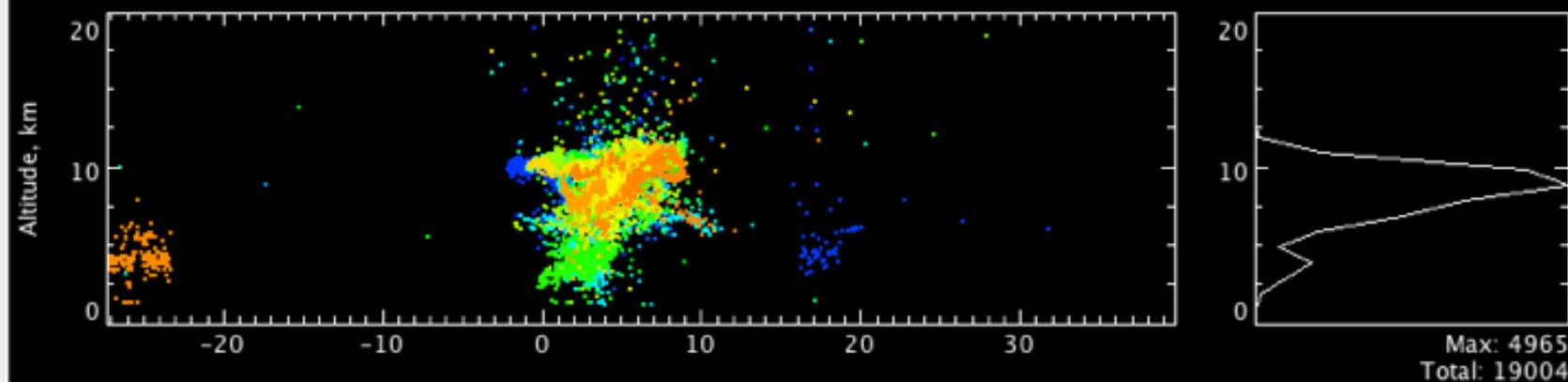
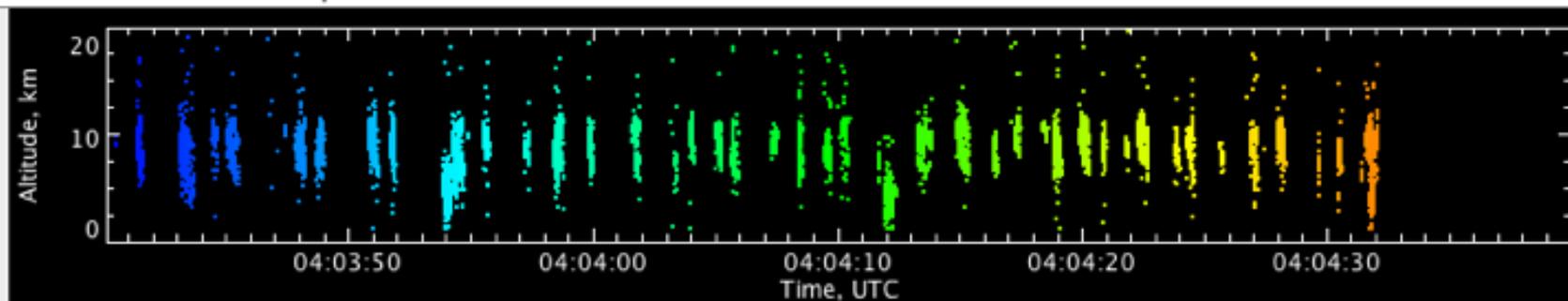
Source size Medium (2 pix...
 Color coding Color by time
 Background White Black
 Terrain On Off

Range Custom
 Selection cursor On Off

| | Min | Max |
|----------------|-------|------|
| Latitude (km) | 12.4 | 79.6 |
| Longitude (km) | -27.5 | 39.7 |
| Altitude (km) | 0.0 | 20.0 |
| Stations | 6 | 12 |
| Chi-squared | 0.0 | 5.0 |

<< Station mask

Redraw



Server 127.0.0.1
 Processing time 11/21/2010 04:04:31
 VHF sources 61
 Data passes 0
 Stations contr. 9 (min. 0)
 Max. chi-sq. 5.0
 Decimation (us) 0

Time interval 1 minute
 Time base UTC
 Real-time mode On Off

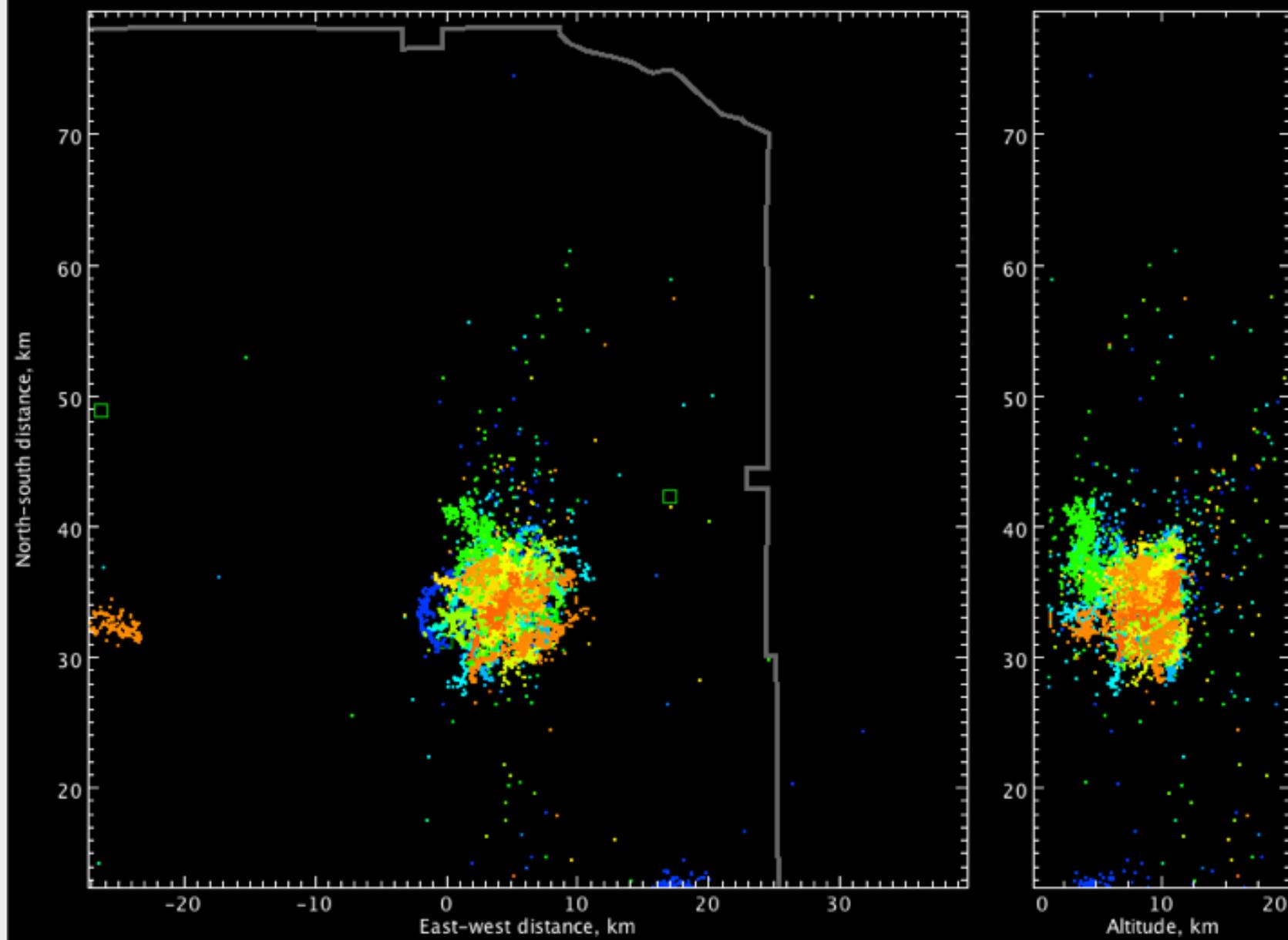
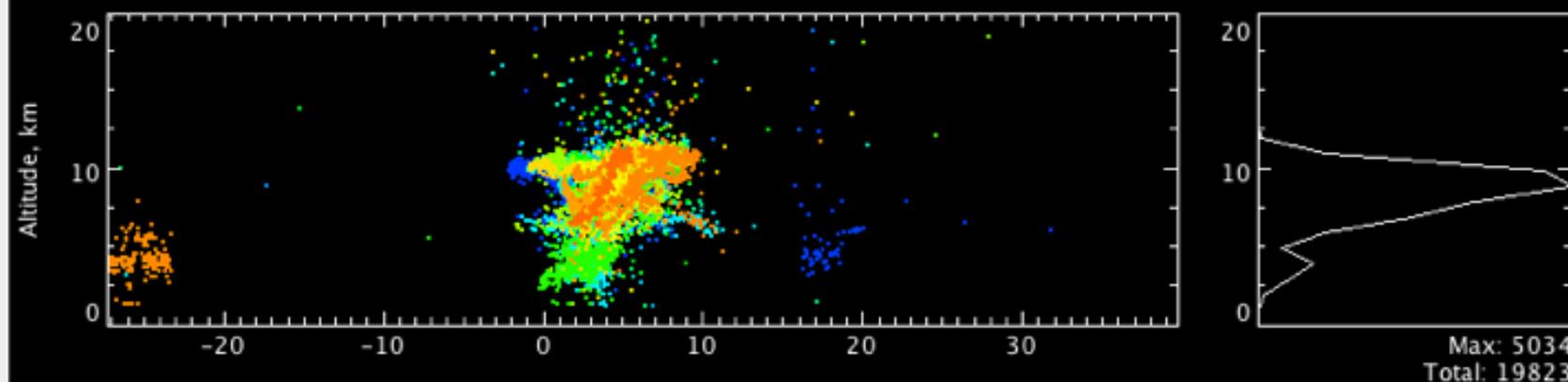
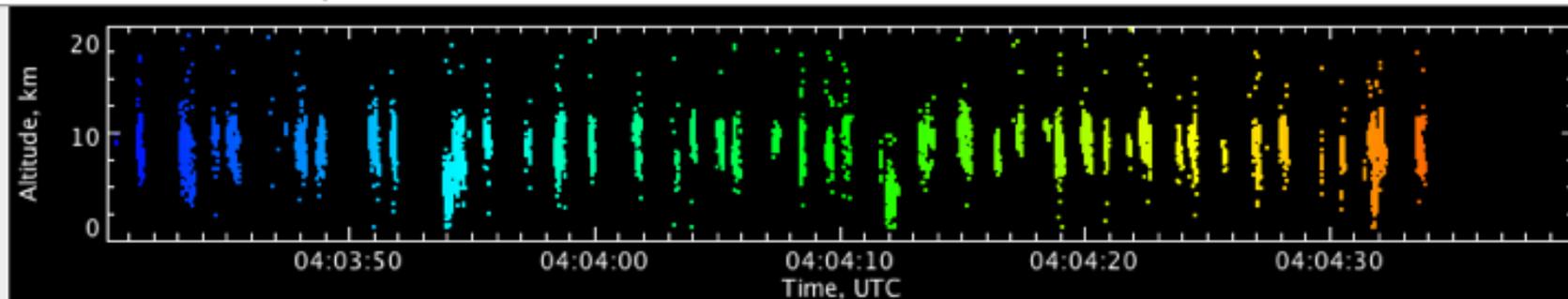
Source size Medium (2 pix...
 Color coding Color by time
 Background White Black
 Terrain On Off

Range Custom
 Selection cursor On Off

| | Min | Max |
|----------------|-------|------|
| Latitude (km) | 12.4 | 79.6 |
| Longitude (km) | -27.5 | 39.7 |
| Altitude (km) | 0.0 | 20.0 |
| Stations | 6 | 12 |
| Chi-squared | 0.0 | 5.0 |

<< Station mask

Redraw



Server 127.0.0.1
 Processing time 11/21/2010 04:04:33
 VHF sources 37
 Data passes 0
 Stations contr. 9 (min. 0)
 Max. chi-sq. 5.0
 Decimation (us) 0

Time interval 1 minute
 Time base UTC
 Real-time mode On Off

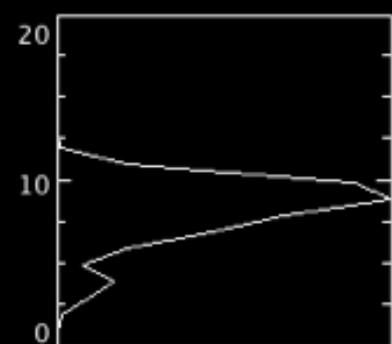
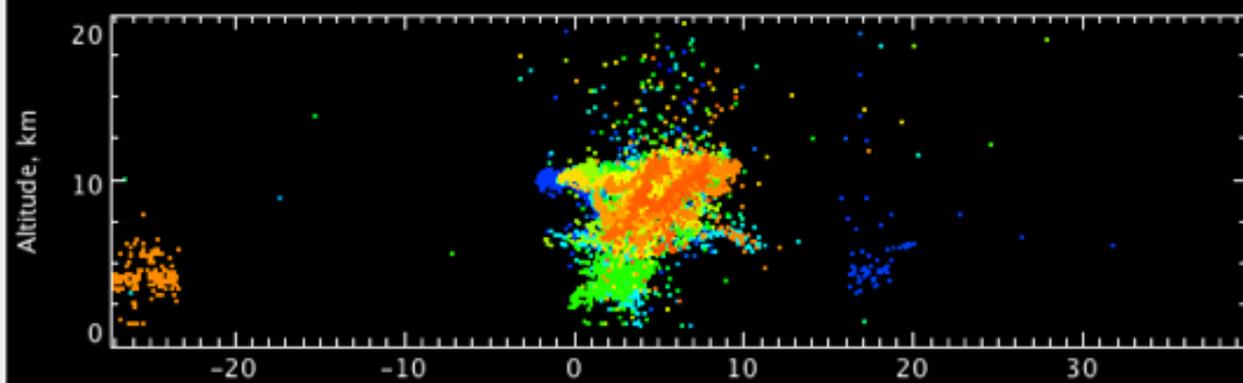
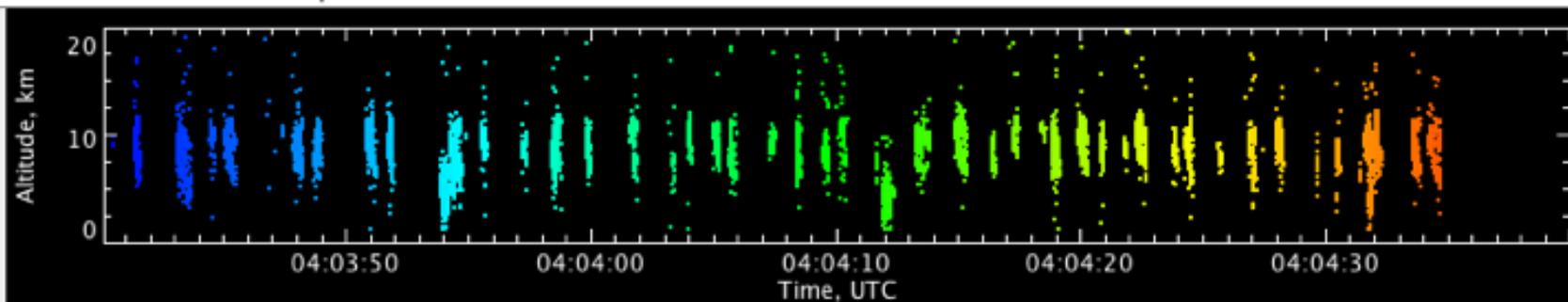
Source size Medium (2 pix...
 Color coding Color by time
 Background White Black
 Terrain On Off

Range Custom
 Selection cursor On Off

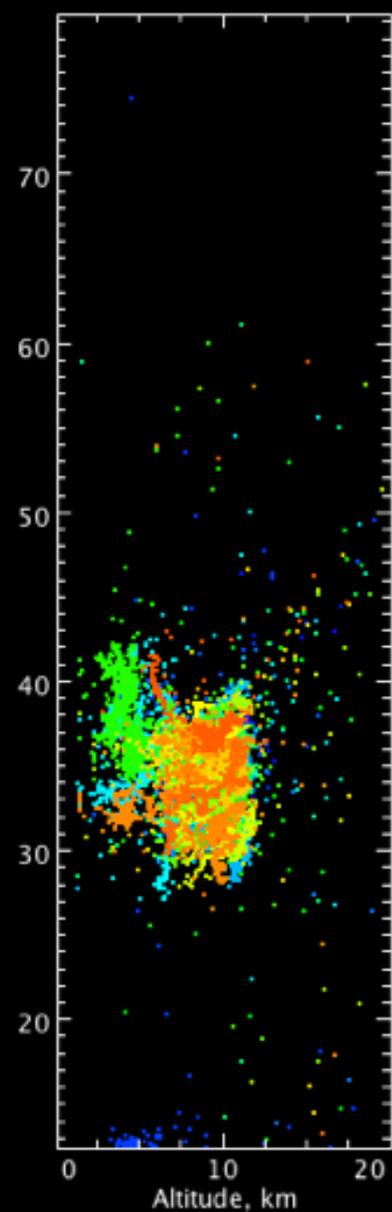
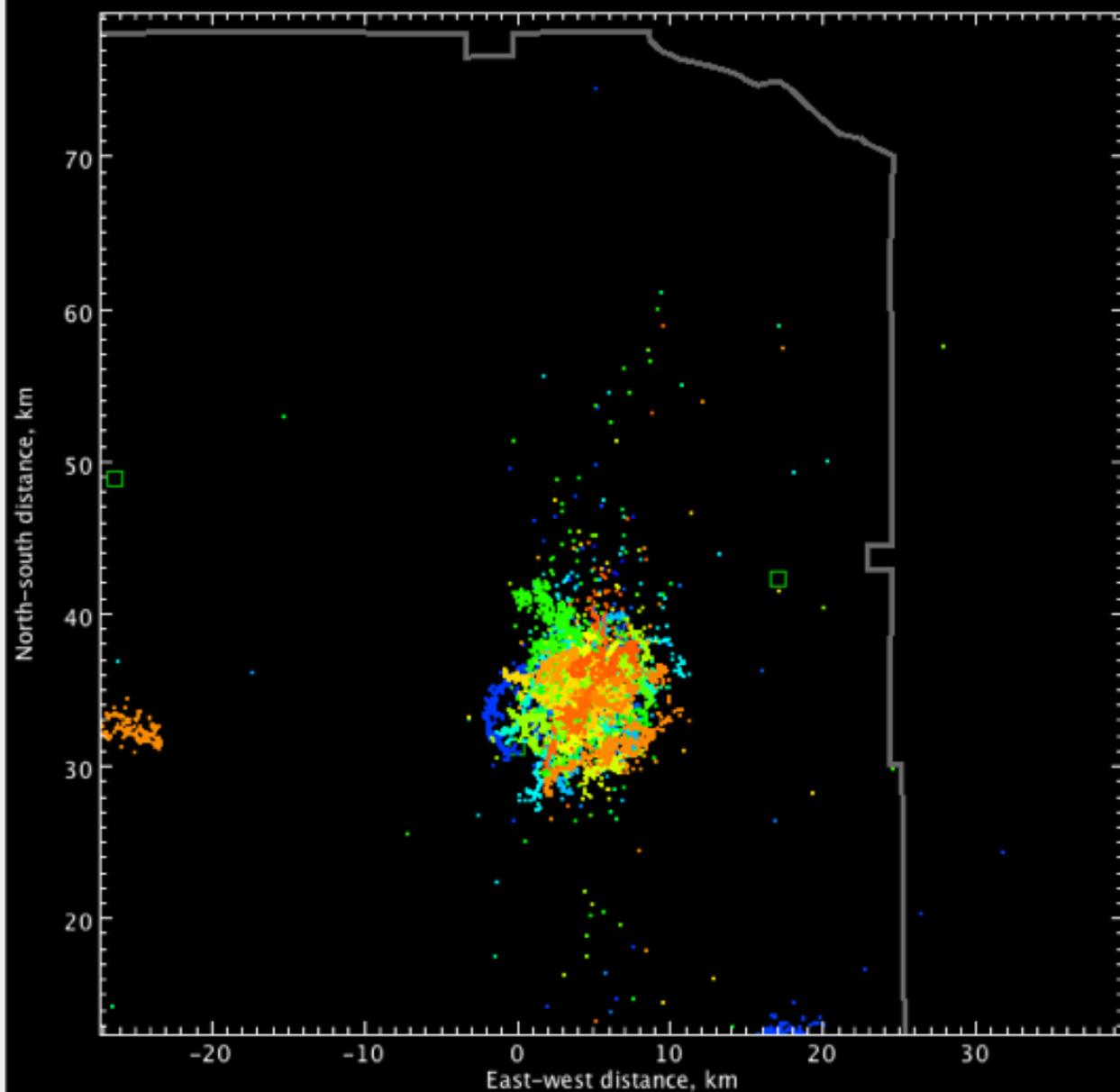
| | Min | Max |
|----------------|-------|------|
| Latitude (km) | 12.4 | 79.6 |
| Longitude (km) | -27.5 | 39.7 |
| Altitude (km) | 0.0 | 20.0 |
| Stations | 6 | 12 |
| Chi-squared | 0.0 | 5.0 |

<< Station mask

Redraw



Max: 5334
Total: 20509



Server 127.0.0.1
Processing time 11/21/2010 04:04:34
VHF sources 22
Data passes 0
Stations contr. 9 (min. 0)
Max. chi-sq. 5.0
Decimation (us) 0

Time interval
Time base
Real-time mode On Off

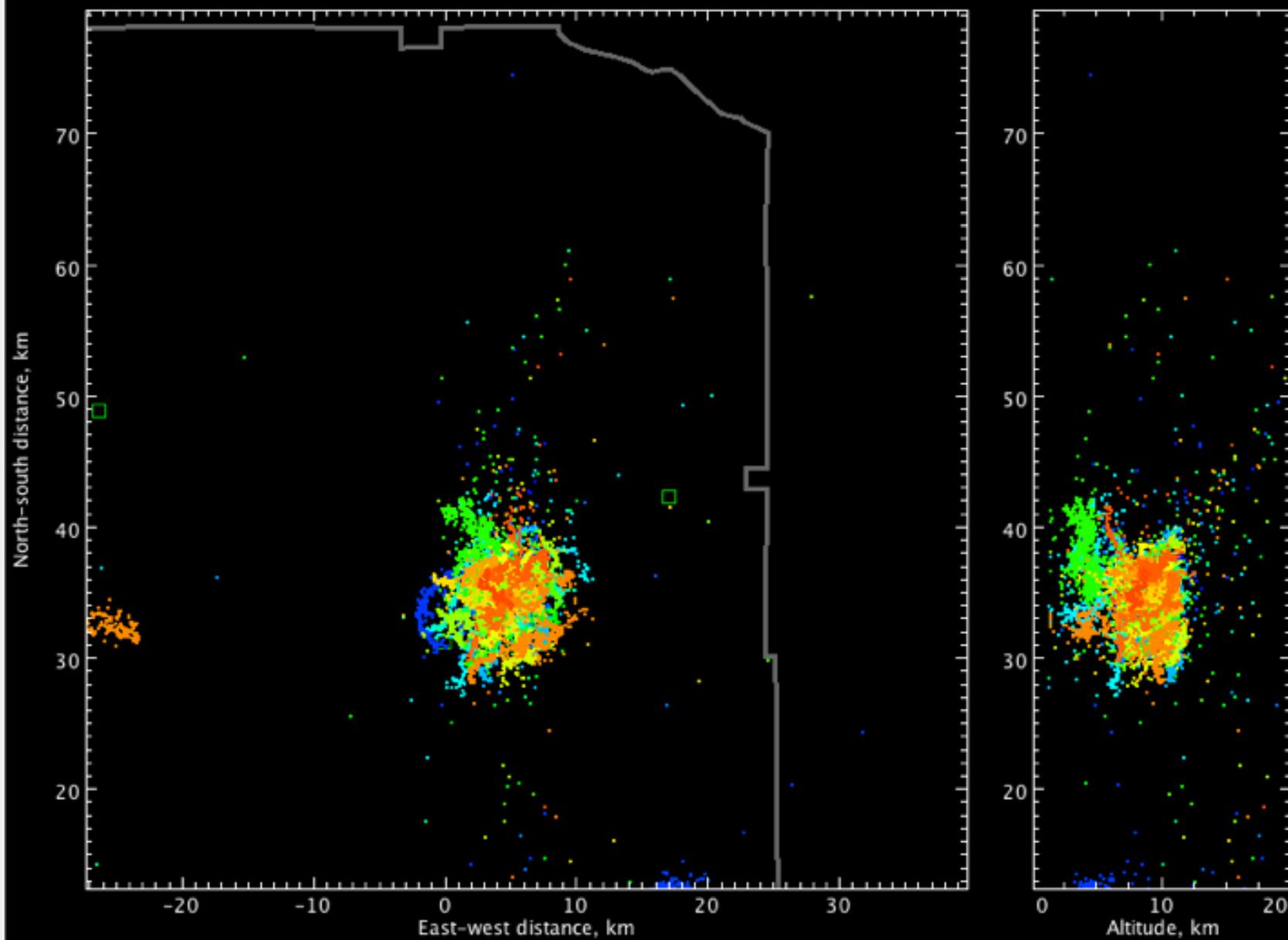
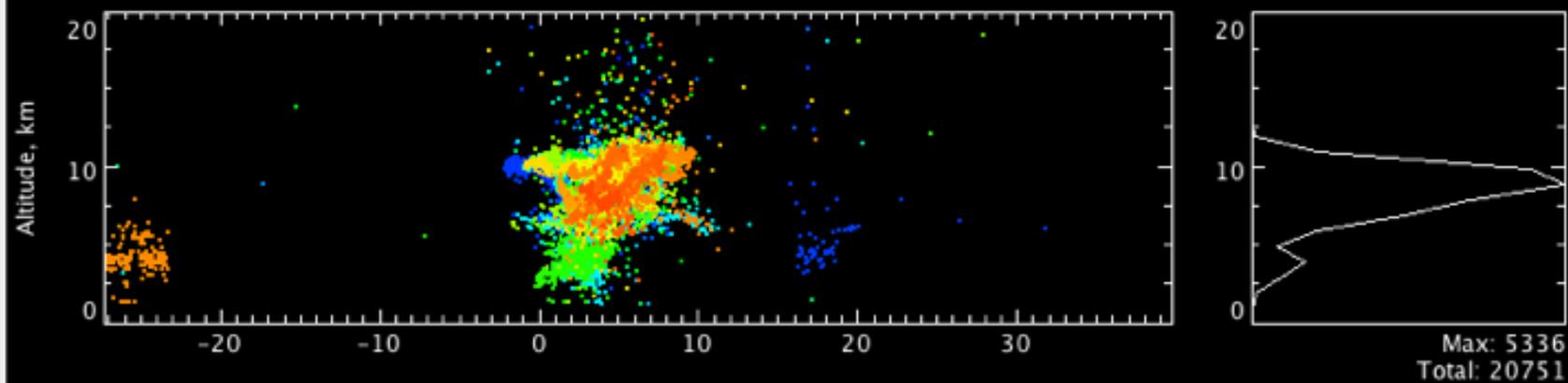
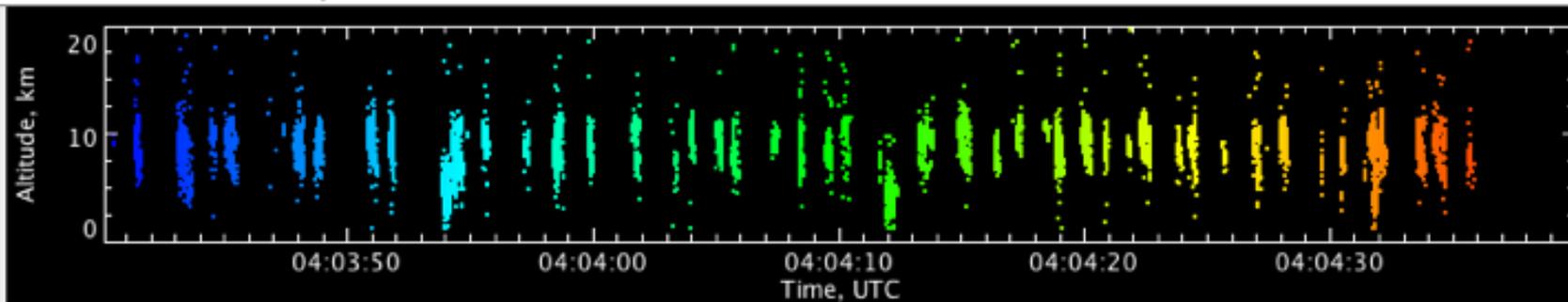
Source size
Color coding
Background White Black
Terrain On Off

Range
Selection cursor On Off

| | Min | Max |
|----------------|------------------------------------|-----------------------------------|
| Latitude (km) | <input type="text" value="12.4"/> | <input type="text" value="79.6"/> |
| Longitude (km) | <input type="text" value="-27.5"/> | <input type="text" value="39.7"/> |
| Altitude (km) | <input type="text" value="0.0"/> | <input type="text" value="20.0"/> |
| Stations | <input type="text" value="6"/> | <input type="text" value="12"/> |
| Chi-squared | <input type="text" value="0.0"/> | <input type="text" value="5.0"/> |

<< Station mask

Redraw



Server 127.0.0.1
 Processing time 11/21/2010 04:04:35
 VHF sources 33
 Data passes 0
 Stations contr. 9 (min. 0)
 Max. chi-sq. 5.0
 Decimation (us) 0

Time interval 1 minute
 Time base UTC
 Real-time mode On Off

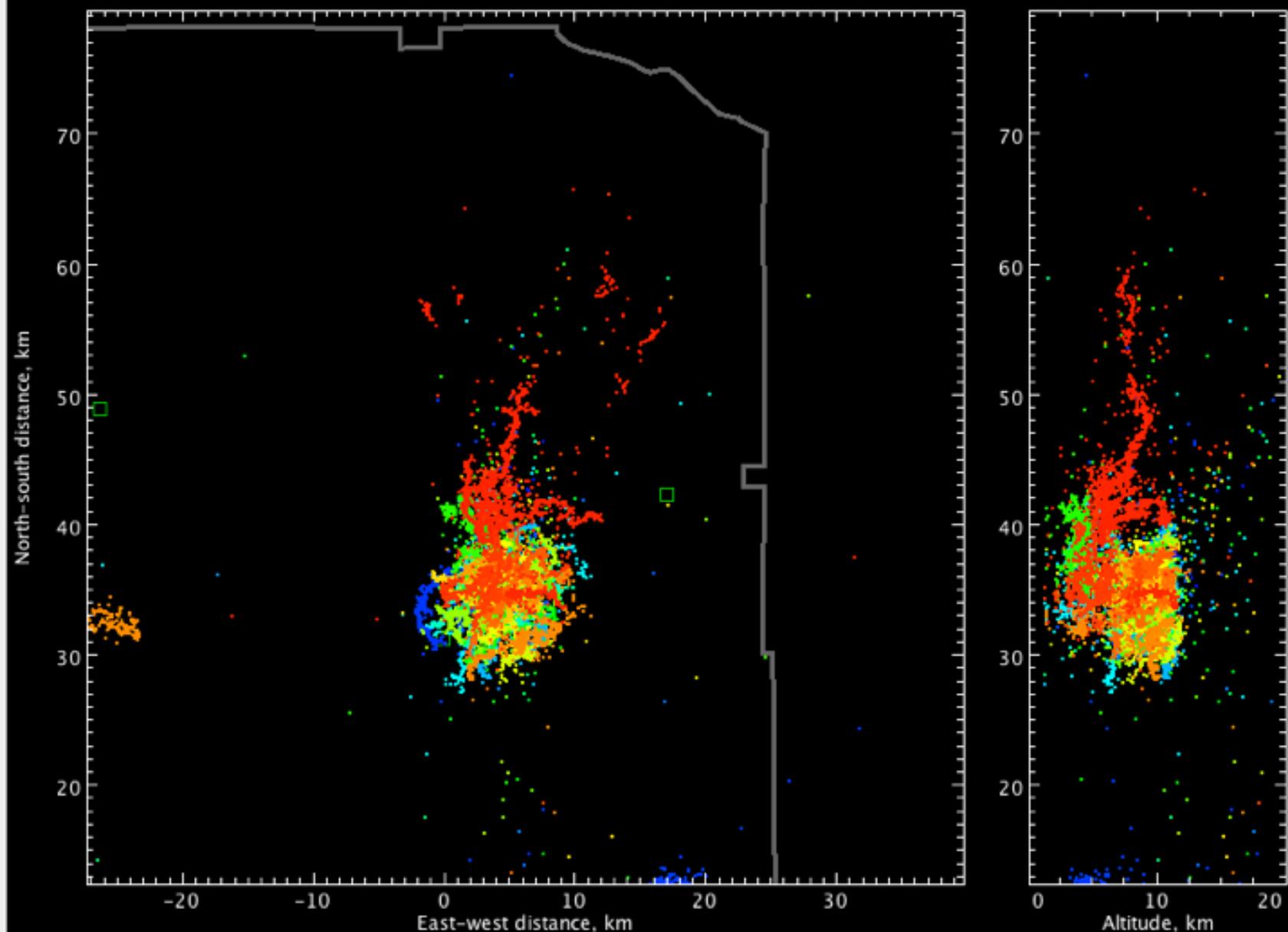
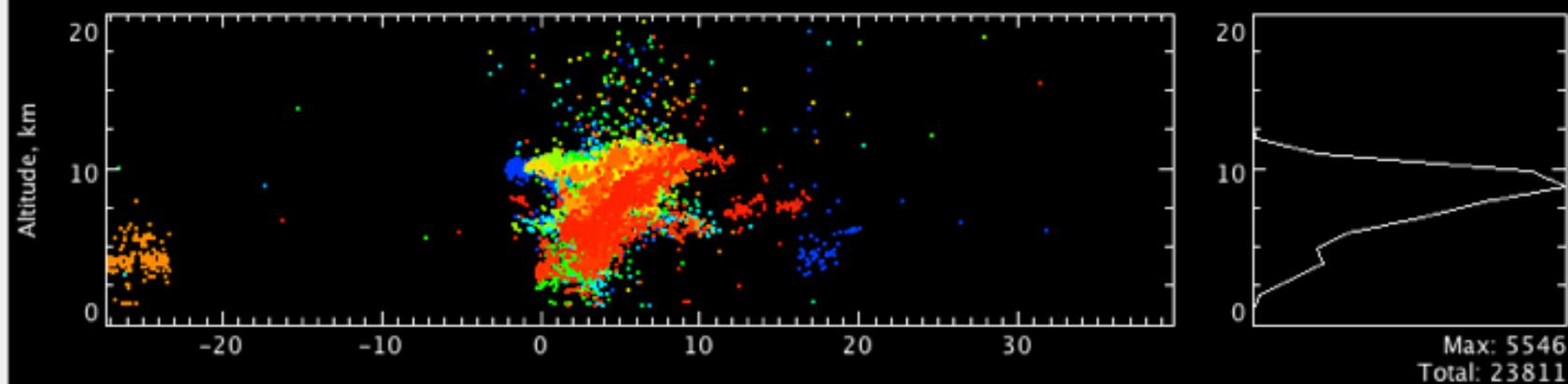
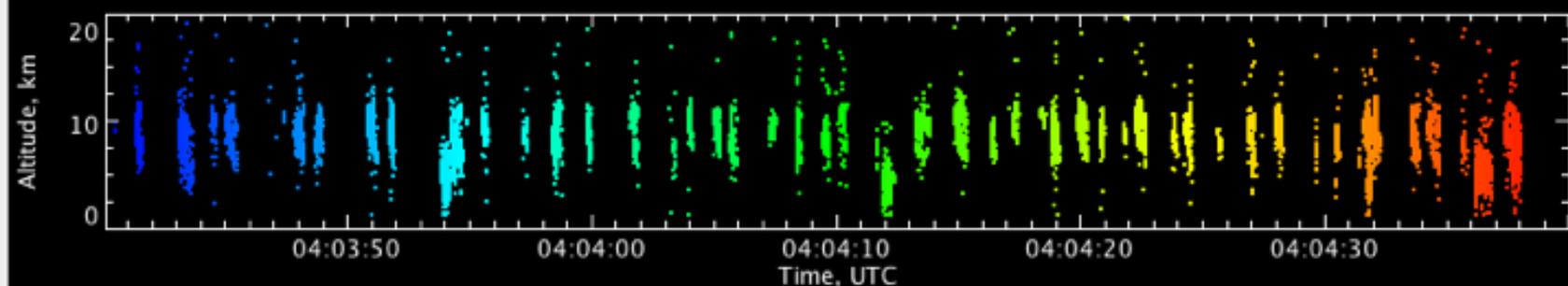
Source size Medium (2 pix...
 Color coding Color by time
 Background White Black
 Terrain On Off

Range Custom
 Selection cursor On Off

| | Min | Max |
|----------------|-------|------|
| Latitude (km) | 12.4 | 79.6 |
| Longitude (km) | -27.5 | 39.7 |
| Altitude (km) | 0.0 | 20.0 |
| Stations | 6 | 12 |
| Chi-squared | 0.0 | 5.0 |

<< Station mask

Redraw



Server 127.0.0.1
 Processing time 11/21/2010 04:04:37
 VHF sources 30
 Data passes 0
 Stations contr. 9 (min. 0)
 Max. chi-sq. 5.0
 Decimation (us) 0

Time interval 1 minute
 Time base UTC
 Real-time mode On Off

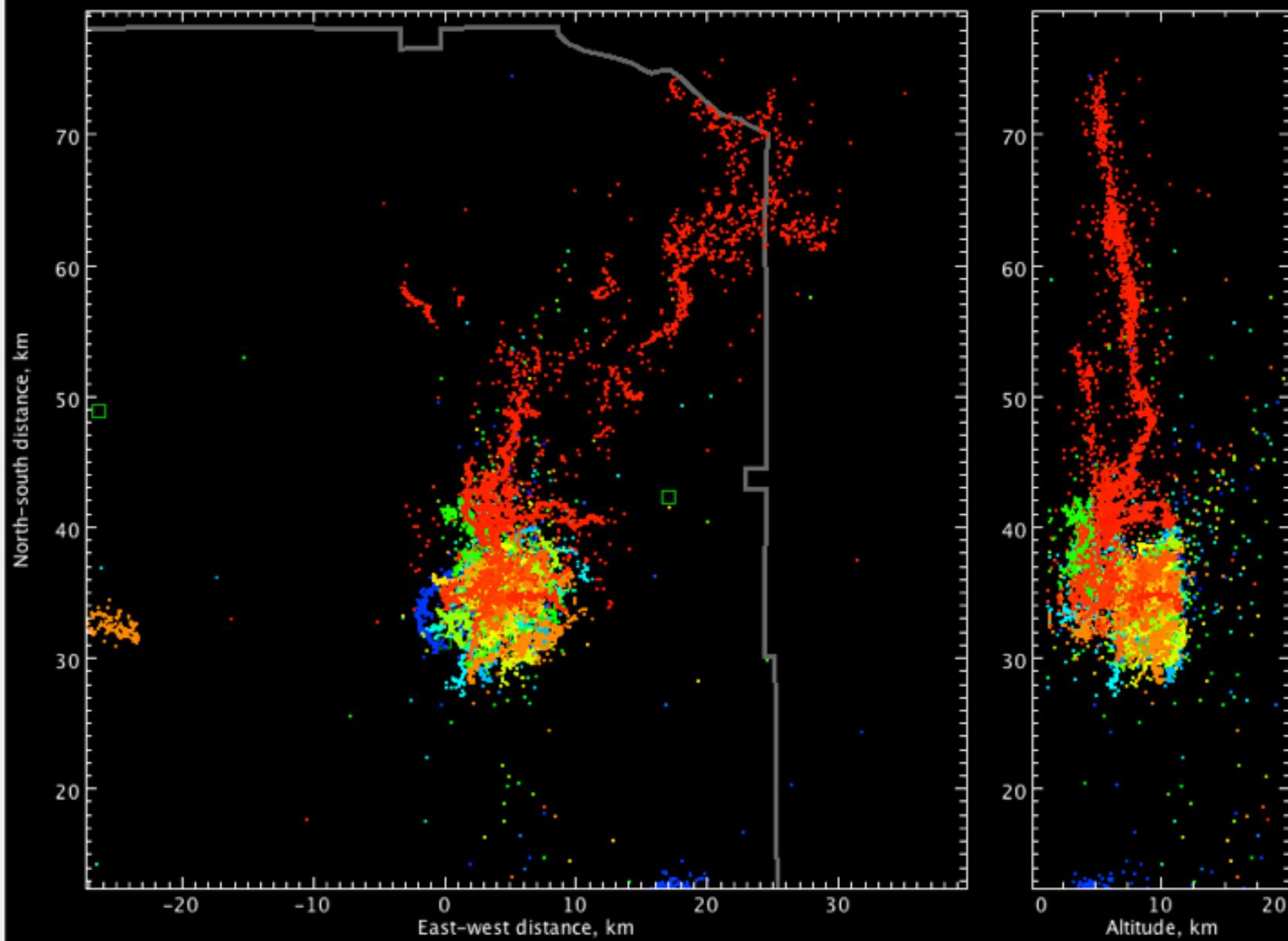
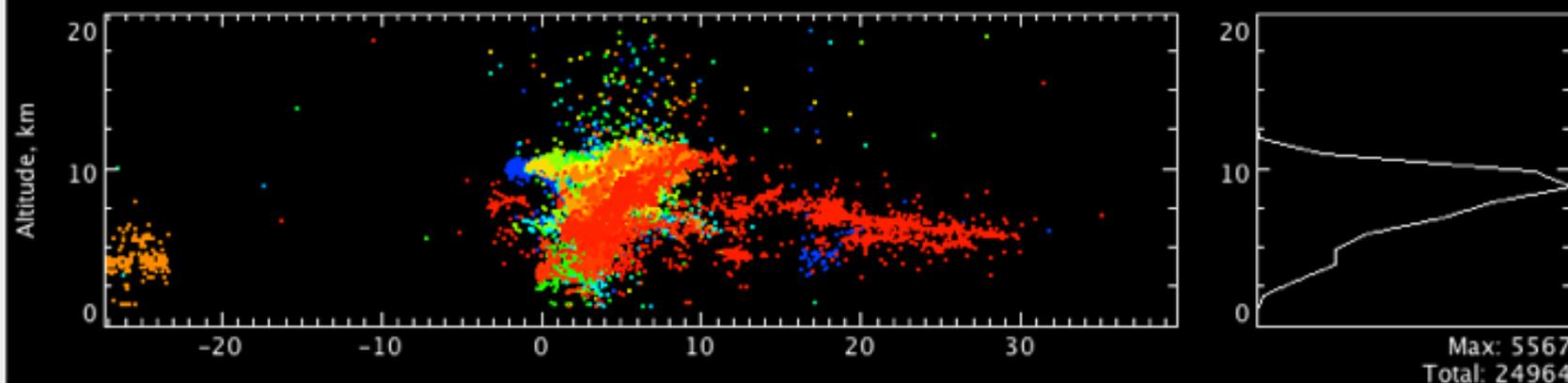
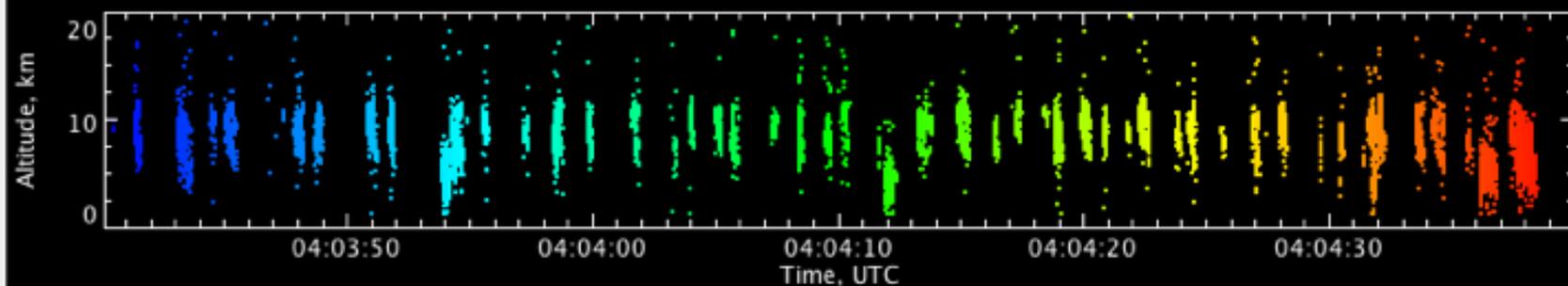
Source size Medium (2 pix...
 Color coding Color by time
 Background White Black
 Terrain On Off

Range Custom
 Selection cursor On Off

| | Min | Max |
|----------------|-------|------|
| Latitude (km) | 12.4 | 79.6 |
| Longitude (km) | -27.5 | 39.7 |
| Altitude (km) | 0.0 | 20.0 |
| Stations | 6 | 12 |
| Chi-squared | 0.0 | 5.0 |

<< Station mask

Redraw



Server 127.0.0.1
 Processing time 11/21/2010 04:04:38
 VHF sources 26
 Data passes 0
 Stations contr. 9 (min. 0)
 Max. chi-sq. 5.0
 Decimation (us) 0

Time interval 1 minute
 Time base UTC
 Real-time mode On Off

Source size Medium (2 pix...
 Color coding Color by time
 Background White Black
 Terrain On Off

Range Custom
 Selection cursor On Off

| | Min | Max |
|----------------|-------|------|
| Latitude (km) | 12.4 | 79.6 |
| Longitude (km) | -27.5 | 39.7 |
| Altitude (km) | 0.0 | 20.0 |
| Stations | 6 | 12 |
| Chi-squared | 0.0 | 5.0 |

<< Station mask

Redraw

Questions?

Next Generation LMA on a chip 2011

- low power 1-2 watts, simple, compact, very robust.
- LMA on a FPGA chip, no computer.
- store data on a compact flash.
- no communication in basic station.
- GPS, log amp, filters, pre amp as in other stations.

- 1996-98 designed initial system under NSF LMA Station development
- 1998 LMA-G1 initial operation in OK and NM using a desk-top computer with custom designed LMA board.
- 2000 LMA-G2 design used a small single board computer. Used for the North Alabama system.
- 2005 LMA-G4 developed the portable LMA under NSF SGER. First use: Augustine Volcano, 2006.
- 2008 compact lower power solar powered design with solid-state hard drive

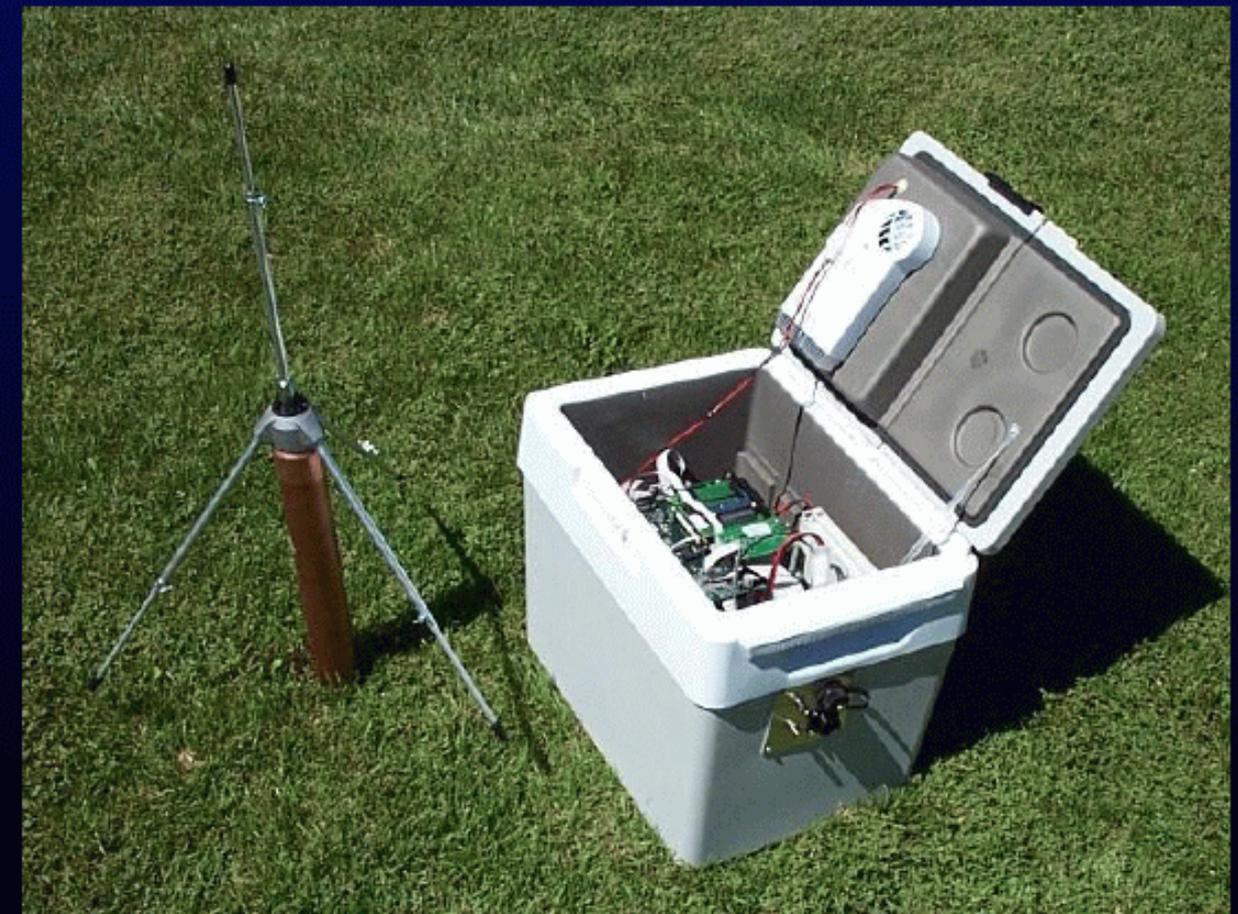
STEPS 2000



Portable Mapping Station

- Electronics housed in shielded thermoelectric cooler enclosure
- Operates from external 12 VDC battery and/or power supply. ~12 watts power (48 W w/ cooling)
- Battery operation: 48+ hours (w/out cooling)
20+ hours (with cooling)
- Lightweight (10 lbs)

- 1/4 wave ground plane antenna
(Ch. 8 shown; 180-186 MHz)
- Connected to receiver inside box by coaxial cable
- Other external connectors:
GPS antenna, ethernet, 12 VDC



Dugway 2010



NEMA enclosure
Solid state hard
drive



Analysis improvements

- data analysis revised in 2007
- Real time processing and display
 - Updates each 2 minutes at OK/NA/DC
 - WSMR faster
 - Langmuir - Live-LMA 2 second delay.

Outline

- Planned AM process networks
 - Dugway
 - DC3/CO Front Range
 - Texas Tech
 - Catalonia
- Station Design
 - Original station
 - Current station types:
 - WSMR/Dugway
 - Portable stations
 - Solar stations
 - Next generation
- Network Capabilities:
 - *Sensitivity* (improvements due to DTV conversion, solar operation)
 - Processing (lma_analysis)
 - Real time processing display
 - OK/NA/DC (2 min updates)
 - WSMR (faster updates)
 - Live LMA

The lightning Mapping Array

- Capabilities
 - Image total lightning and individual flashes
 - Detect 100% of the flashes - 100 km radius or more
- LMA Arrays and stations - an ongoing evolution
- Analysis and real time data

Storm detection

note limitations due to curvature of earth

