Use of VHF Bands for Remotely Sensing Lightning

Paul Krehbiel, William Rison, Ronald Thomas
Physics and Electrical Engineering Departments
Langmuir Laboratory, Geophysical Research Center
New Mexico Institute of Mining and Technology
Socorro, NM 87801
krehbiel@ibis.nmt.edu

Presentation to Committee on Radio Frequencies (CORF)
October 16, 2006

Total Lightning Observations

- Clouds are transparent at RF – therefore can use to sense intracloud (IC) discharges as well as in-cloud parts of cloud-to-ground (CG) lightning.
  => Hence, "total" lightning.
- Lightning is a good indicator of vigorous convective activity -- valuably complements radar observations of storms by showing most active and intensifying parts of a storm system.
- Total lightning observations now being made at several locations around U.S.
- Data starting to be used by National Weather Service to nowcast potentially severe weather situations, lightning ground hazards.
- Potential benefit to air traffic control, airport operations.
- VHF observation technique potentially useful in other applications -- commercial, defense-related.

Types of VHF lightning mapping systems

- Time of arrival (TOA) systems:

  Measure arrival times at networks of 8-10 stations, 40-60 miles in diameter. Inherently 3-D technique (x,y,z,t).
- Interferometric systems:

  Network of direction-finding (DF) stations, obtain source locations by triangulation (2-D or 3-D).
- Focus on TOA systems – more accurate, better, cheaper.

  -- Lightning Mapping Array (LMA, New Mexico Tech)

  -- LDAR-II system (Vaisala)

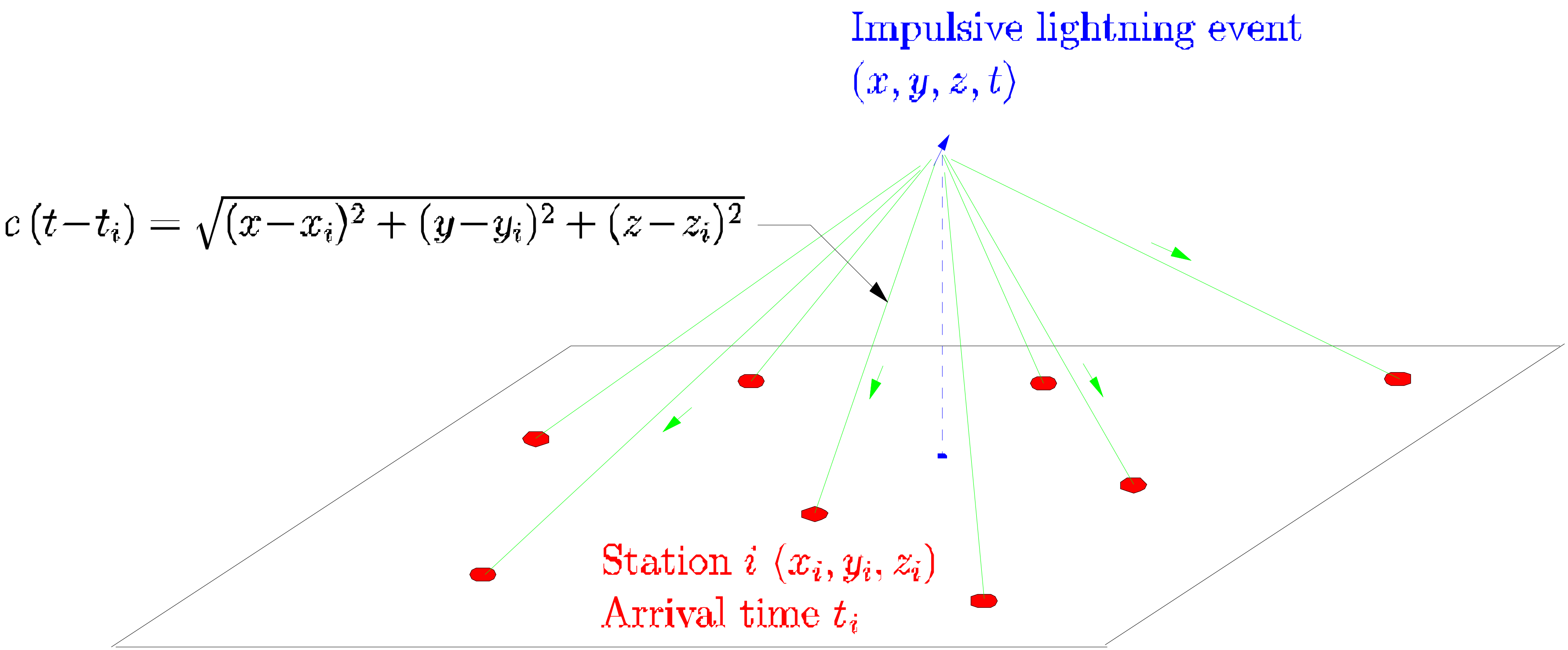
  -- Listen on a locally unused TV channel (e.g., Ch. 3, 5 – lower VHF)
- VLF/LF systems:

  -- Measure 'sferic' or 'static' pulses produced by lightning at lower frequency (10 – 500 kHz)

  -- Primarily locate ground strike points (DF and/or TOA)

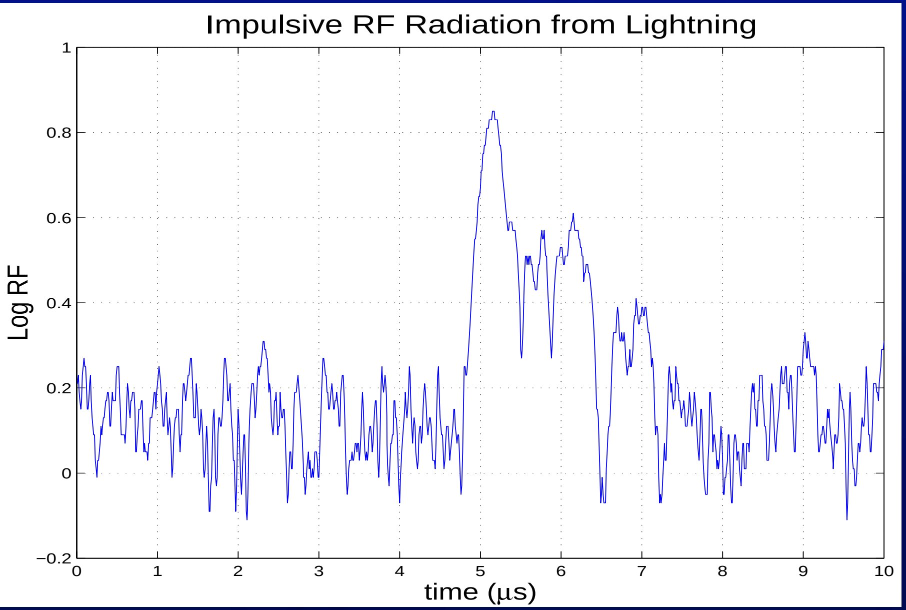
  -- Can locate some in-cloud activity

Time-of-Arrival (TOA) technique:

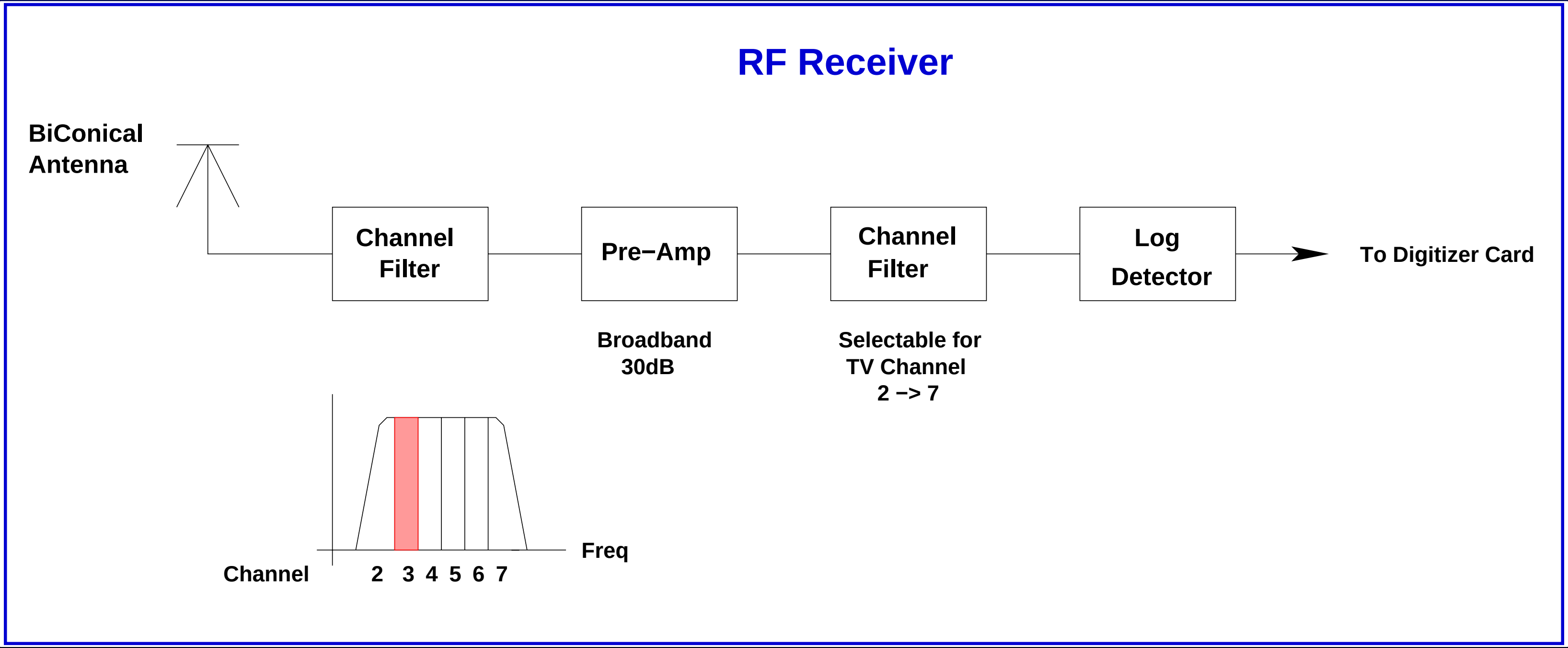


- Measure t_i at $N \geq 4$ locations (50 ns accuracy)
- Solve for x, y, z, t (4 unknowns)
- Inherently 3-dimensional technique

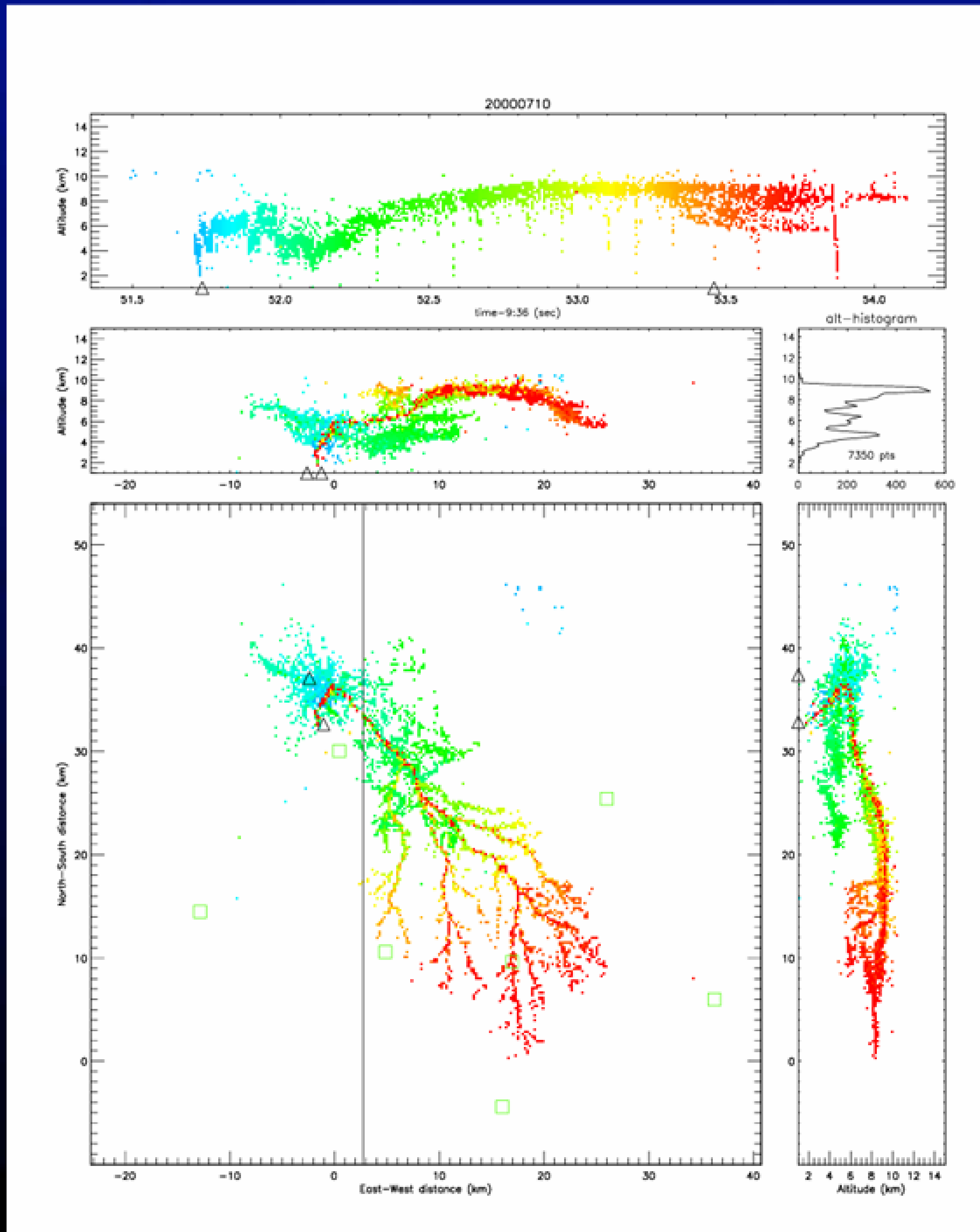
LMA Operation



- Simple receiver
- 6 Mhz bandwidth, t_rise ~160 ns
- Detect peak event in successive 80 microsecond time intervals
- Measure arrival time within 40 ns (25 MHz A/D converter)
- Up to 12,500 arrival times / second



Example of a highly dendritic negative cloud-to-ground (CG) flash



Height vs. time

Height vs. E-W

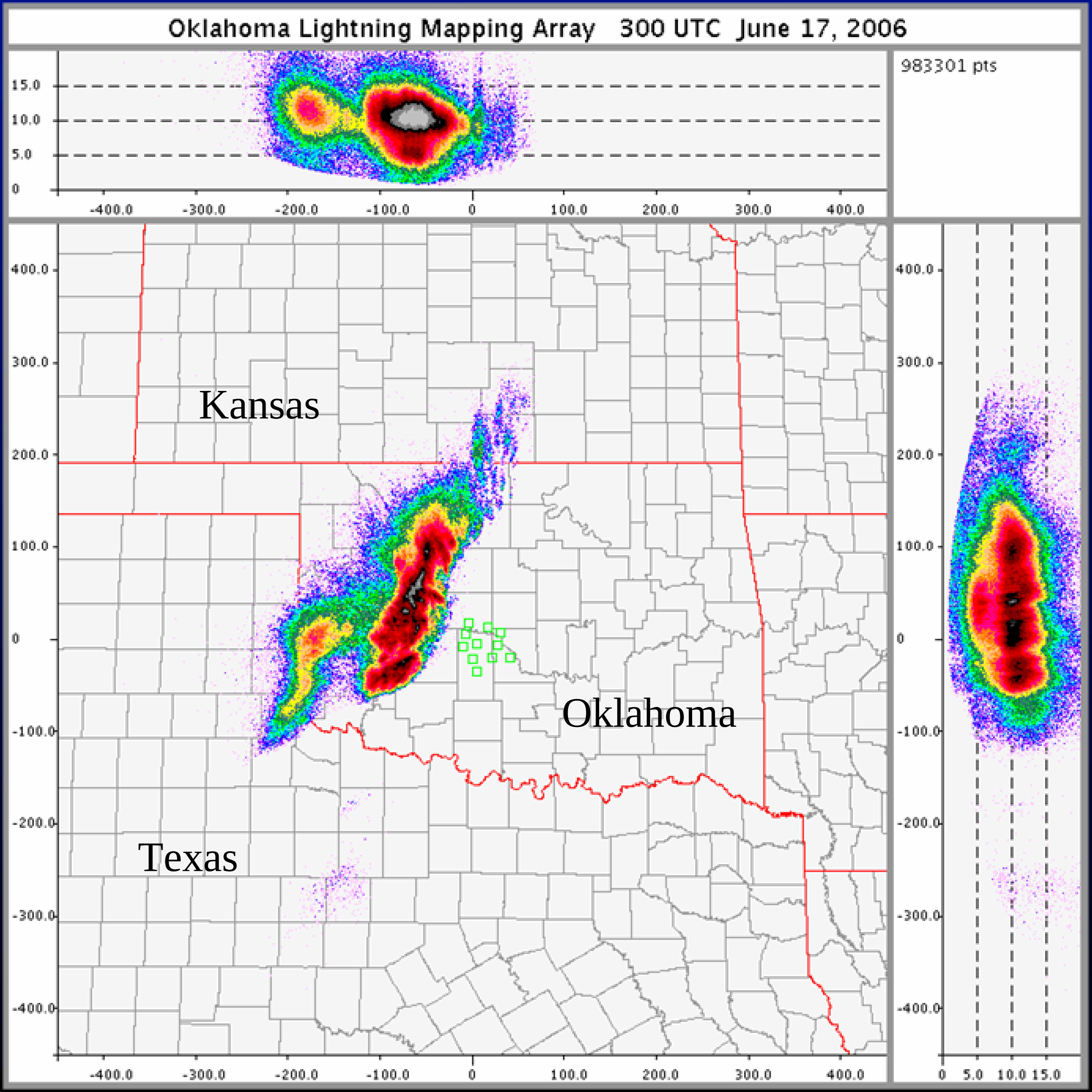
60 km extent,
2.5 sec duration,
7350 sources

Plan view

Height vs. N-S

New Mexico Tech

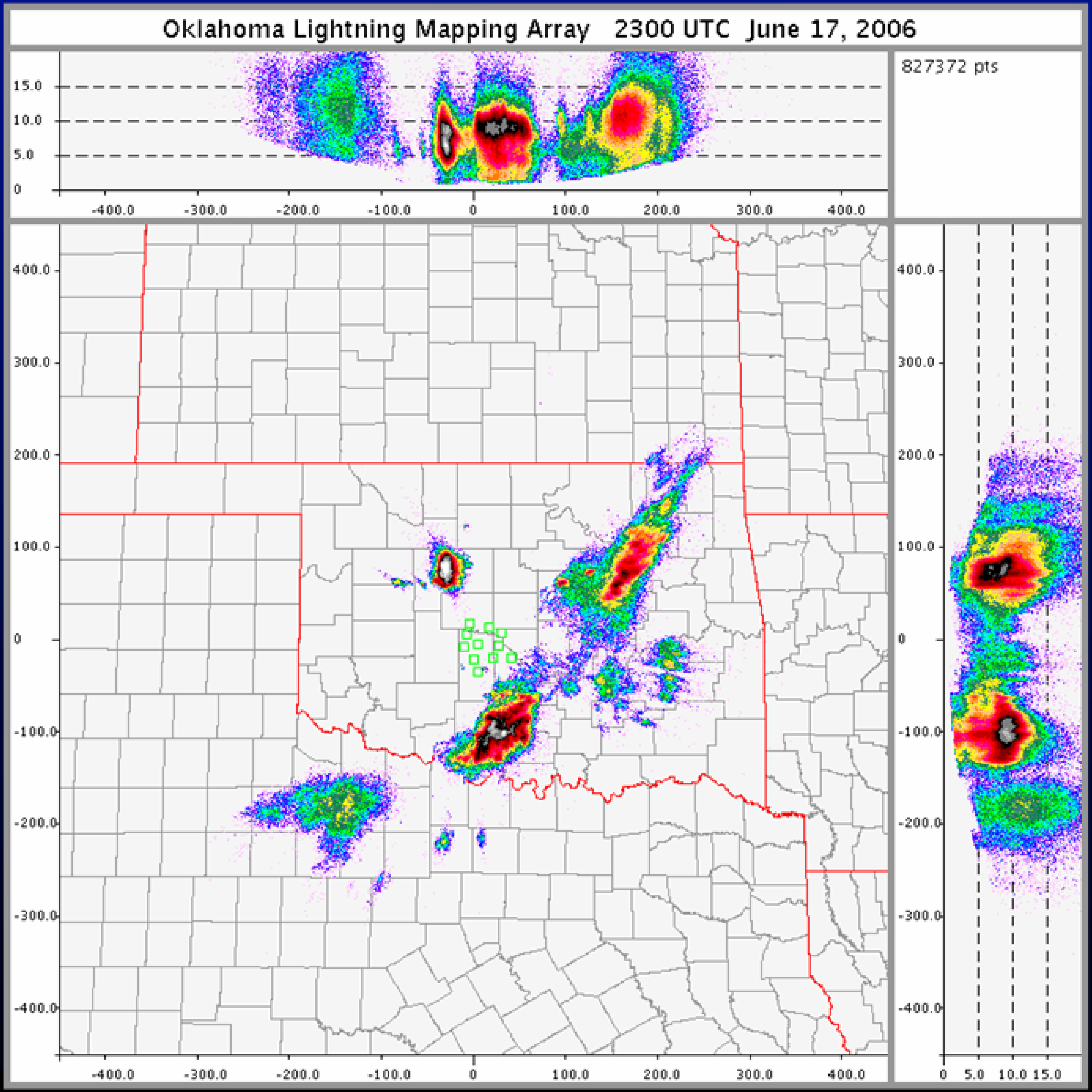
Oklahoma Lightning Mapping Array (Univ. of Okla., National Severe Storms Lab)



- One hour of data.
- Eleven-station network, 60 km diameter, southwest of Oklahoma City.
- Density of points display
- Squall line approaching Oklahoma City from west.
- Operates on TV Ch. 3 (60-66 Mhz, lower VHF)
- Array covers most of OK and into KS and TX. (400-500 km diameter area)
- Data ingested over wireless ethernet links, processed in real time; 1-2 min updates.

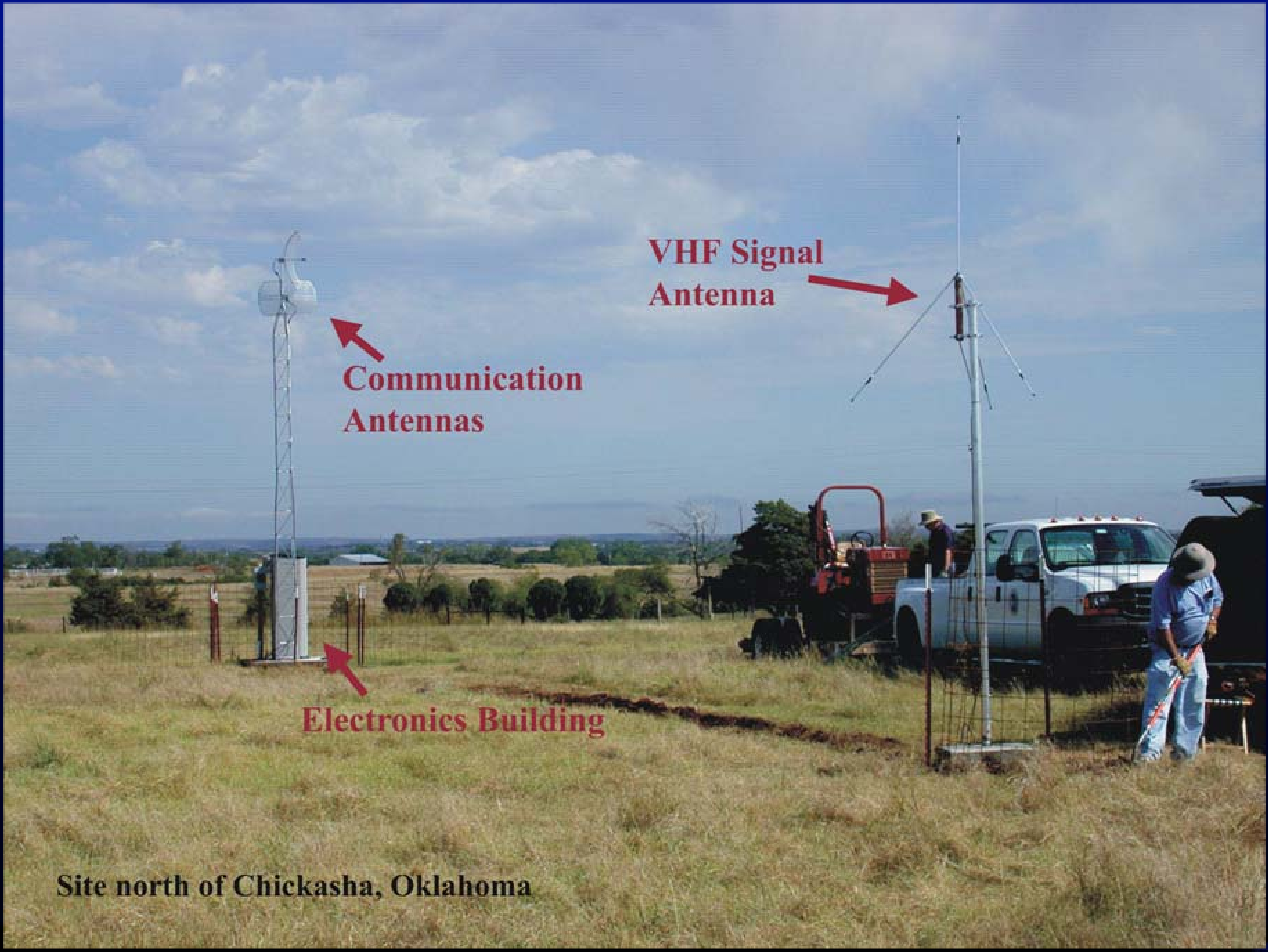
(http://lightning.nmt.edu/oklma)

Multiple storm observations – June 17, 2006



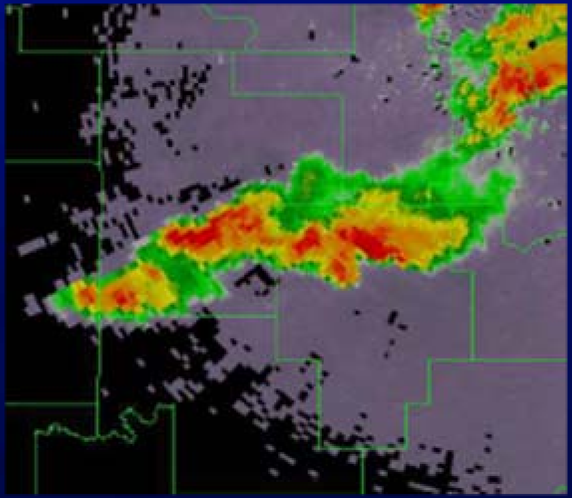
- 830,000 sources in 1 hr; (200-250 per sec)
- Increasing minimum height in vertical projections due to earth's curvature (line of sight propagation)
- Difference from radar: Essentially instantaneous pictures of storm activity (no need to scan).

Oklahoma Lightning Mapping Station (Ch. 3)

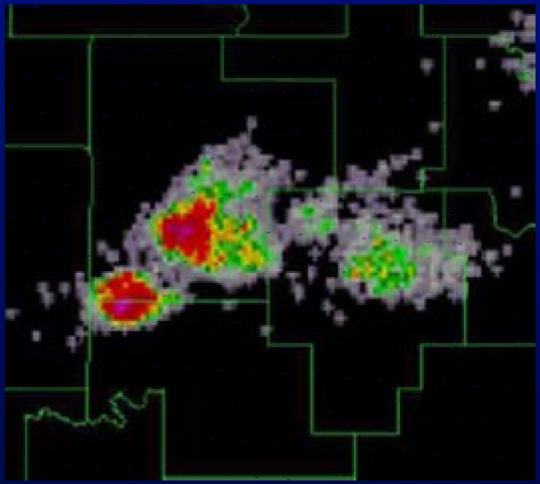


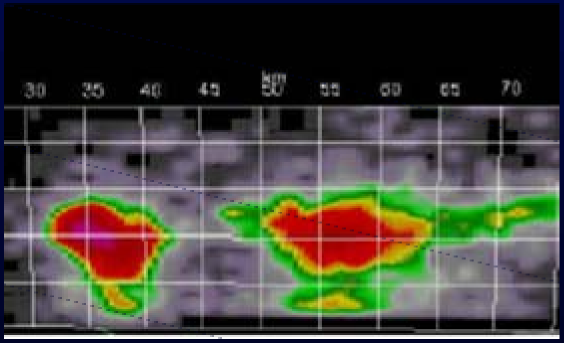
Comparison of NEXRAD and Lightning Source Density (Oklahoma LMA)

Radar



LMA (plan view)

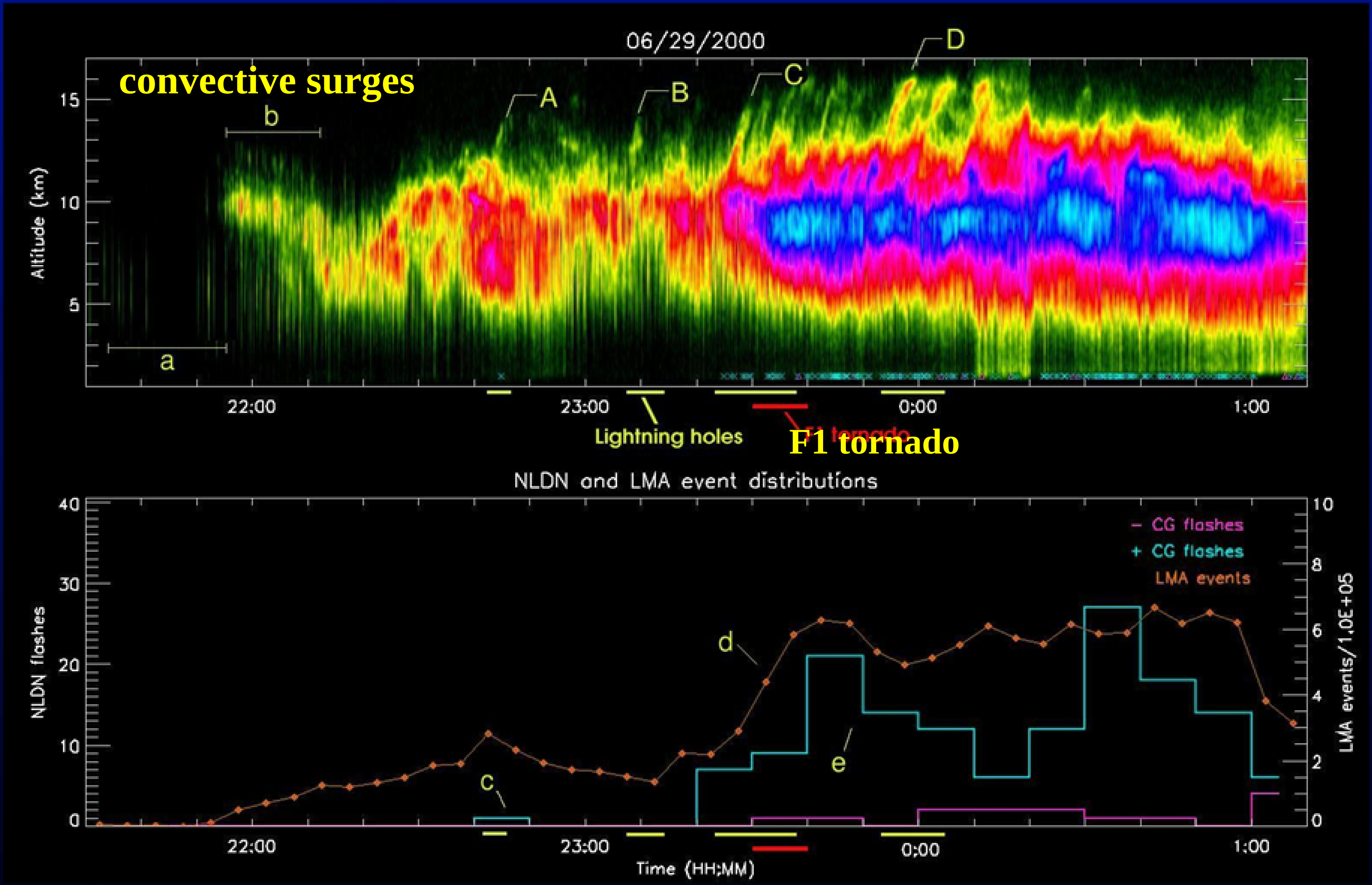




LMA (vertical cross-section)

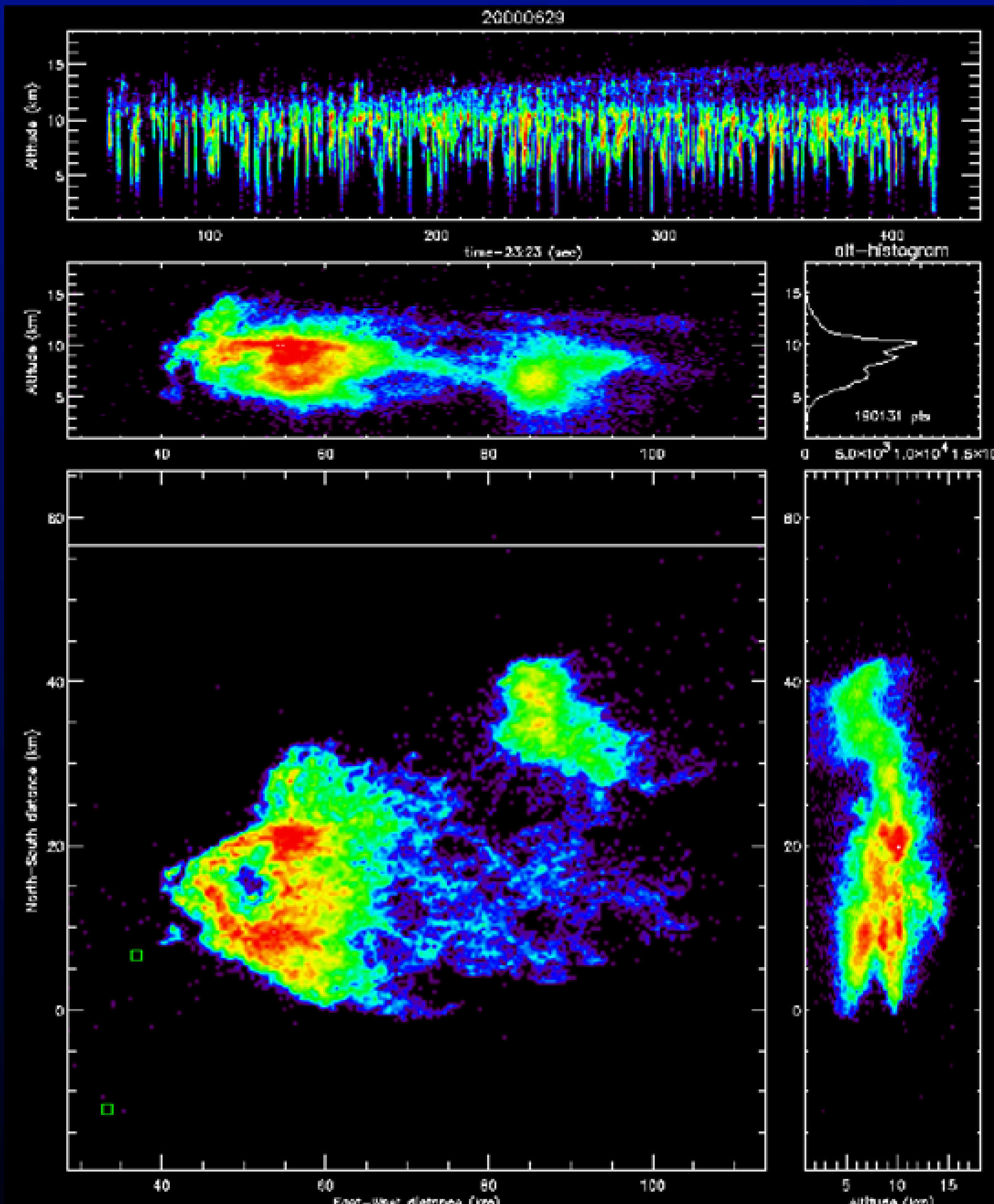
Courtesy of Lakshmanan, Hondl, MacGorman, Stumpf (CIMMS, 2004)

Tornadic Storm, June 29, STEPS 2000: Height vs. time density plot

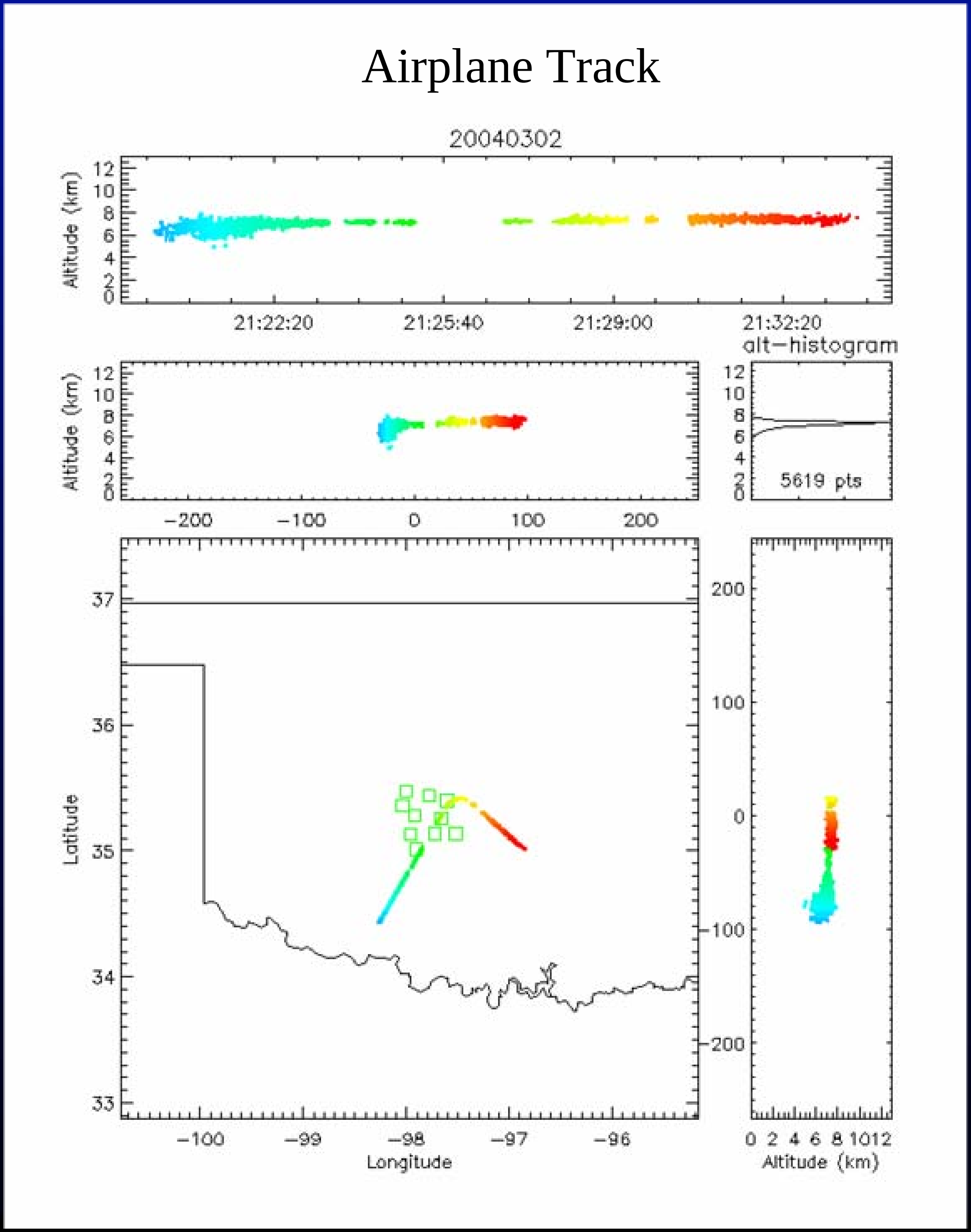


F1 tornado preceded by 2 convective surges (A, B) 45 min earlier; accompanied by 3rd surge and by onset of +CG discharges

Lightning 'hole' associated with F1 tornado

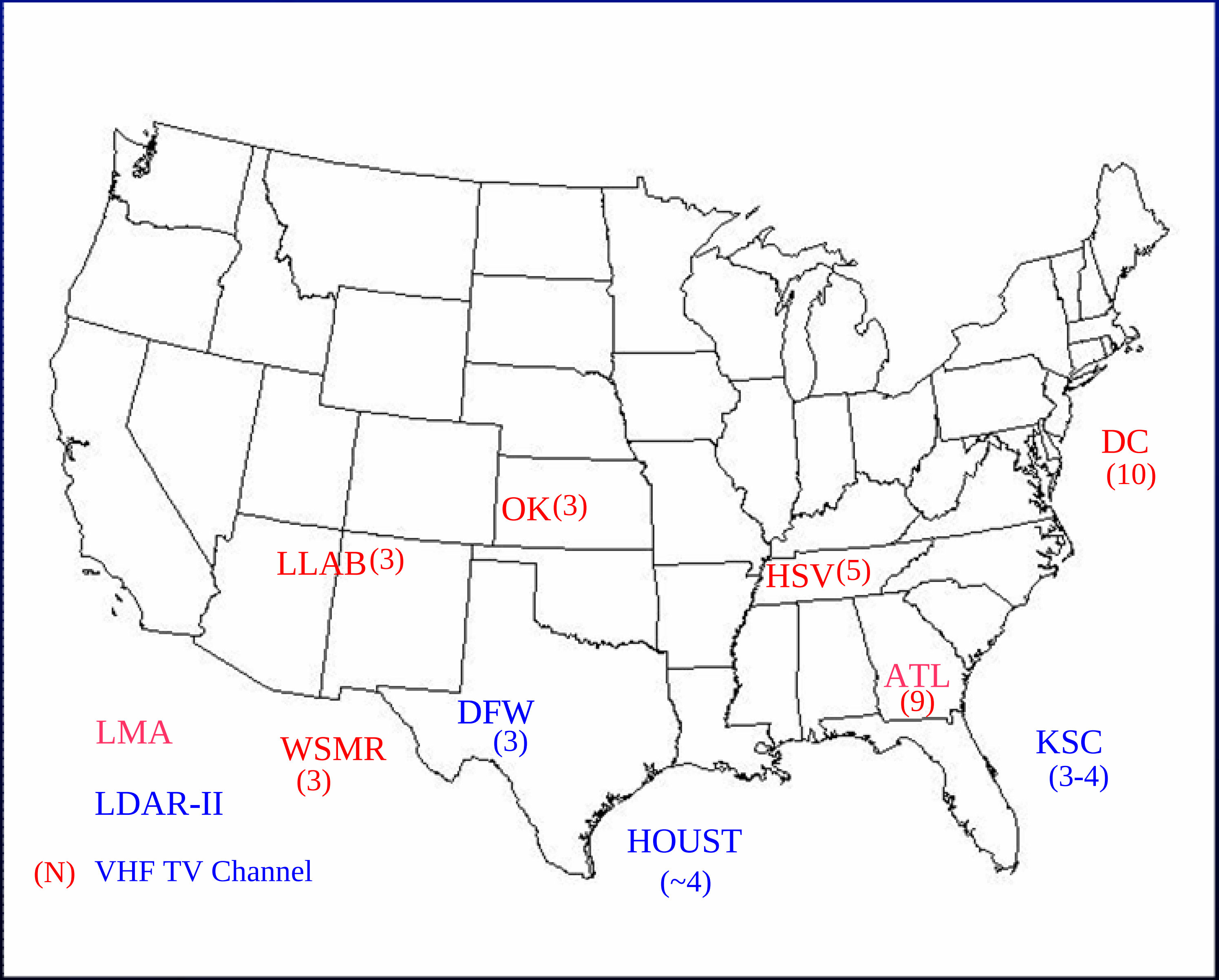


- Tornado on west side of hole
- Associated with 3rd convective surge of storm – note upward surge in height-time panel (top).
- Hole co-located with strong (100+ mph) updraft



Aircraft becomes electrically charged in flying through ice crystal clouds (cirrus, thunderstorm anvils). Emits steady stream of weak sparks that can be located by the LMA.

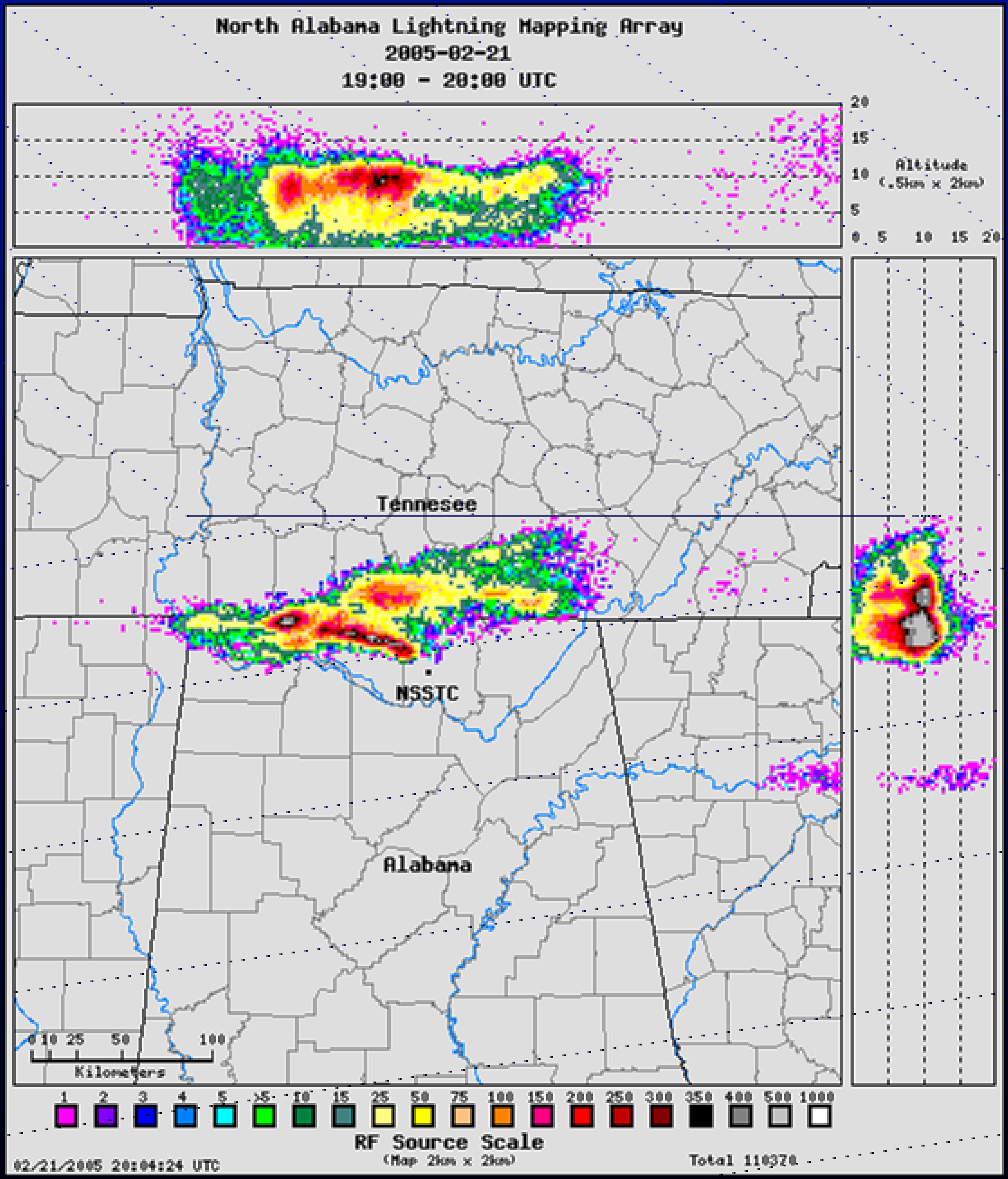
VHF time-of-arrival Total Lightning Mapping Systems



North Alabama Lightning Mapping Array (NASA)

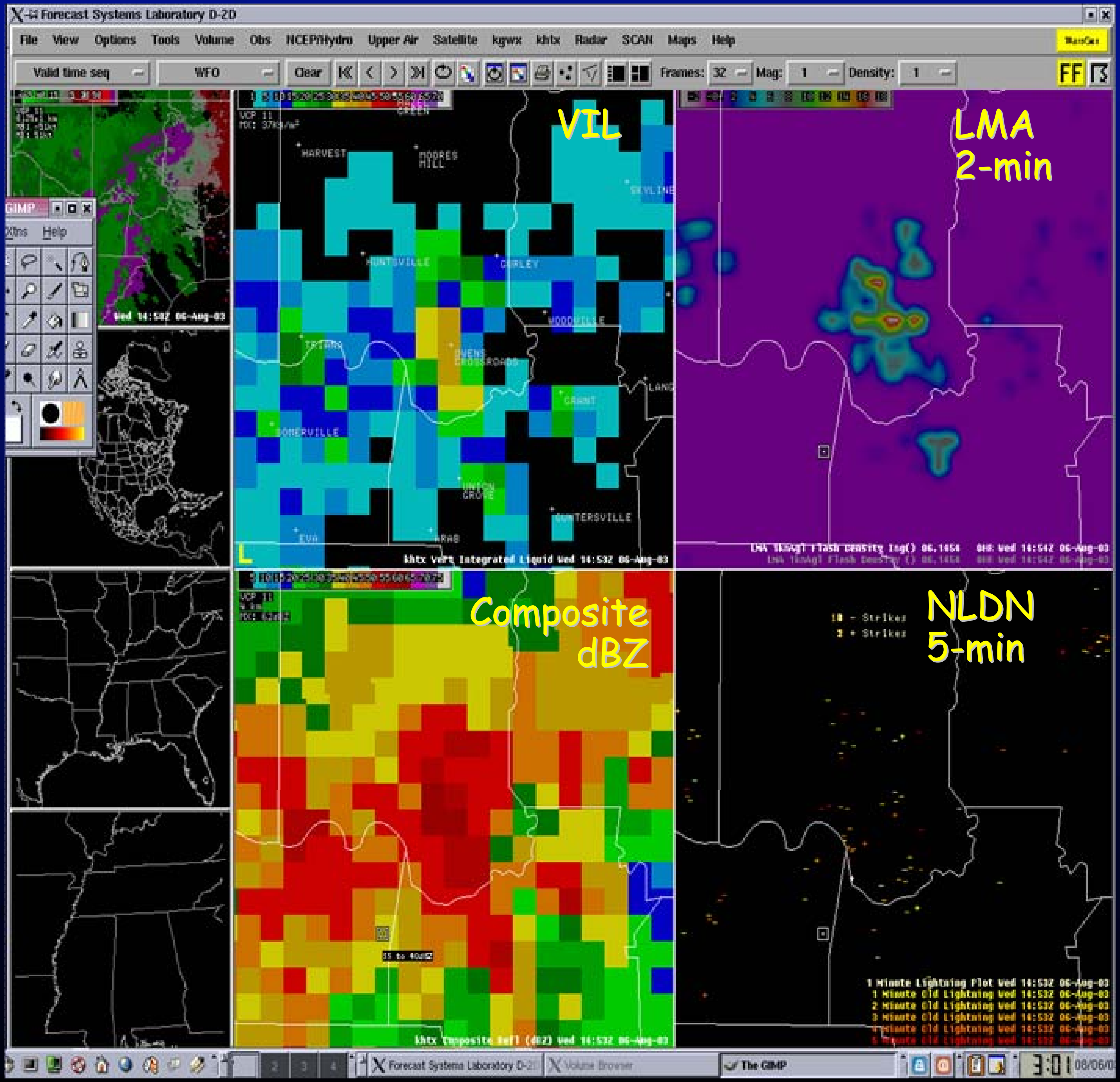
Map (10 stations)

http://branch.nsstc.nasa.gov/



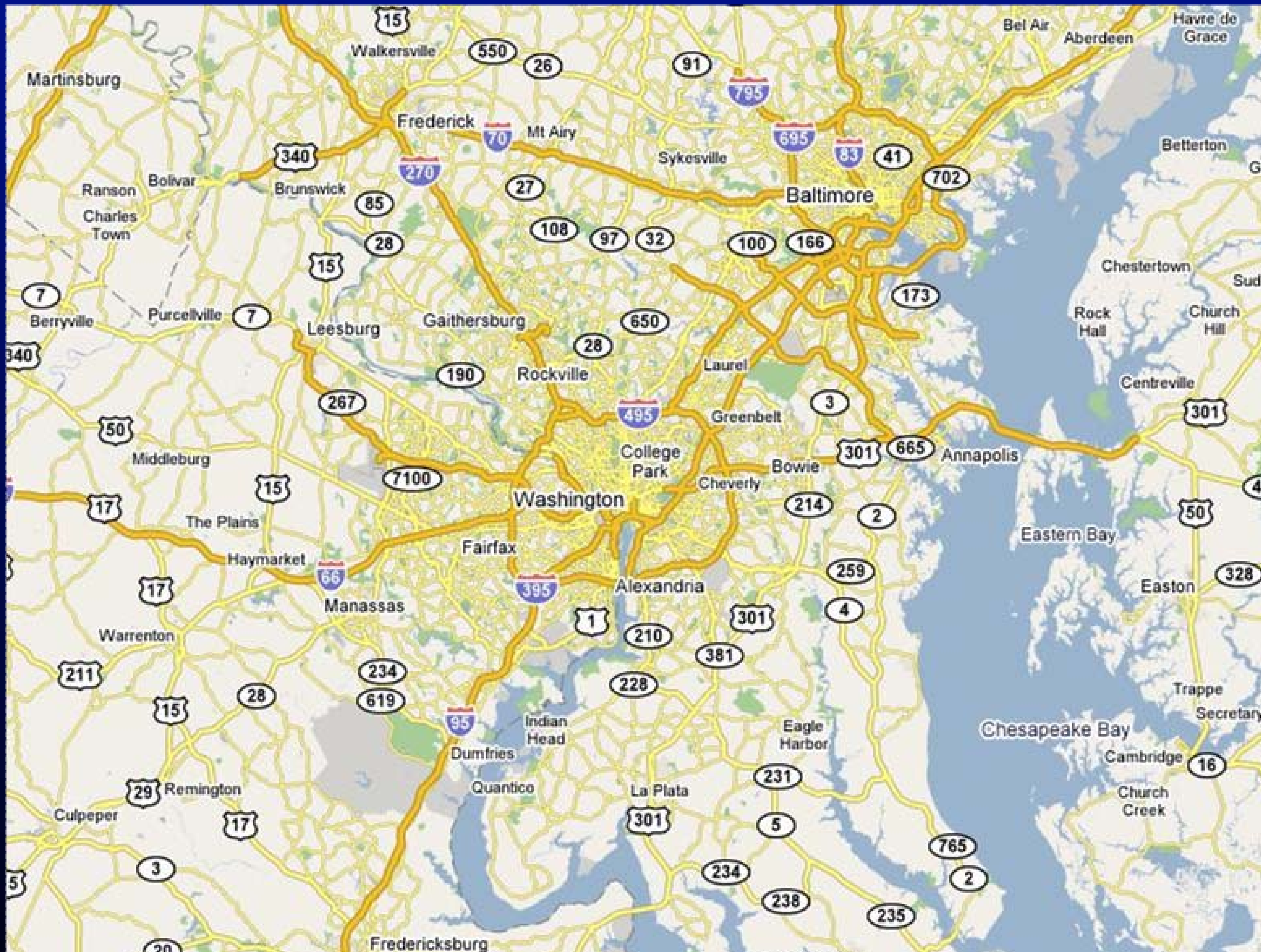
One hour of real-time data

AWIPS Display, NWS Forecast Office, Huntsville, AL



Washington, DC Greater Metro Area Lightning Mapping Stations

Channel 10, 192-198 MHz (upper VHF), 8-10 stations



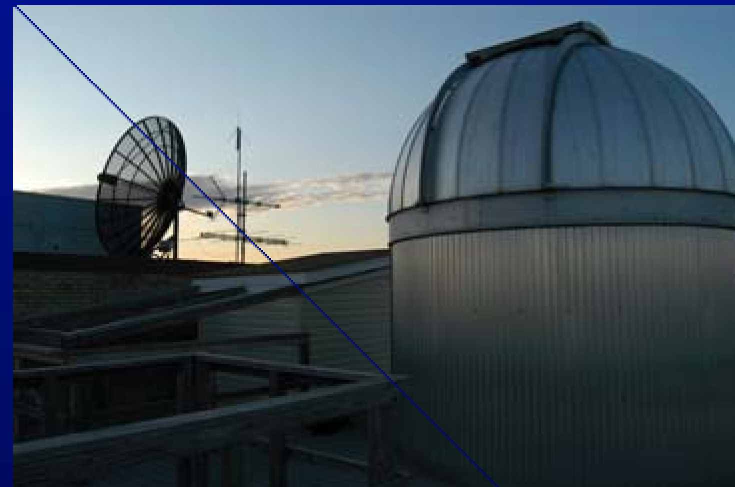
Joint Project: New Mexico Tech, NASA National Space Sci. & Tech. Center, NOAA National Weather Service

Portable LMA Stations

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

DC LMA Stations (Urban Network)

Howard University



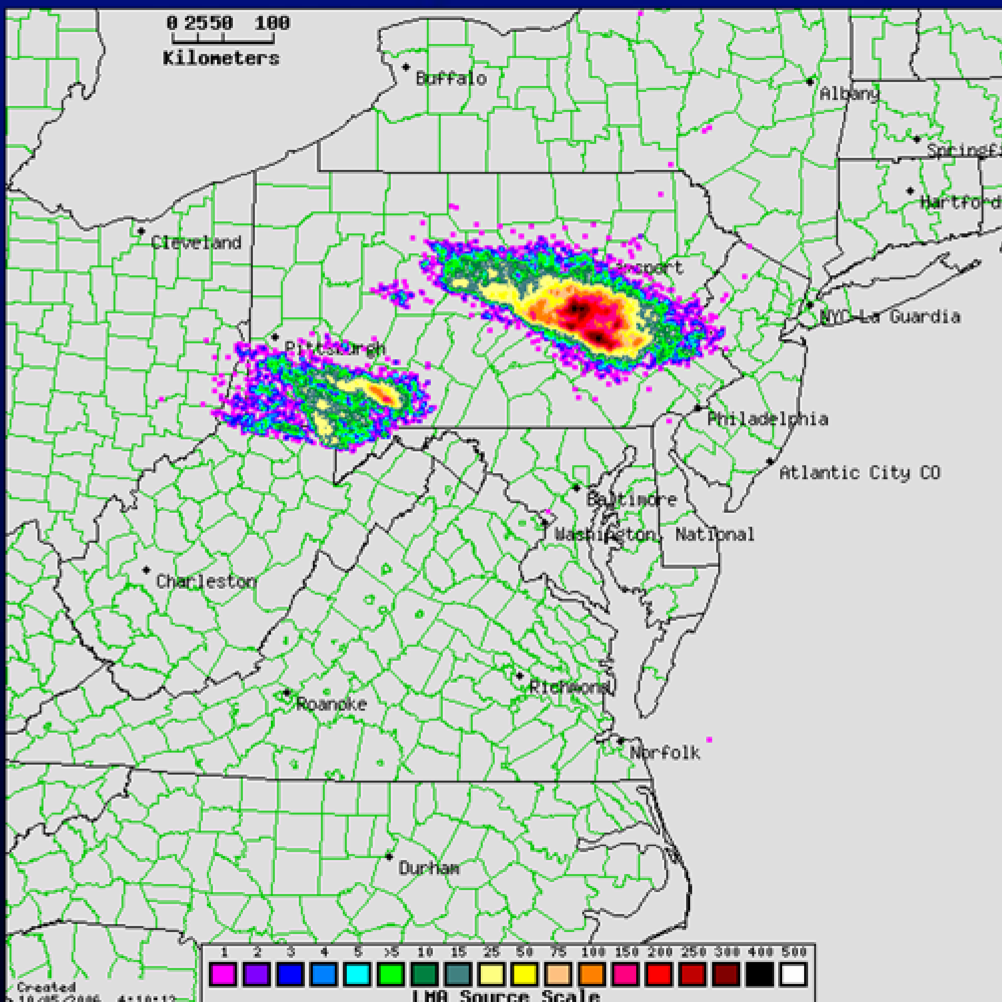
Montgomery Comm. College, Rockville

North VA Comm College, Annandale

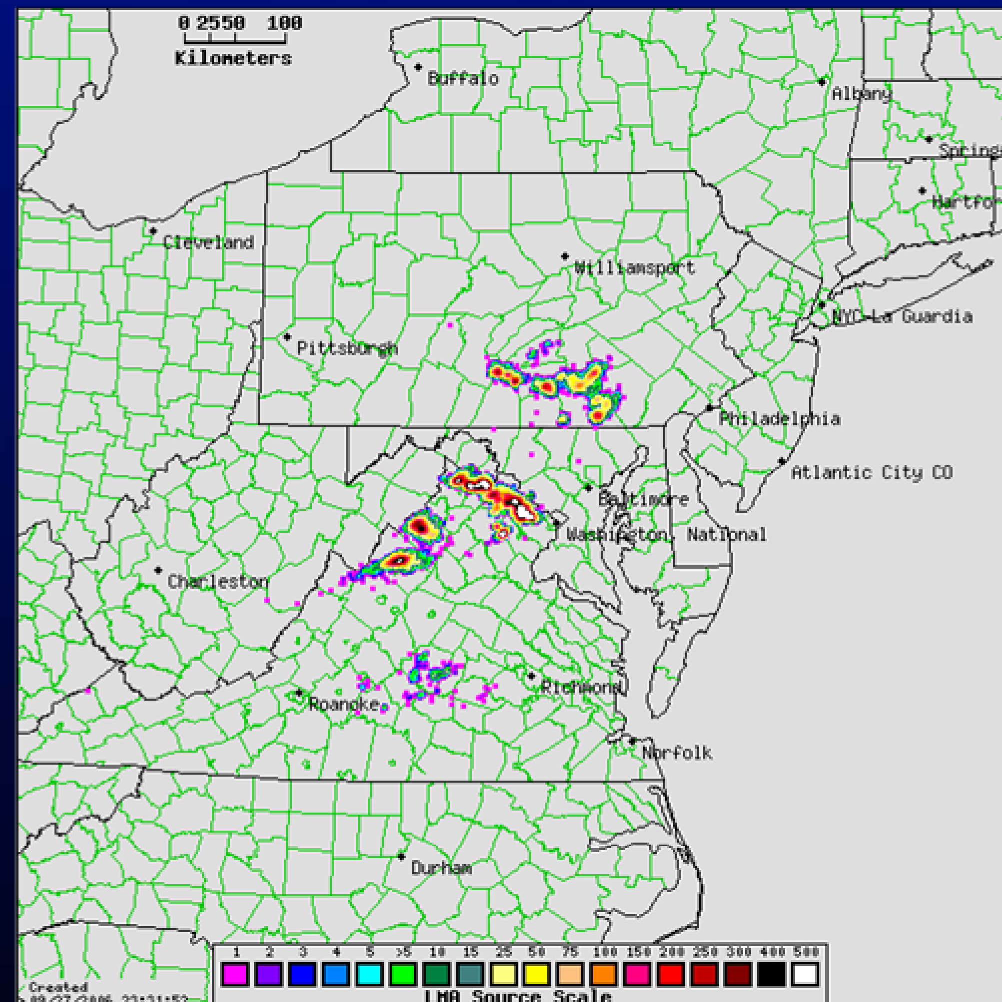
Sterling Nat'l Weather Service Site

Examples of 24-hour lightning activity, DC mapping array

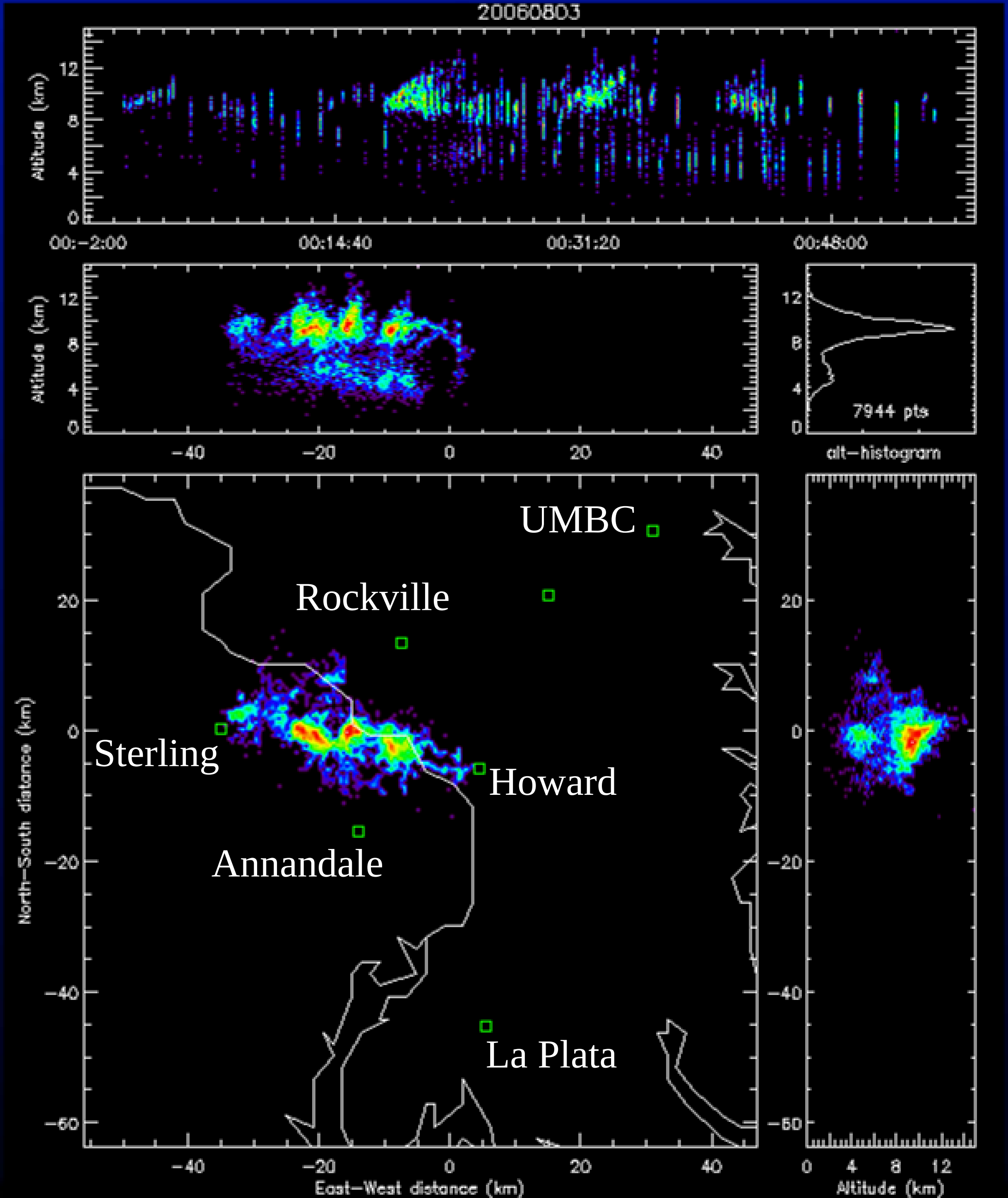
Oct 4, 2006



Sept 8, 2006



(http://branch.nsstc.nasa.gov/public/dclma)



Isolated storm, Washington DC August 3, 2006

- 1 hour of data; storm propagates west to east, from Sterling, VA to over DC area (40 km)
- Note vertical growth phases in height-time panel (top).
- Indicates growth of successive cells in the storm (plan view)
- Storm produces a number of 'bolt-from-the-blue' discharges out the sides and ahead of the storm ('spider'-like channels).

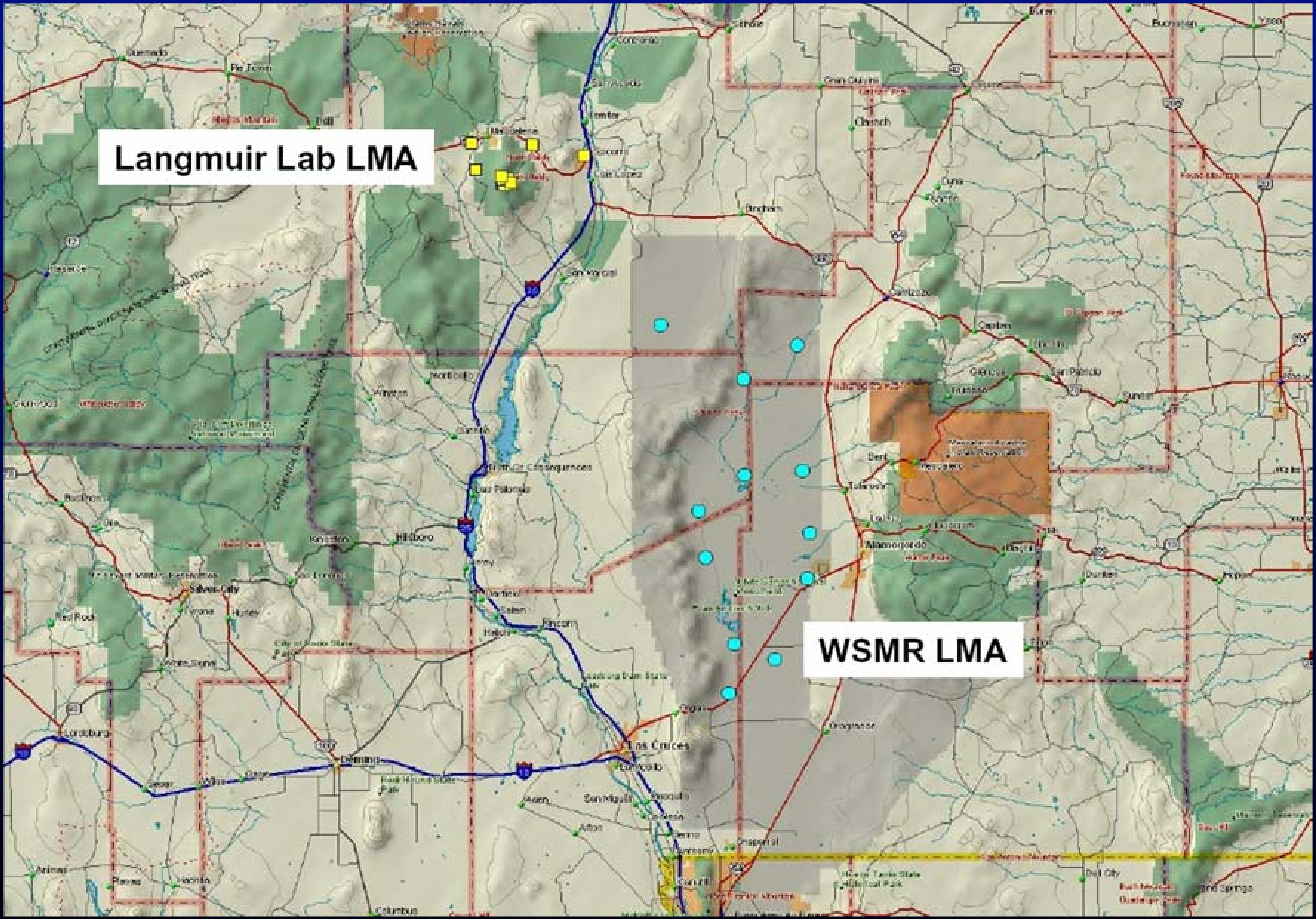
Concluding Remarks

- Very helpful to have locally unused TV channels in the VHF.
  6 Mhz bandwidth provides good timing accuracy, sensitivity.
- Lightning measurements are best made in the lower VHF
  -- Radiated source power decreases as ~1/f^2
  -- Antenna gain decreases as 1/f^2 [(1/2)-wave dipole antennas]
- Lower versus upper VHF (Ch 2-6 vs. Ch. 7-13):
  -- factor of 2-3 difference in frequency
  -- (6-10 dB)*2 = 12-20 dB decrease in sensitivity
  -- decreased detectability, range in upper VHF
- Urban environments: Stronger local noise in lower VHF, can benefit from operating in upper VHF.
- Lightning data will be increasingly useful to the NWS and other governmental departments and agencies (public safety, national security).
- If at all possible, leave a lower VHF channel free for this and future remote sensing applications

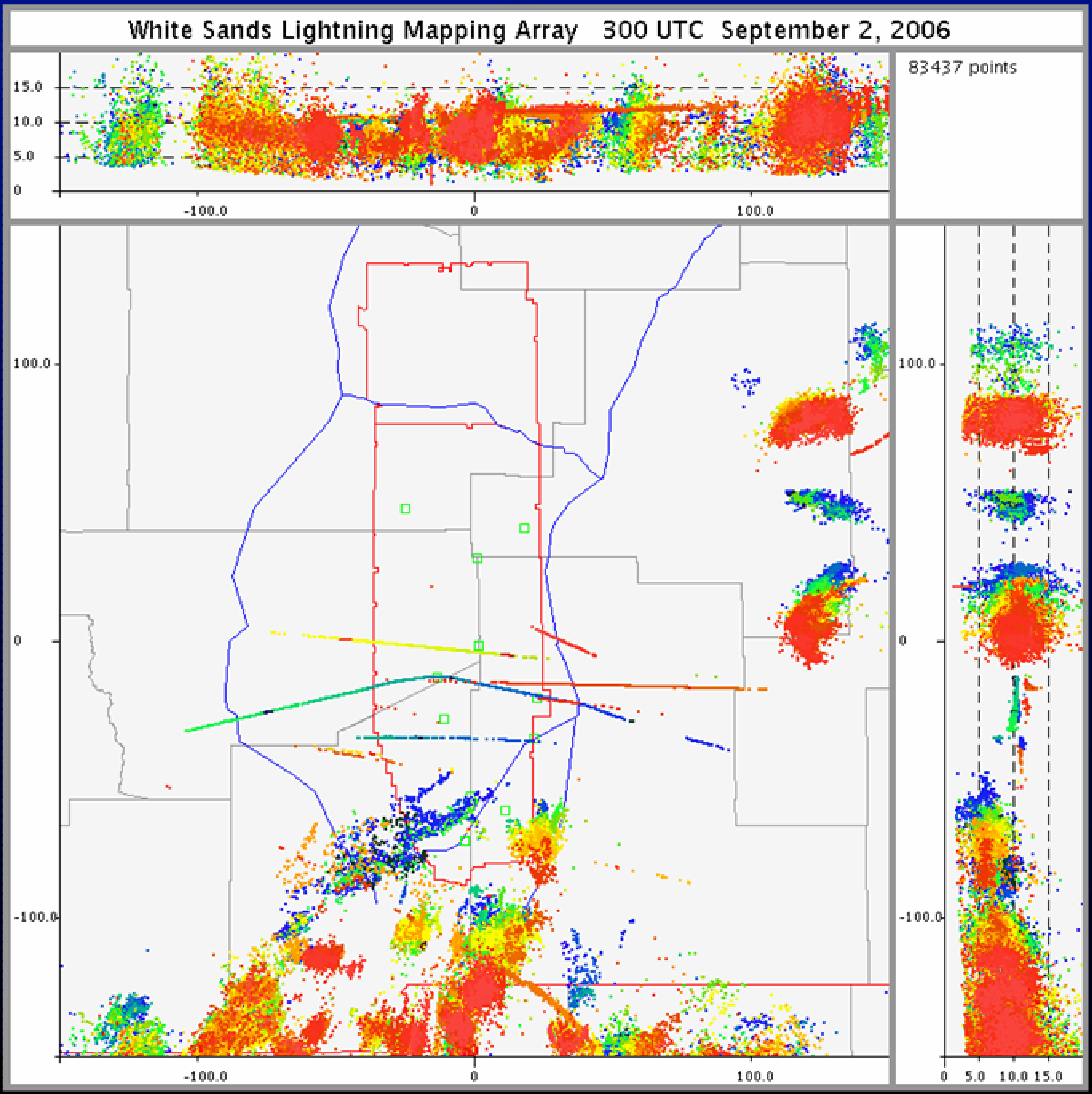
REFERENCE:

Thomas, R.J., P.R. Krehbiel, W. Rison, S.J. Hunyady, W.P. Winn, T. Hamlin, and J. Harlin, Accuracy of the lightning mapping array, J. Geophys. Rsch., 109, D14207, doi:10.1029/2004/JD004549, 2004.

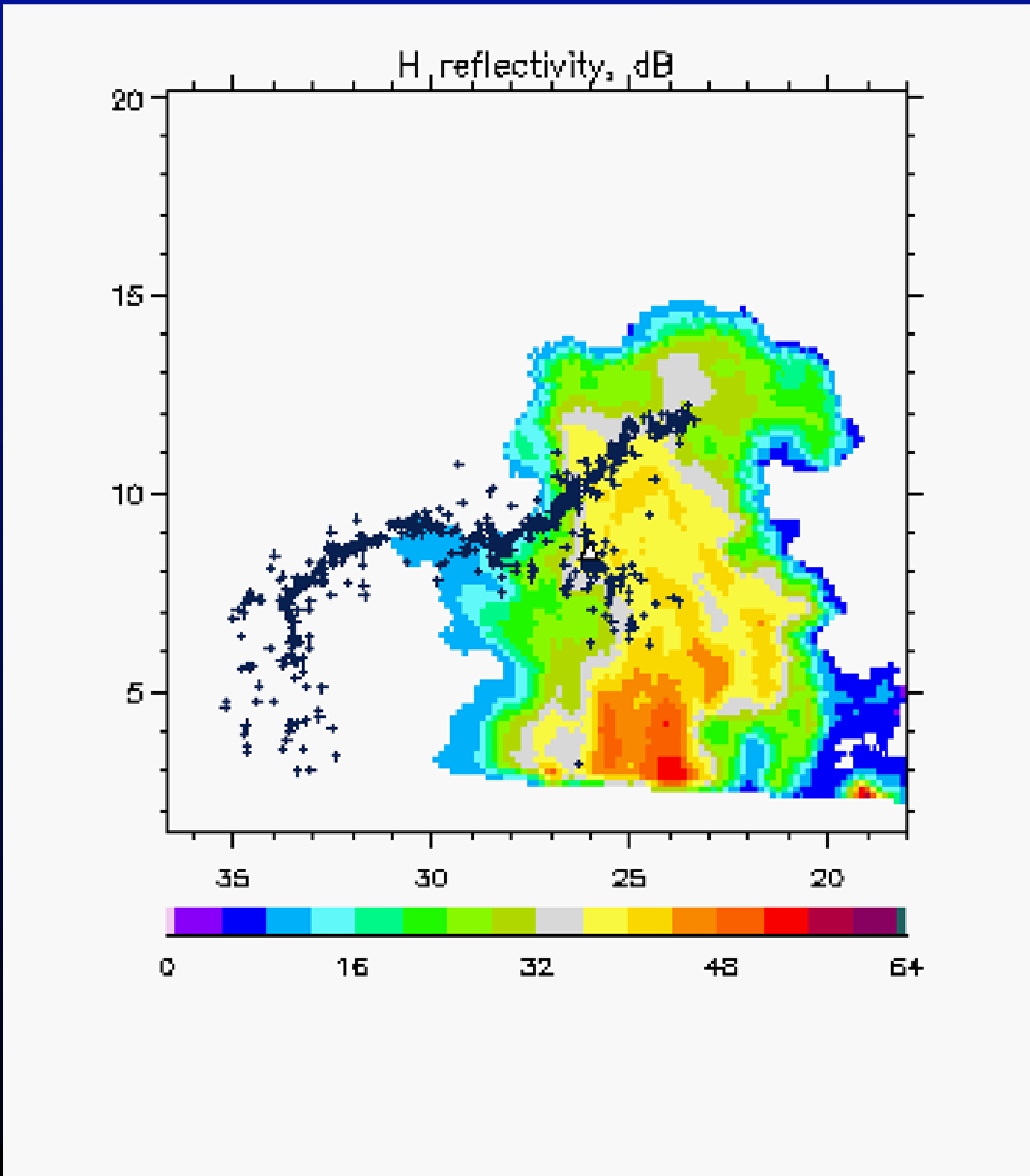
New Mexico LMA Networks



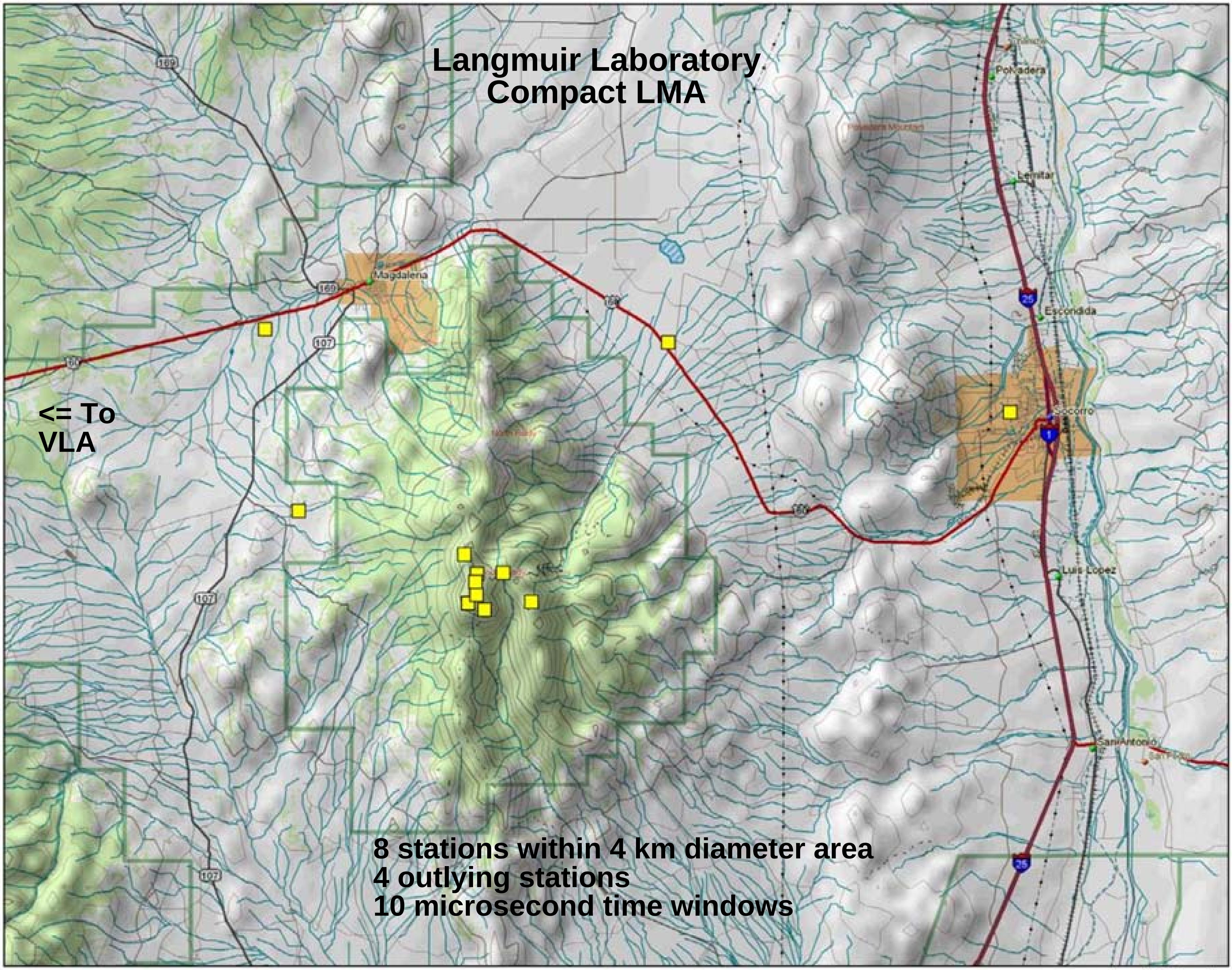
WSMR – Aircraft sparking observations



Aircraft becomes electrically charged in flying through ice crystal clouds (cirrus, thunderstorm anvils). Emits steady stream of weak sparks that can be located by the LMA. 100 to 10,000 sparks per second, depending on charging rate.



Bolt from the blue lightning discharge (negative cloud-ground)



Scale: 1 : 250,000 Zoom Level: 9-6 Datum: WGS84 Map Rotation: 0° Magnetic Declination: 10.5°E