

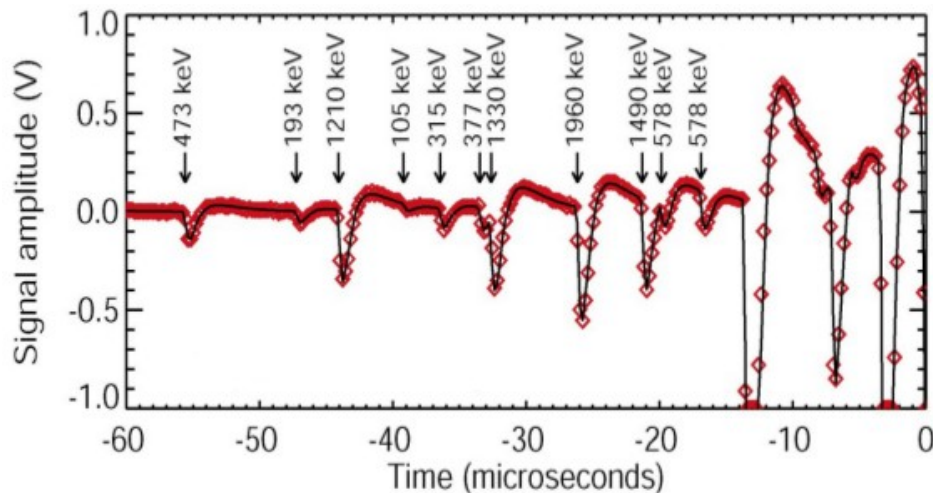


# **Novel Usage for a Cosmic Ray Detector: Study of Lightning at Telescope Array**

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University of Utah  
UHECR2014  
13 October, 2014**

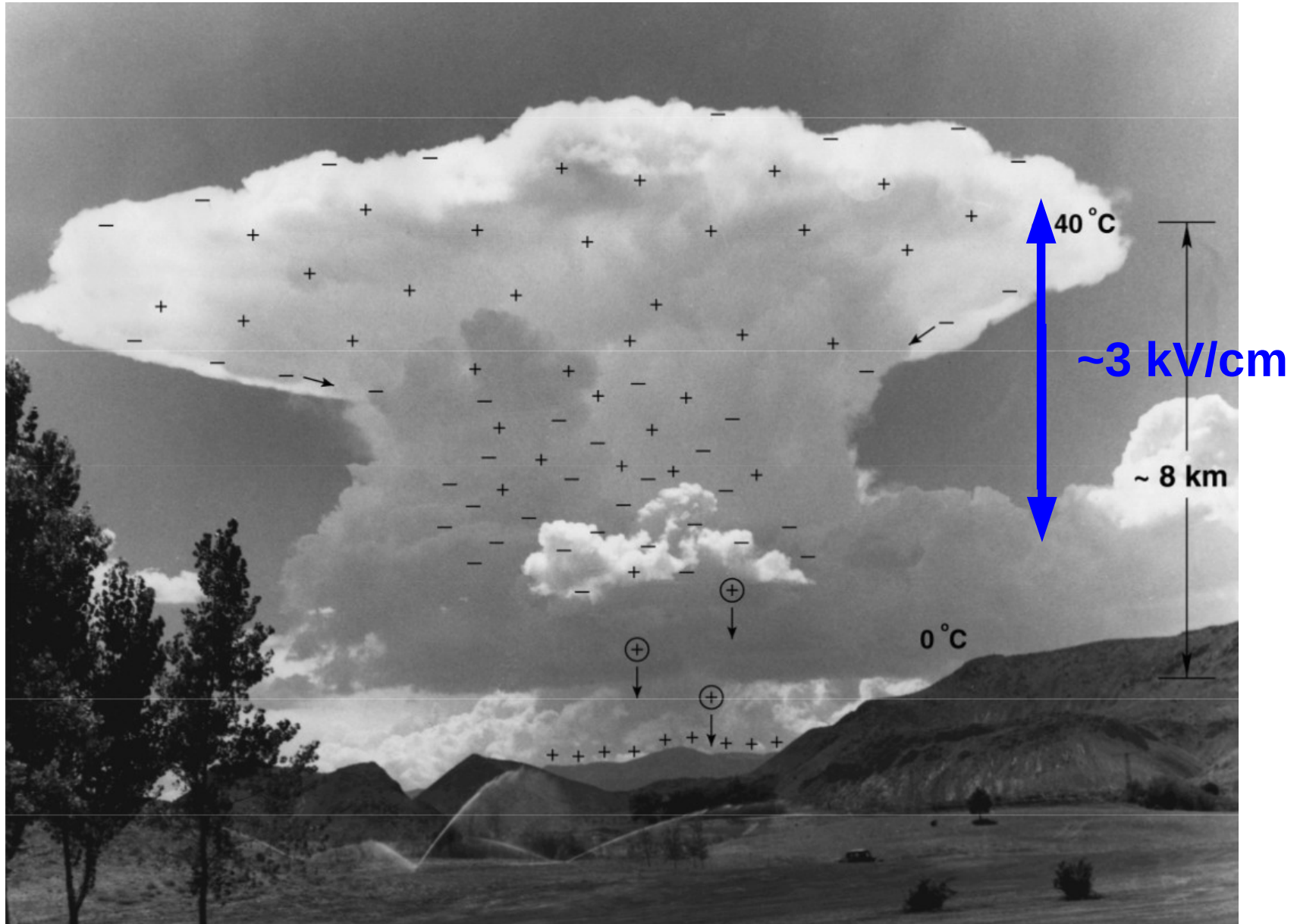
# Lightning Emits High-Energy Particles

- x- and  $\gamma$ -rays observed in-time with lightning strikes
  - Satellites (TGF);  
Fishman et al, *Science* 1994
  - Terrestrial;  
Moore et al, *Science* 2001
  - Rocket triggered (right);  
Dwyer et al, *Science* 2003
- Can we pinpoint mechanisms, origins?



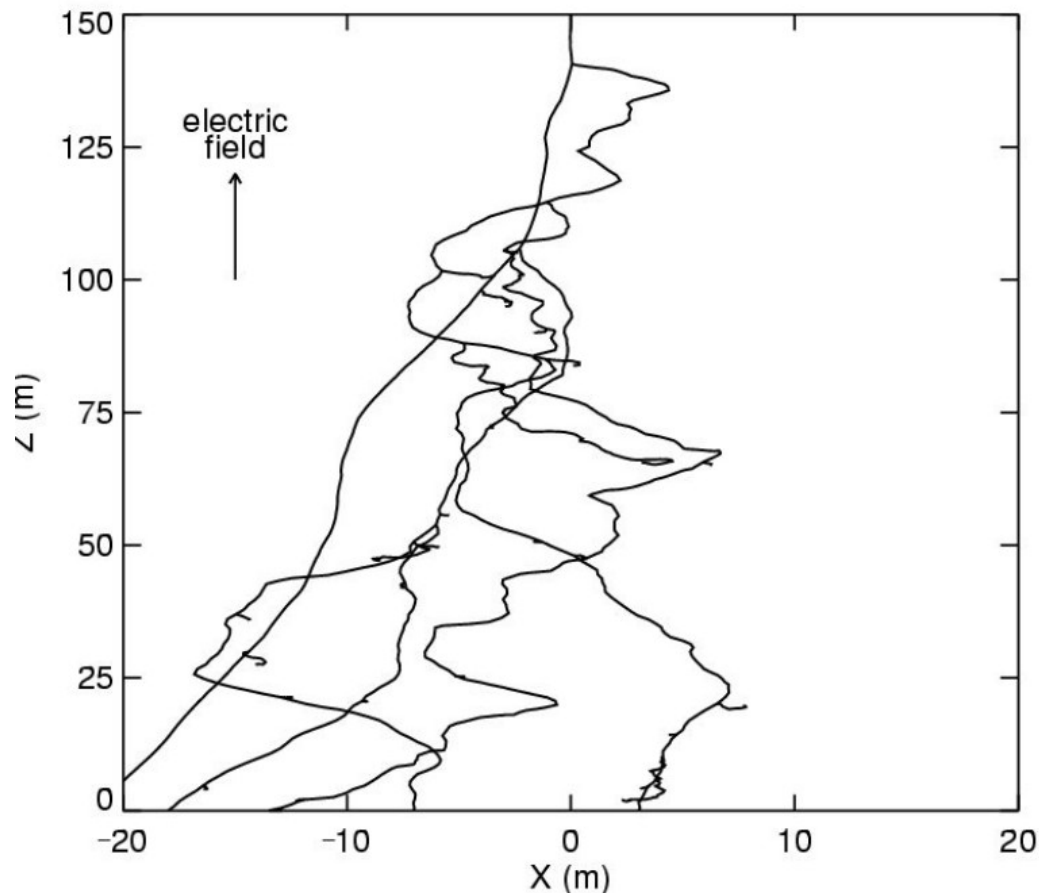


# Another Question: Do cosmic rays seed lightning?



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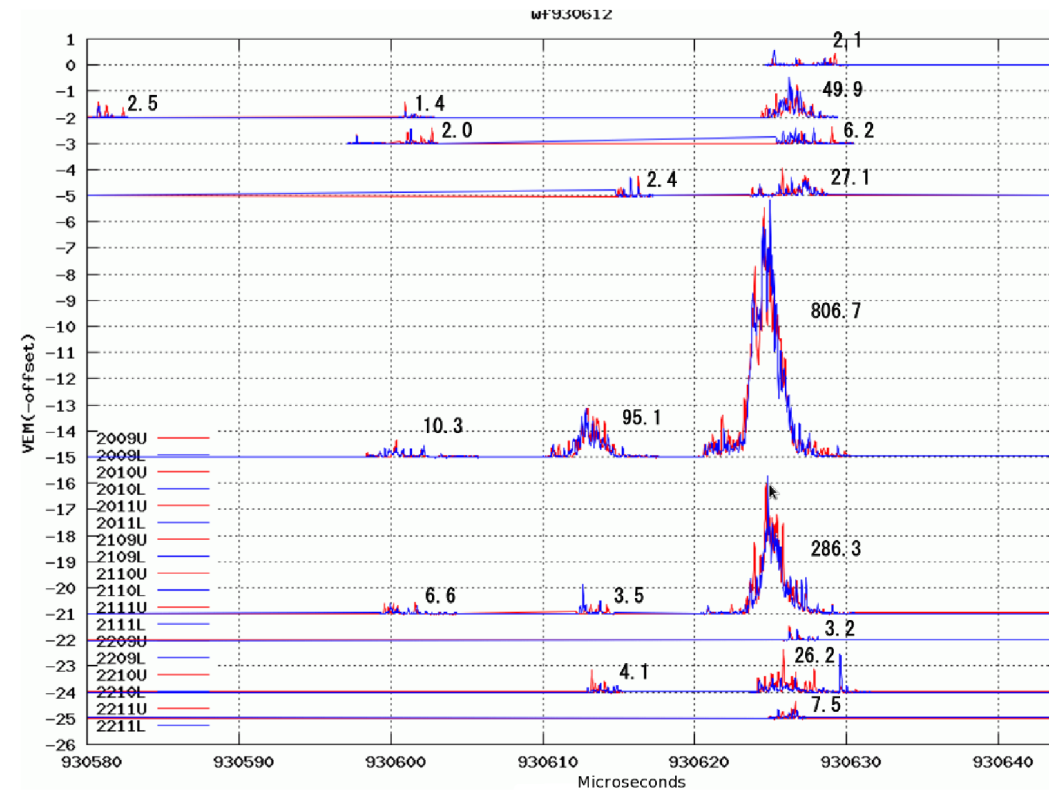
25 MeV electron moving through air at 1 atm  
in a 3 kV/cm electric field



Source: J. Dwyer

- Fields not typically large enough for spontaneous breakdown.
- Are runaway relativistic electrons the “seed”?
- Possible source:  $> 10^{16}$  eV cosmic ray air showers

# TA Observation: “Burst” Events

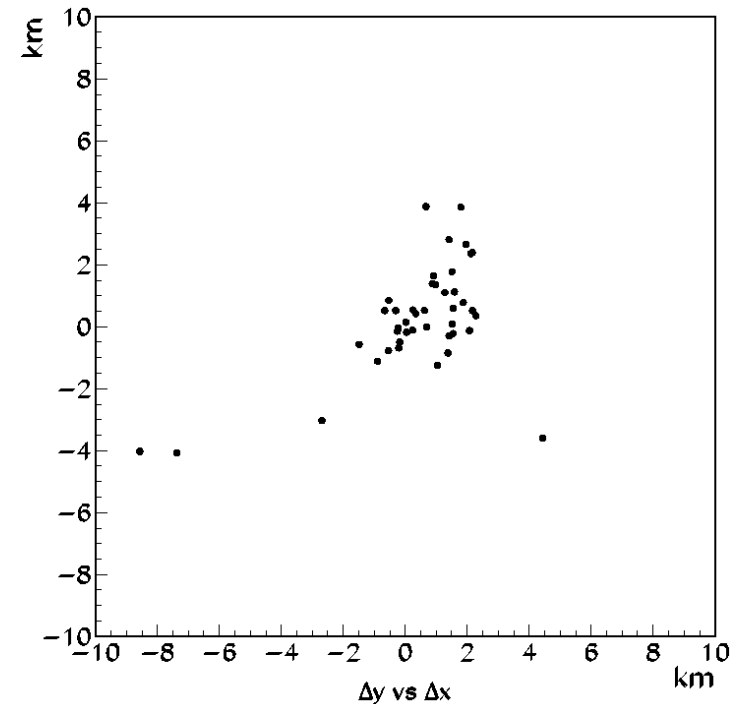
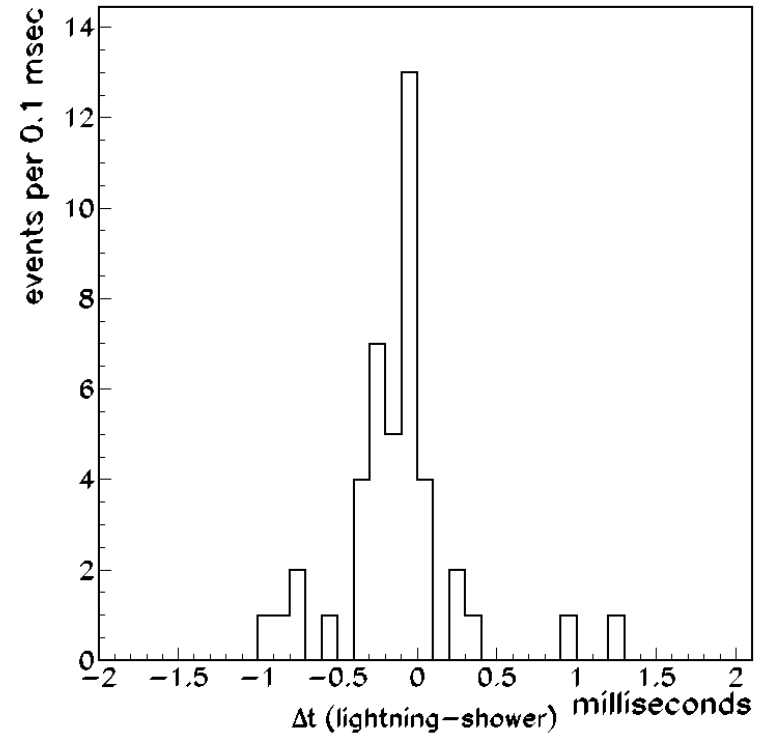


Plot: T. Okuda

- 5 year data (2008-2013)
- 10 surface detector burst events seen
  - 3 or more SD triggers
  - $\Delta t < 1$  msec
  - Occasional  $\Delta t \sim 1$   $\mu$ sec
- “Normal” SD trigger rate  $< 0.01$  Hz

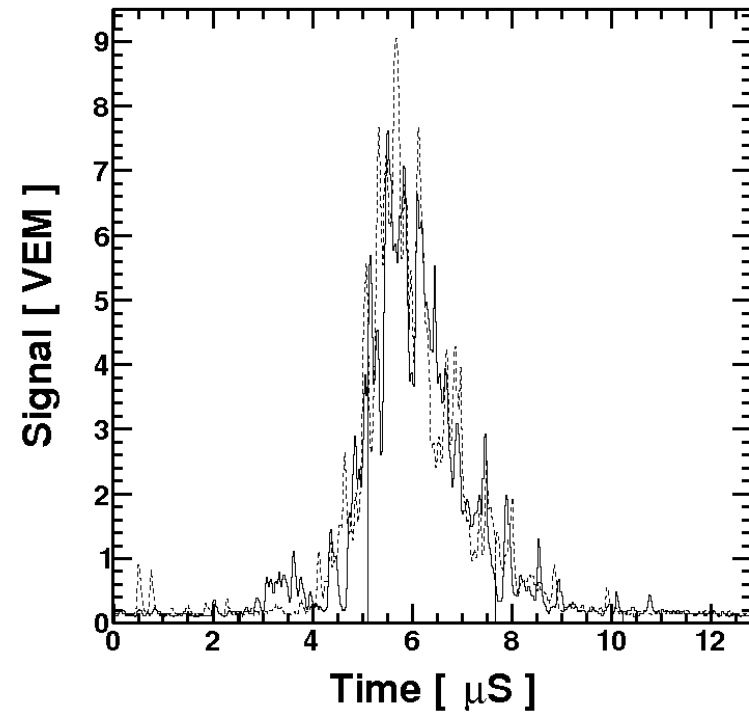
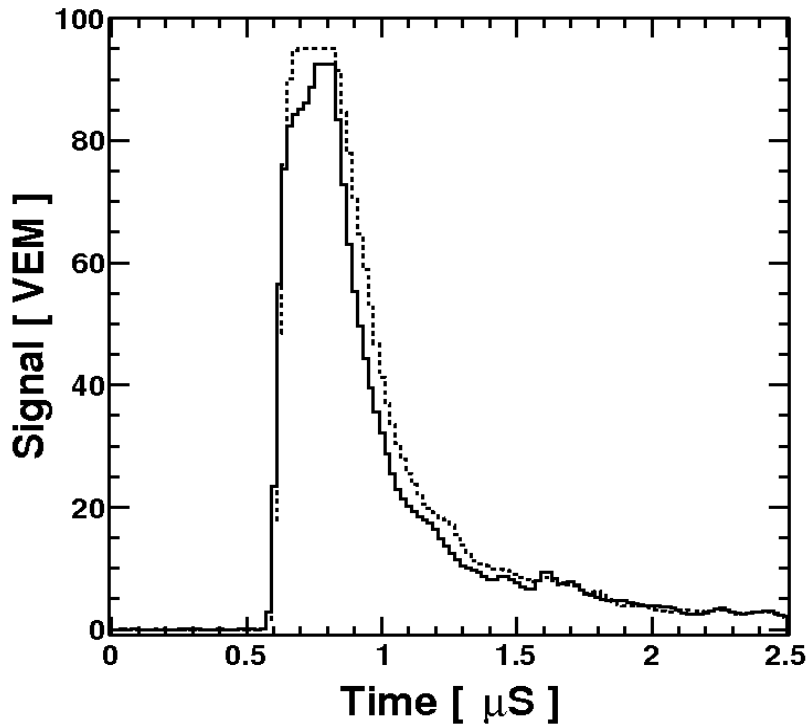
# NLDN

- Each lightning event in U.S. is recorded by *National Lightning Detection Network* (Vaisala).
  - Low-resolution.
  - Single time, position, peak current and polarity
  - cloud-cloud or cloud-ground.
- Burst events are subset of space/time coincidences of T ASD triggers with NLDN events.



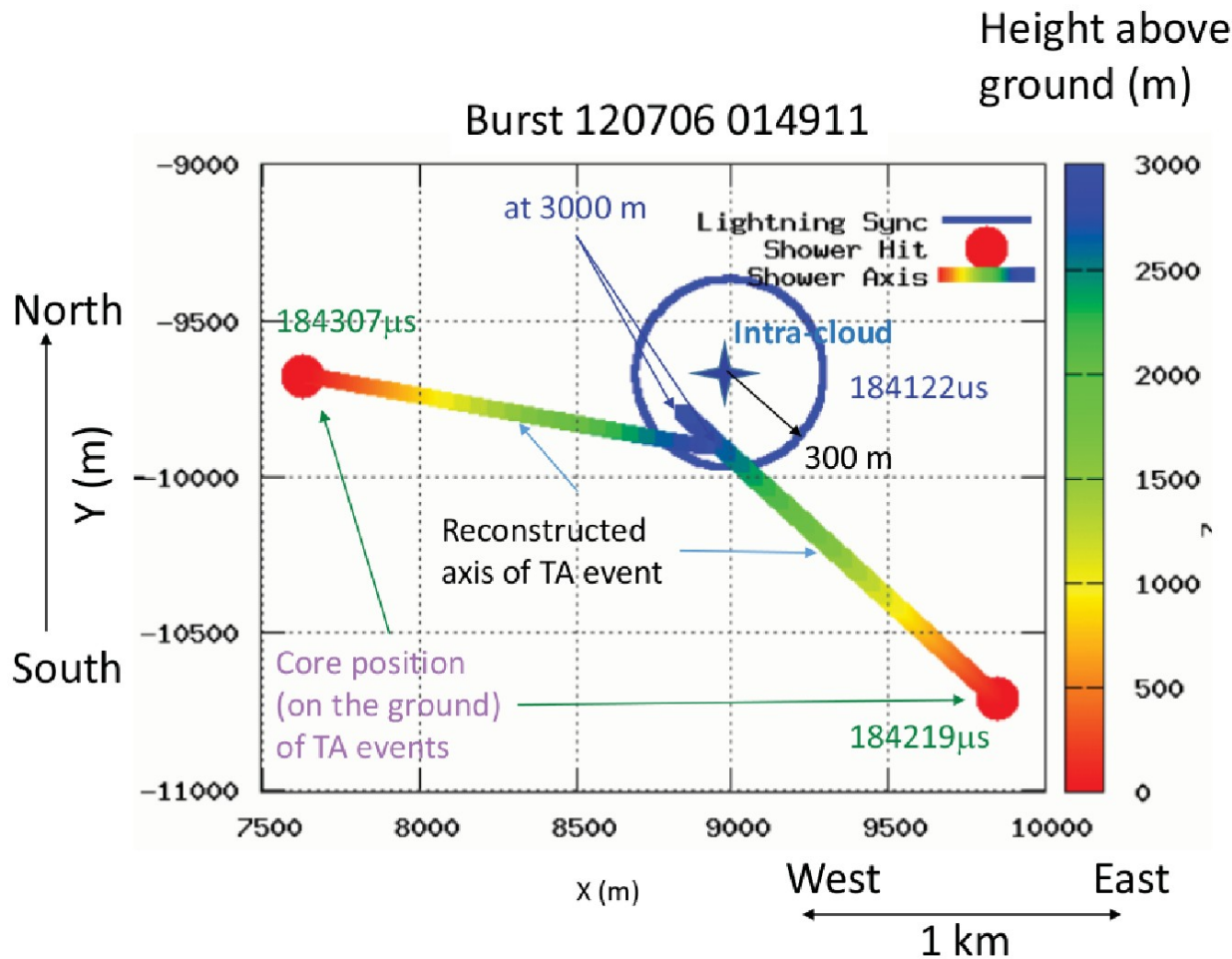
# Characteristics of NLDN-Coincident Events

Plots: D. Ivanov



- Typical T ASD core waveform
- Sharp leading edge
- Upper/lower scintillator similar
- $\sim 1 \mu\text{sec}$  duration
- NLDN-coincident core waveform
- Slower rise
- Upper/lower scintillator differ
- Several  $\mu\text{sec}$  duration

# Characteristics of NLDN-Coincident Events



Plot: T. Okuda

- 5 of 10 original “burst” events contain one or more *reconstructable* particle showers.
- A more detailed lightning reconstruction would enable better study of these events.
- Also ideal tool for “cosmic ray trigger” search.



# TA/LMA Project:

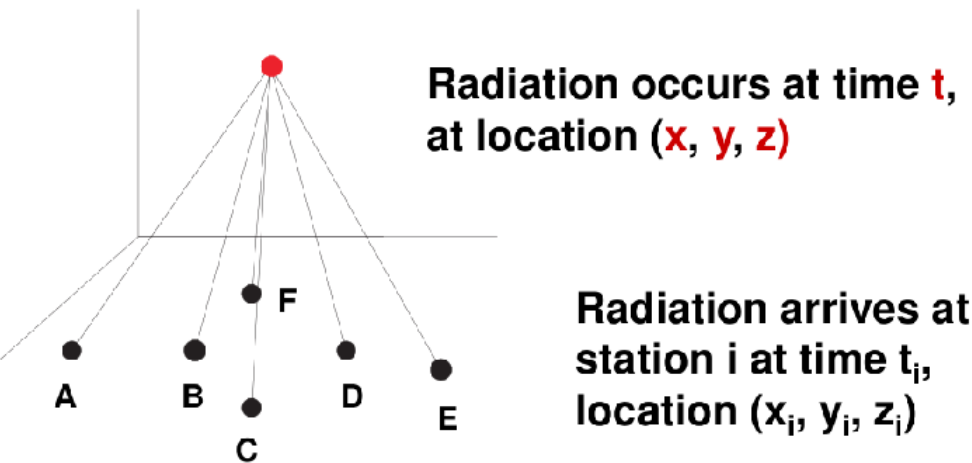
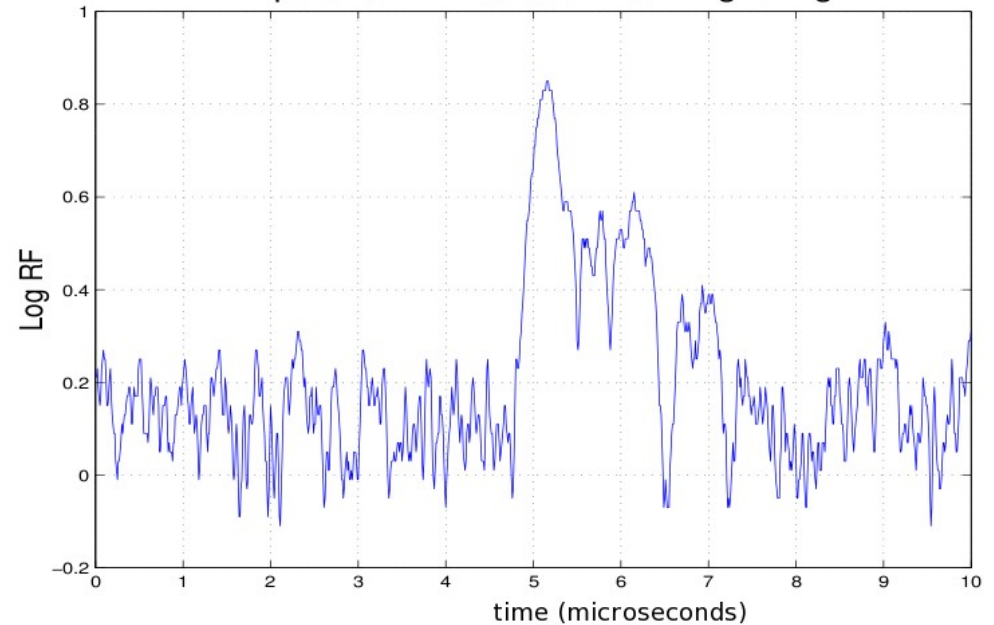
J. Belz, M. Byrne, D. Ivanov, W. Hanlon,  
P. Krehbiel, T. Okuda, W. Rison, H. Takai,  
R. Thomas, S. Thomas, G. Thomson, M. Wallace



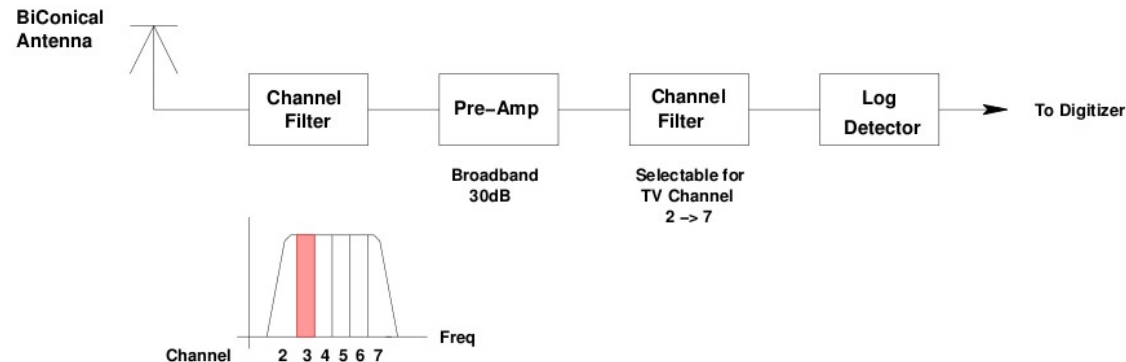
# How is Lightning Mapped?

- On microsecond timescale, lightning produces series of RF impulses
- Detect impulses with multiple VHF detectors to determine their x,y,z,t
- Large flashes may consist of  $10^2 - 10^3$  impulses

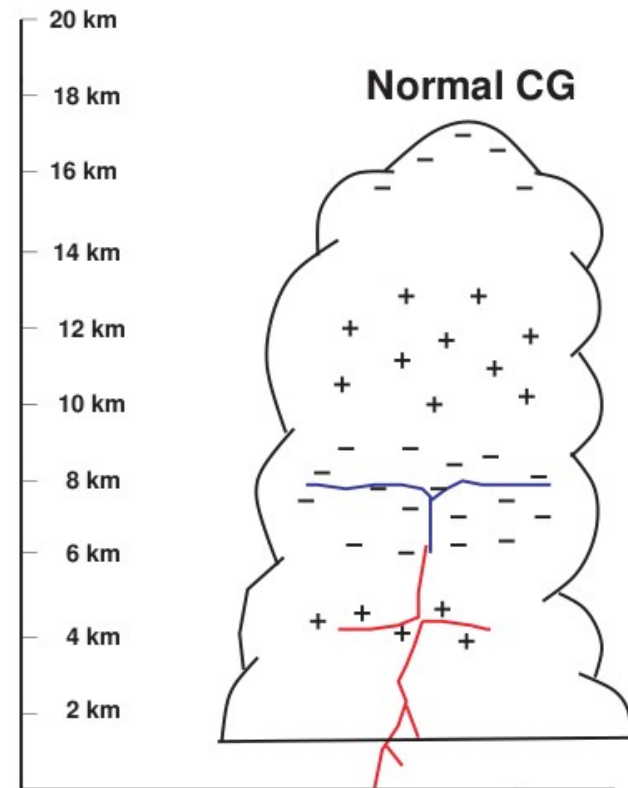
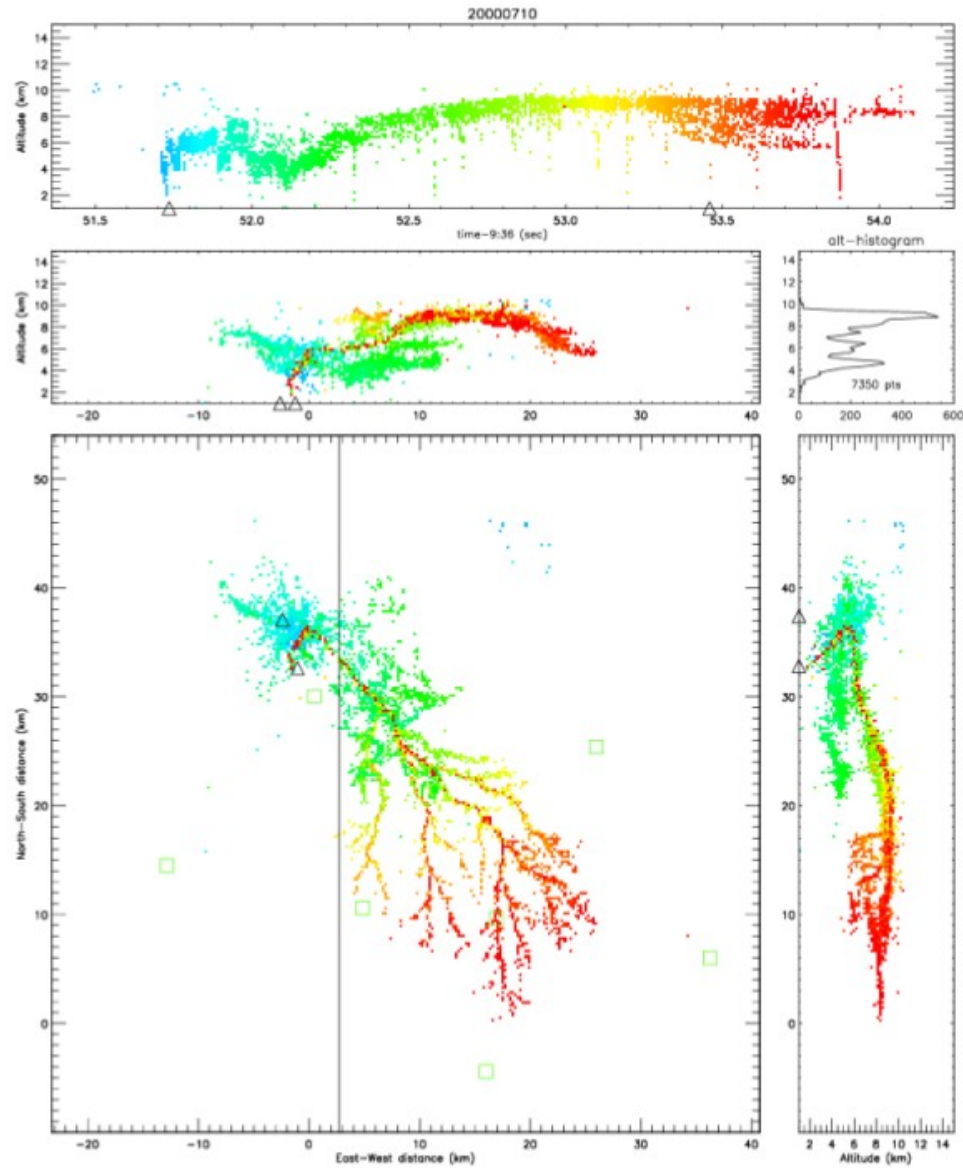
Impulsive RF Radiation from Lightning

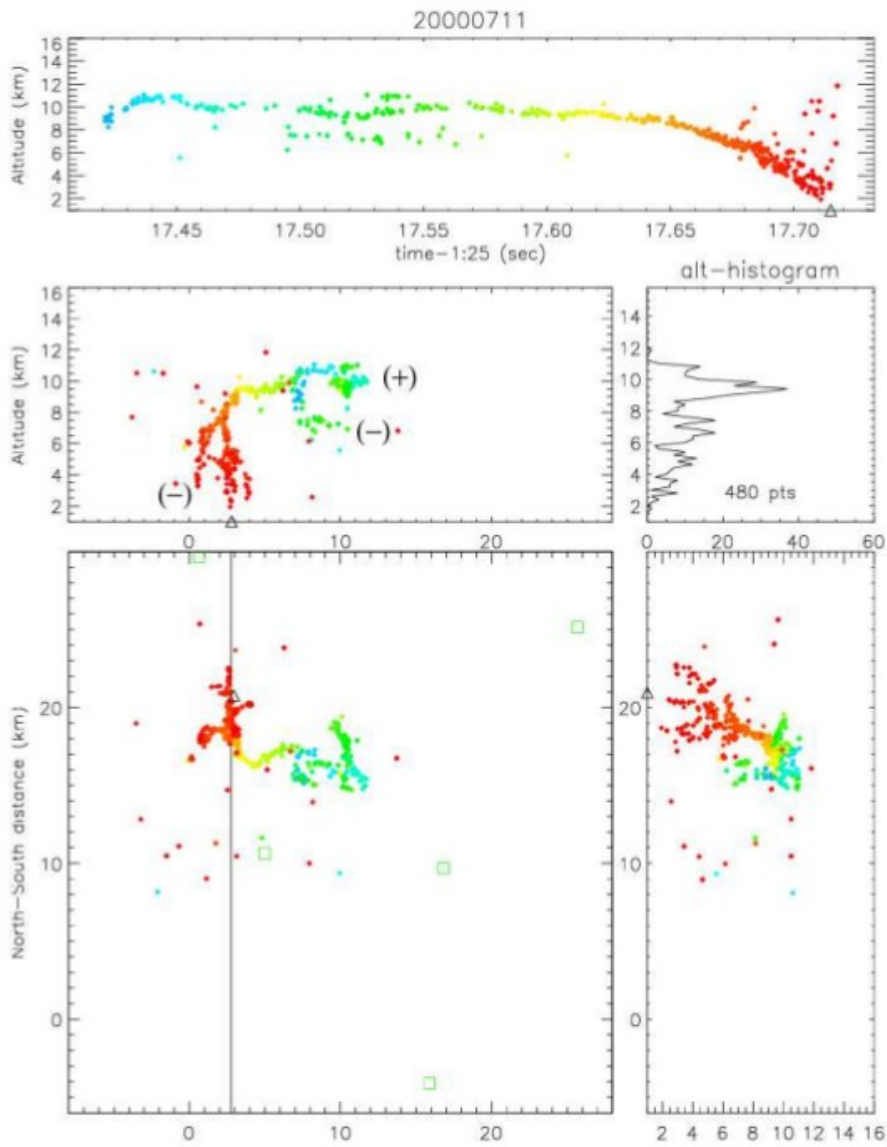


$$t_i = t + \frac{\sqrt{(x - x_i)^2 + (y - y_i)^2 + (z - z_i)^2}}{c}$$

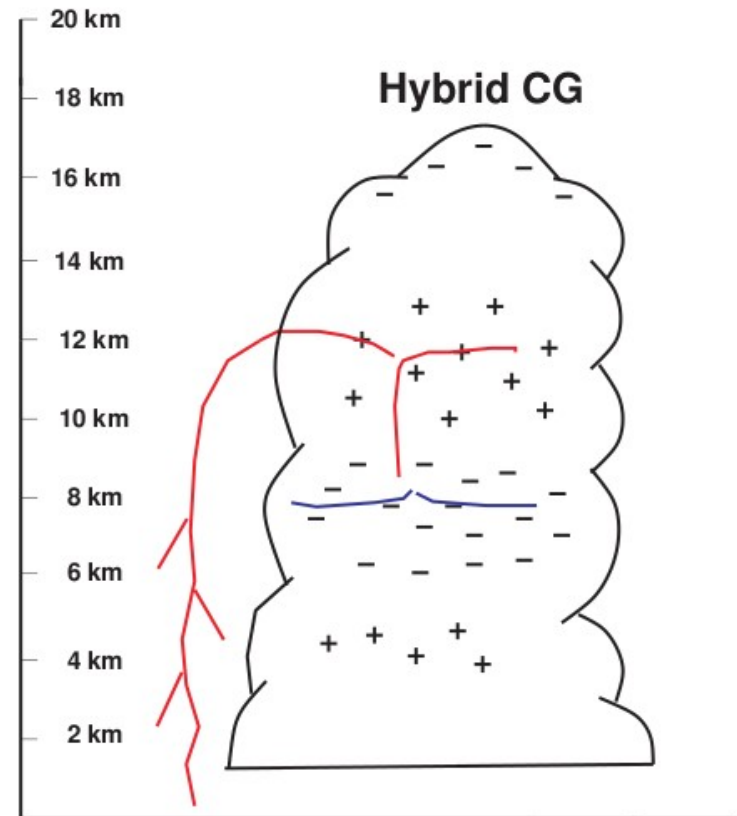


# Cloud-to-Ground Lightning





## Bolt from the Blue

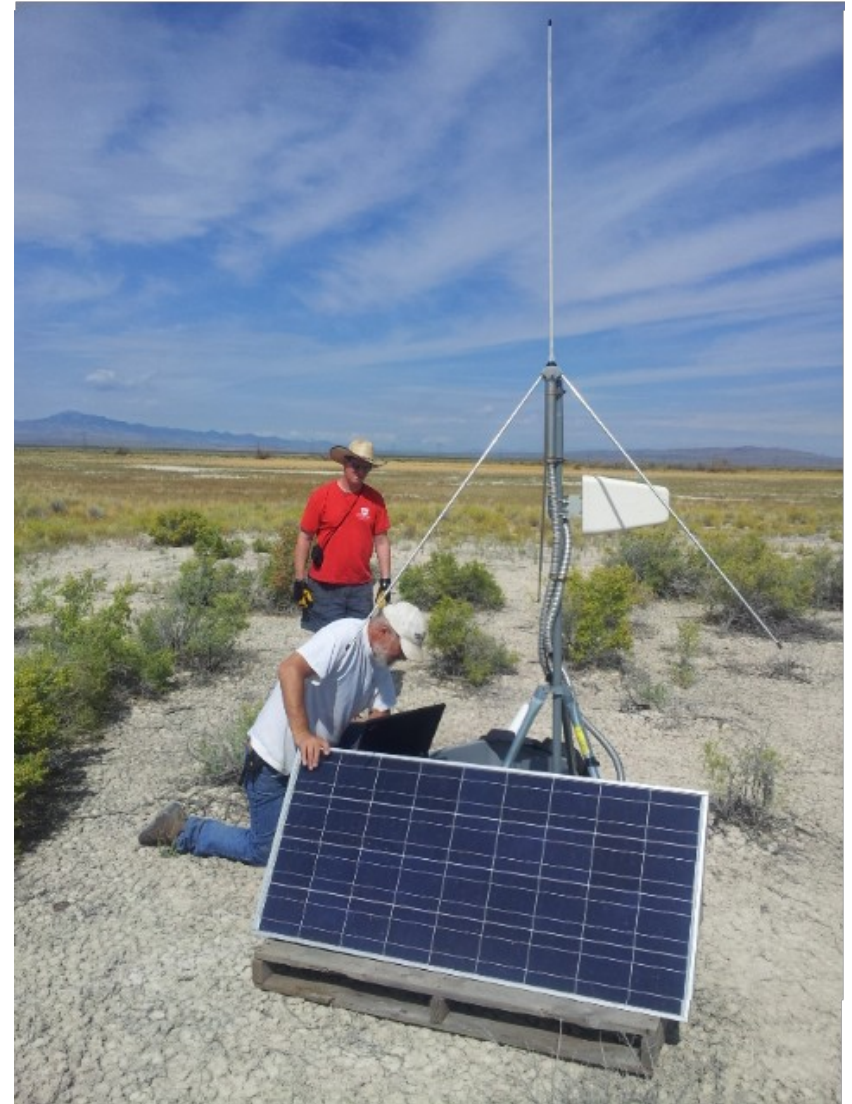
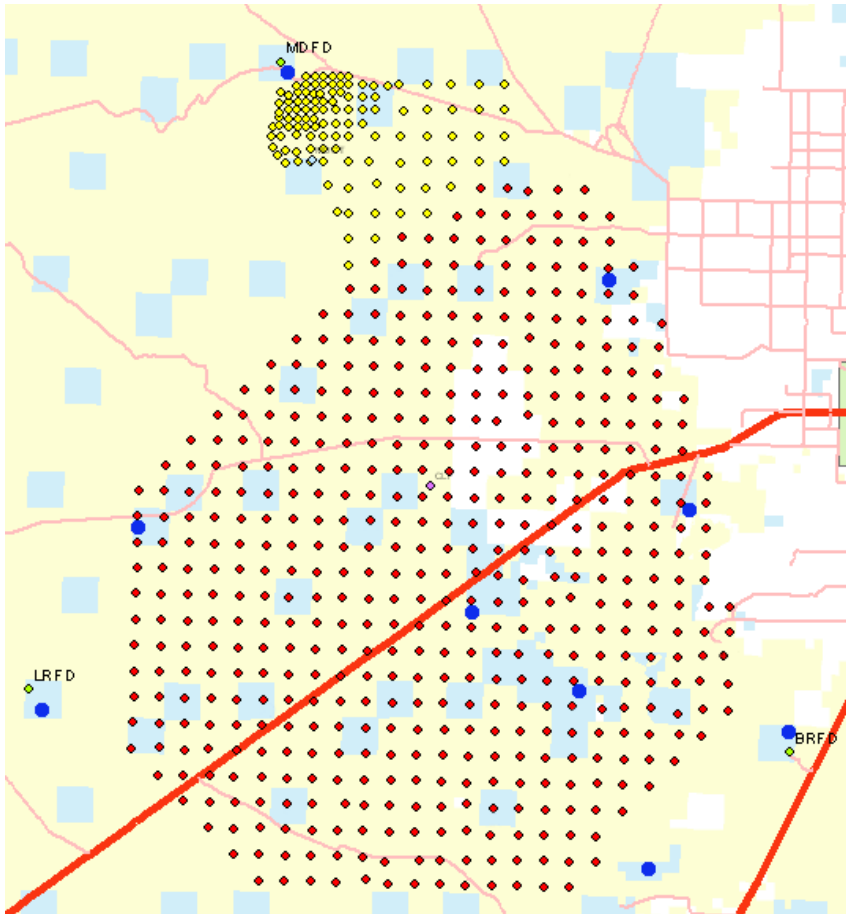






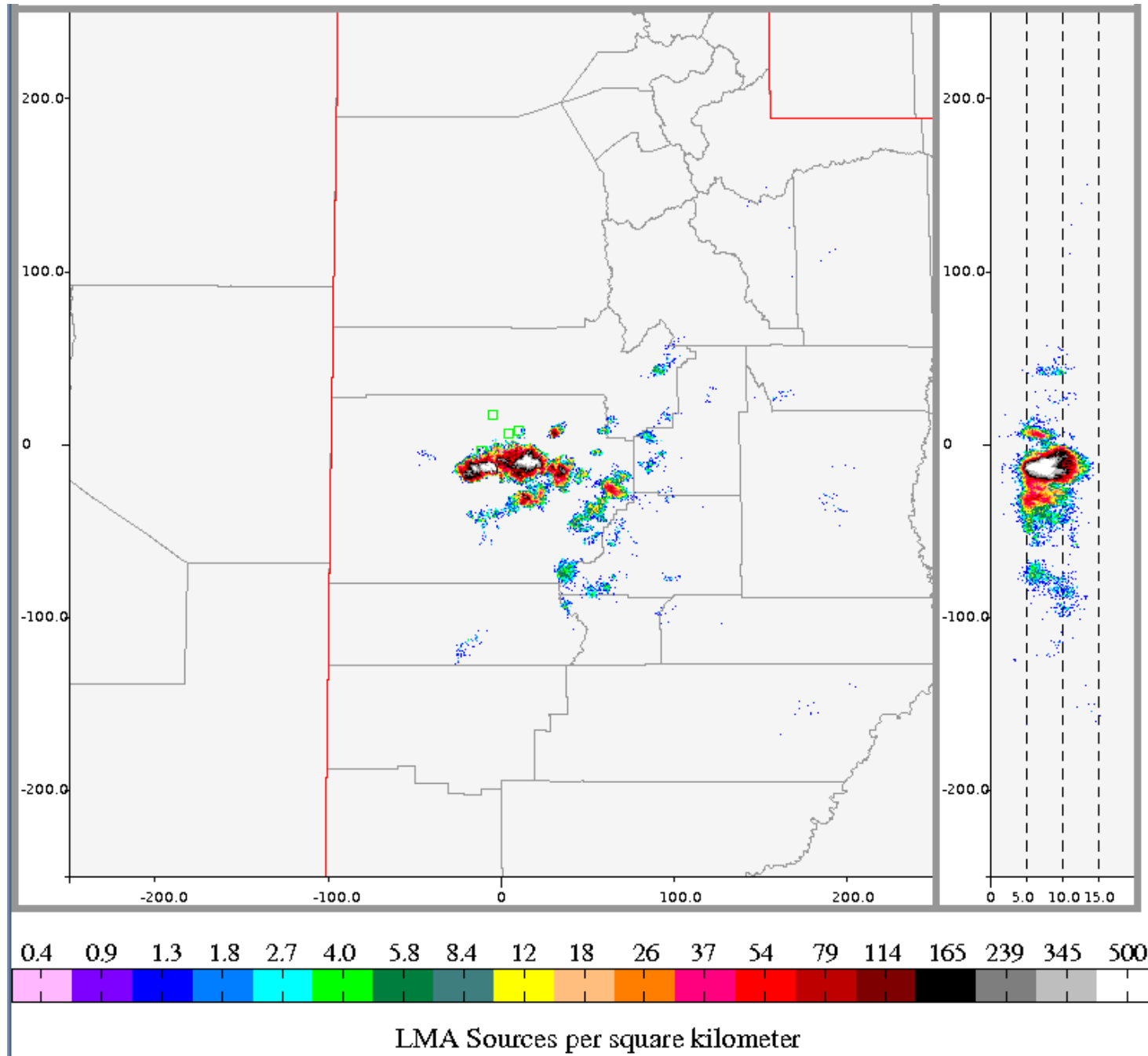
- Fall 2013 installed temporary Lightning Mapping Array at TA site. (w/ **Langmuir Institute NM Tech**)
- Hourly updates at: <http://lightning.nmt.edu/talma>
- Proposal for permanent array to be submitted to NSF Physical Meteorology

# TALMA



**W. Hanlon (UU) with  
B. Rison (NM Tech)**

# LMA Output; 29 July 2014



# TA Lightning Summary

- Telescope Array has observed **and in some cases reconstructed** showers of high energy particles coincident with lightning (T. Okuda).
- TA is deploying a high resolution **Lightning Mapping Array** to further study origins of these particles within lightning.
- TA/LMA merger has potential for very compelling physics:
  - What are mechanisms for high-energy particle production in lightning? **Straightforward contribution to atmospheric science.**
  - Do cosmic rays seed lightning strikes? **Speculative, but profound if true.**