Validation of lightning detection and classification beyond GLM

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Operational lightning detection then and now

- A new, multi-sensor, multi-physics era of lightning measurements means that our concept of lightning detection must evolve from an undifferentiated whole (“I saw a lightning strike”) to one that correctly classifies components of the lightning discharge, reports their spatial extent, and ultimately relates the discharge to the three dimensional, time-evolving meteorological structure of thunderstorms.

- This challenging task has arisen time and again during GLM cal/val, and has also been raised by forecasters in the NWS total lightning working group who are trying to understand observed differences in reported stroke classifications.

- The old problem: what is the peak current and location of CG strokes?

- The new problem: how do we fit together mapping and stroke detection instruments into a dataset that correctly classifies components of the lightning discharge, and reports their spatial extent?

  - Datasets give a conflicting picture right now.

  - Because it’s sensed and reported, operational users wonder what it means, and complain!

- **We have to take on this challenge if we want to relate lightning to the three-dimensional, time-evolving meteorological structure of thunderstorms.**

1st Generation

Singular focus on CGs
peak current and location

Shared knowledge
among academia, federal, and industry

Instrument

NLDN (CG)

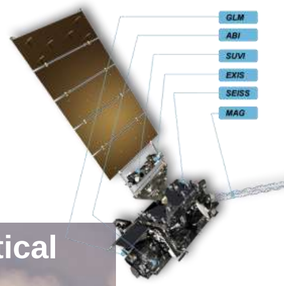
Radio Band
3-30 kHZ
1 - 350 kHz
1 Hz - 12 MHz
60-66 MHz

Today

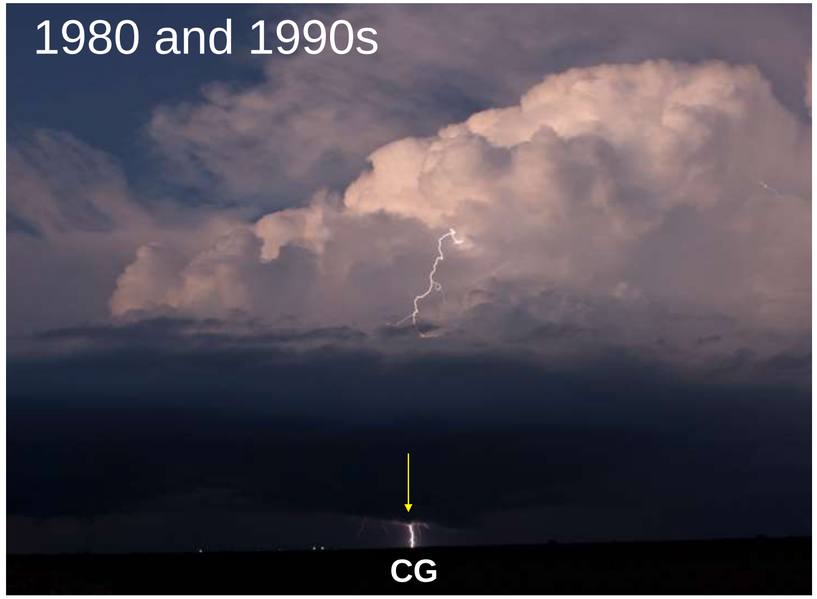
Diversification of measurements
IC, CG strokes; channel mapping

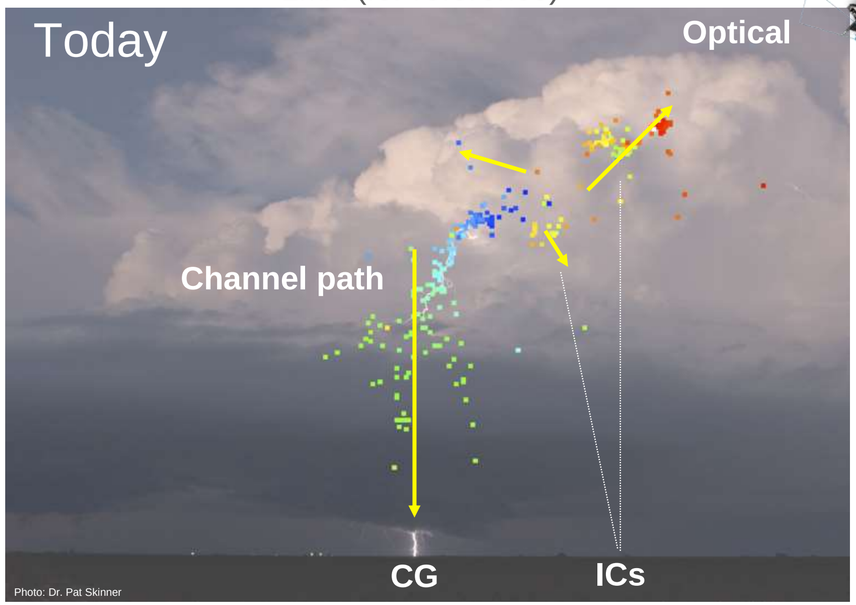
Specialization
among academic, federal, and industry scientists

Instrument
WWLLN
NLDN (CG, IC)
ENI
LMA (for reference)



777.4 nm





Electric field change waveform shapes and polarity information greatly aid validation
Their study and those skills have become a speciality instead of a universal expectation of lightning scientists.
It’s time to bring that back.

A proposal

The FiDeLiTy Initiative

Fiducial Detection of Lightning Types

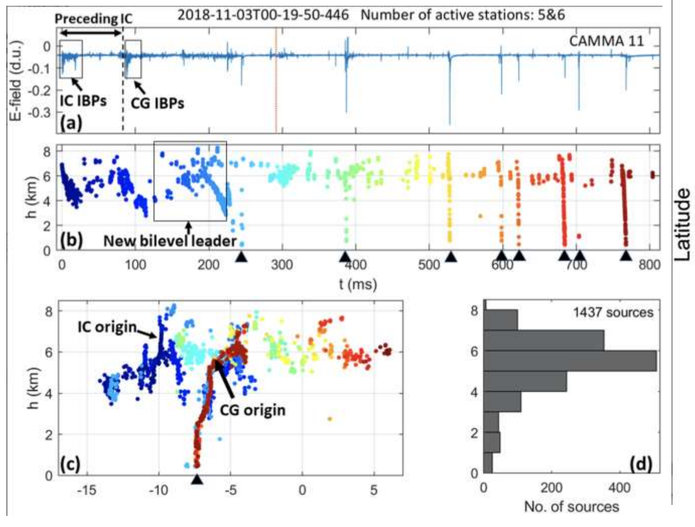
- **What?**
  - Within each LMA:
    - 12 field change sensors + pan tilt zoom optical cameras
    - Must operate continuously and be designed for automatic synthesis
  - Open dataset as a shared resource for industry, federal, and academic scientists
    - Supports research, development, and assessment
- **Why?**
  - Our concept of lightning detection must evolve from an undifferentiated whole (“I saw a lightning strike”) to one that correctly classifies components of the lightning discharge
  - Provides a geographically distributed capability for characterizing charge motions along any lightning flash in a small domain.
    - Consolidates lessons learned from GLM validation and NWS TLWG
    - Captures variability over GLM field of view, meteorological variability in lightning behavior (e.g., inverted and severe storms), rare events
- **How?** Proof of concept datasets:
  - RELAMPAGO CAMMA deployment
  - Camera system prototype at Pantex

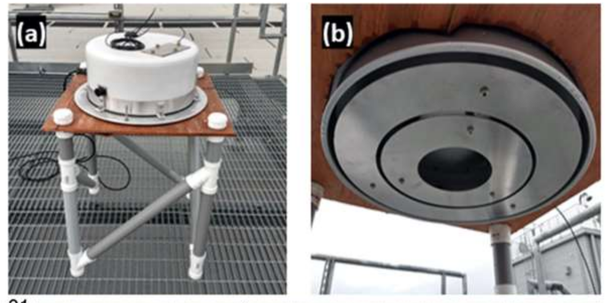
Portable and fixed LMAs

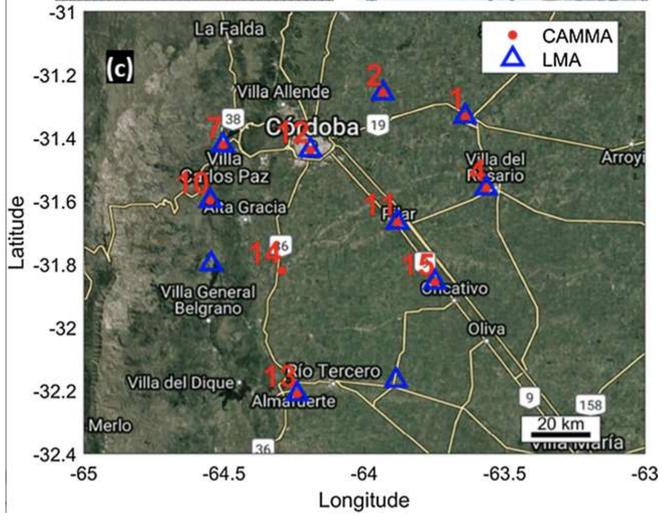
COLMA, WTLMA, OKLMA, Langmuir HLMA, NALMA, NGLMA, DCLMA…

Pantex Optical Lightning Detection System
Courtesy David Haatz

Electric field change (e.g., CAMMA; Zhu et al. 2020, doi:10.1029/2020EA001111)





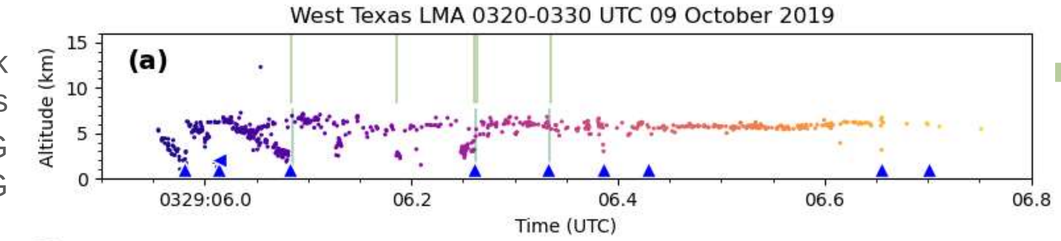


Classification: mixed messages

Network differences

1 –CG

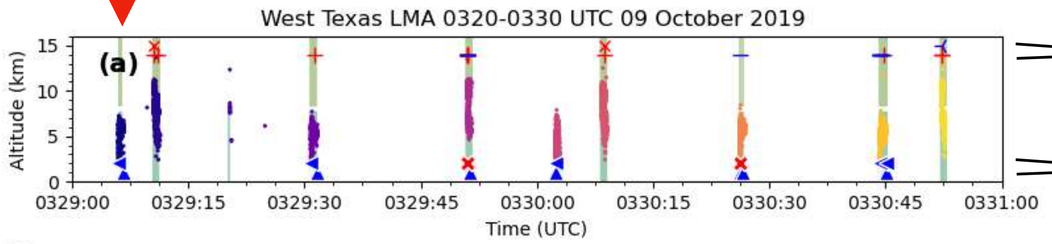
9 –CG



G17

G16

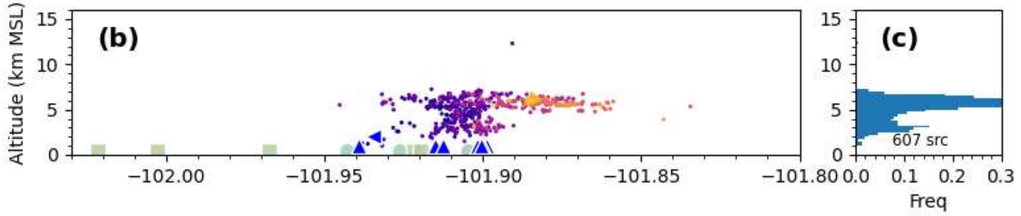
9 flashes, two minutes, quite a bit of disagreement

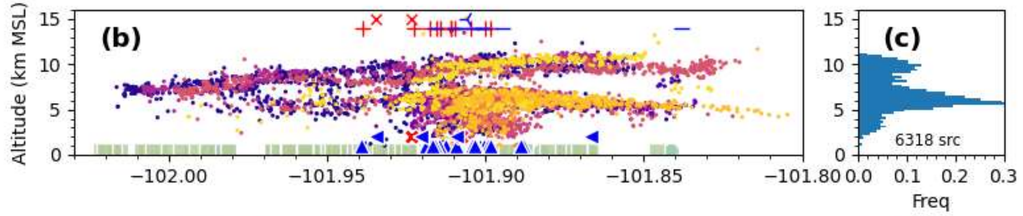


Two stroke/pulse networks

IC

CG



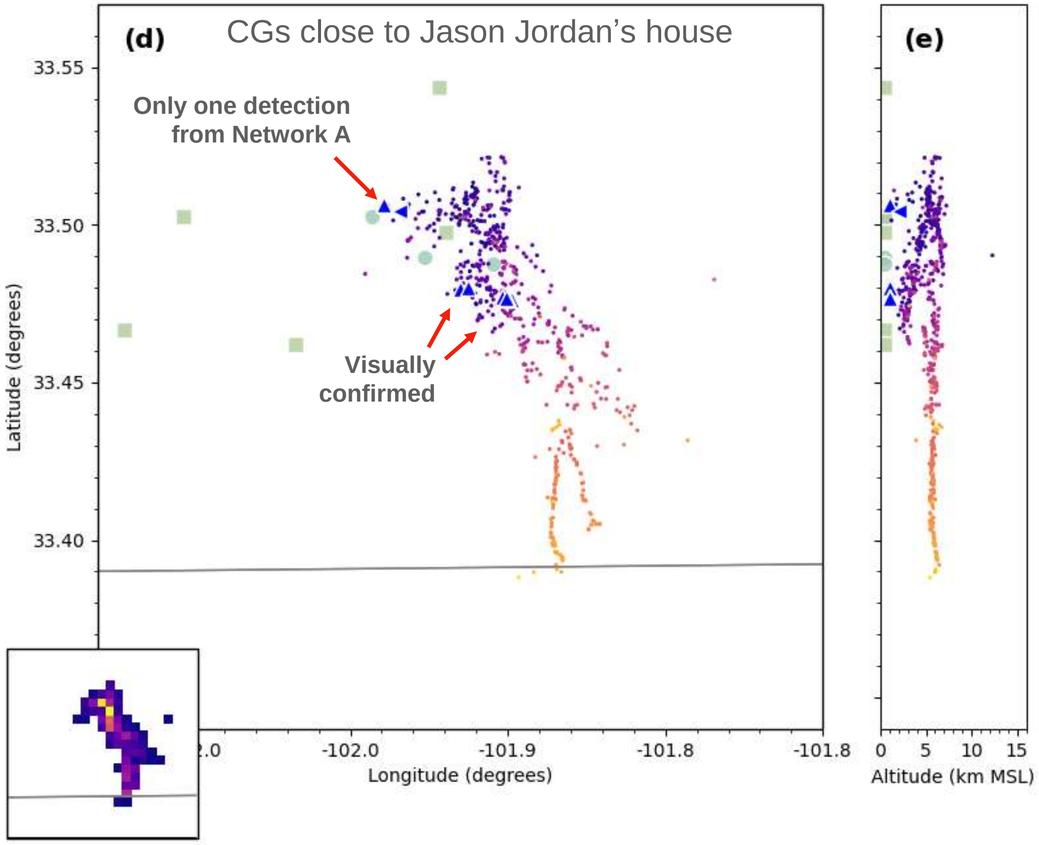


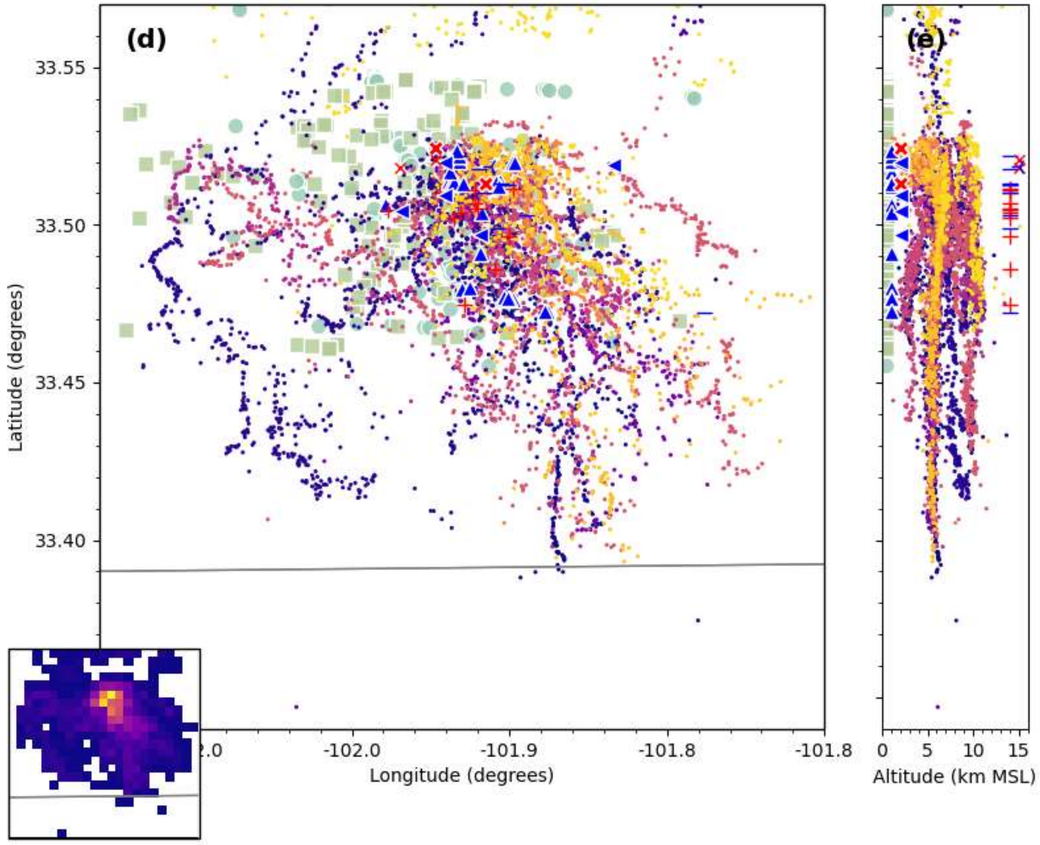
\+ Storm charge

– from flash

\+ analysis

Histogram gives wrong storm charge





Network with -CG sees various IC polarities

Probably should be a +IC instead of +CG from other network

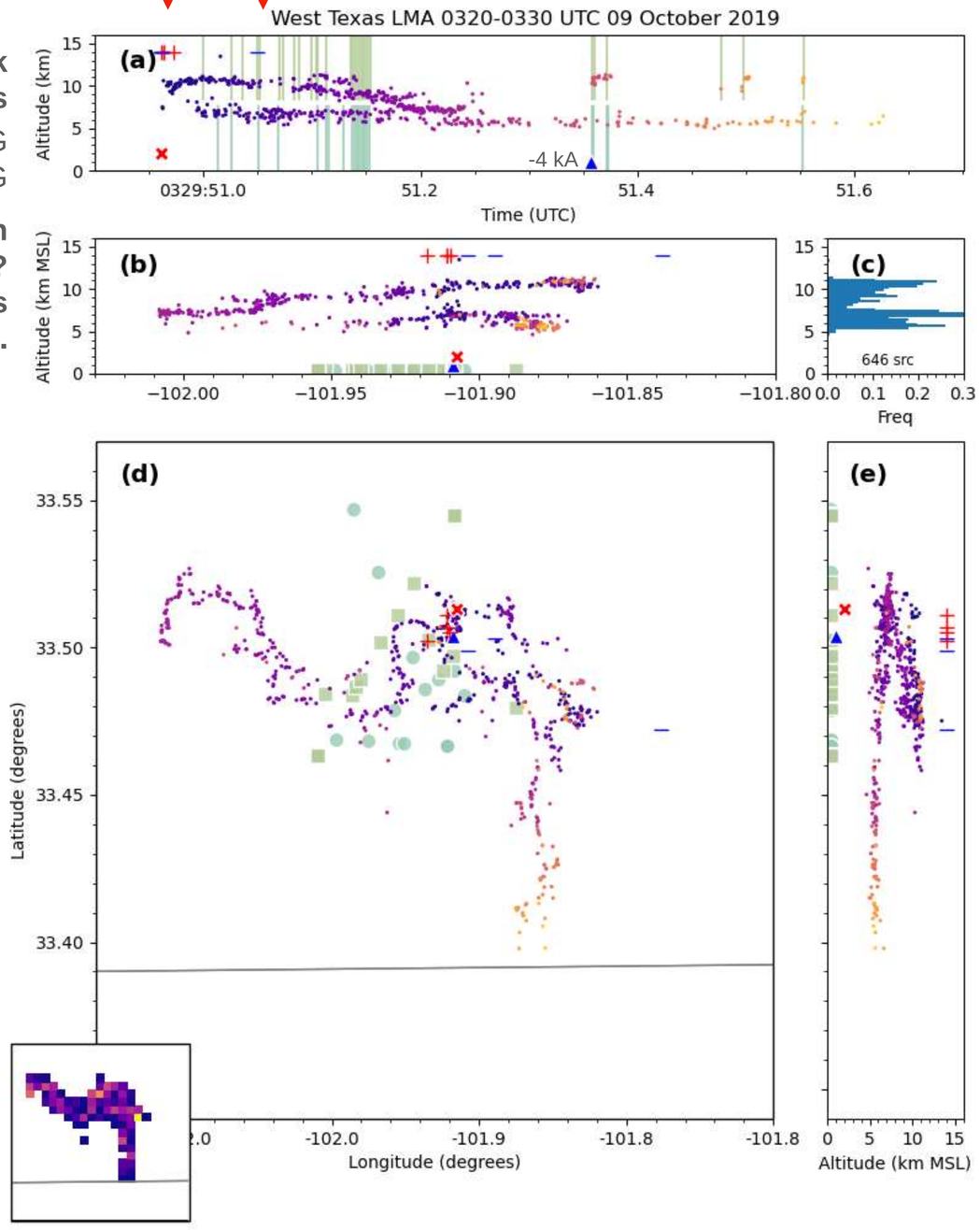
Two stroke/pulse networks

Network differences

+CG

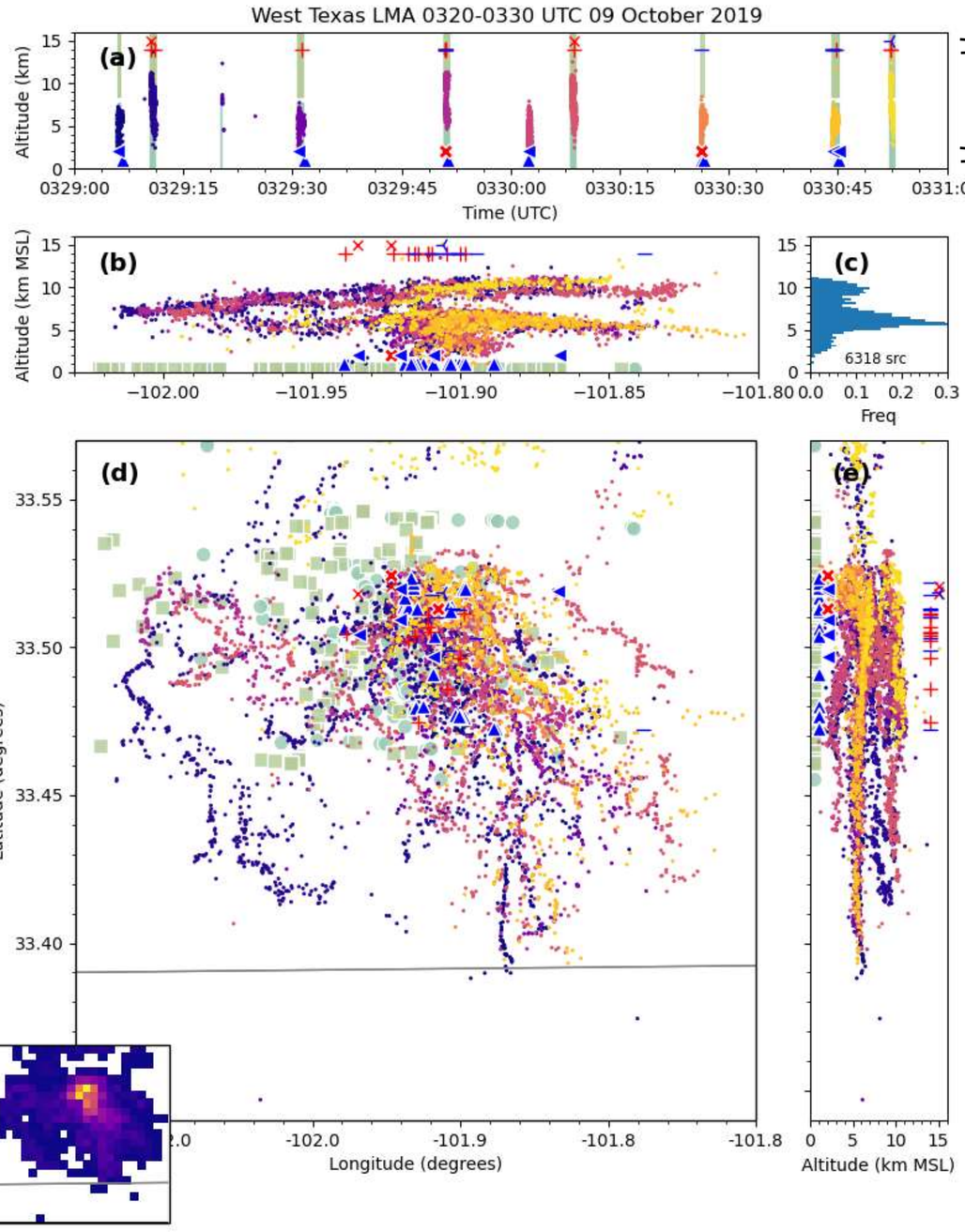
–CG

Both wrong? LMA has a +IC.



G17

G16



IC

CG

\+ Storm charge

– from flash

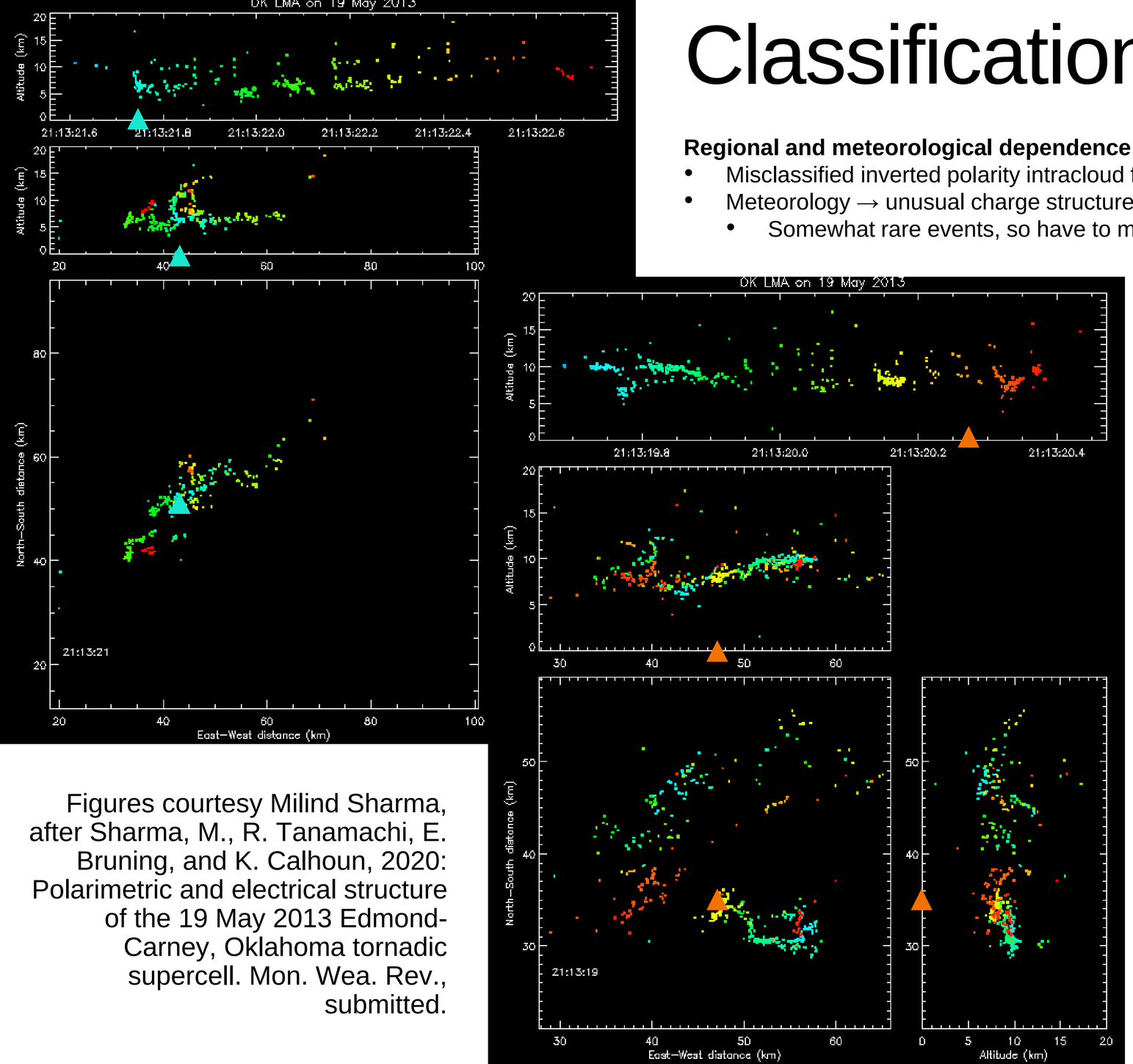
\+ analysis

Histogram gives wrong storm charge

Classification problems

Regional and meteorological dependence

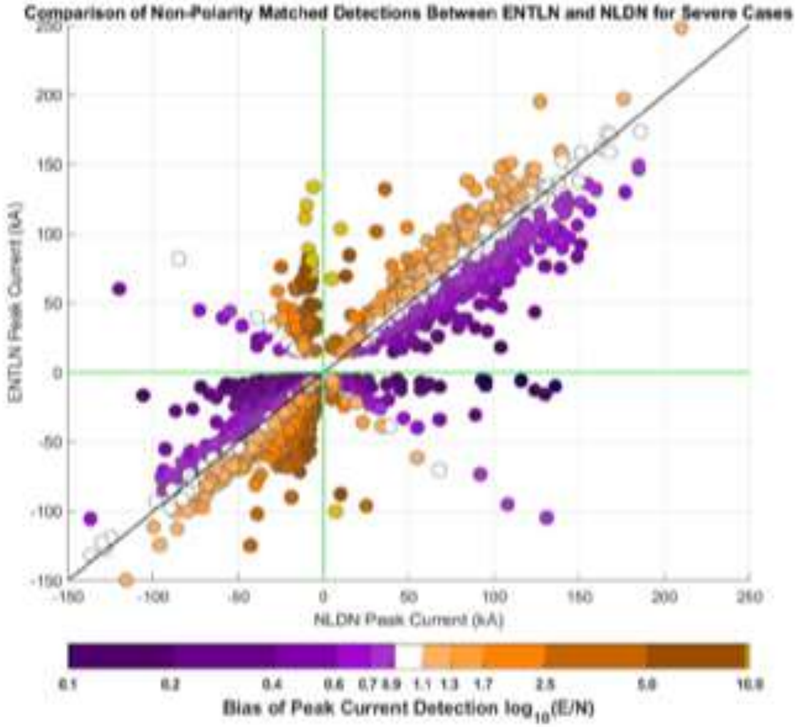
- Misclassified inverted polarity intracloud flashes. Peak currents between –15 and –25 kA
- Meteorology → unusual charge structure → flashes that don't fit the historical model for –CGs
  - Somewhat rare events, so have to monitor continuously to capture waveforms.



Figures courtesy Milind Sharma, after Sharma, M., R. Tanamachi, E. Bruning, and K. Calhoun, 2020: Polarimetric and electrical structure of the 19 May 2013 Edmond-Carney, Oklahoma tornadic supercell. Mon. Wea. Rev., submitted.

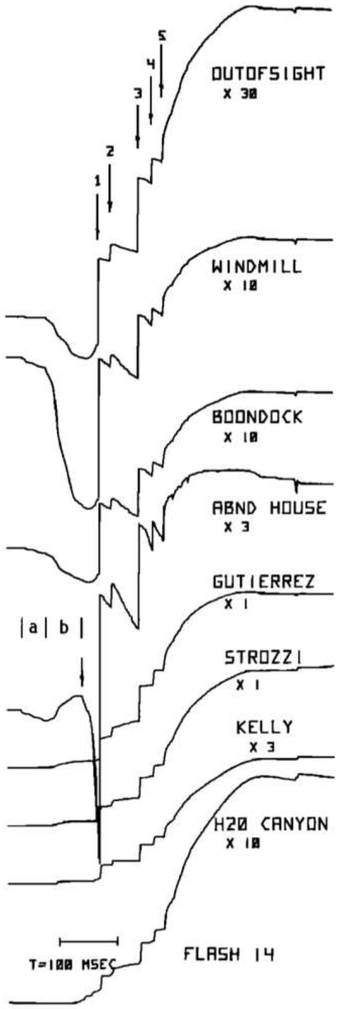
Polarity and Peak Current Uncertainty

7613 flashes. Well-correlated magnitudes (r^2=0.93), except when it's not. RMSE=15 kA. Can we reduce this spread? Why are the polarities sometimes different? From Calhoun et al. (2020, OU senior capstone project)



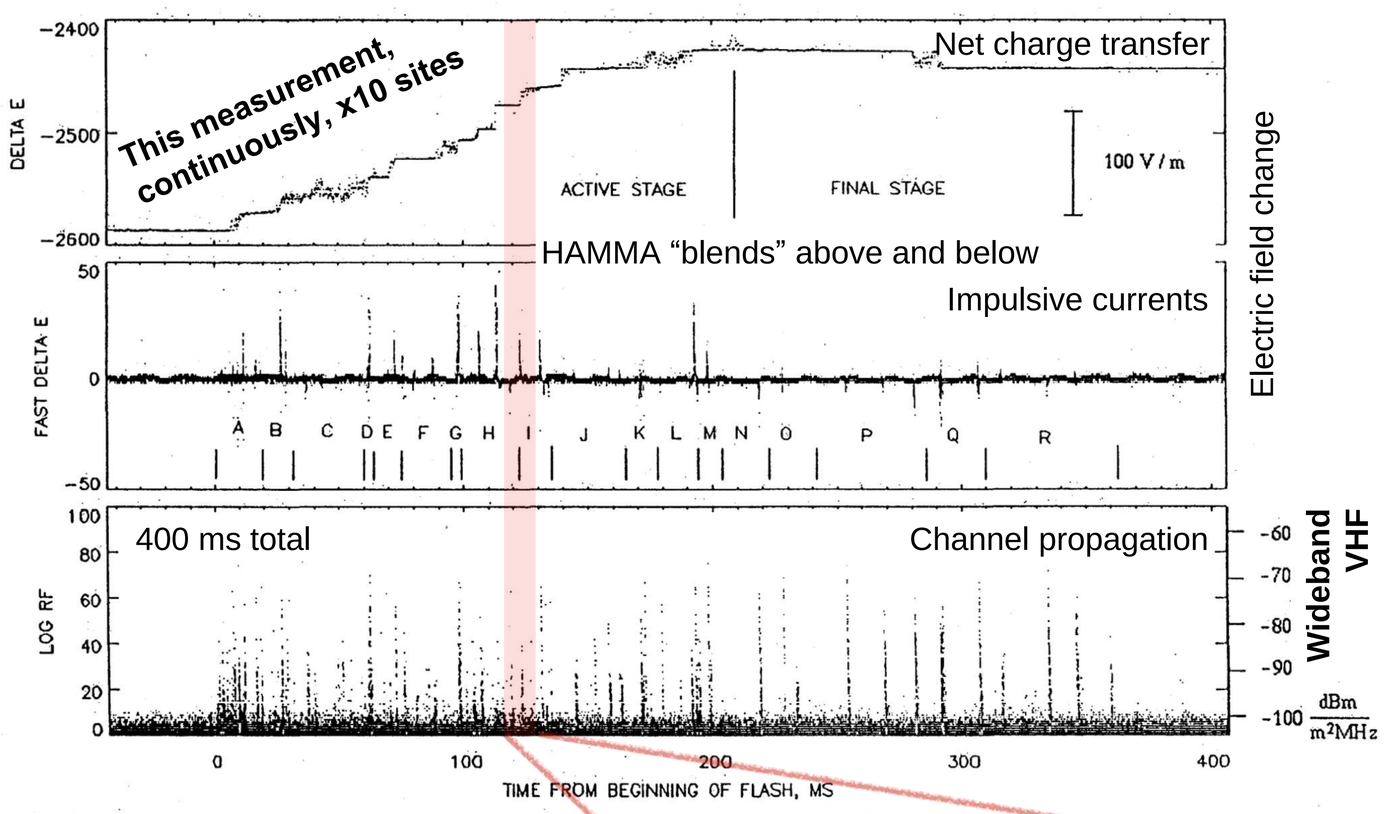
We know how to do this; We don’t do it systematically

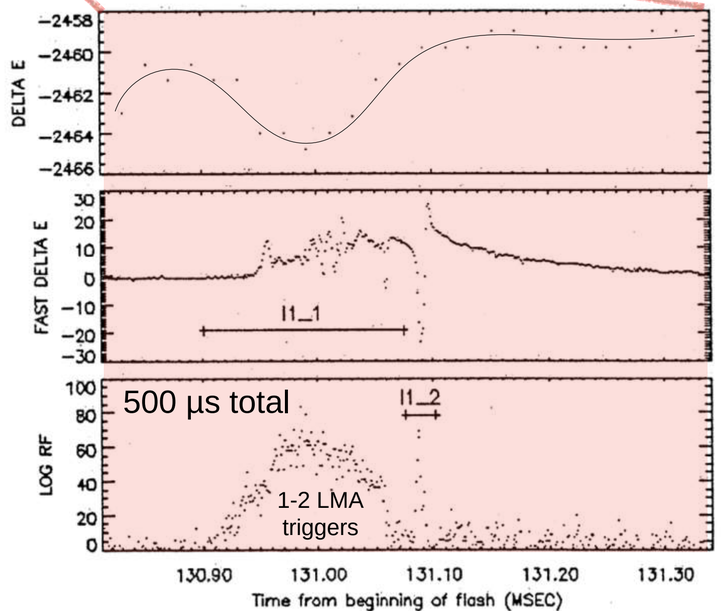
Short validation campaigns and a few flashes
Focus on single instruments and regions instead of synthesis



Krehbiel et al. (1979)

- Understanding how charge moves in the sky has, since the 1960s, relied on electric field change measurements.
  - Still deployed to do validation of classification and deep study of individual discharges
  - Time to revisit this work and make it routine.
- Newer VHF mapping systems provide essential context
  - We learned so much by making this measurement routine.
- Everyone has limited resources to do validation, from industry to academia
- **A hard problem, but we have the instruments, computing power, and experience to push the science.**





Shao and Krehbiel (1996, JGR)