Large Charge Moment Change Lightning in an Oklahoma Mesoscale Convective System

Timothy J. Lang[1], Steven Cummer[2], Danyal Petersen[3], Lizxandra Flores-Rivera[4], Walt Lyons[5], Donald MacGorman[6], and William Beasley[3]

1. NASA Marshall Space Flight Center
2. Duke University
3. University of Oklahoma
4. University of Puerto Rico – Mayaguez
5. FMA Research, Inc.
6. NOAA National Severe Storms Laboratory

ICAE 2014

Cloud-to-ground strokes can be associated with a parameter called Charge Moment Change:

$$CMC(t) = Q(t) * Z(t)$$

Q is charge lowered, **Z** is height from which it is lowered

CMC is generally thought to be a critical parameter for the initiation of sprites/halos

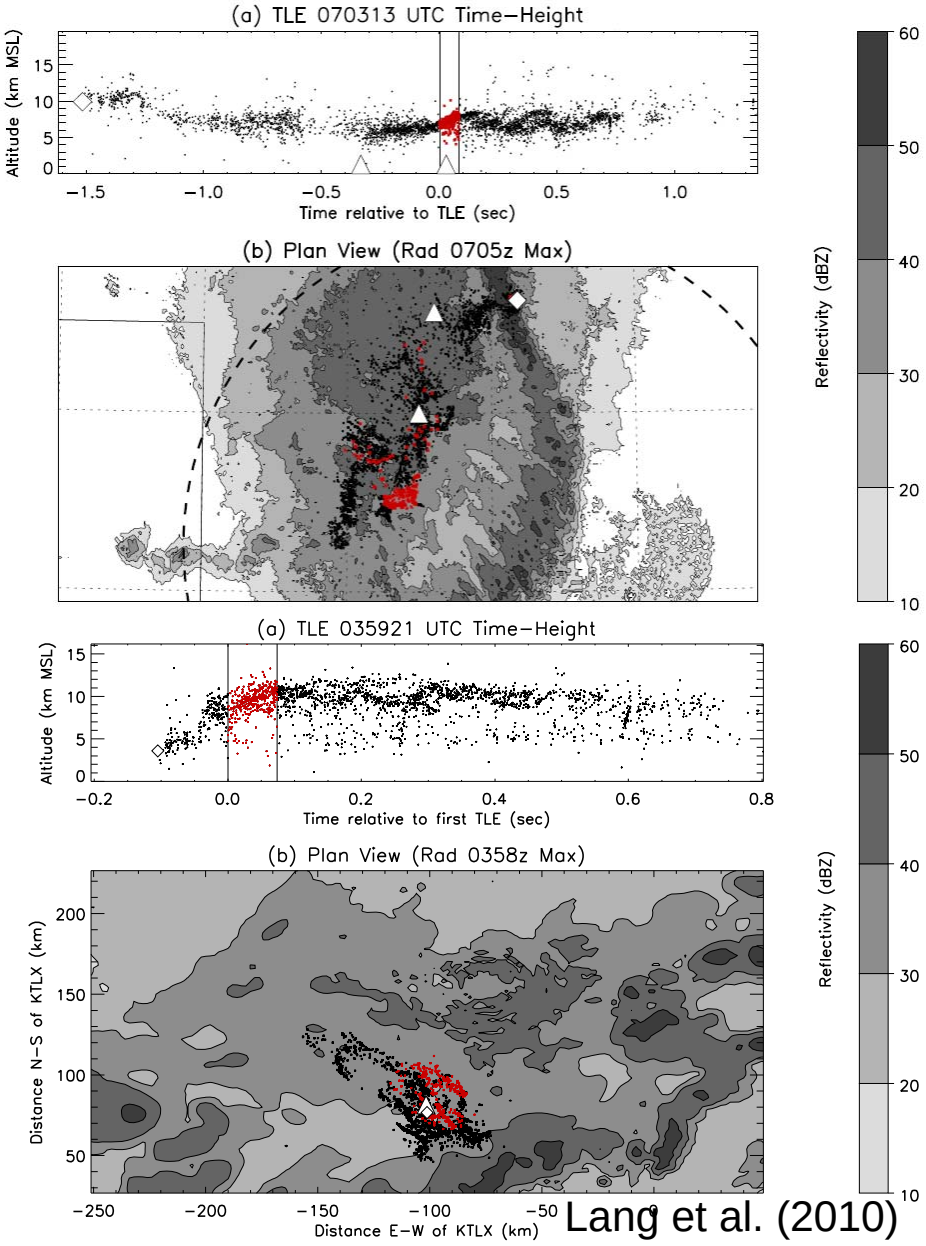
The higher it is, the greater chance for sprite initiation;
~100s of C km generally associated with sprite-parent CGs

Impulse CMC (**iCMC**) is measured in real-time by the Duke Charge Moment Change Network (CMCN), full CMC can be retrieved in post-processing

iCMC > 100 C km = ~10% chance of sprite (*Large iCMC*)
iCMC > 300 C km = 75-80% chance of sprite (*Sprite-Class iCMC*)

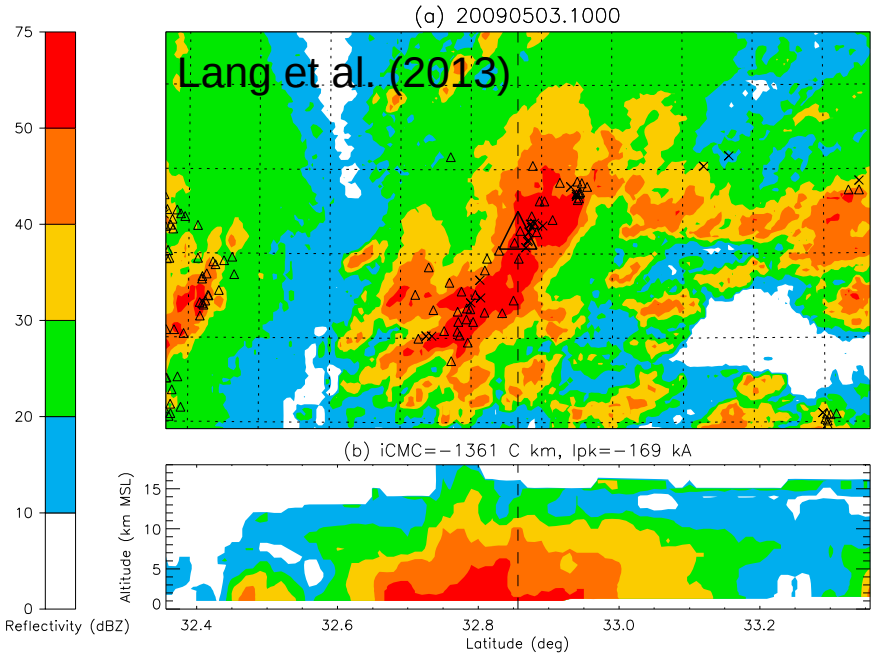
Sprite-Class Lightning Archetypes

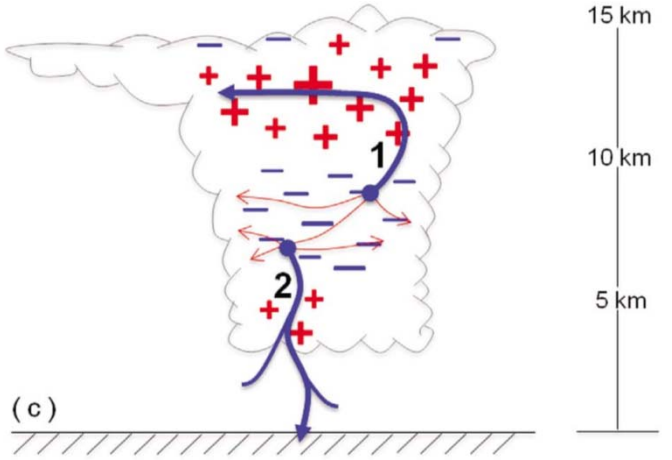
Positive



Lang et al. (2010)

Negative

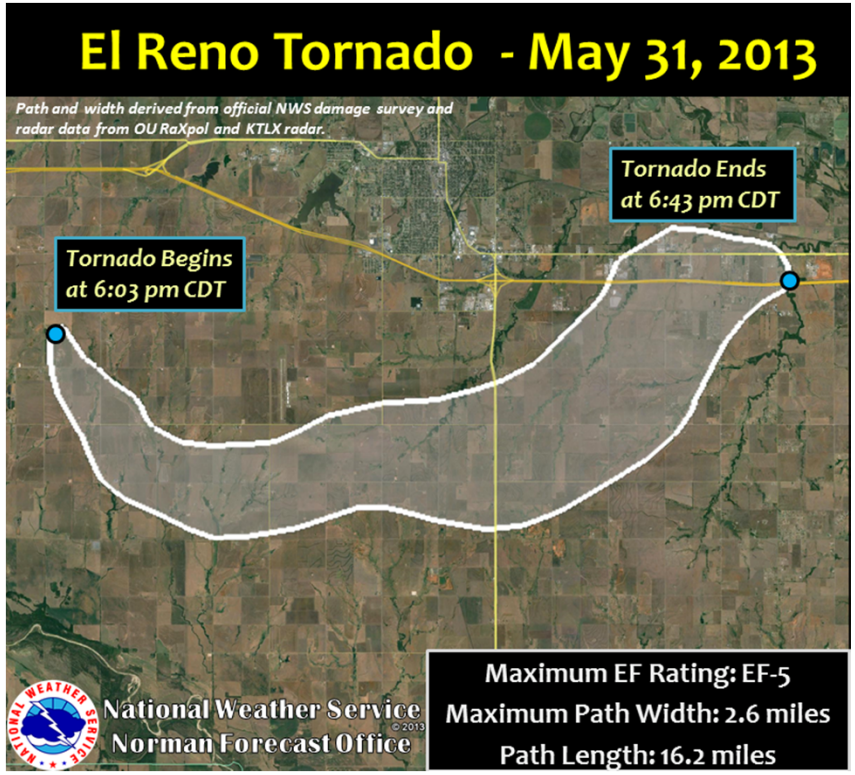


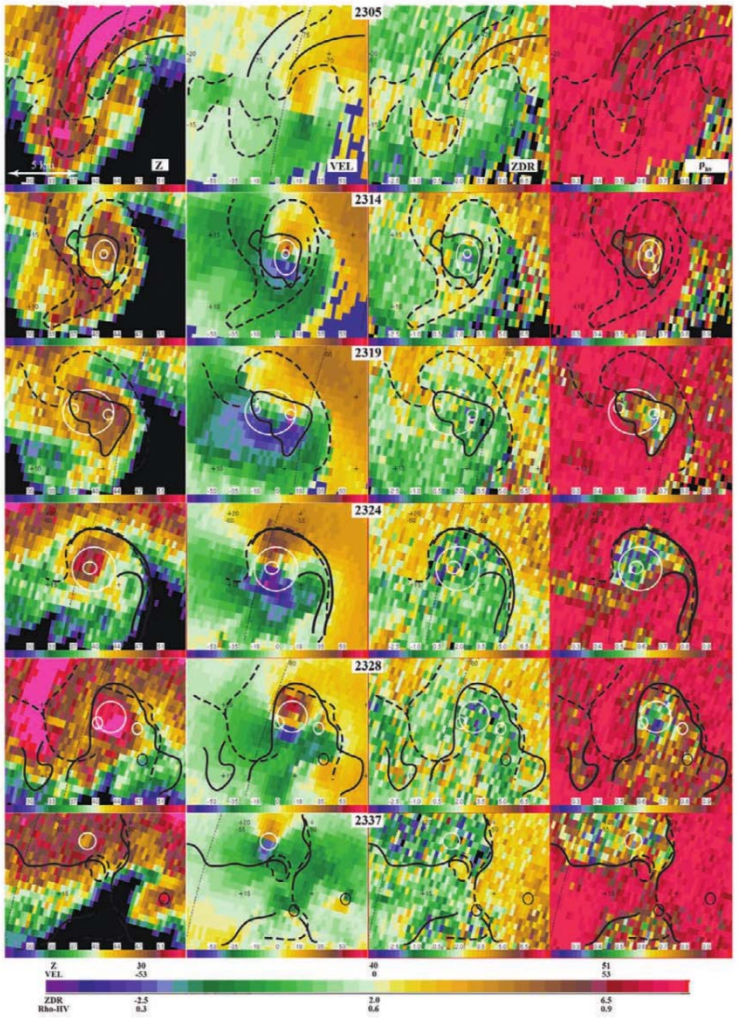


Lu et al. (2012)

El Reno Storm (5/31-6/1 2013)

- Best known for deadly tornado that killed PhOCAL researcher Tim Samaras and 7 others
- Developed into large MCS that affected multiple states
- Lightning behavior both confirmed developing model for large-CMC lightning but also suggests refinements are needed

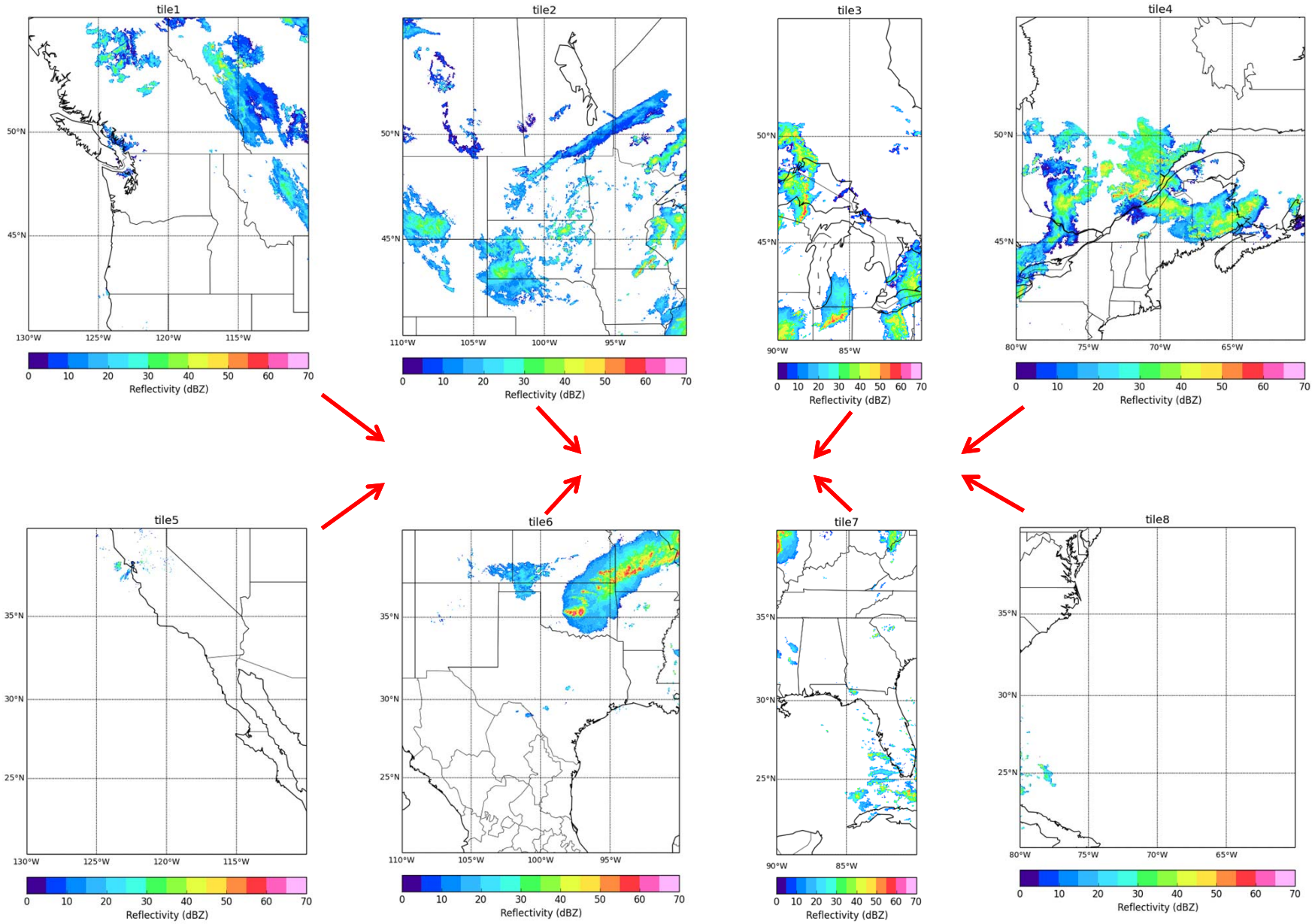




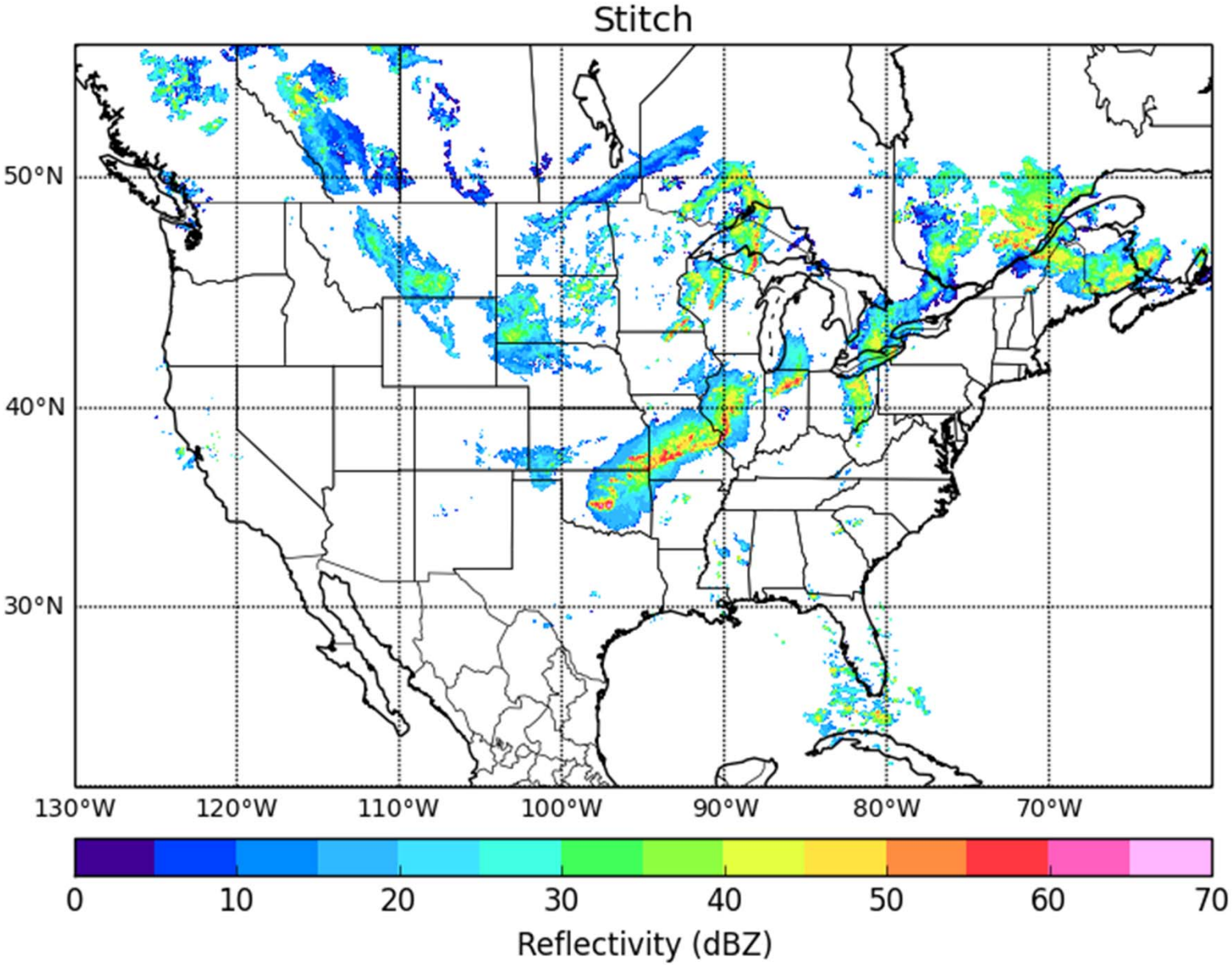
Wurman et al. (2014)

Before Showing the Results, a Brief Aside …

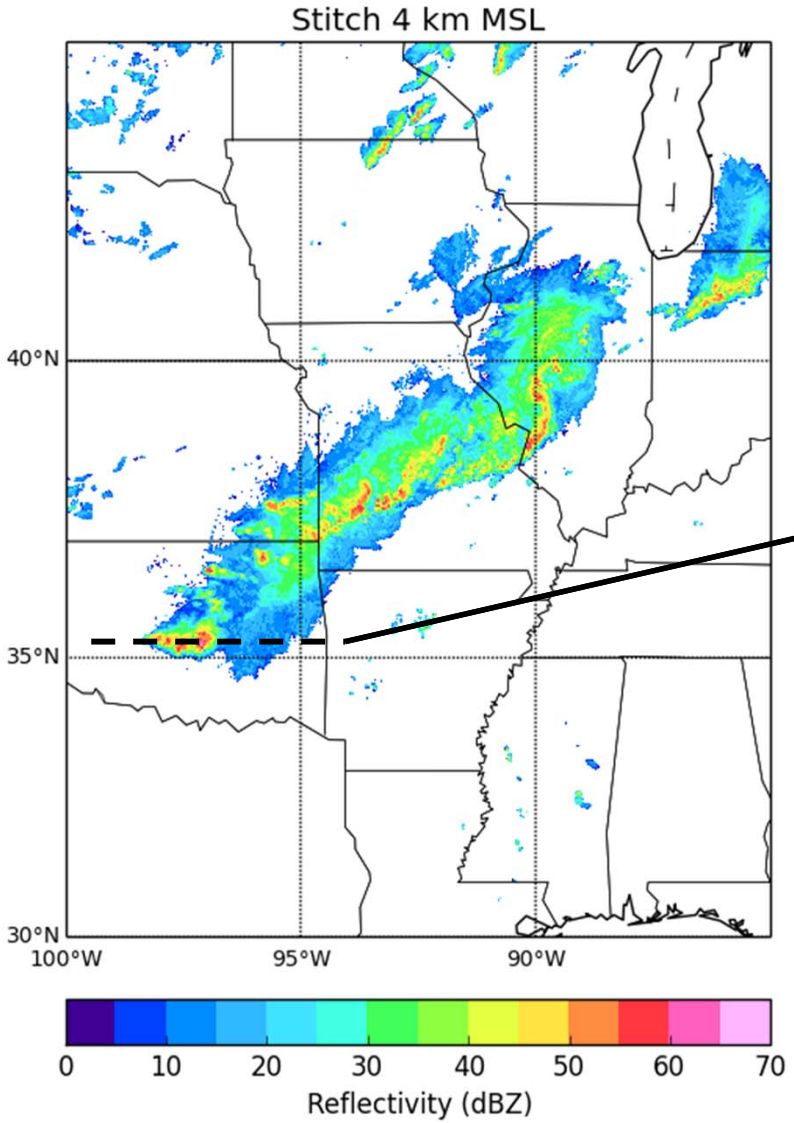
The Problem: NSSL 3-D Reflectivity Mosaics distributed as individual regional tiles

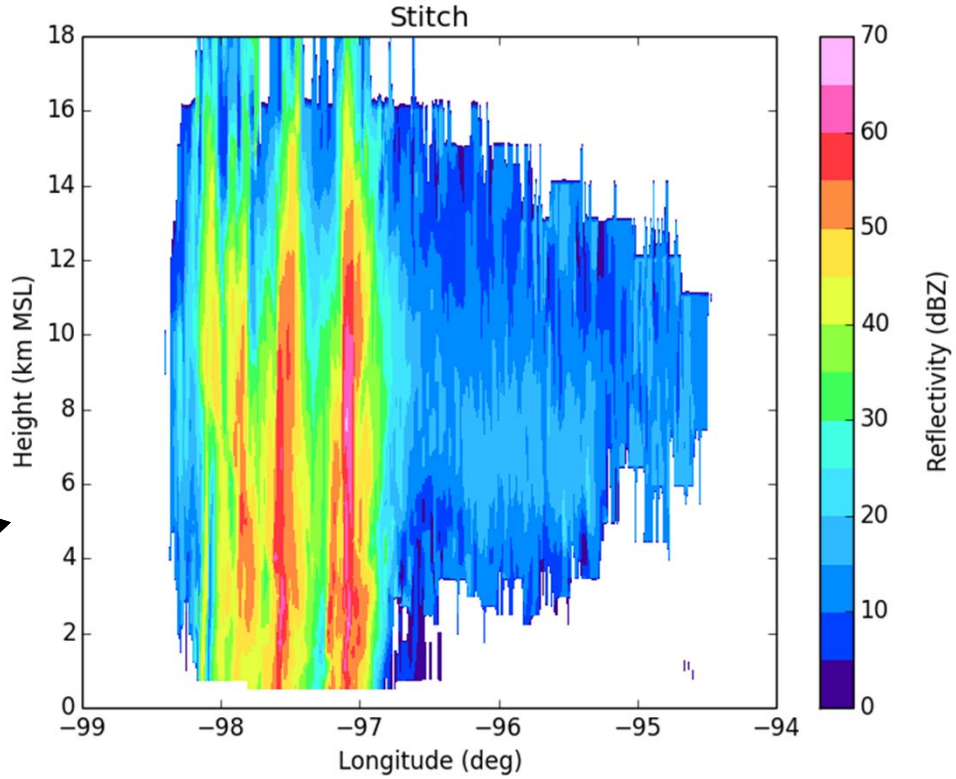


The Need: New <u>research</u> software framework for ingest, stitching, and visualization



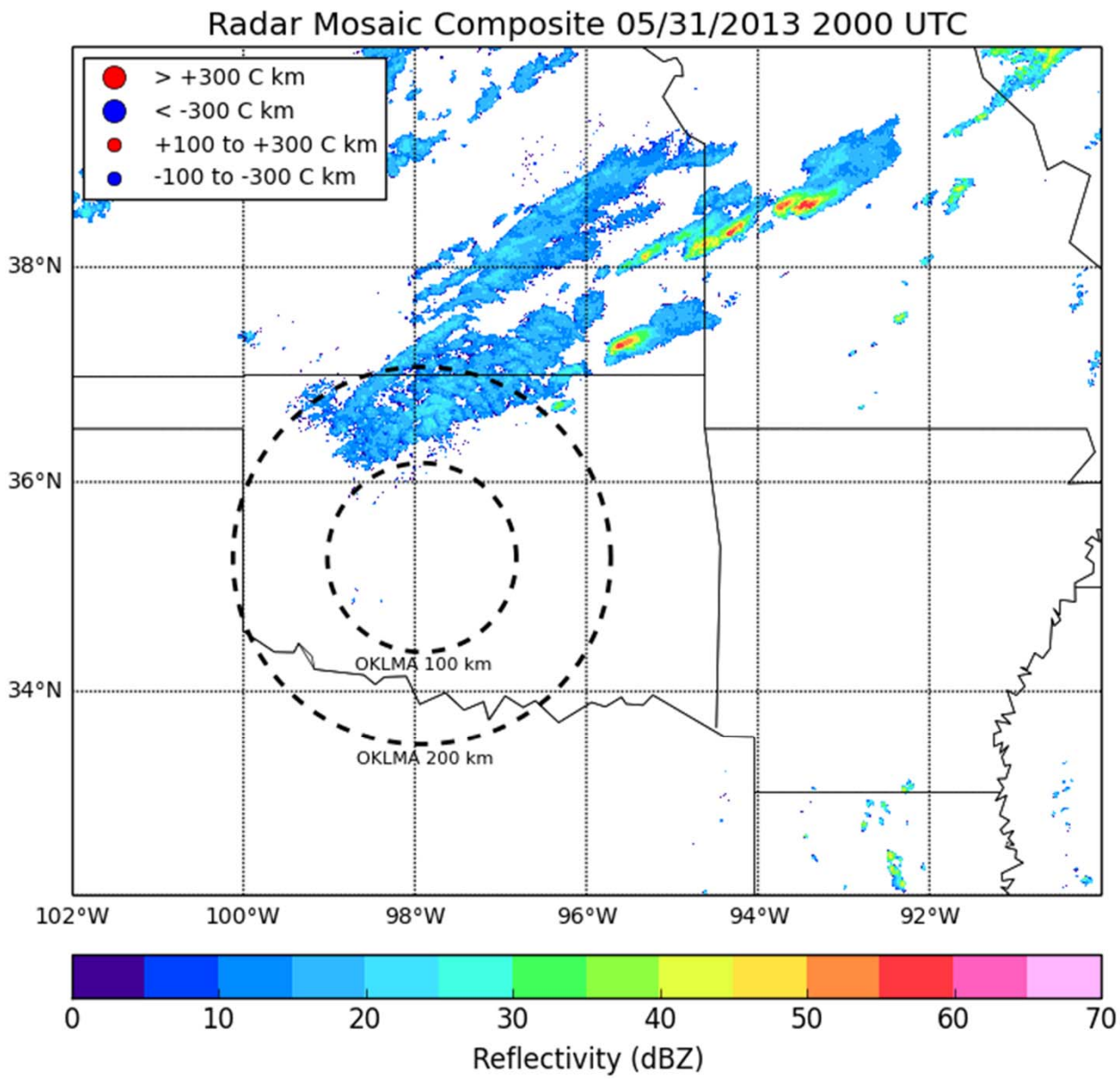
Task complete!

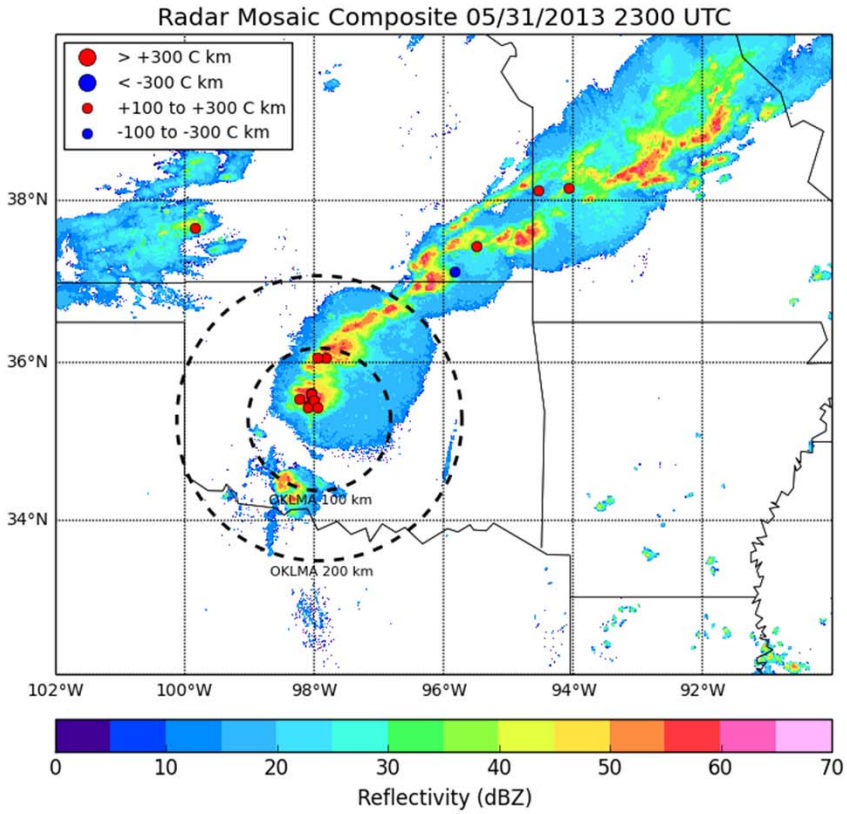




Features

- Object-oriented, open-source, scalable Python framework
- Interactive or batch mode
- Arbitrary, user-defined stitching
- Customizable visualization
- Simple to add lightning data to plots/analysis

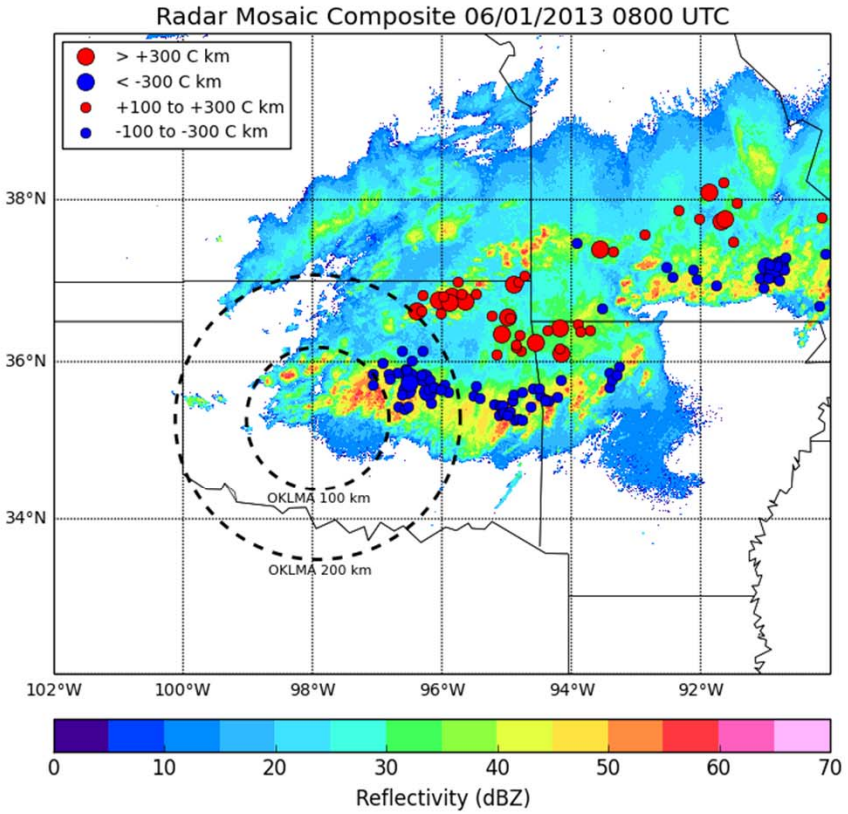

Radar Mosaic Composite 05/31/2013 2000 UTC
> +300 C km
< -300 C km
+100 to +300 C km
-100 to -300 C km
38°N
36°N
34°N
OKLMA 100 km
OKLMA 200 km
102°W
100°W
98°W
96°W
94°W
92°W
0
10
20
30
40
50
60
70
Reflectivity (dBZ)



Early (2300 UTC)

Supercells, Tornado

Large +iCMCs in convection



Late (0800 UTC)

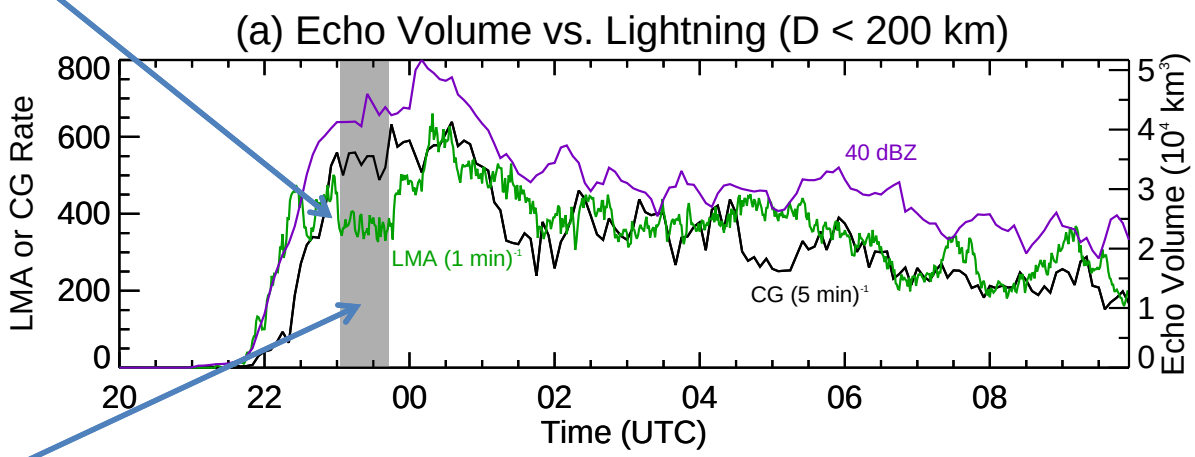
Mesoscale Convective System

Large +iCMCs in stratiform

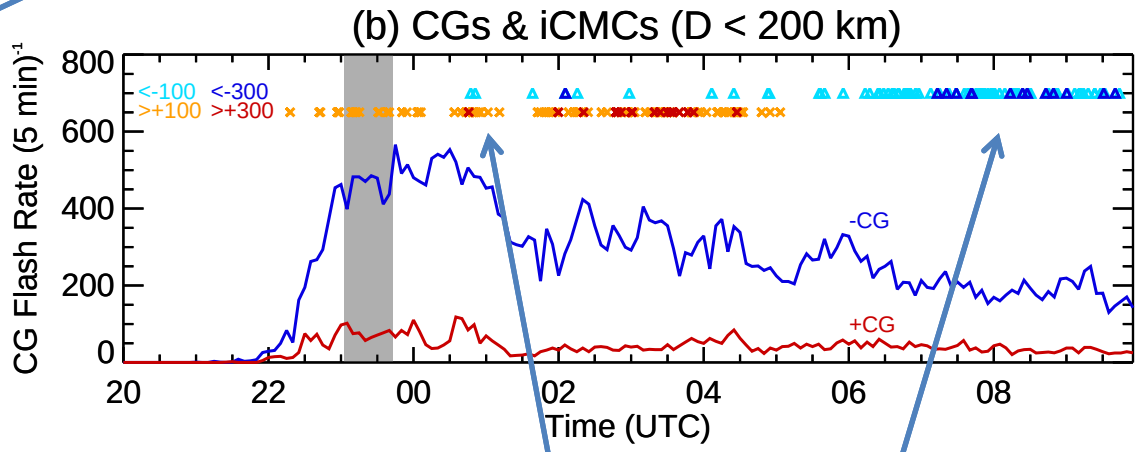
Large -iCMCs in convection

Time Series View

TFR Reduction



Tornado



-CG dominant

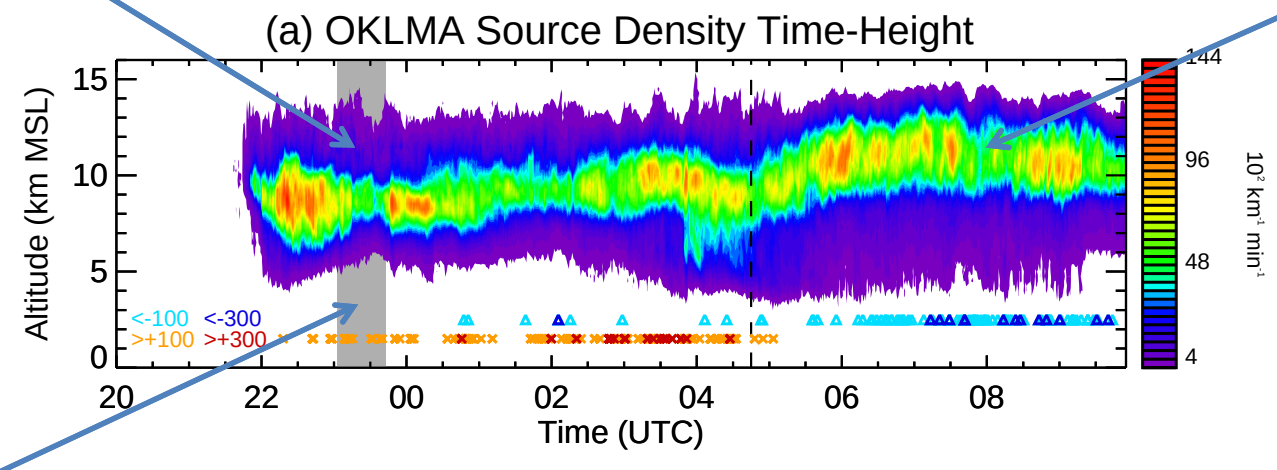
+iCMCs
Early

-iCMCs
Late

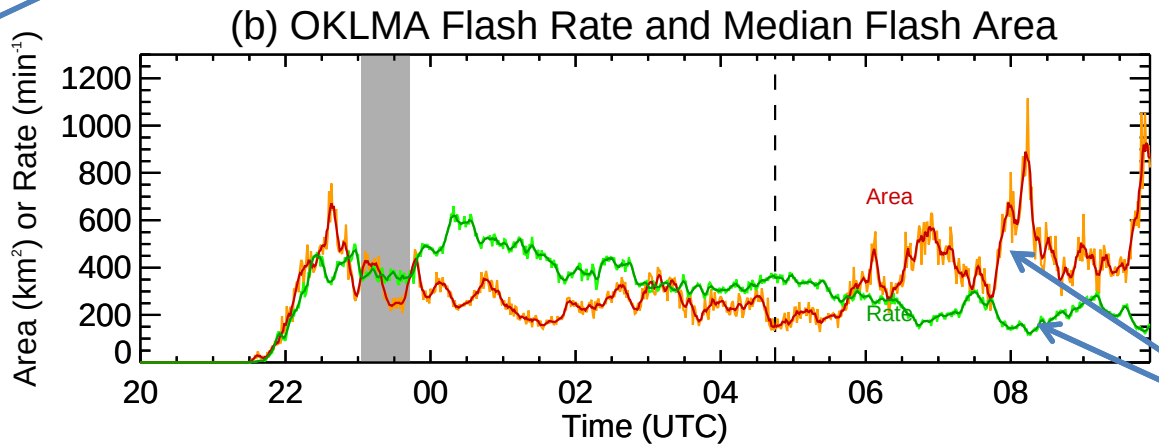
Time Series View (cont.)

Source Density Reduction

Source altitude change after 0445-0500 UTC

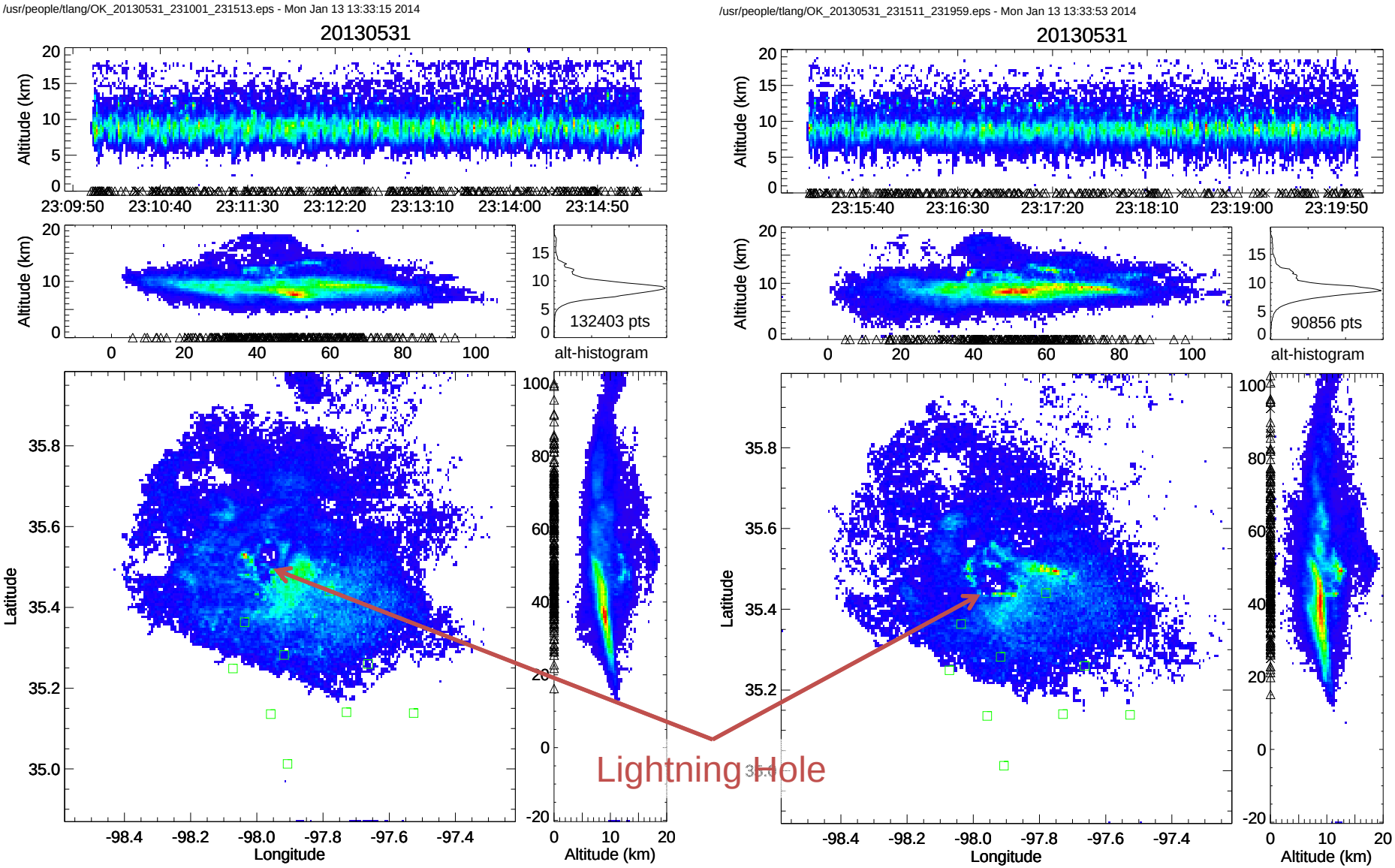


Tornado

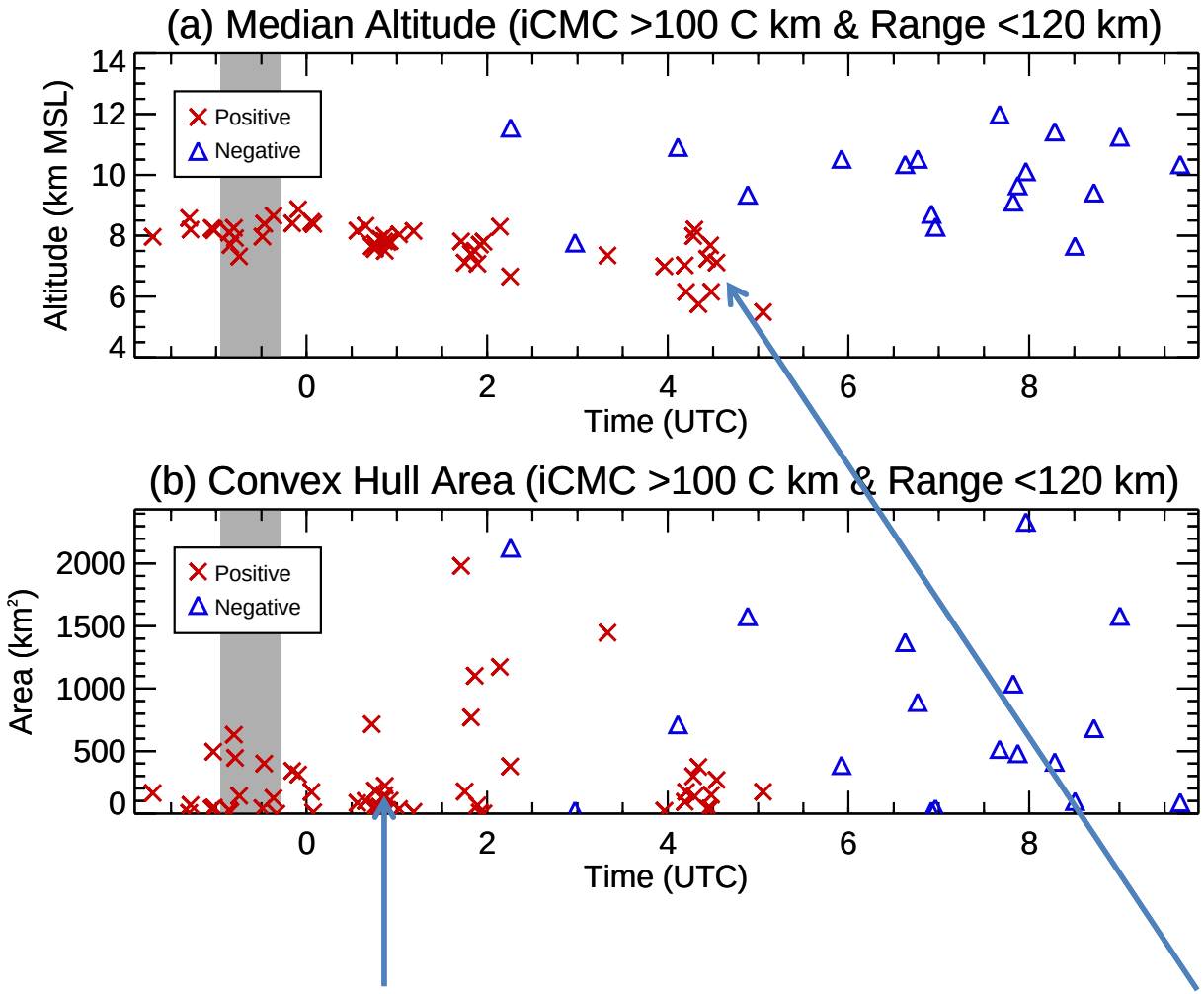


Quasi-anticorrelated behavior between flash rate and flash size after 0445-0500 UTC

Lightning Hole During El Reno Tornado



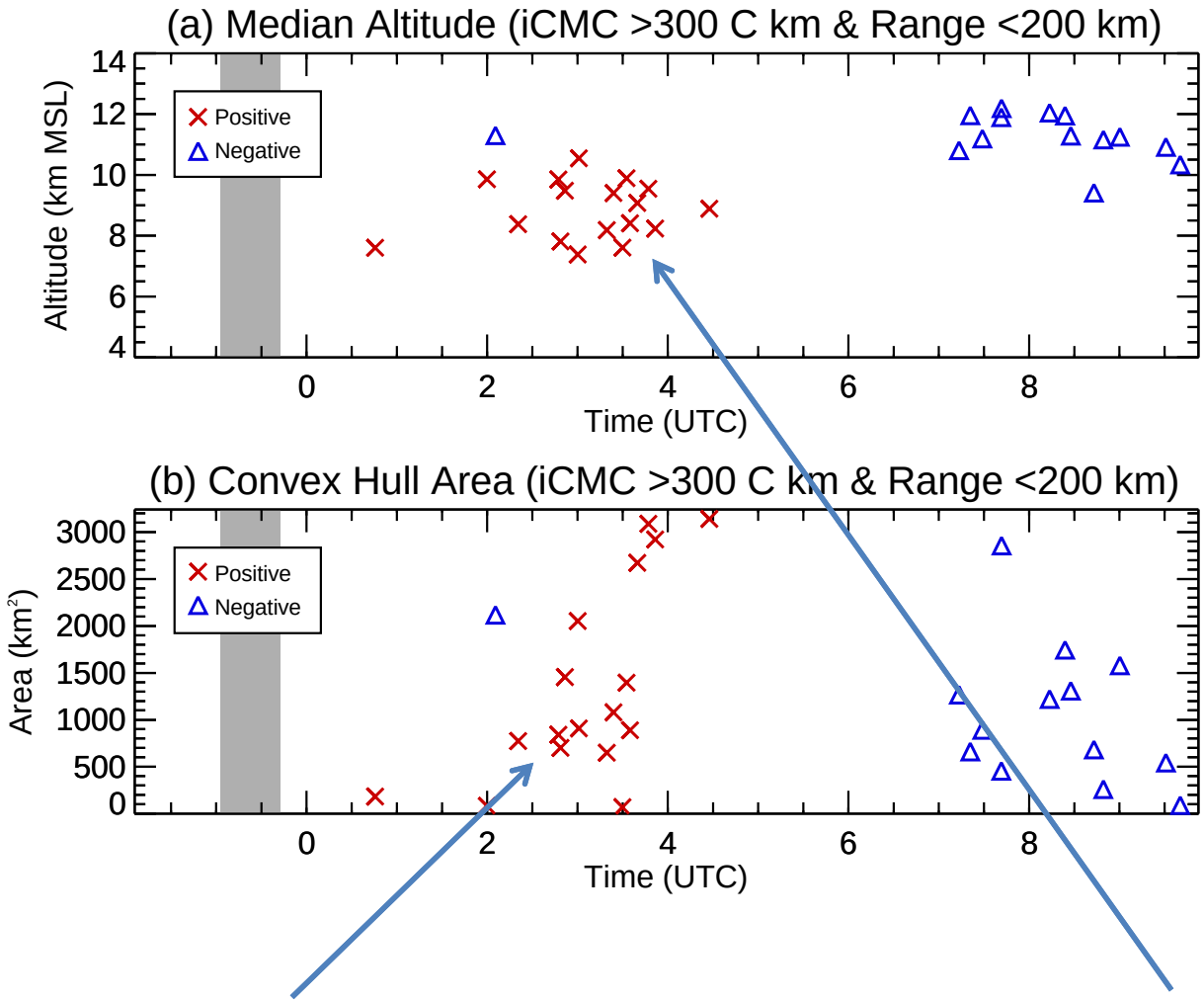
Large-iCMC Strokes, < 120 km from OKLMA



+iCMCs normally smaller in area than -iCMCs

+iCMCs lower in altitude than -iCMCs

Sprite-Class Strokes, < 200 km from OKLMA

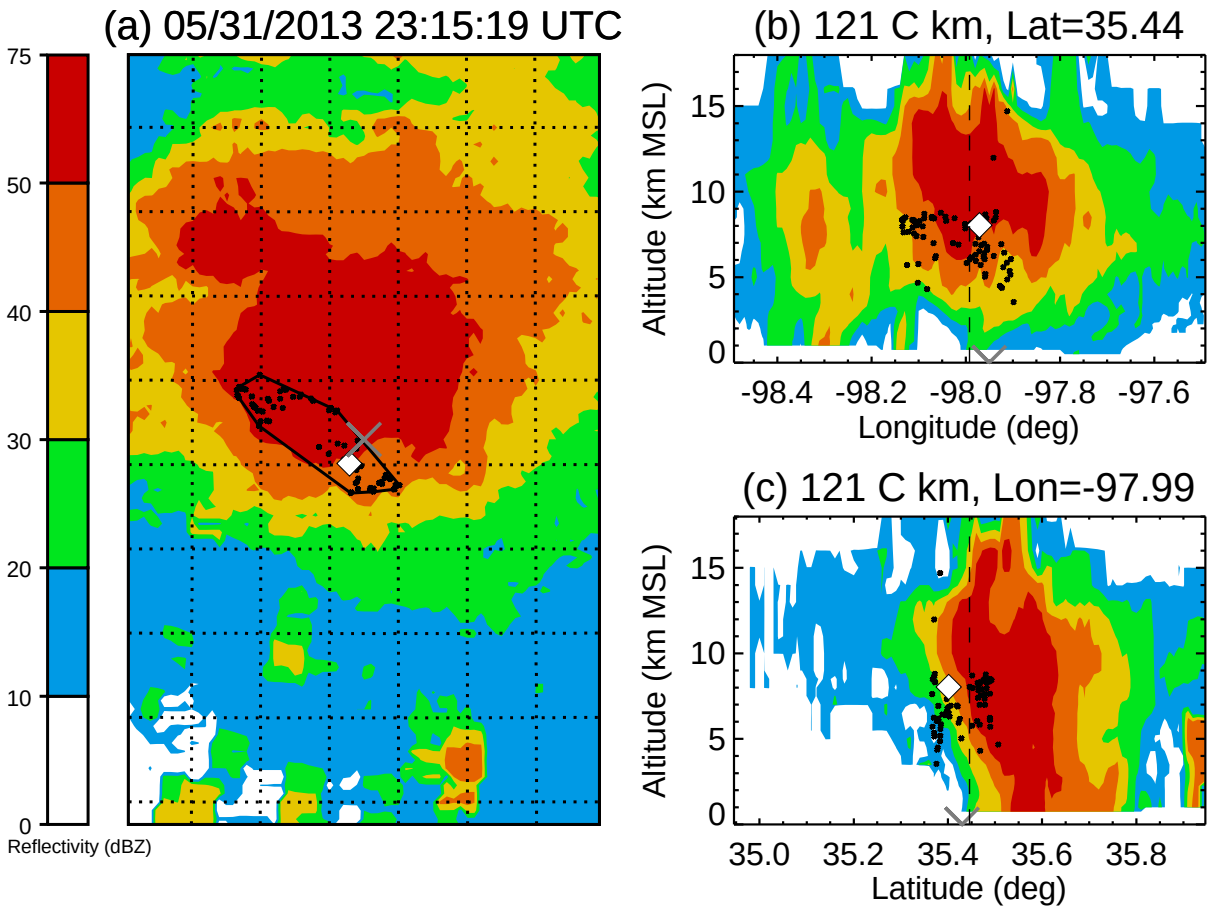


+iCMCs now about as big as -iCMCs
Sprite-class 02-04 UTC

+iCMCs still lower than -iCMCs

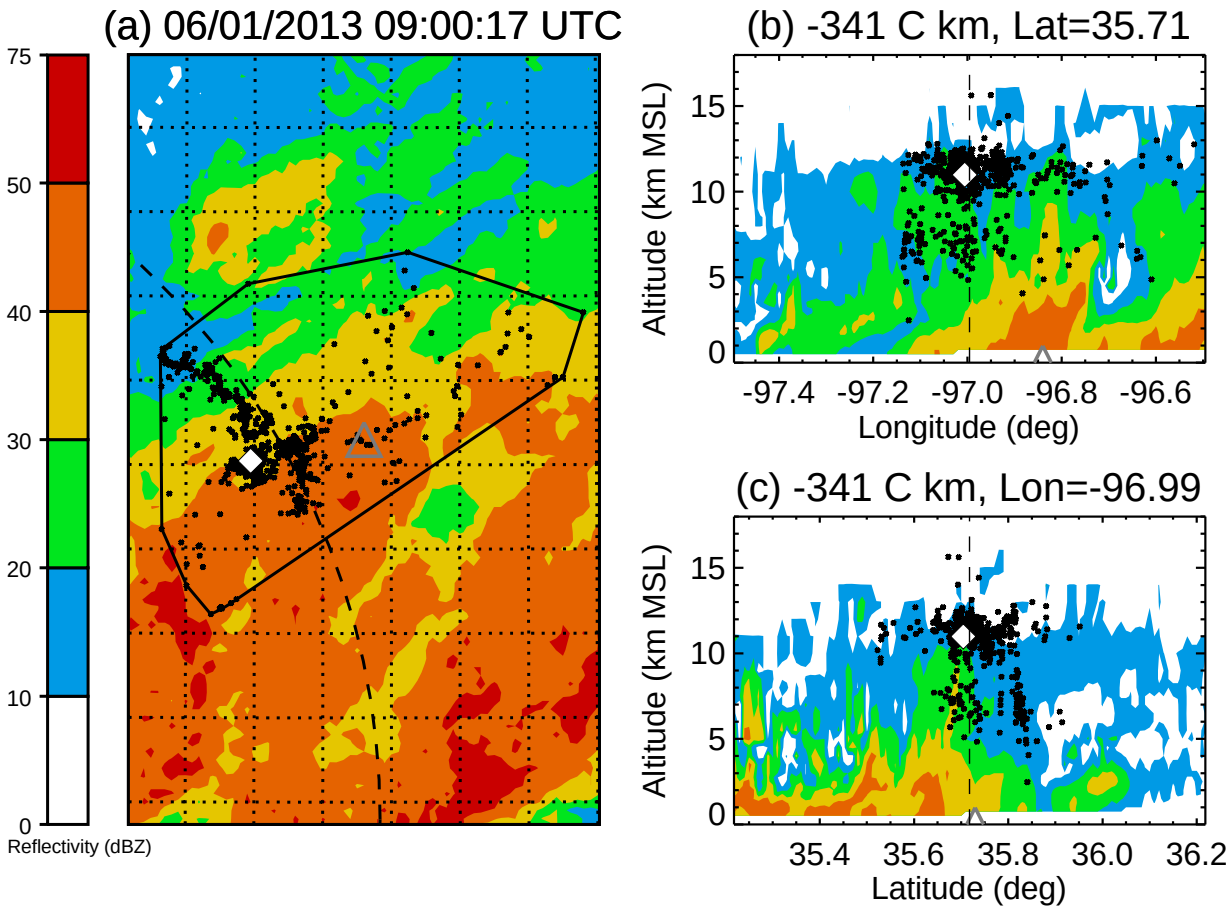
Typical Large-iCMC +CG
23:15:19 UTC 5/31
121 C km
116 kA

X = Large-iCMC +CG
Triangle = Large-iCMC -CG
Diamond = Initiation
Black Dots = LMA sources
Black Polygon = Convex Hull
Gridlines = 0.1 deg



Typical Large-iCMC -CG
09:00:17 UTC 6/01
-341 C km
-175 kA

X = Large-iCMC +CG
Triangle = Large-iCMC -CG
Diamond = Initiation
Black Dots = LMA sources
Black Polygon = Convex Hull
Gridlines = 0.1 deg



Conclusions

- El Reno storm developed upscale from line of supercells to large MCS over the course of many hours
- Early (< 0500 UTC): Supercells, Tornado, Lightning Hole, Large-iCMC +CGs in convection despite -CG dominance, +CGs at edge of convective cores (tilted dipole?)
- Late (> 0500 UTC): MCS, Large-iCMC -CGs in convection, still -CG dominant, Large-iCMC +CGs in stratiform region
- In-cloud portions of large-iCMC +CGs covered smaller area and were lower in altitude than large-iCMC -CGs
- Sprite-class iCMCs larger than in area than smaller iCMC counterparts
- Python mosaic software tools being made available to community