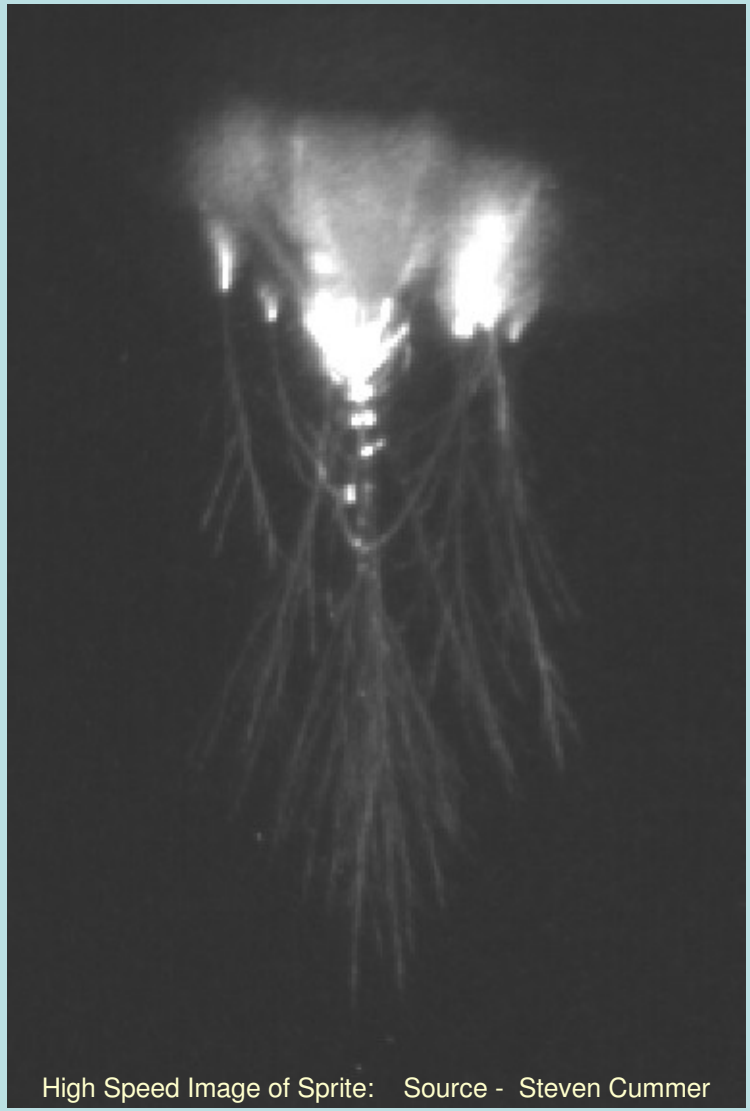


High Speed Image of Sprite: Source - Steven Cummer

Evolution of Radar Structure, Total Lightning and Sprite Production in an Oklahoma Mesoscale Convective System on 20 June 2007

Steven Rutledge and Timothy Lang

Colorado State University

Walter Lyons, CCM and Jonathan Meyer

FMA Research, Ft. Collins, CO

Steven Cummer

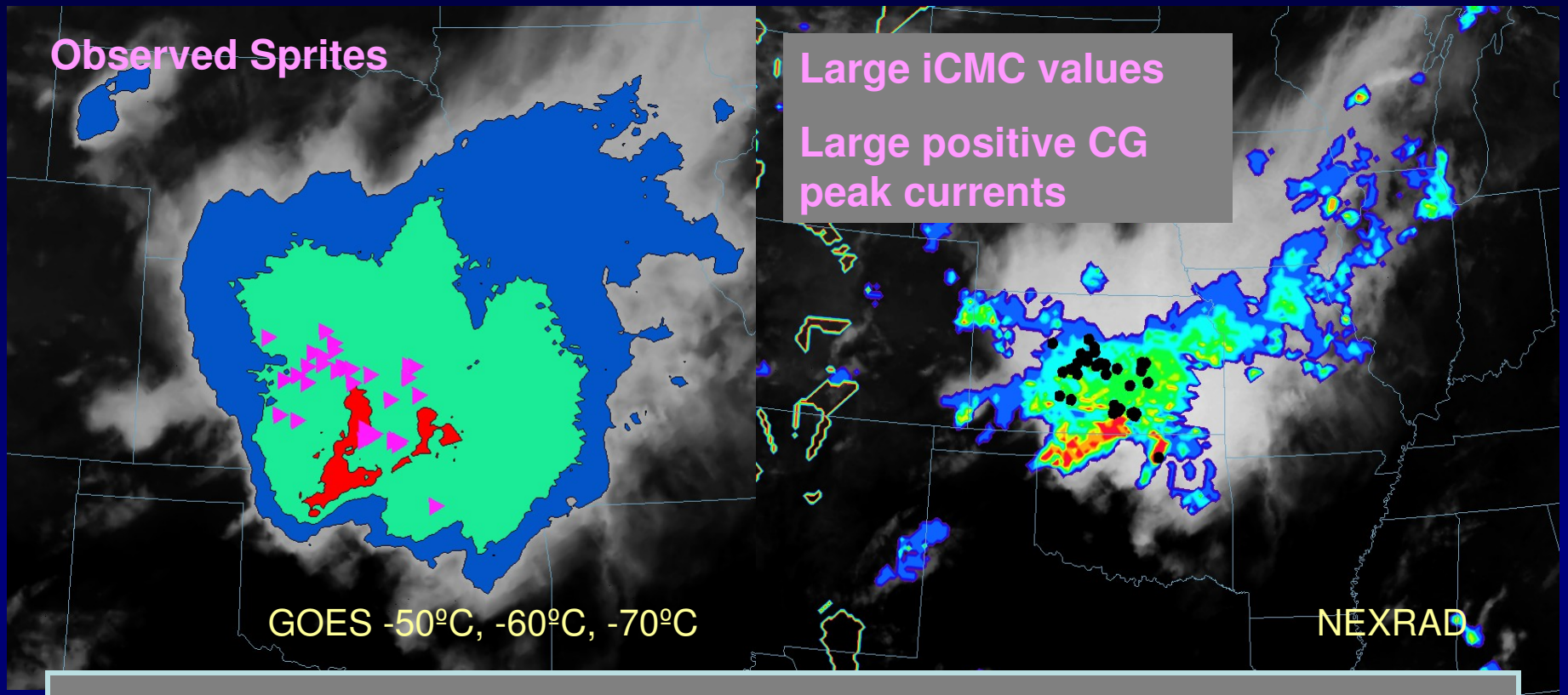
Duke University, Durham, NC

Supported by the NSF

Thanks to: Don MacGorman for LMA data and NMIMT for analysis software

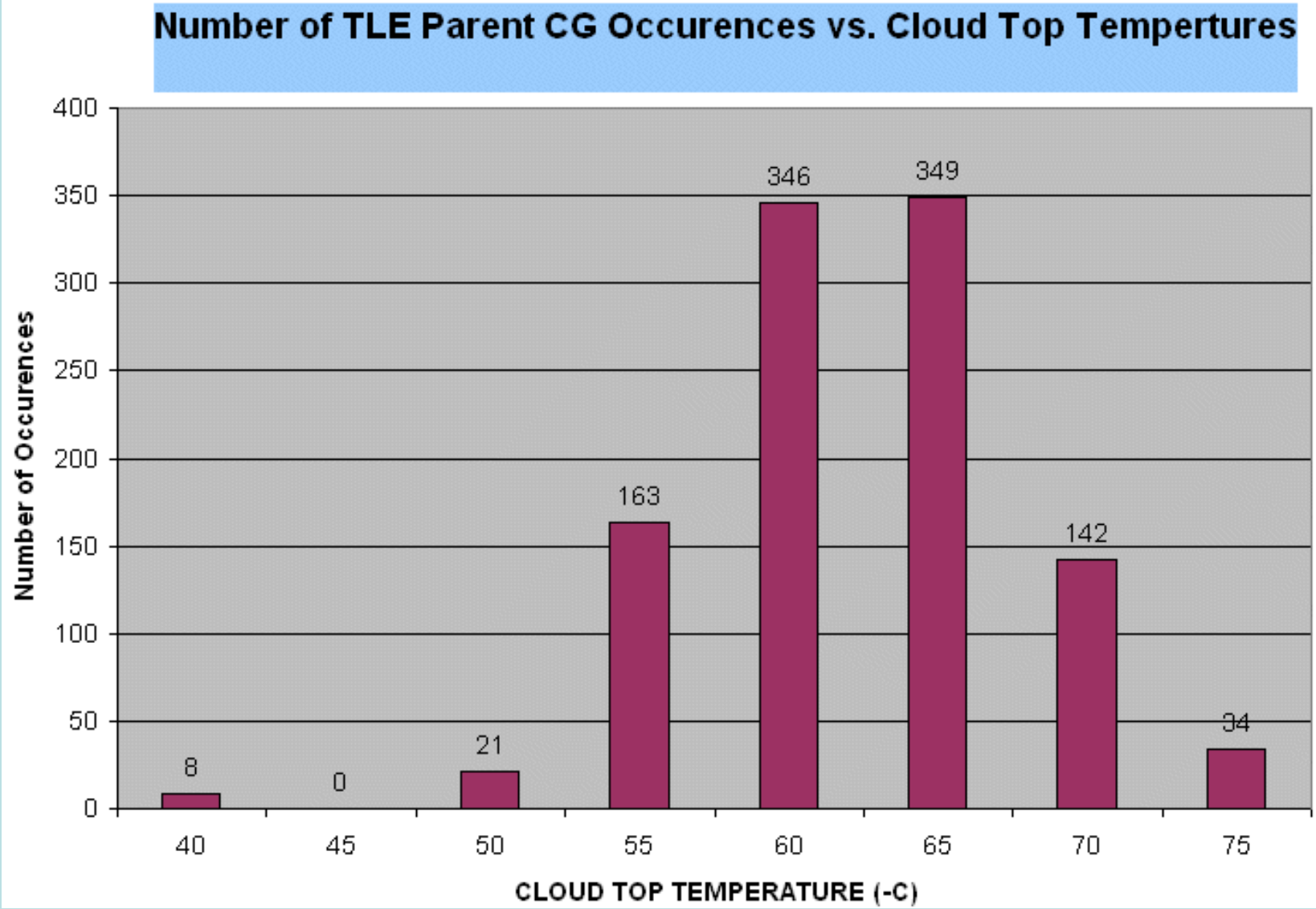
AGU FALL MEETING 2007 SAN FRANCISCO

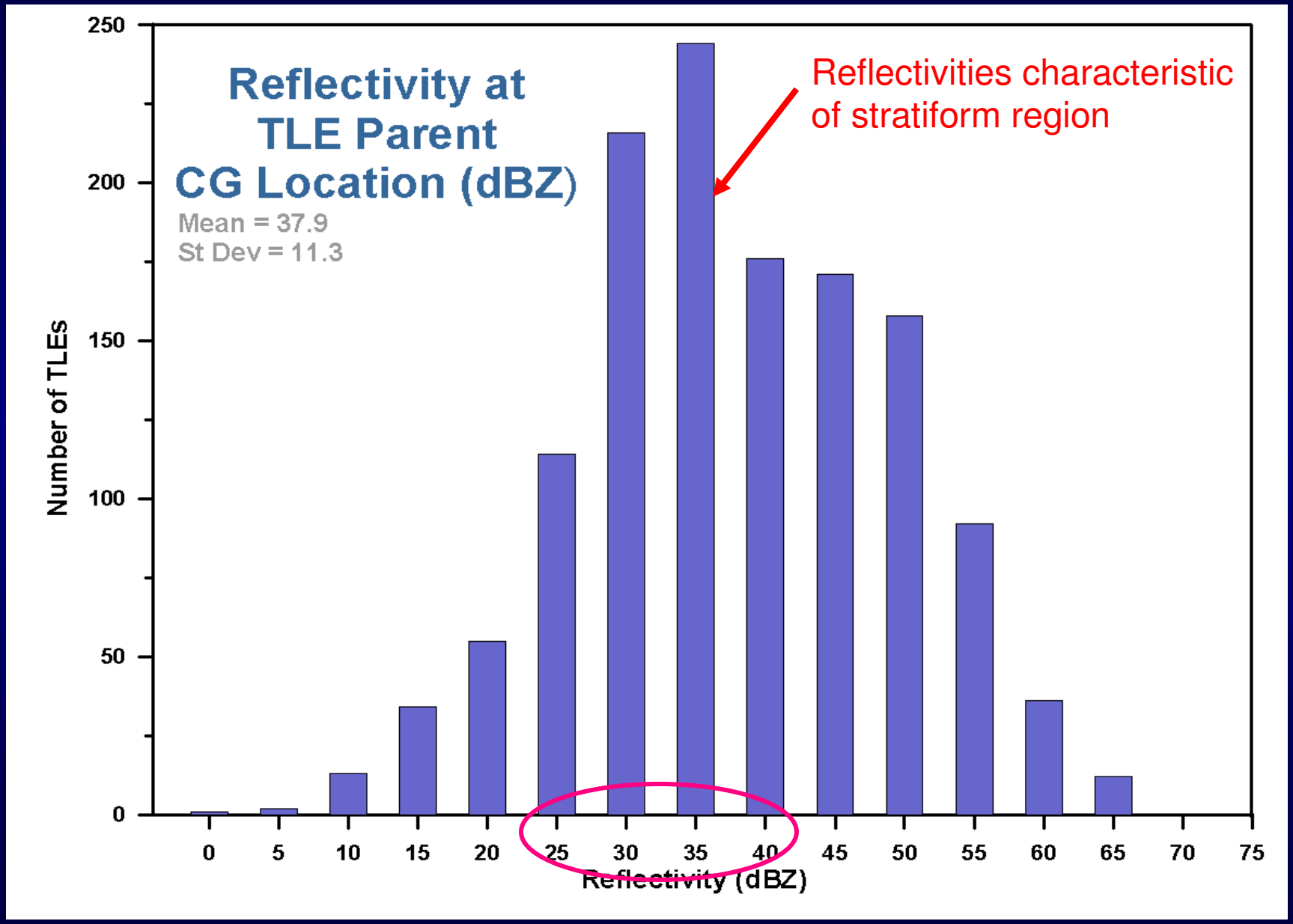
Paper AE41A-06

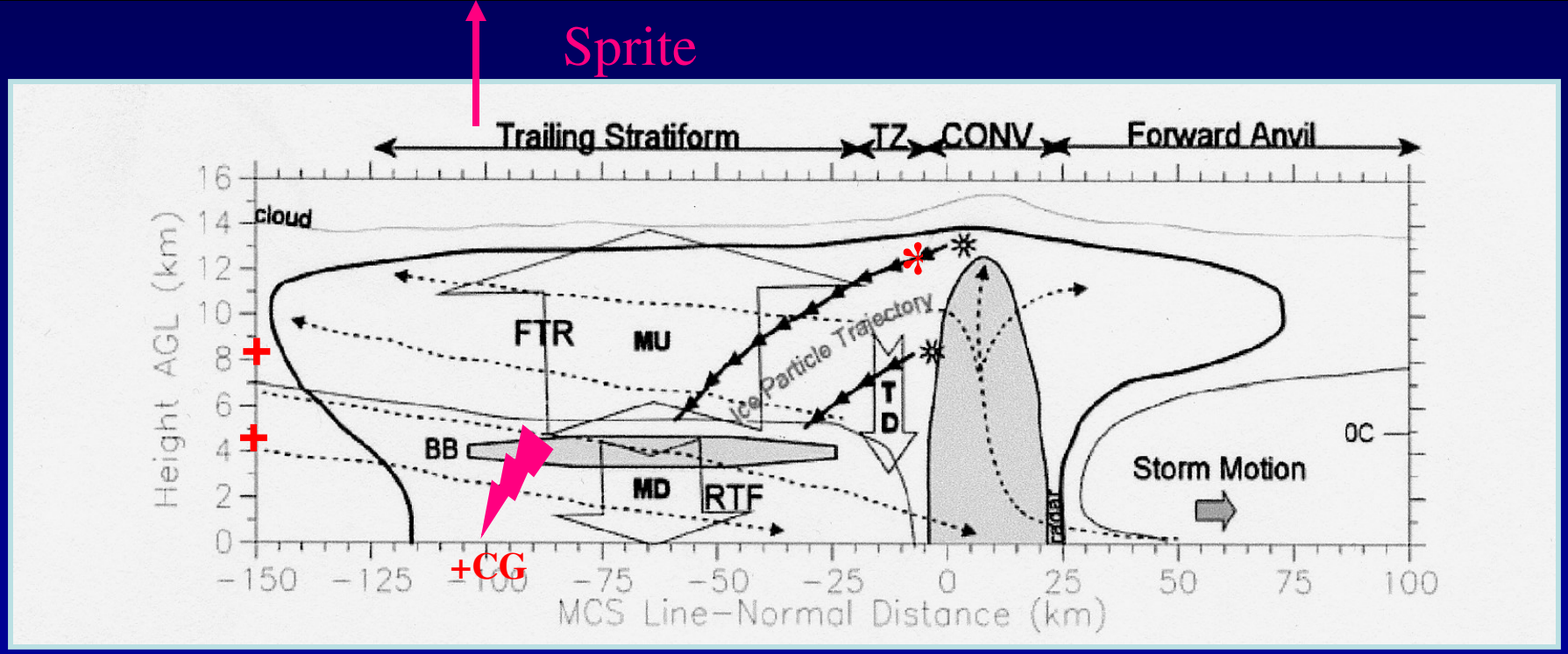


Are there repeatable patterns in High Plains MCSs which produce TLEs? We seek to further understand couplings between TLE's and MCS structure and lifecycle? Are their particular characteristics of positive CG's that produce sprites?

SP+CGs are found beneath cold, but not coldest, tops; consistent with MCS stratiform region




Reflectivity at
TLE Parent
CG Location (dBZ)
Mean = 37.9
St Dev = 11.3
Reflectivities characteristic
of stratiform region
Number of TLEs
250
200
150
100
50
0
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
Reflectivity (dBZ)



Carey et al. (2005)

Intense convective cores of the MCS eject massive amounts of condensate at high levels above the stratiform region, where the material slowly descends in the FTR circulation, forming the secondary precipitation region. It is likely that both advection and in situ charge generation play a role in forming the extensive charge layers in the stratiform region. We seek to use LMA data to better understand nature of SP+CG's.

SPRITES 2007 at Yucca Ridge

FMA Research * CSU * Duke University * Stanford * MSU Mankato

24x7 Automated TLE Detection

The National Charge Moment Change Network (CMCN)

CMCN Sensor at YRFS

CMCN Sensor at Duke

Developed for FMA Research by Duke University

Output: Geolocated ULF/ELF/VLF impulse charge moment change (~2 ms)

NEW TERMINOLOGY:

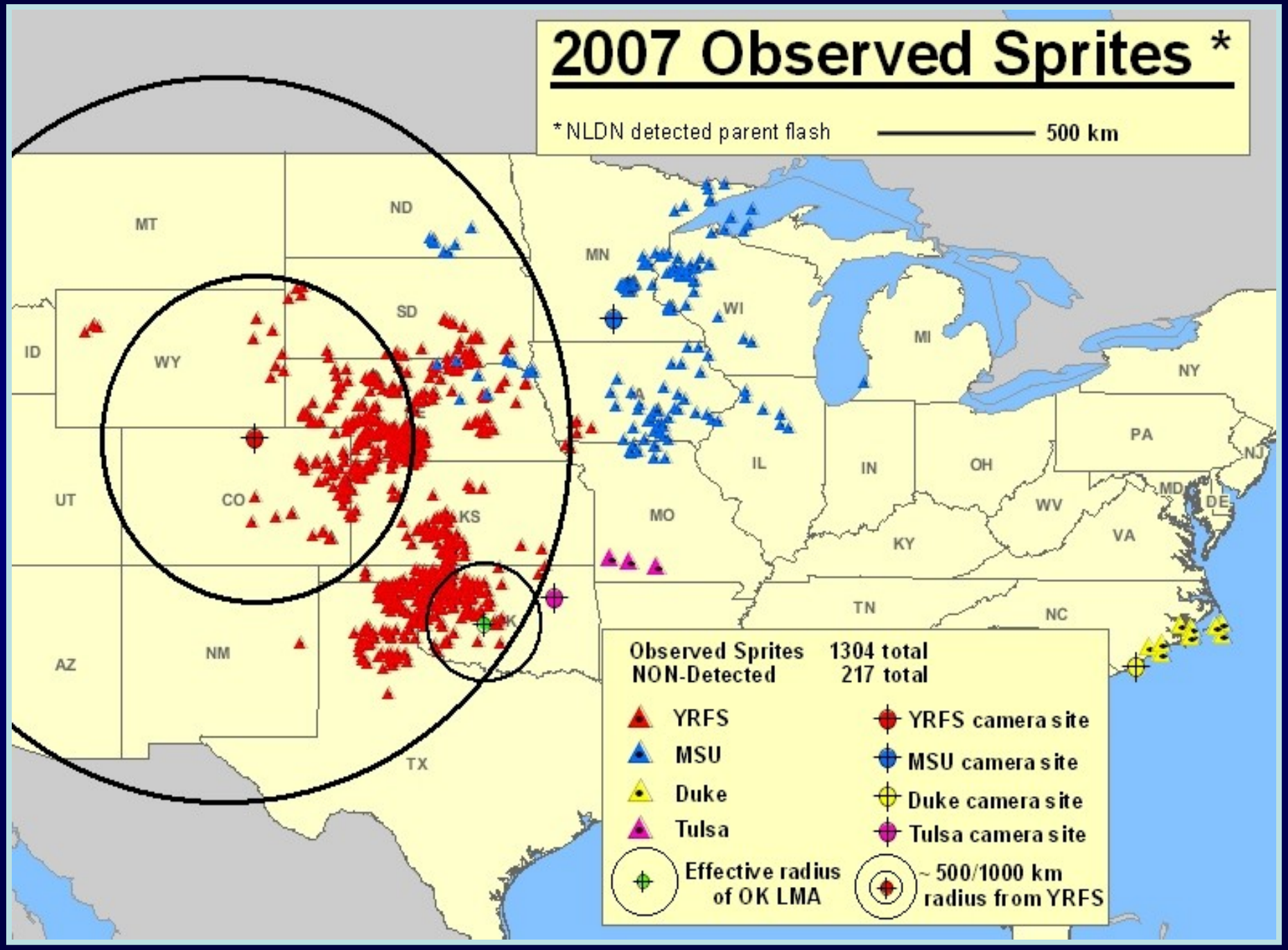
Charge Moment Change

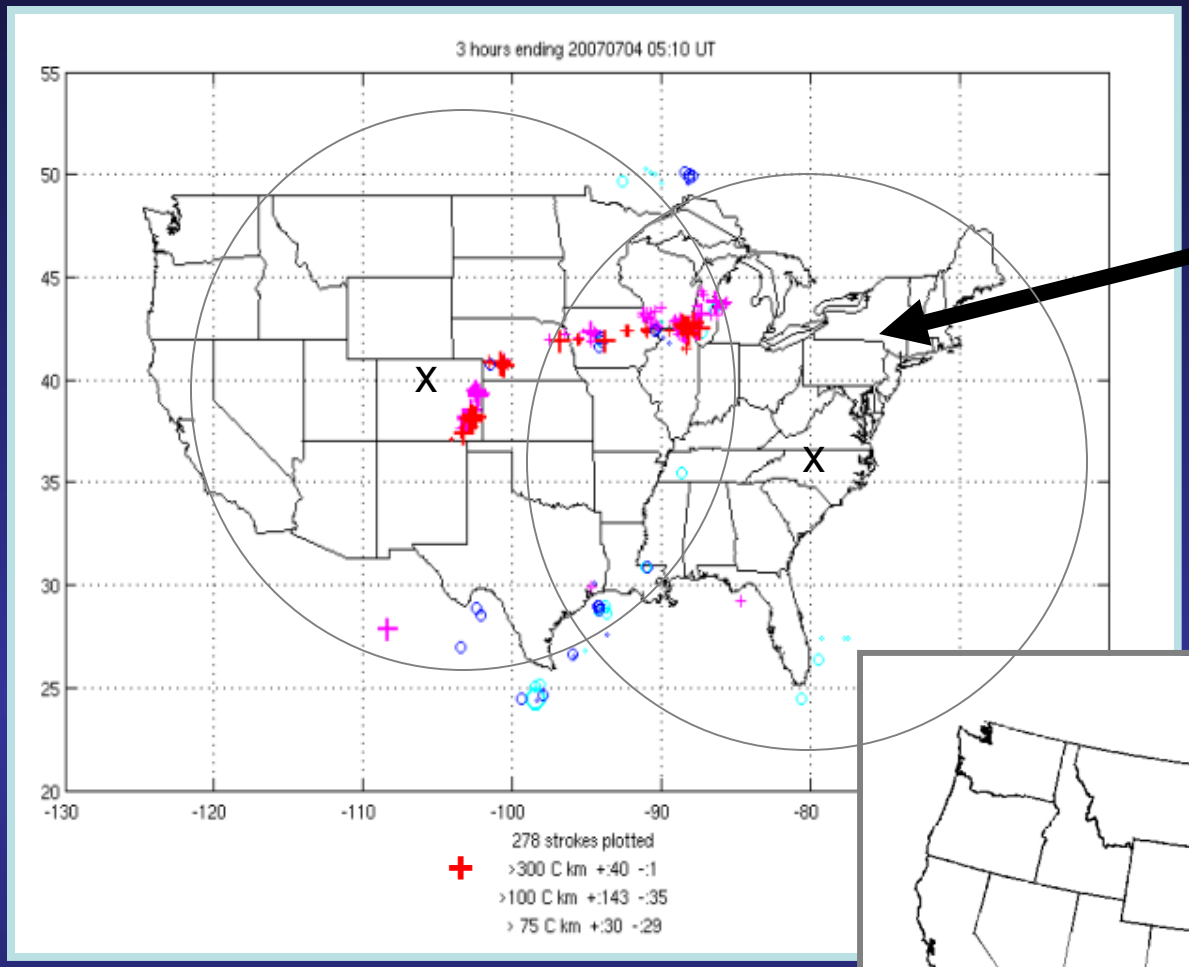
Impulse Charge Moment Change

Charge Moment Change = $\Delta Mq\ (t) = Q\ (t) \times Zq$ [C km]

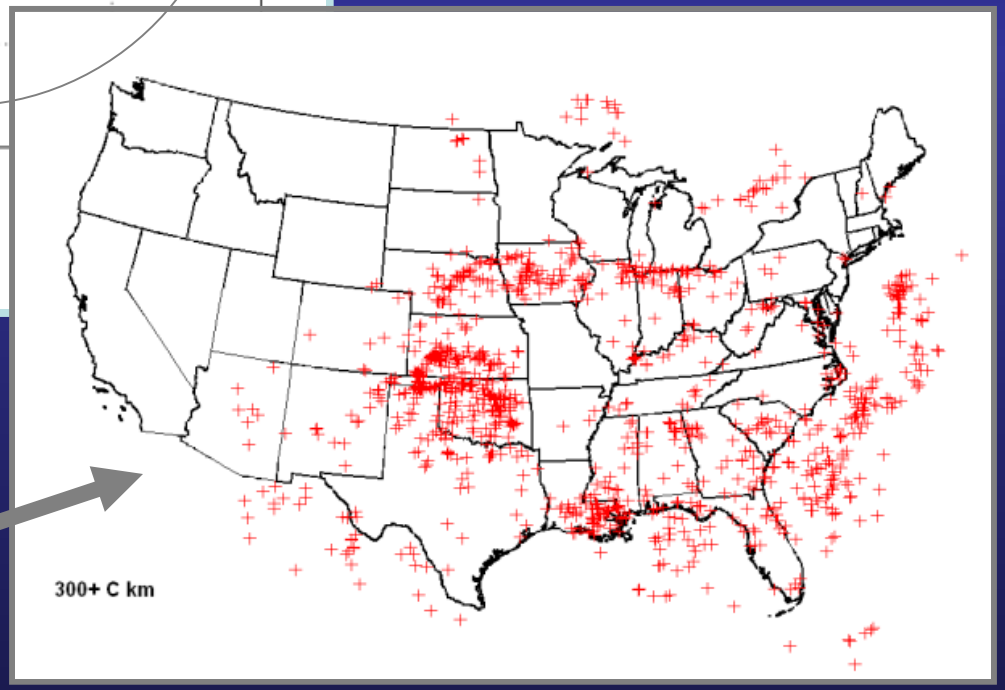
Impulse Charge Moment Change = $i\Delta Mq\ (t) = Q\ (\sim 2\ ms) \times Zq$ [C km]

The product of the charge lowered to ground and the altitude in the cloud from which it is removed. *This is a function of TIME.*

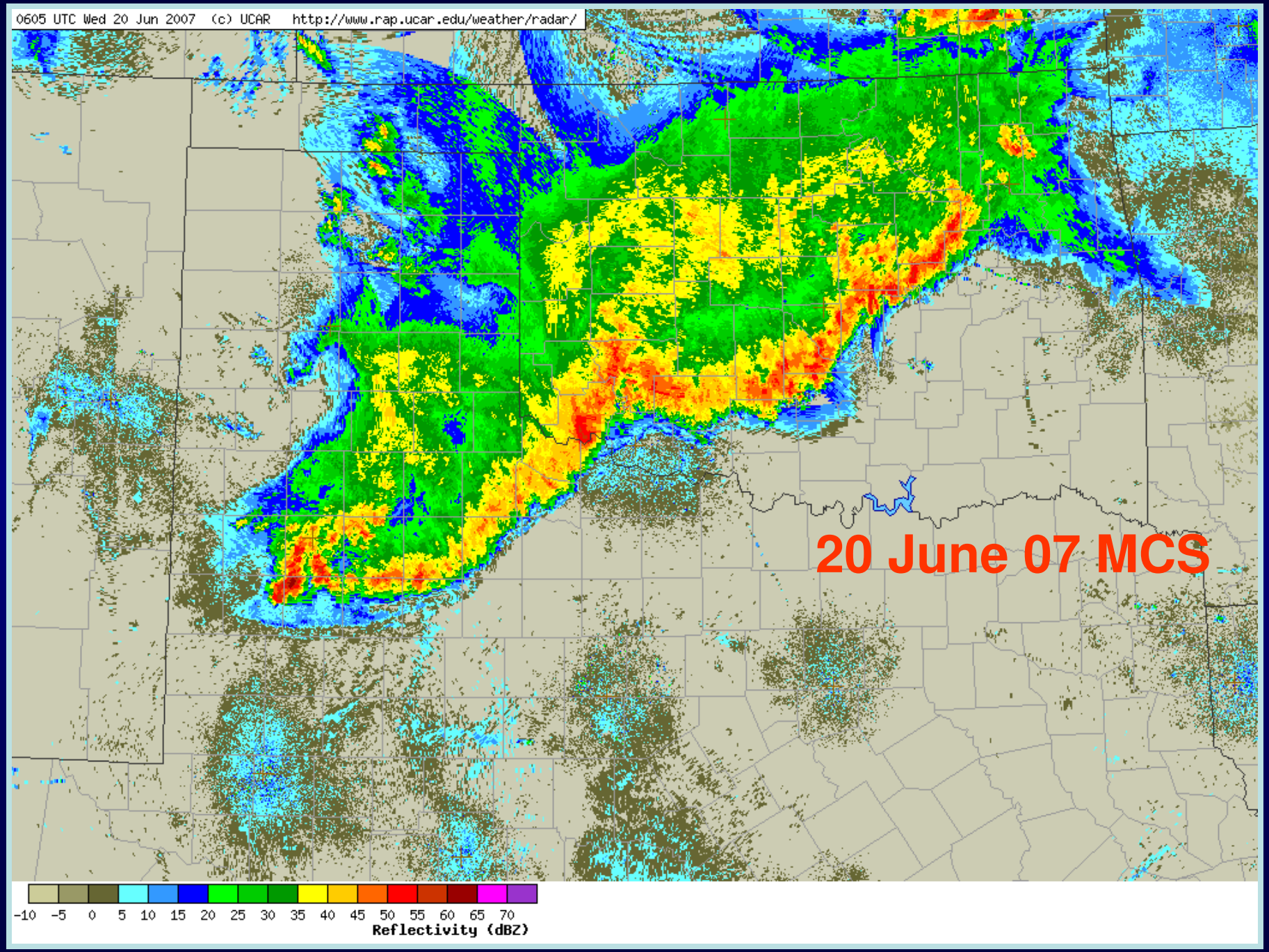

2007 Observed Sprites *
* NLDN detected parent flash
500 km
MT
ND
MN
SD
WI
MI
ID
WY
NY
PA
NJ
IL
IN
OH
UT
CO
KS
MO
MD
DE
WV
VA
KY
TN
NC
AZ
NM
TX
Observed Sprites 1304 total
NON-Detected 217 total
YRFS
MSU
Duke
Tulsa
YRFS camera site
MSU camera site
Duke camera site
Tulsa camera site
Effective radius of OK LMA
~ 500/1000 km radius from YRFS



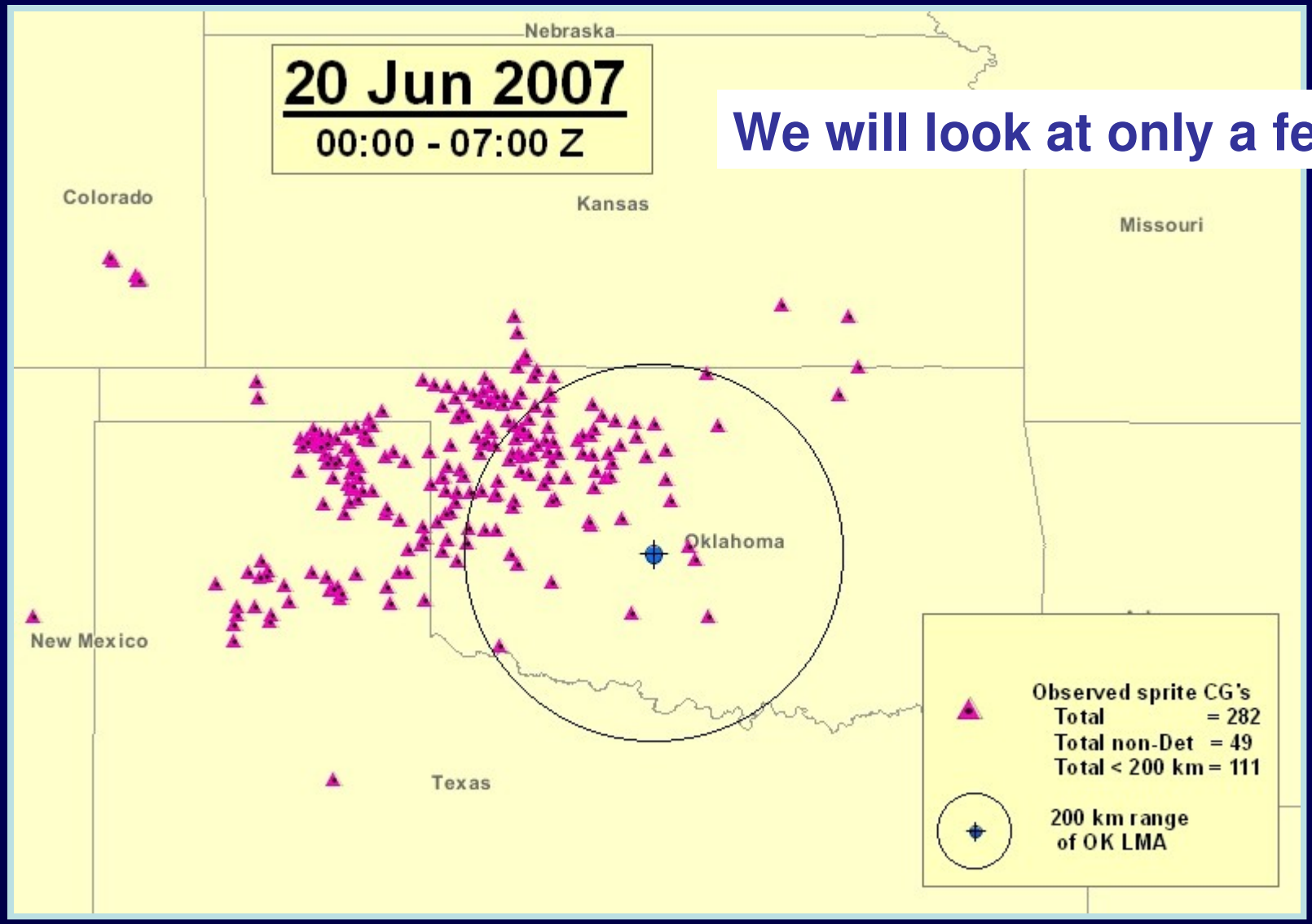
CMCN **Real Time** Display (3 hr running total updated every 5 minutes). Large red crosses are likely from sprite parent +CGs



Late June to early July 2007 locations of high probability sprite parent +CGs

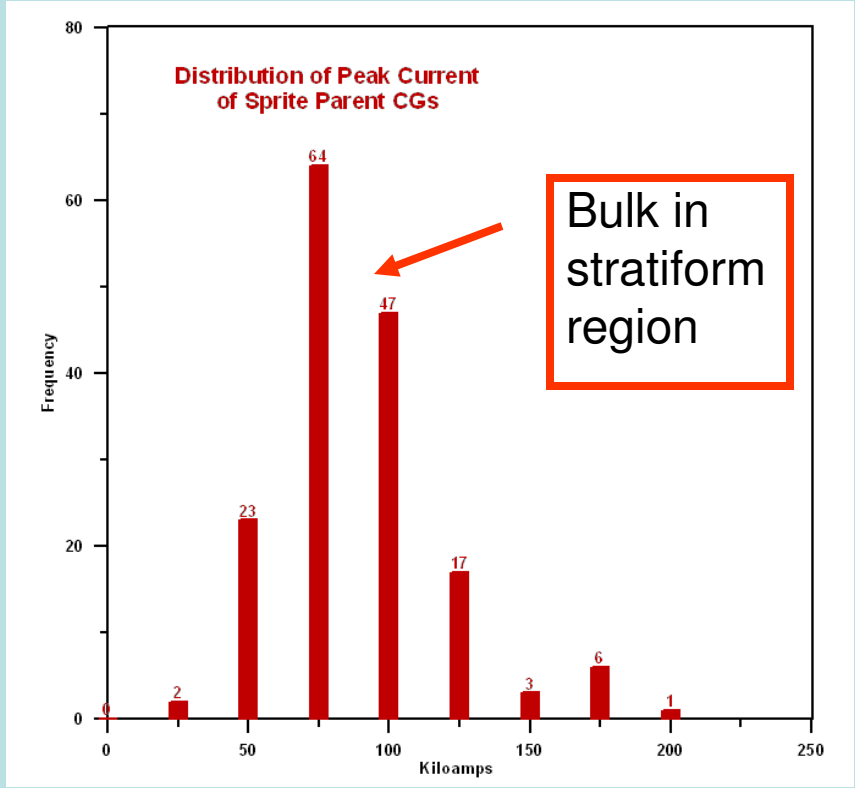

0605 UTC Wed 20 Jun 2007 (c) UCAR http://www.rap.ucar.edu/weather/radar/
20 June 07 MCS
-10 -5 0 5 10 15 20 25 30 35 40 45 50 55 60 65 70
Reflectivity (dBZ)

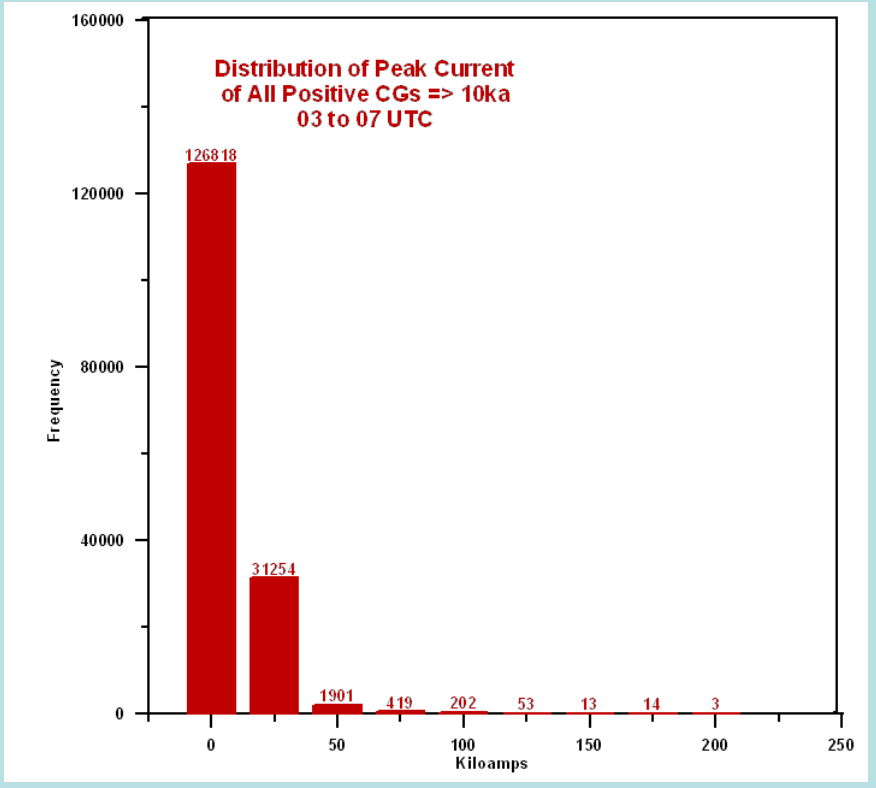
83% OF SPRITES HAD A NLDN-DETECTED SPRITE PARENT +CG

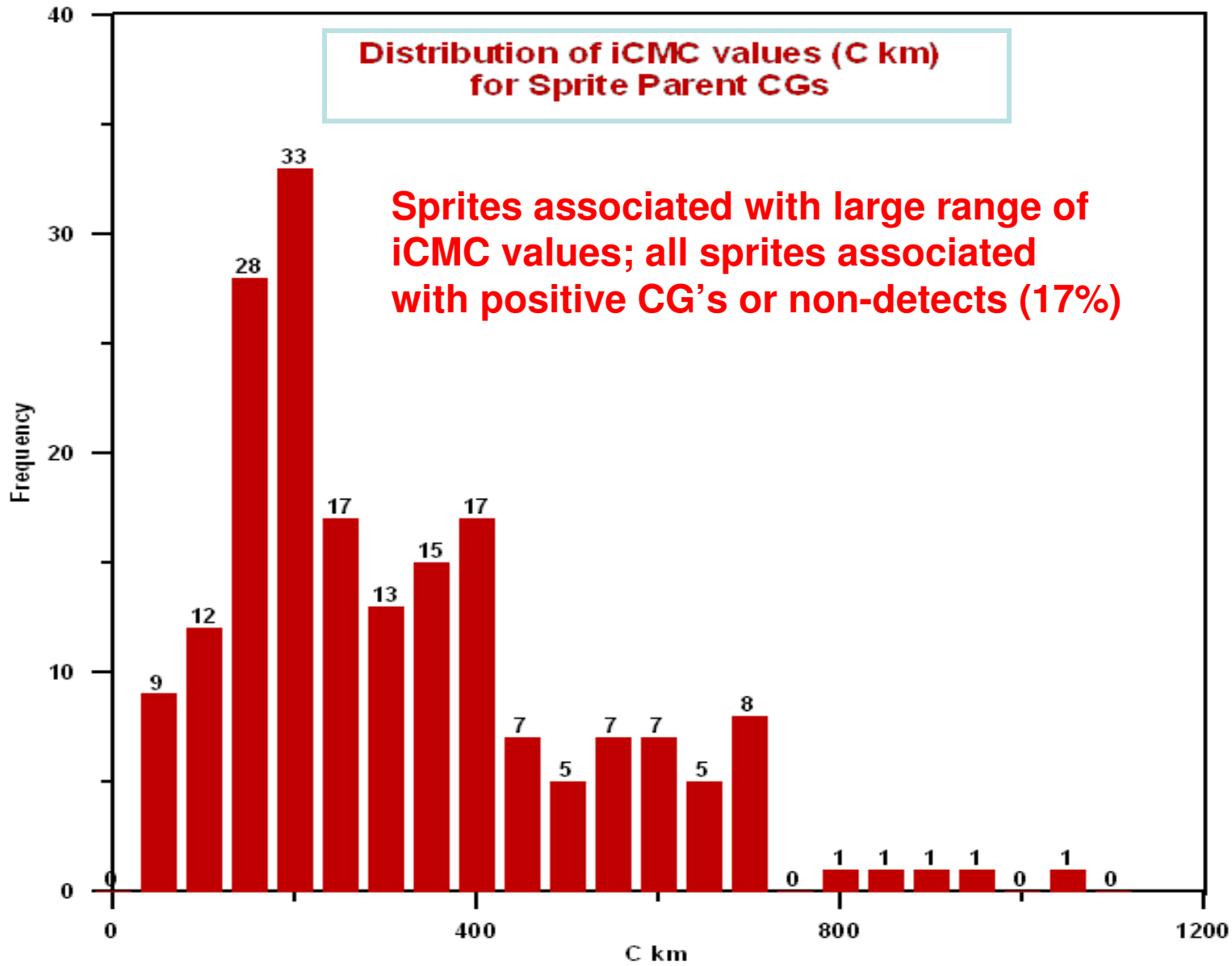


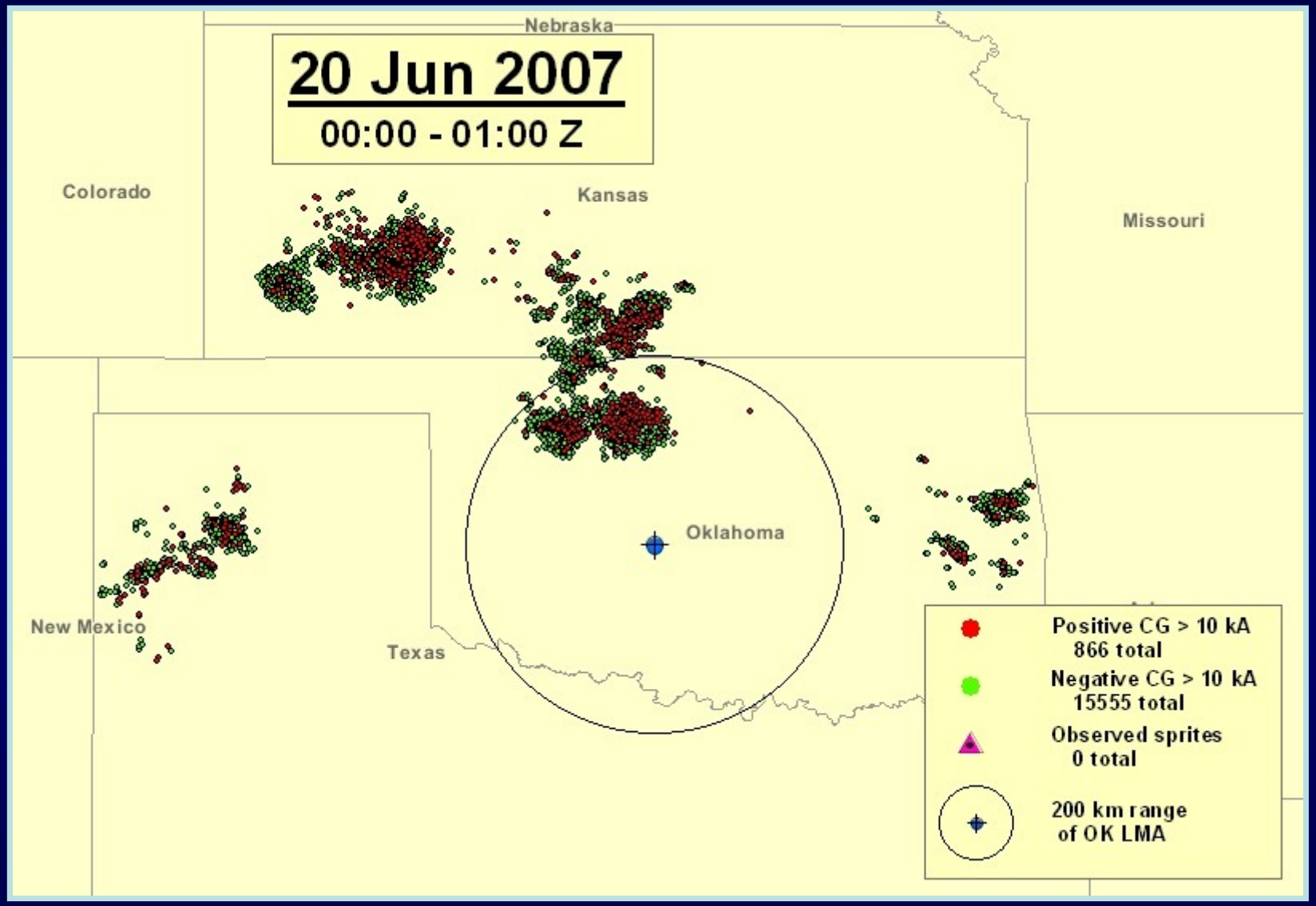
Distribution of NLDN peak currents for sprite parent +CGs (20 June 2007)

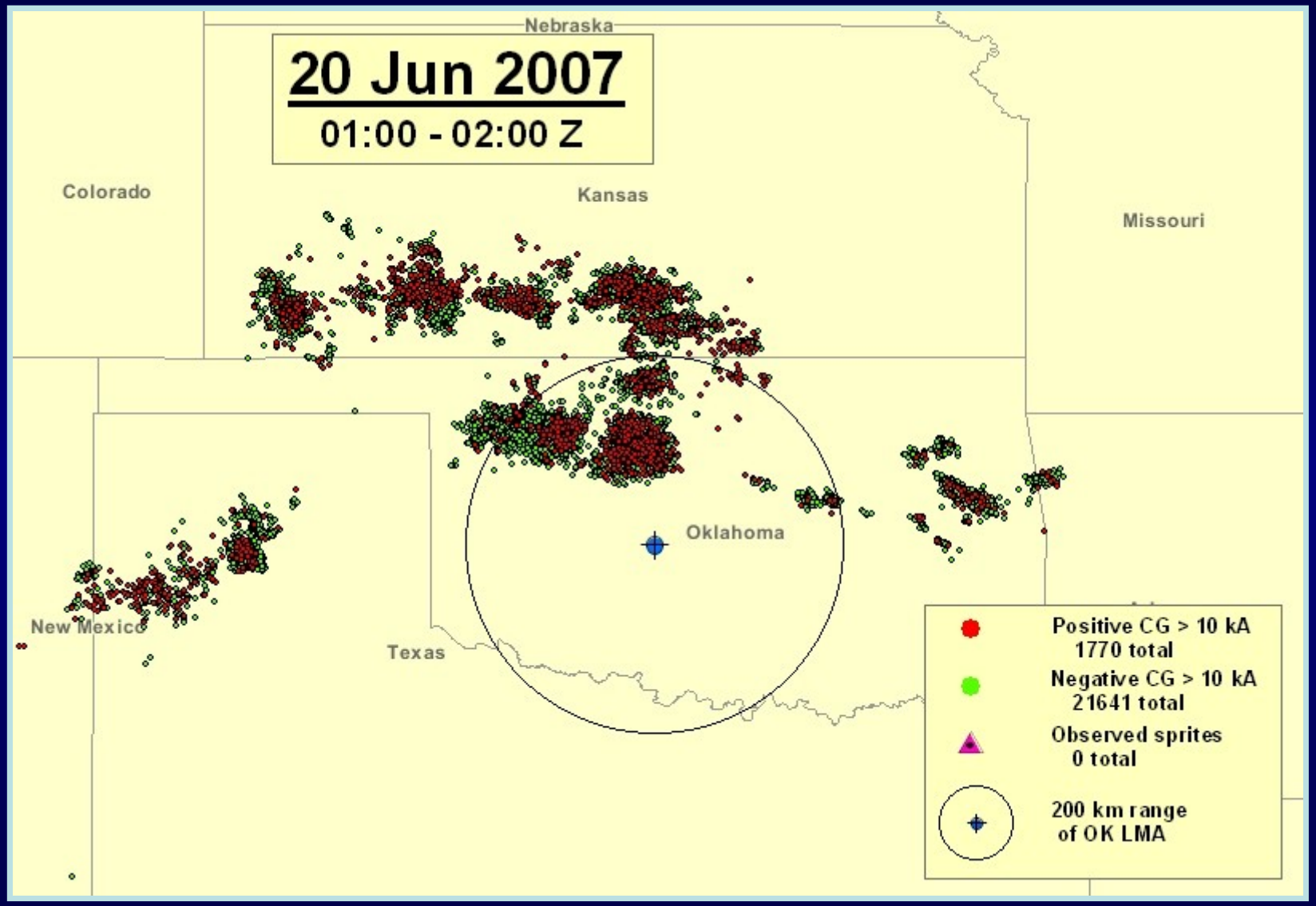
Distribution of NLDN peak currents for all +CGs 10 kA (20 June 2007)

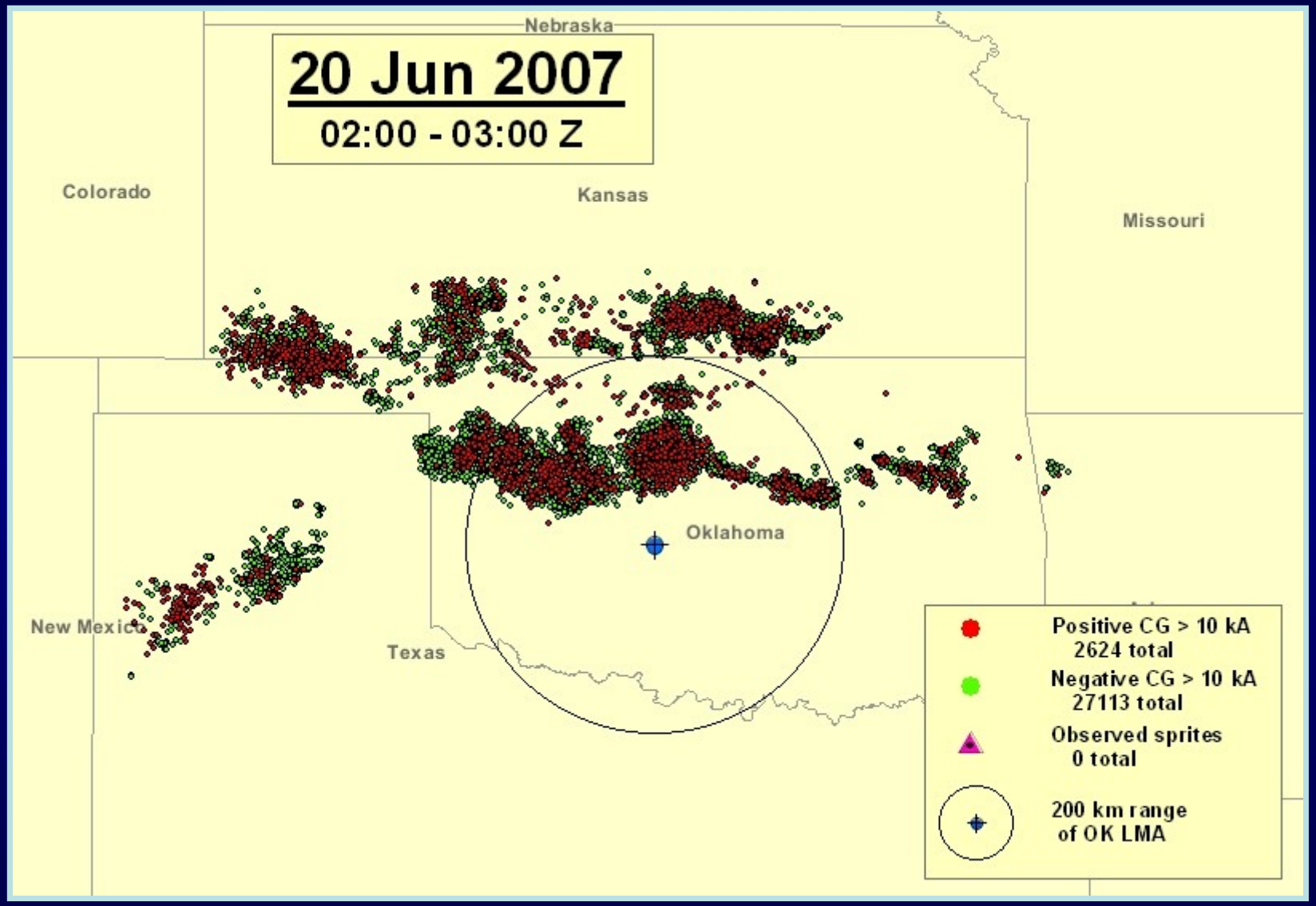


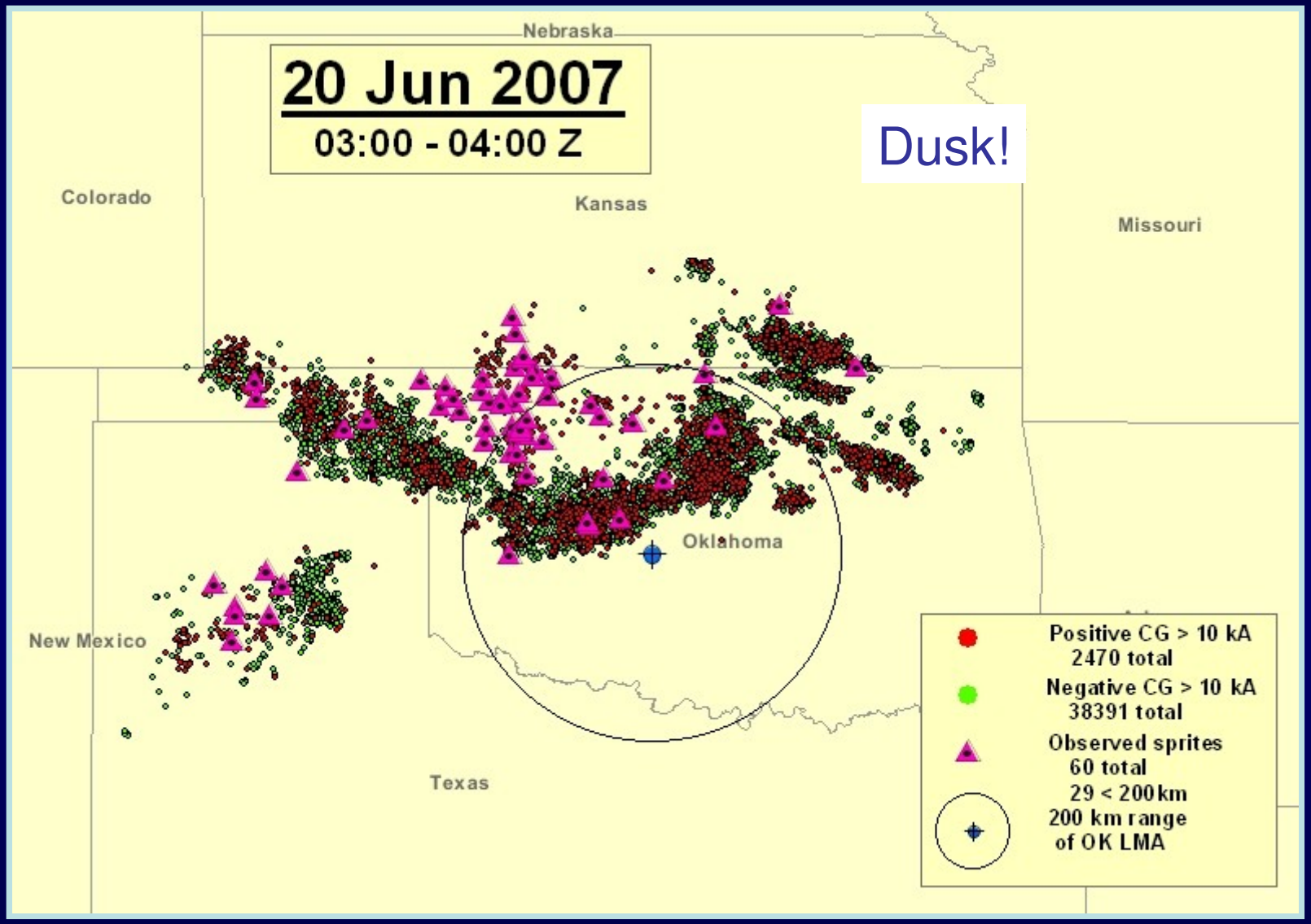


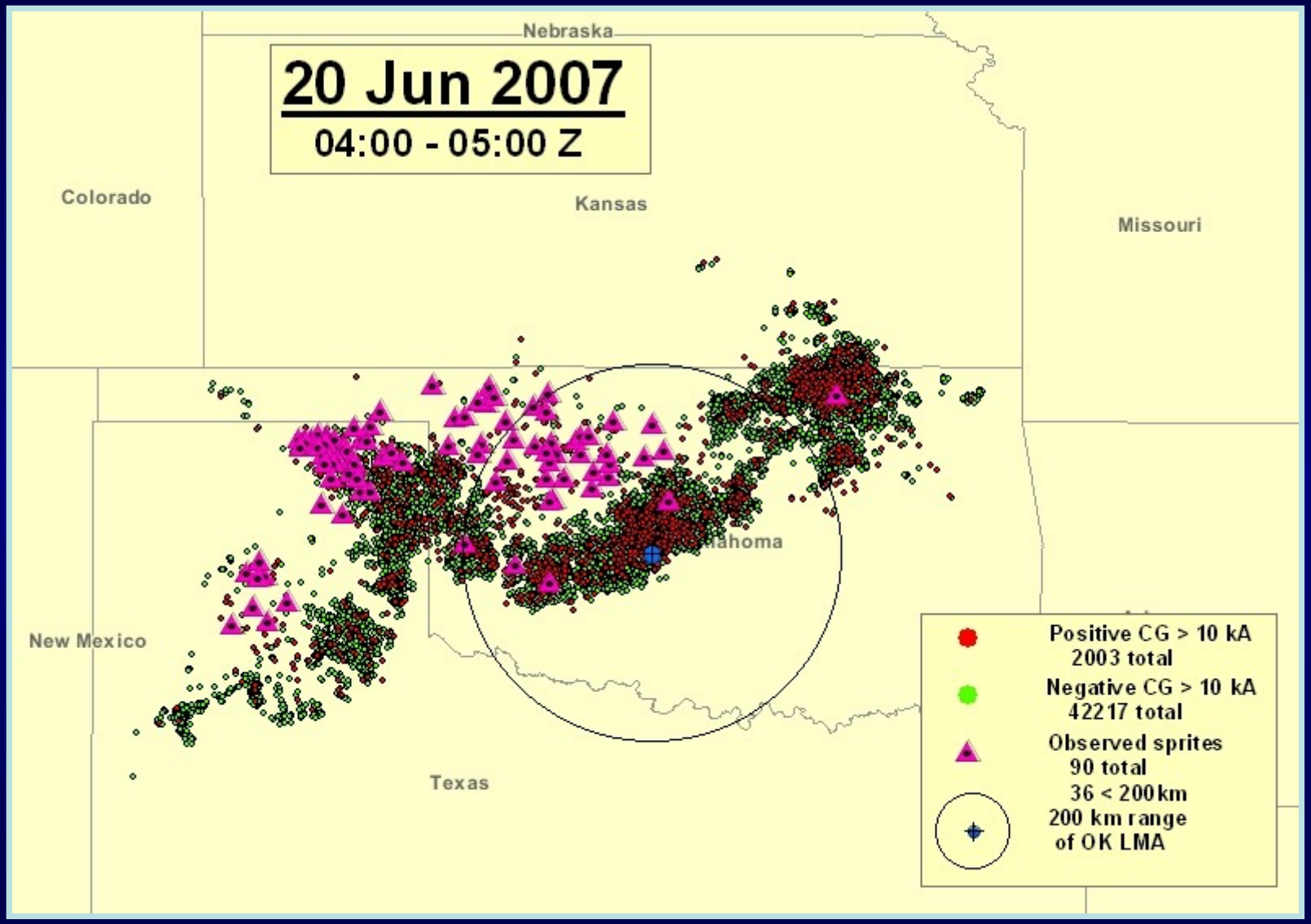

Distribution of iCMC values (C km)
for Sprite Parent CGs
Sprites associated with large range of iCMC values; all sprites associated with positive CG's or non-detects (17%)
Frequency
C km
0
10
20
30
40
0
400
800
1200
0
9
12
28
33
17
13
15
17
7
5
7
7
5
8
0
1
1
1
1
0
1
0

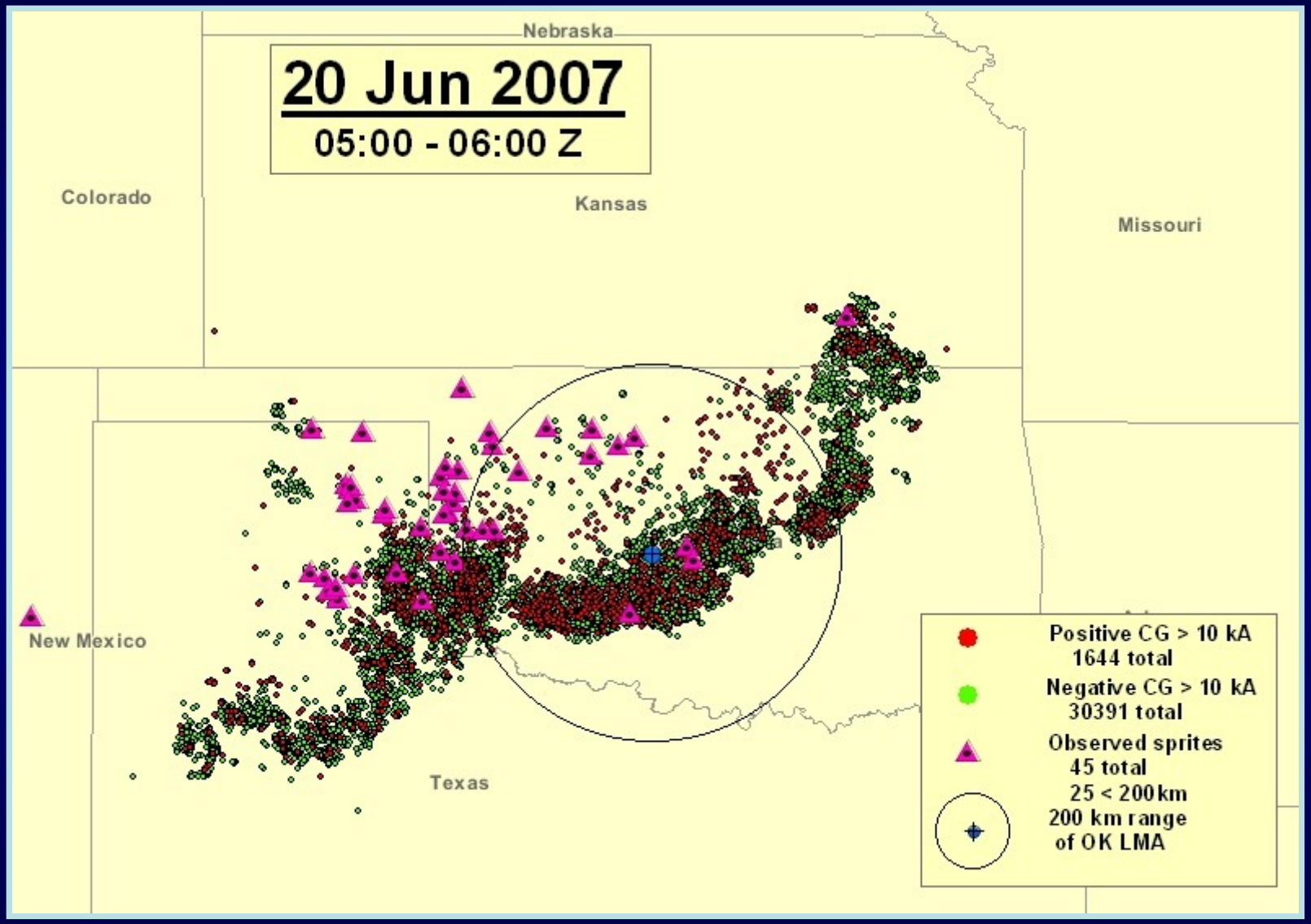

20 Jun 2007
00:00 - 01:00 Z
Nebraska
Colorado
Kansas
Missouri
Oklahoma
New Mexico
Texas
Positive CG > 10 kA
866 total
Negative CG > 10 kA
15555 total
Observed sprites
0 total
200 km range
of OK LMA

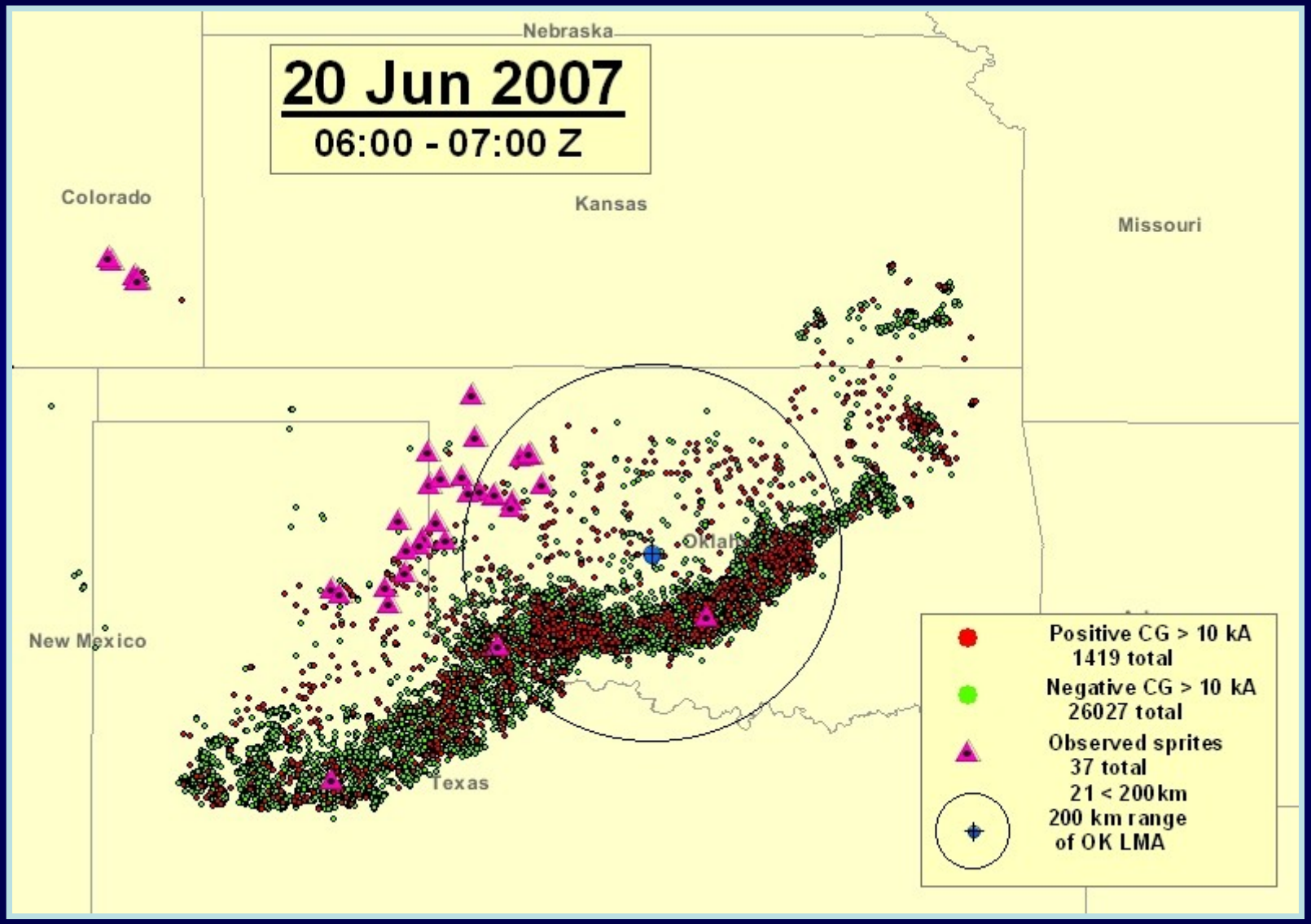

20 Jun 2007
01:00 - 02:00 Z
Nebraska
Colorado
Kansas
Missouri
Oklahoma
New Mexico
Texas
Positive CG > 10 kA
1770 total
Negative CG > 10 kA
21641 total
Observed sprites
0 total
200 km range
of OK LMA

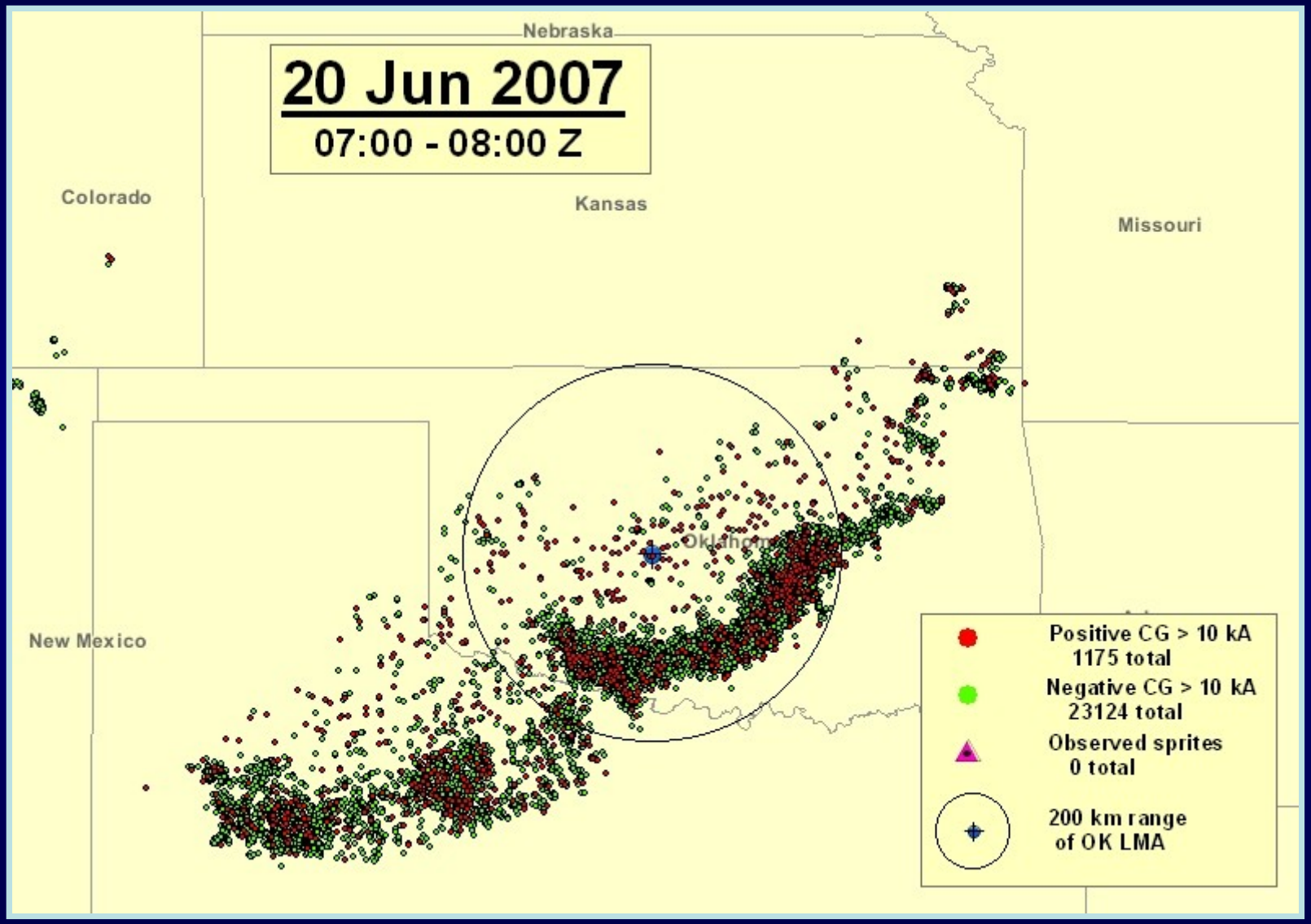

20 Jun 2007
02:00 - 03:00 Z
Nebraska
Colorado
Kansas
Missouri
Oklahoma
New Mexico
Texas
Positive CG > 10 kA
2624 total
Negative CG > 10 kA
27113 total
Observed sprites
0 total
200 km range
of OK LMA

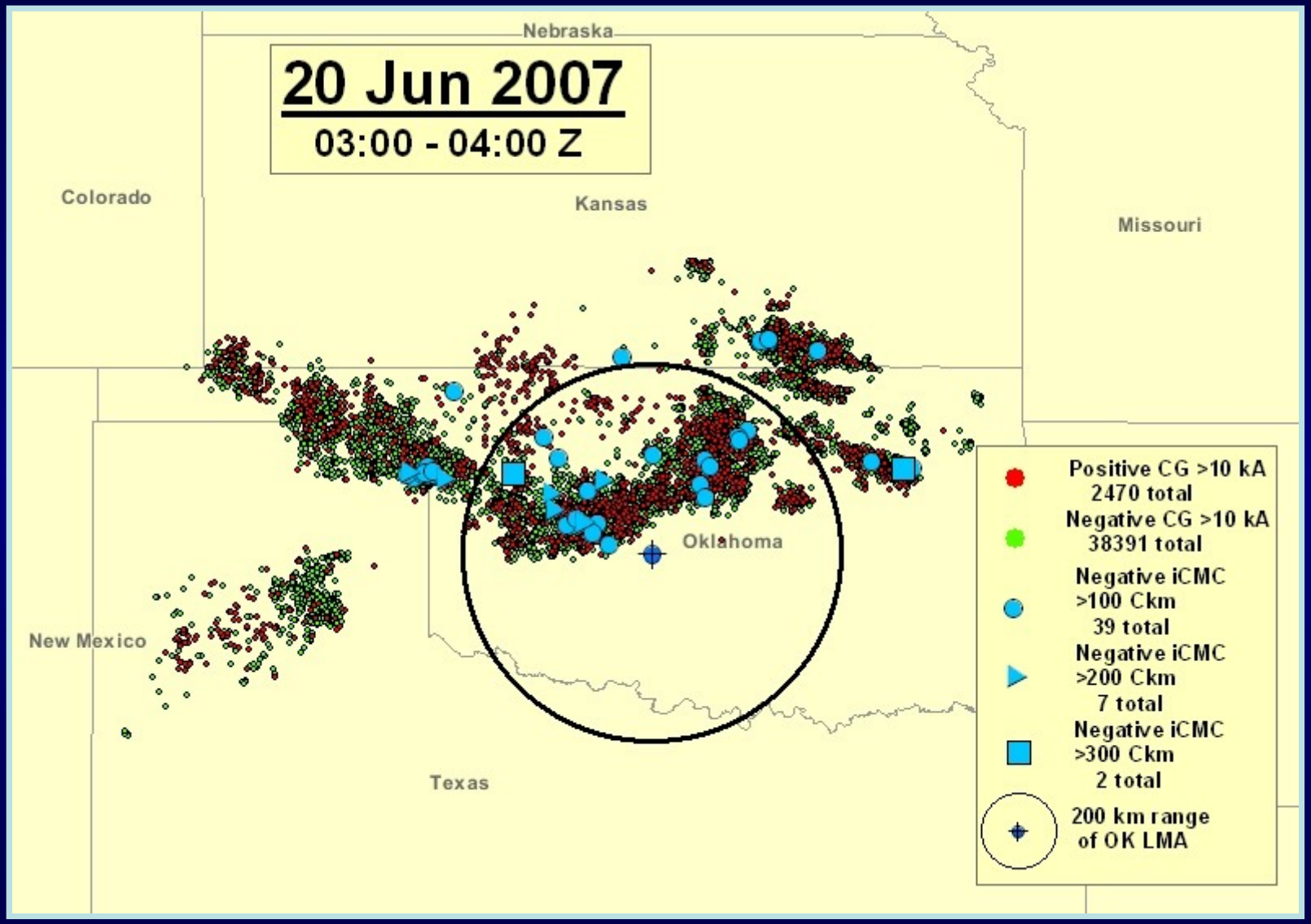

20 Jun 2007
03:00 - 04:00 Z
Dusk!
Nebraska
Colorado
Kansas
Missouri
Oklahoma
New Mexico
Texas
Positive CG > 10 kA
2470 total
Negative CG > 10 kA
38391 total
Observed sprites
60 total
29 < 200km
200 km range
of OK LMA

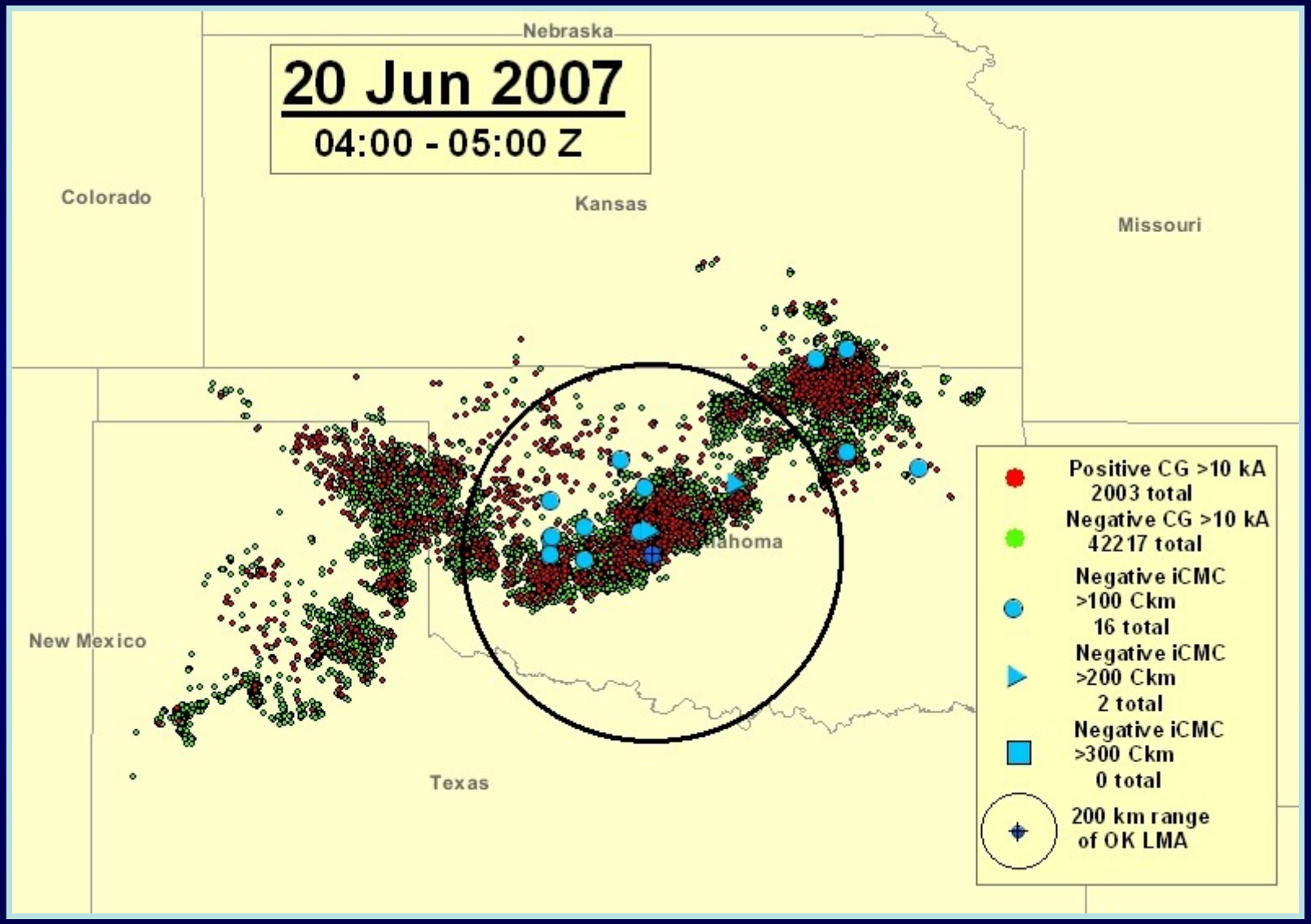

20 Jun 2007
04:00 - 05:00 Z
Nebraska
Colorado
Kansas
Missouri
New Mexico
Texas
Positive CG > 10 kA
2003 total
Negative CG > 10 kA
42217 total
Observed sprites
90 total
36 < 200km
200 km range
of OK LMA

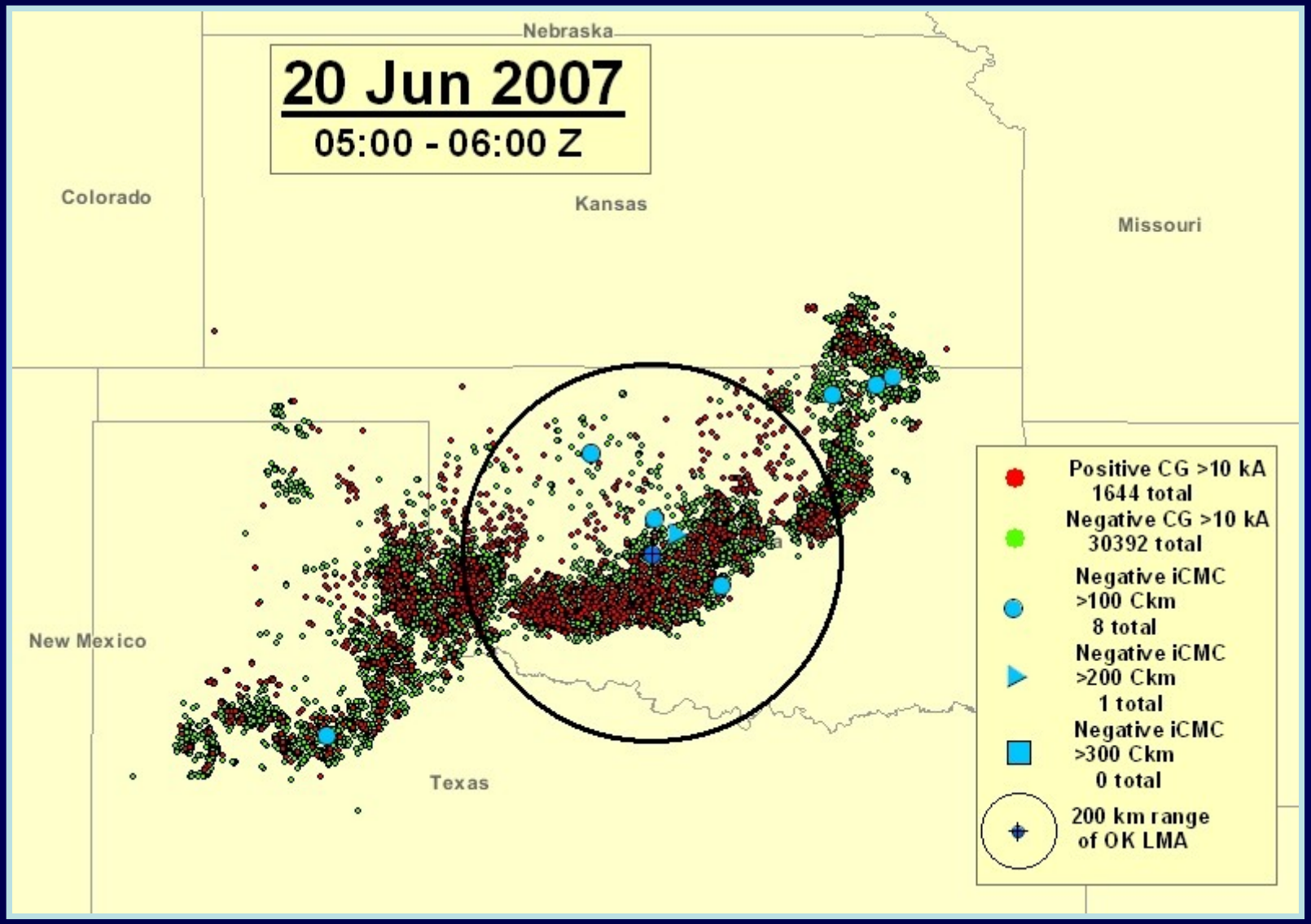

20 Jun 2007
05:00 - 06:00 Z
Nebraska
Colorado
Kansas
Missouri
New Mexico
Texas
Positive CG > 10 kA
1644 total
Negative CG > 10 kA
30391 total
Observed sprites
45 total
25 < 200 km
200 km range
of OK LMA

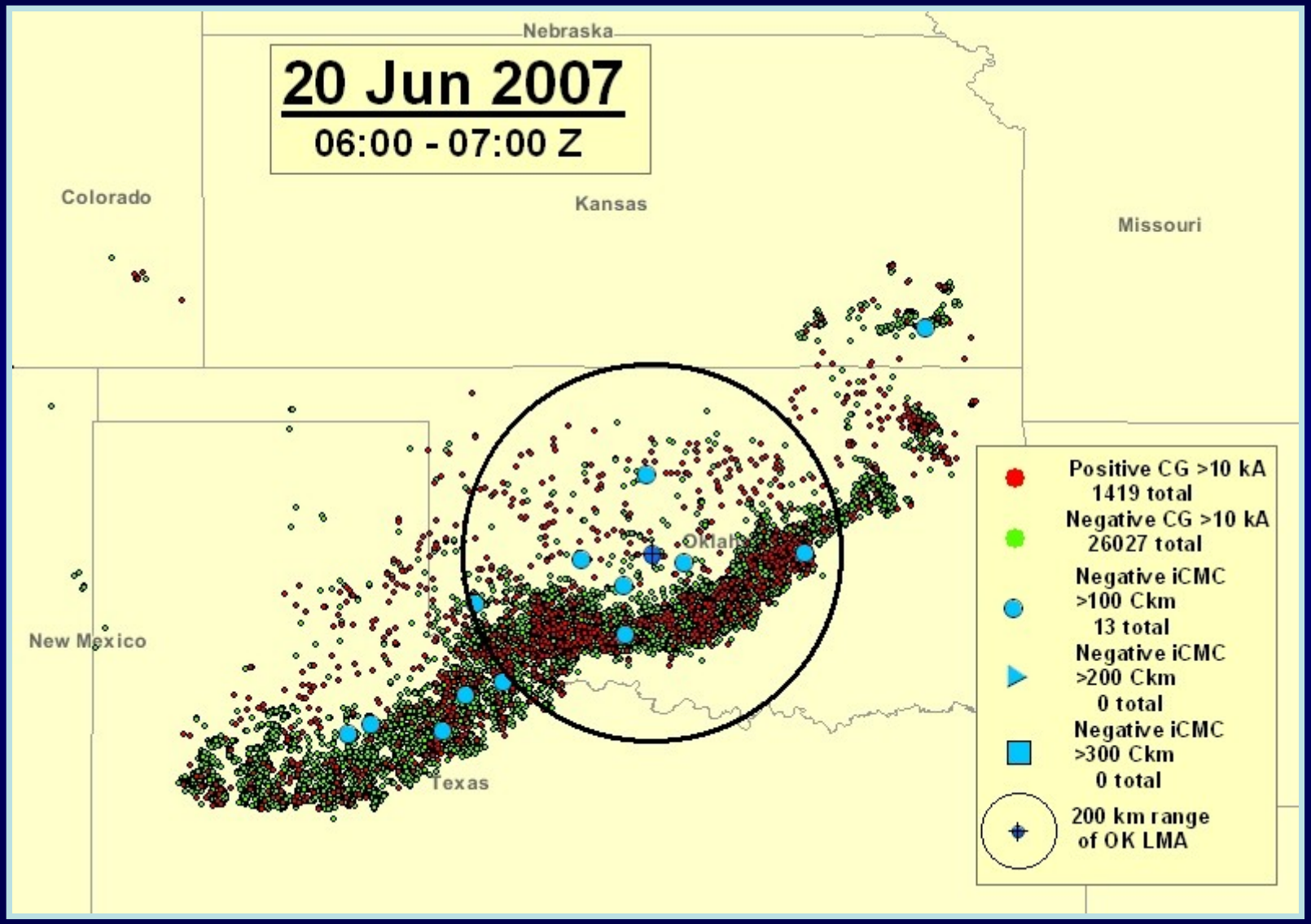

20 Jun 2007
06:00 - 07:00 Z
Nebraska
Colorado
Kansas
Missouri
New Mexico
Texas
Positive CG > 10 kA
1419 total
Negative CG > 10 kA
26027 total
Observed sprites
37 total
21 < 200km
200 km range
of OK LMA

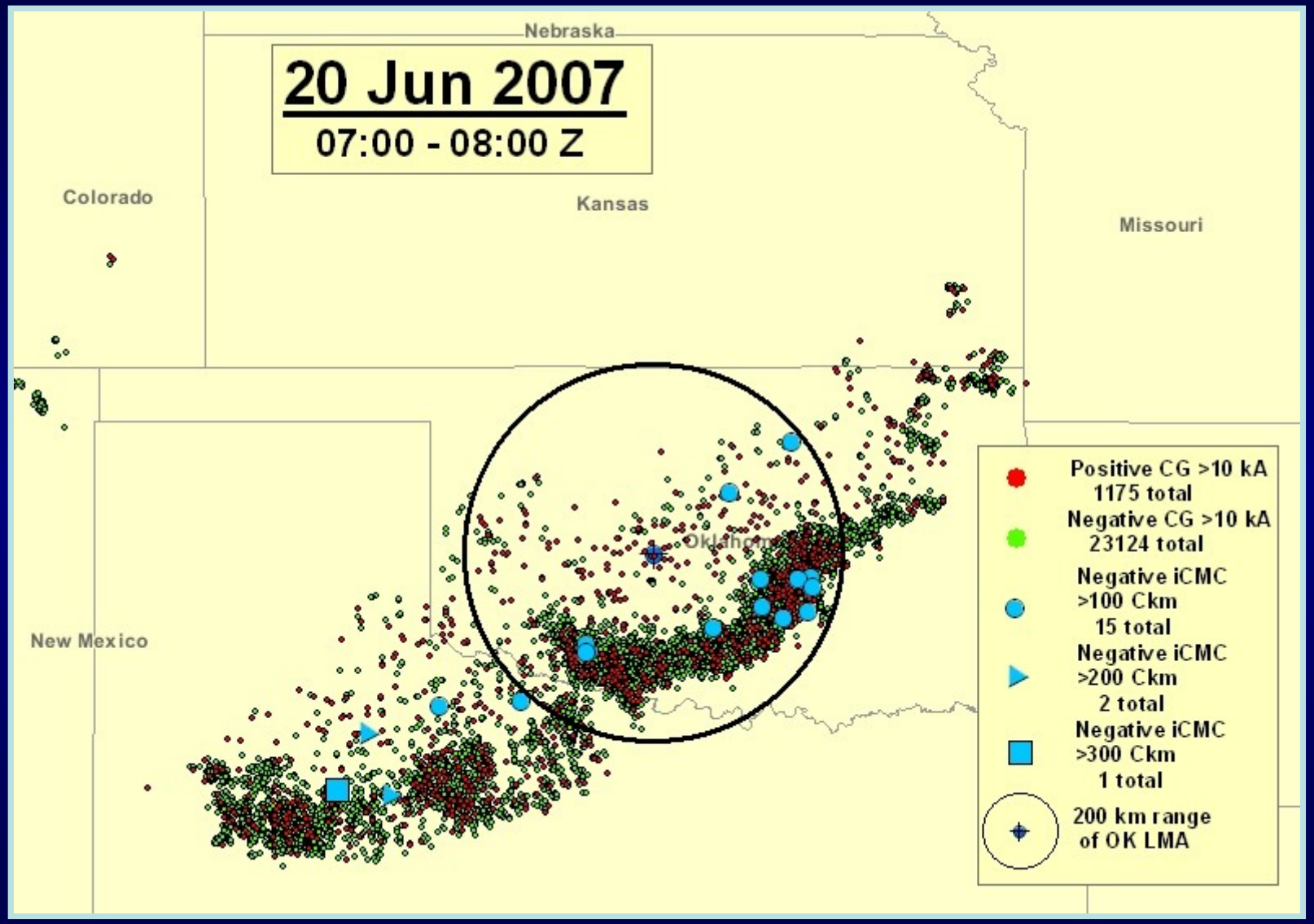

20 Jun 2007
07:00 - 08:00 Z
Nebraska
Colorado
Kansas
Missouri
New Mexico
Oklahoma
Positive CG > 10 kA
1175 total
Negative CG > 10 kA
23124 total
Observed sprites
0 total
200 km range
of OK LMA

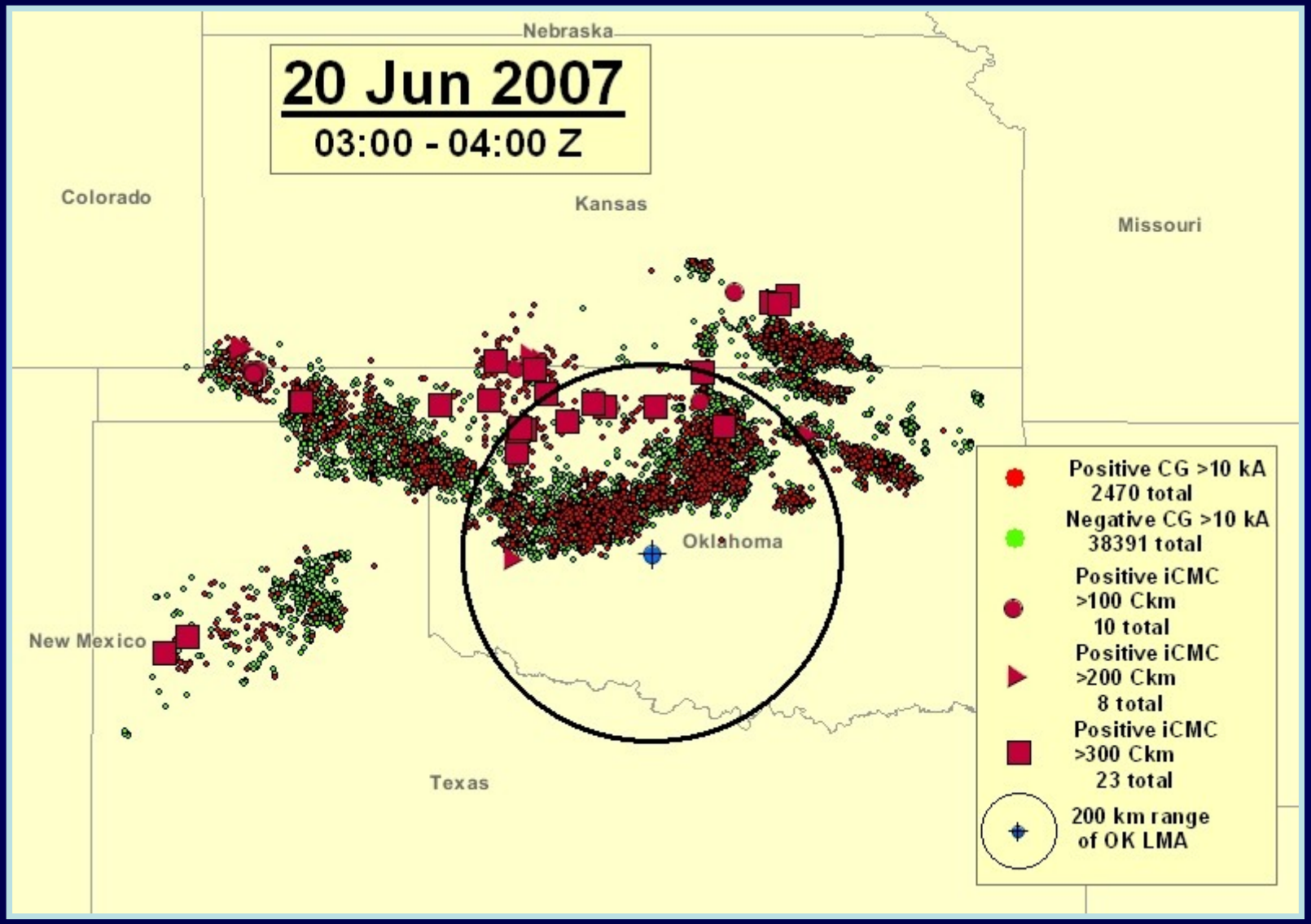

20 Jun 2007
03:00 - 04:00 Z
Nebraska
Colorado
Kansas
Missouri
Oklahoma
New Mexico
Texas
Positive CG >10 kA
2470 total
Negative CG >10 kA
38391 total
Negative iCMC
>100 Ckm
39 total
Negative iCMC
>200 Ckm
7 total
Negative iCMC
>300 Ckm
2 total
200 km range
of OK LMA

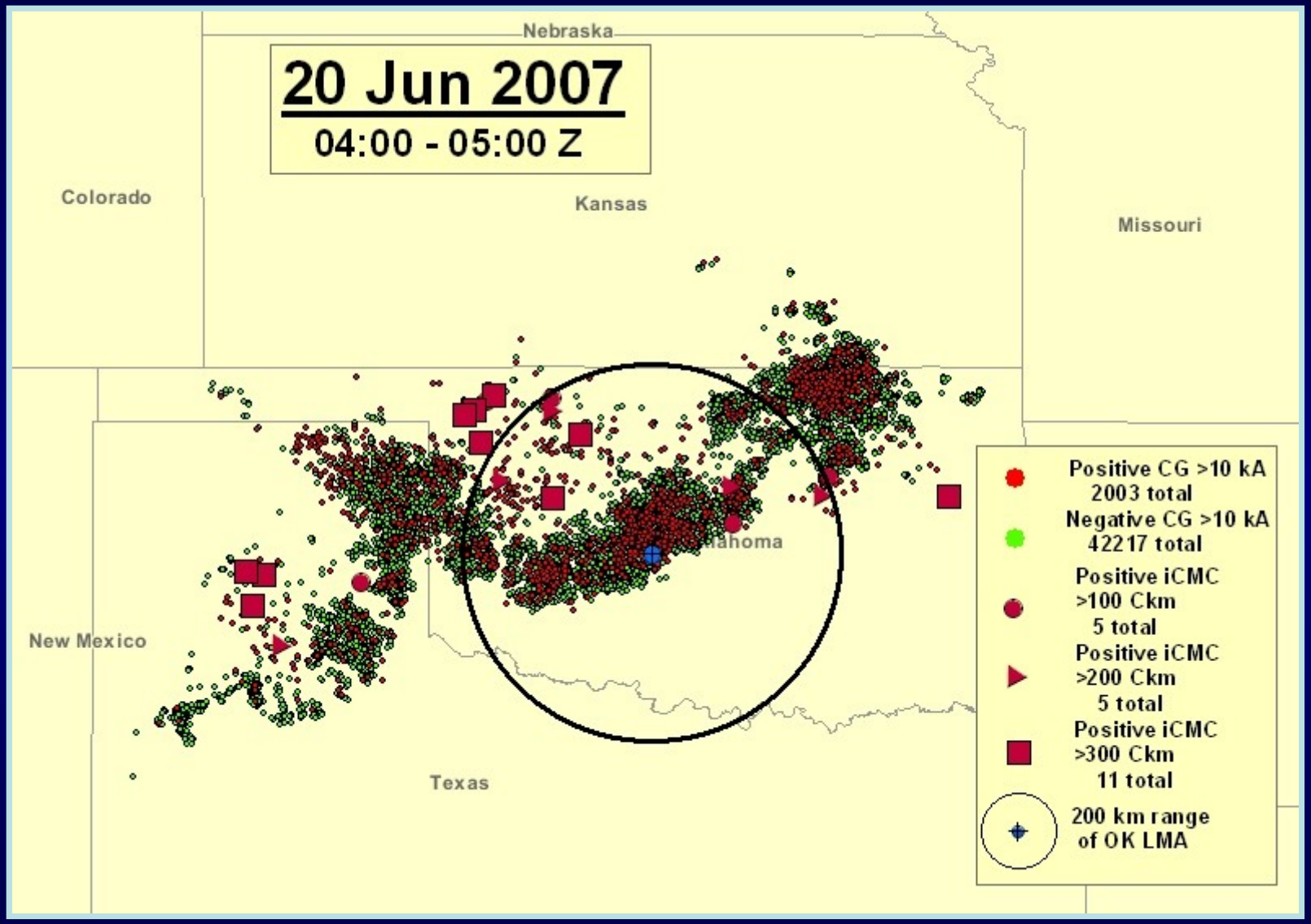

20 Jun 2007
04:00 - 05:00 Z
Nebraska
Colorado
Kansas
Missouri
New Mexico
Texas
Positive CG >10 kA
2003 total
Negative CG >10 kA
42217 total
Negative iCMC
>100 Ckm
16 total
Negative iCMC
>200 Ckm
2 total
Negative iCMC
>300 Ckm
0 total
200 km range
of OK LMA

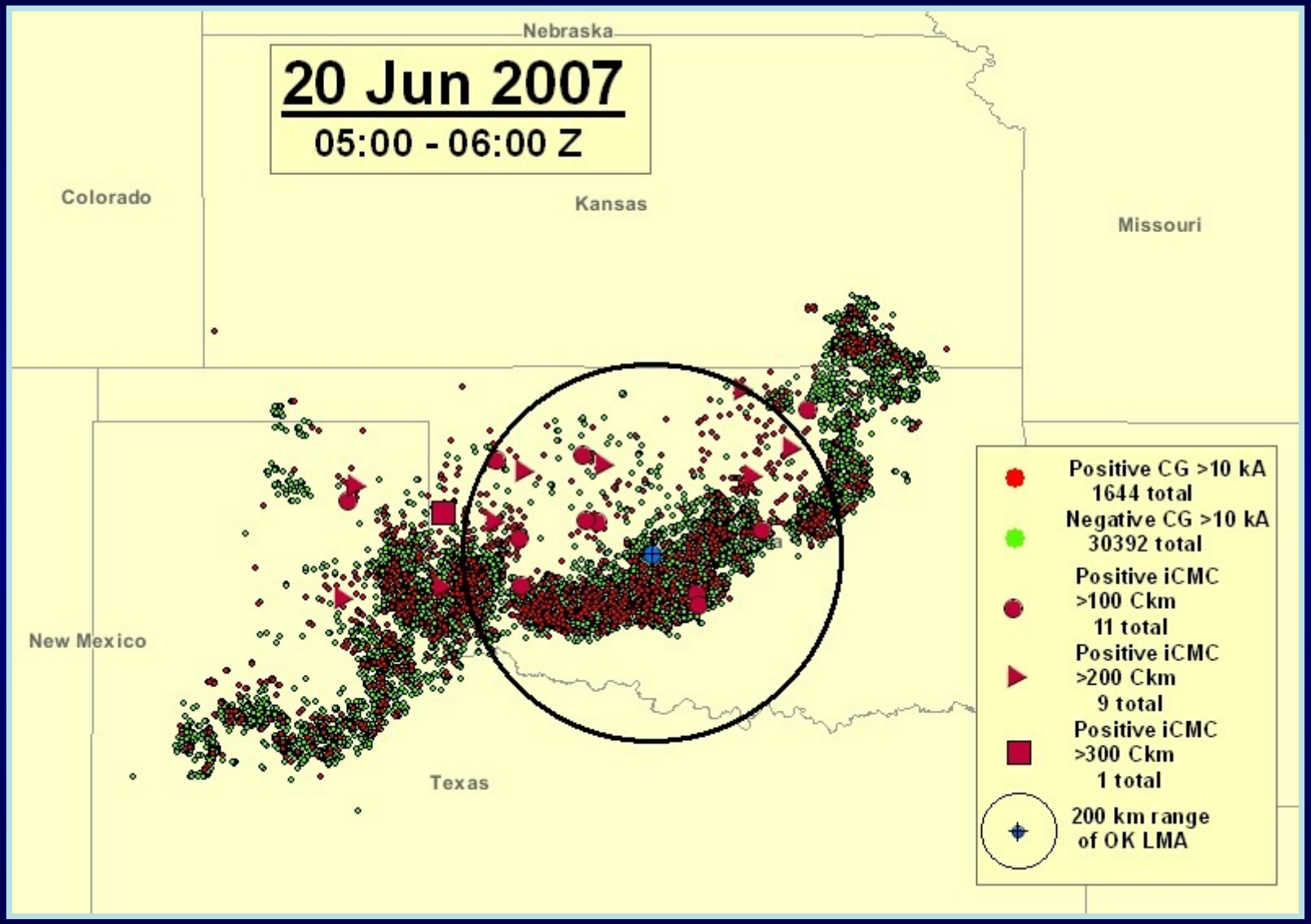

20 Jun 2007
05:00 - 06:00 Z
Nebraska
Colorado
Kansas
Missouri
New Mexico
Texas
Positive CG >10 kA
1644 total
Negative CG >10 kA
30392 total
Negative iCMC
>100 Ckm
8 total
Negative iCMC
>200 Ckm
1 total
Negative iCMC
>300 Ckm
0 total
200 km range
of OK LMA

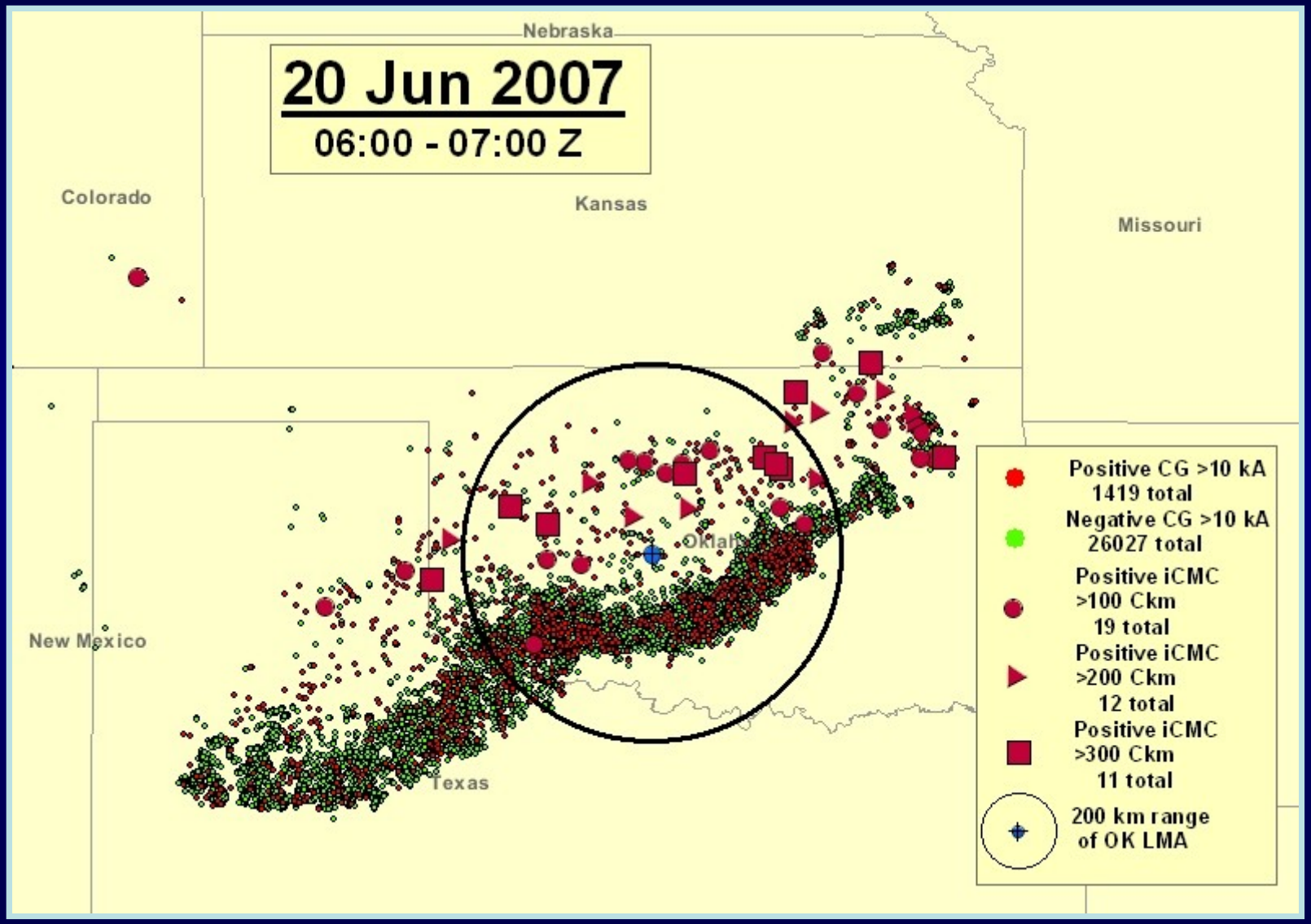

20 Jun 2007
06:00 - 07:00 Z
Nebraska
Colorado
Kansas
Missouri
New Mexico
Texas
Positive CG >10 kA
1419 total
Negative CG >10 kA
26027 total
Negative iCMC
>100 Ckm
13 total
Negative iCMC
>200 Ckm
0 total
Negative iCMC
>300 Ckm
0 total
200 km range
of OK LMA

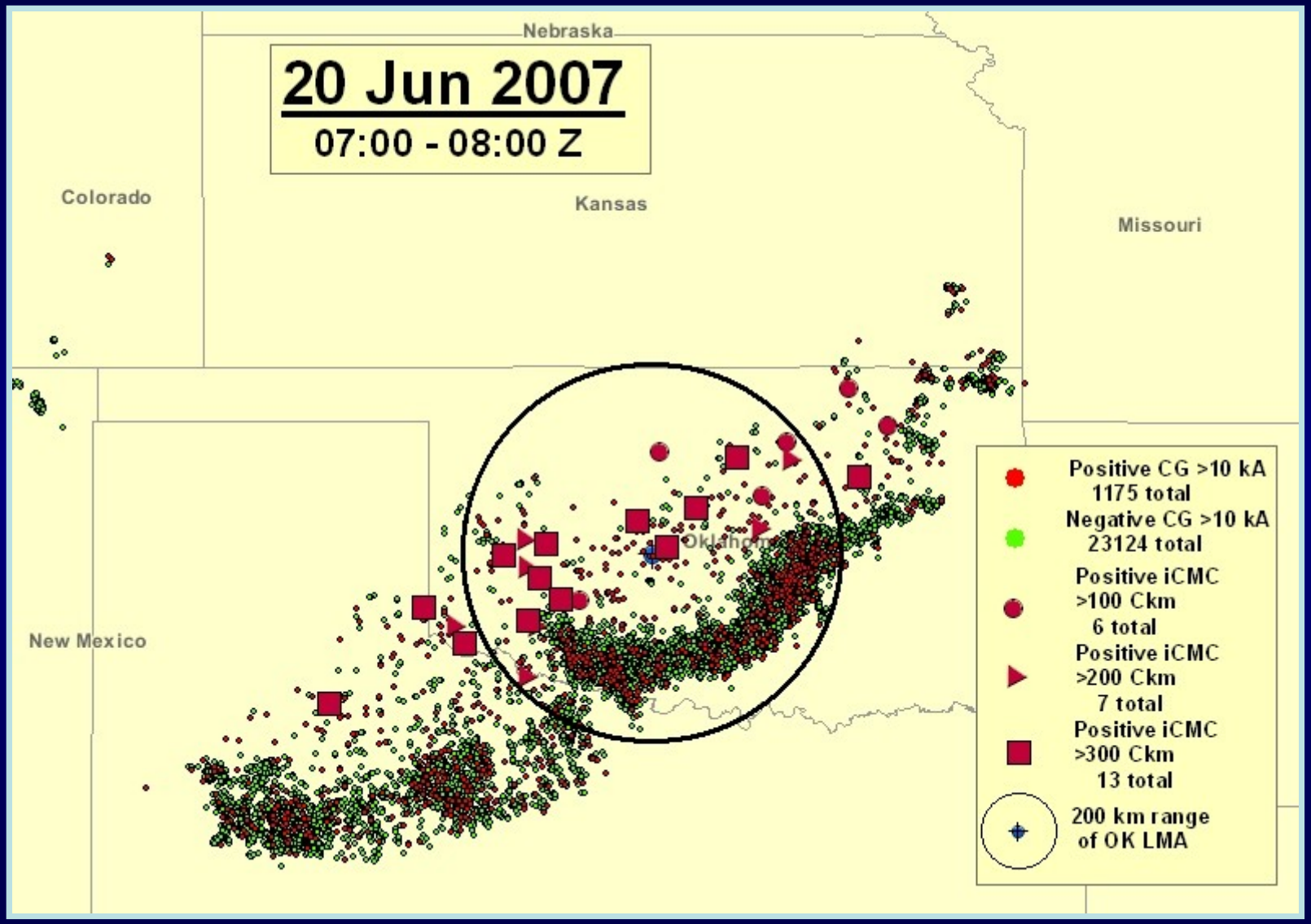

20 Jun 2007
07:00 - 08:00 Z
Nebraska
Colorado
Kansas
Missouri
New Mexico
Oklahoma
Positive CG >10 kA
1175 total
Negative CG >10 kA
23124 total
Negative iCMC
>100 Ckm
15 total
Negative iCMC
>200 Ckm
2 total
Negative iCMC
>300 Ckm
1 total
200 km range
of OK LMA

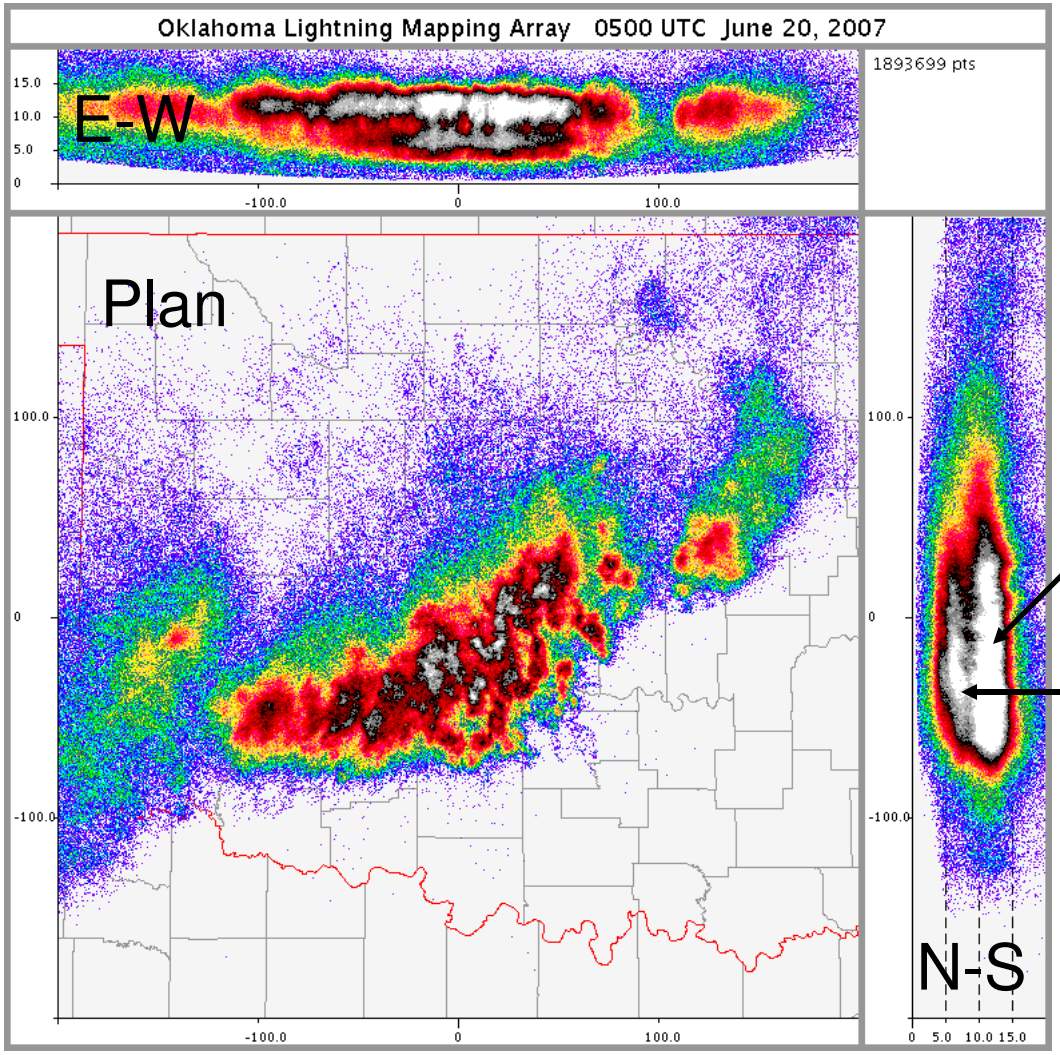

20 Jun 2007
03:00 - 04:00 Z
Nebraska
Colorado
Kansas
Missouri
Oklahoma
New Mexico
Texas
Positive CG >10 kA
2470 total
Negative CG >10 kA
38391 total
Positive iCMC
>100 Ckm
10 total
Positive iCMC
>200 Ckm
8 total
Positive iCMC
>300 Ckm
23 total
200 km range
of OK LMA


20 Jun 2007
04:00 - 05:00 Z
Nebraska
Colorado
Kansas
Missouri
New Mexico
Texas
Positive CG >10 kA
2003 total
Negative CG >10 kA
42217 total
Positive iCMC
>100 Ckm
5 total
Positive iCMC
>200 Ckm
5 total
Positive iCMC
>300 Ckm
11 total
200 km range
of OK LMA


20 Jun 2007
05:00 - 06:00 Z
Nebraska
Colorado
Kansas
Missouri
New Mexico
Texas
Positive CG >10 kA
1644 total
Negative CG >10 kA
30392 total
Positive iCMC
>100 Ckm
11 total
Positive iCMC
>200 Ckm
9 total
Positive iCMC
>300 Ckm
1 total
200 km range
of OK LMA


20 Jun 2007
06:00 - 07:00 Z
Nebraska
Colorado
Kansas
Missouri
New Mexico
Texas
Positive CG >10 kA
1419 total
Negative CG >10 kA
26027 total
Positive iCMC
>100 Ckm
19 total
Positive iCMC
>200 Ckm
12 total
Positive iCMC
>300 Ckm
11 total
200 km range
of OK LMA


20 Jun 2007
07:00 - 08:00 Z
Nebraska
Colorado
Kansas
Missouri
New Mexico
Oklahoma
Positive CG >10 kA
1175 total
Negative CG >10 kA
23124 total
Positive iCMC
>100 Ckm
6 total
Positive iCMC
>200 Ckm
7 total
Positive iCMC
>300 Ckm
13 total
200 km range
of OK LMA



05-06 UTC
LMA Source Density

Convective Line over LMA network

Bi-level Structure Consistent with Normal Tripole
(Carey et al. 2005; JGR)

Upper Density Max 11-12 km (+)
Lower Density Max 7-8 km (+)

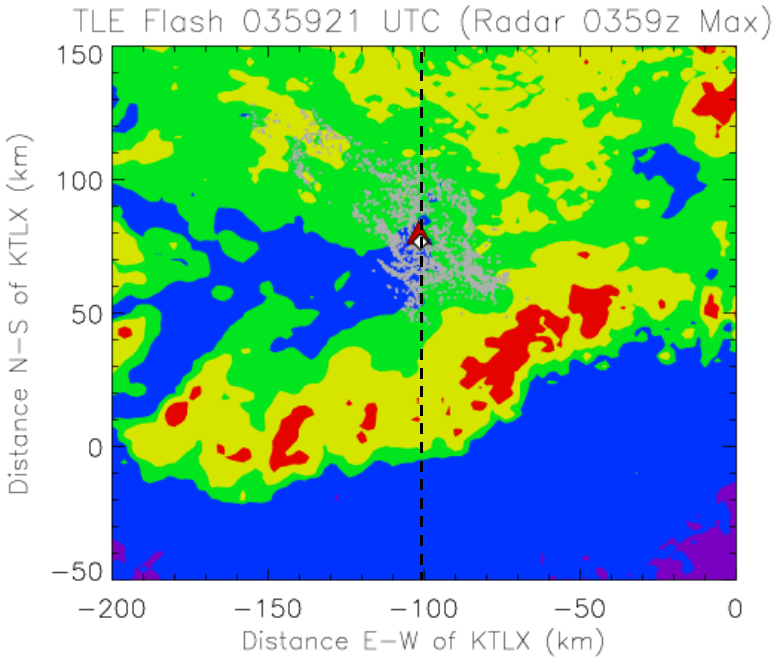
(High resolution analysis suggests third maximum near 4-5 km - another positive charge layer?)

No evidence for significant evolution during passage

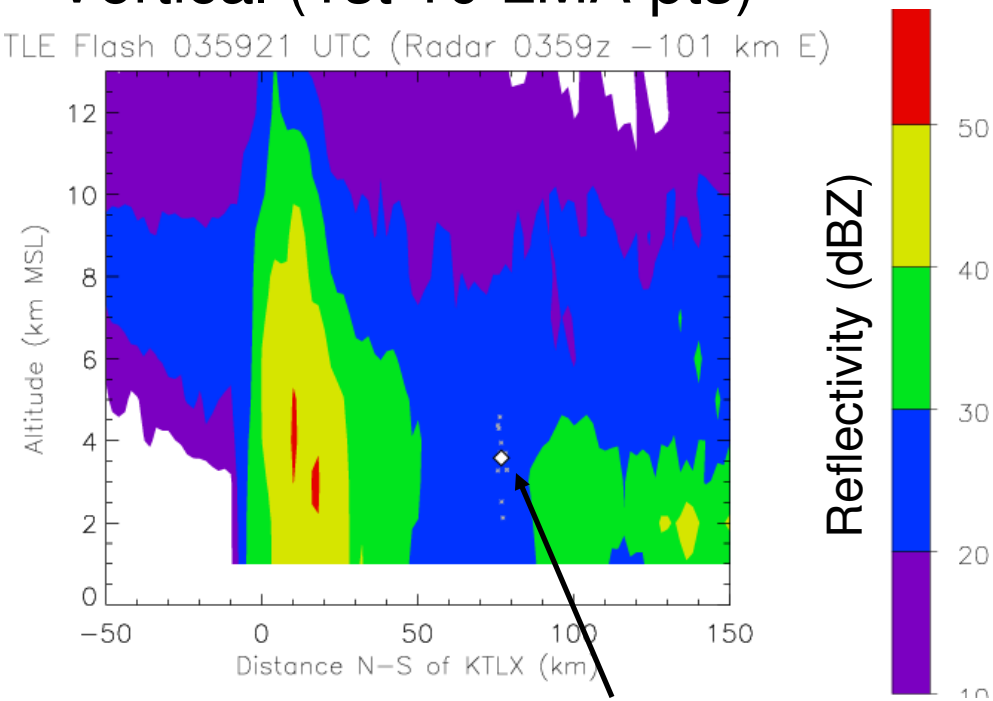
<u>Norman Sounding - 00 UTC 20 Jun</u>

0 °C ~ 4.8 km MSL
-10 °C ~ 6.3 km MSL
-20 °C ~ 7.5 km MSL
-40 °C ~ 10.0 km MSL

Plan View



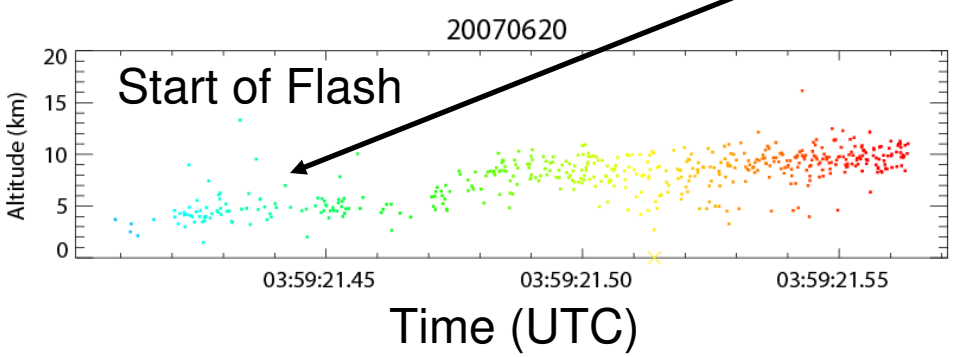
Vertical (1st 10 LMA pts)

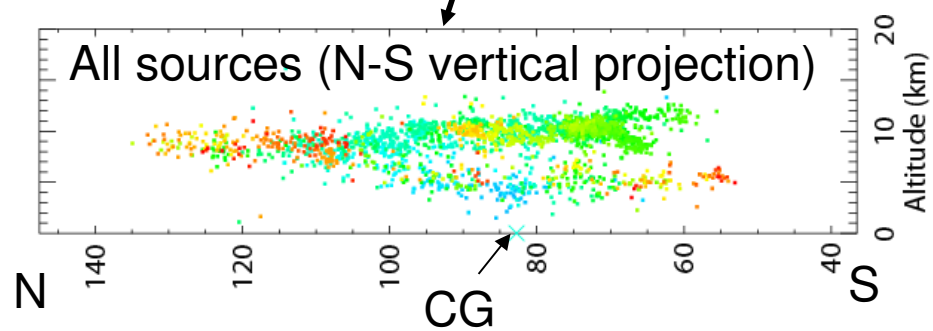


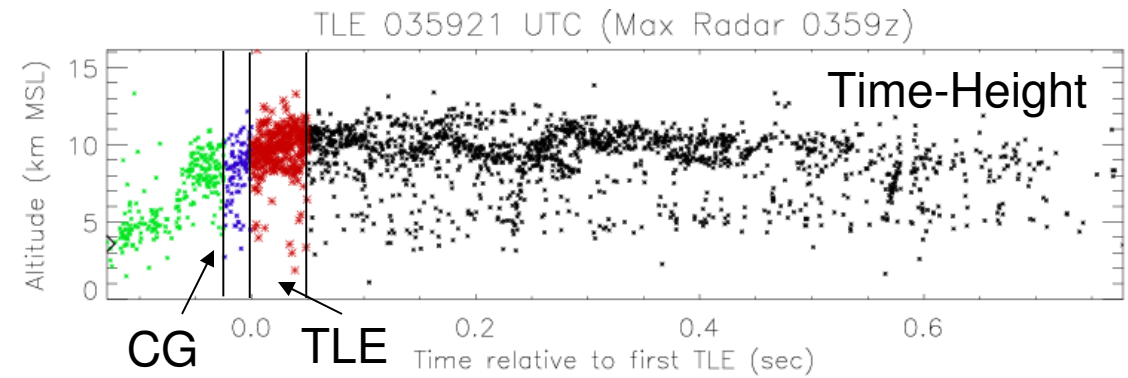
White Diamond - Mean loc of 1st 10 LMA pts
Red Triangle - SP+CG strike location
Grey Points - LMA sources

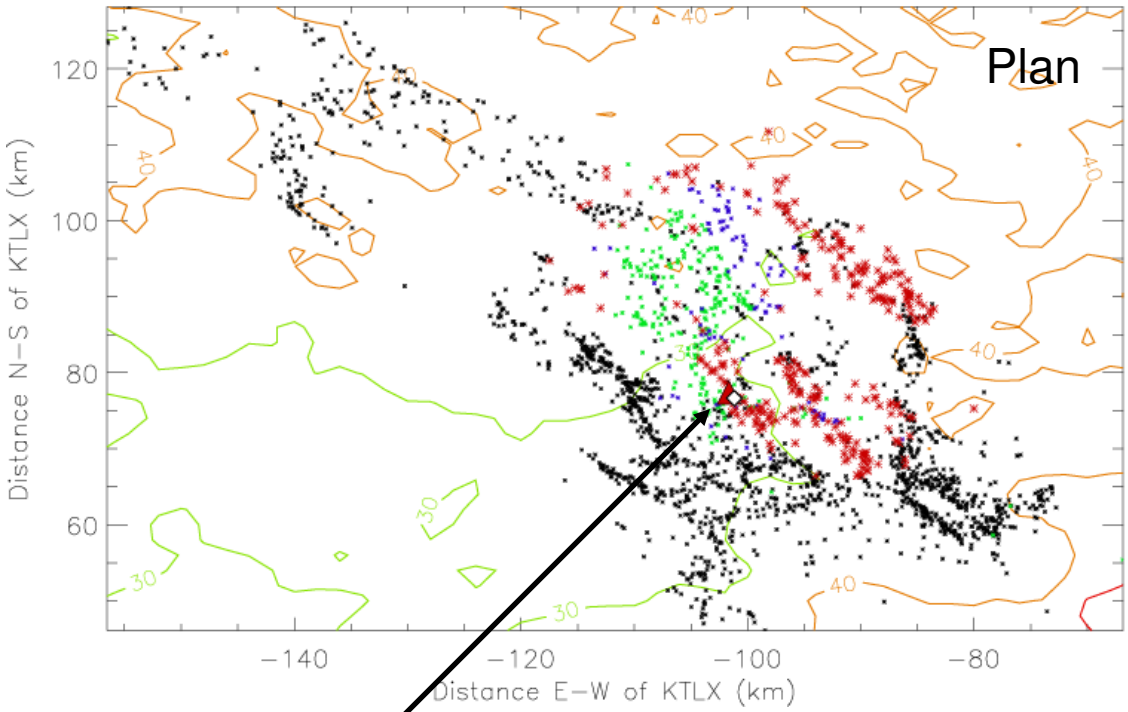
Initiation in Transition Zone just below Melting Level

Bi-level flash w/ sloping upper +



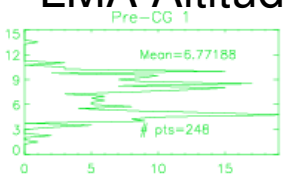




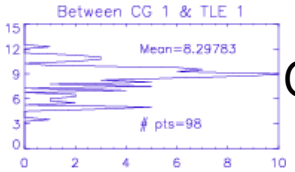


White Diamond - Mean loc of 1st 10 LMA pts
Red Triangle - SP+CG strike location

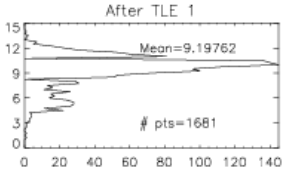
LMA Altitude Histograms



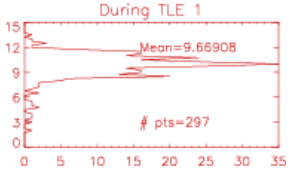
Pre-CG (6.8 km)



CG to TLE (8.3 km)



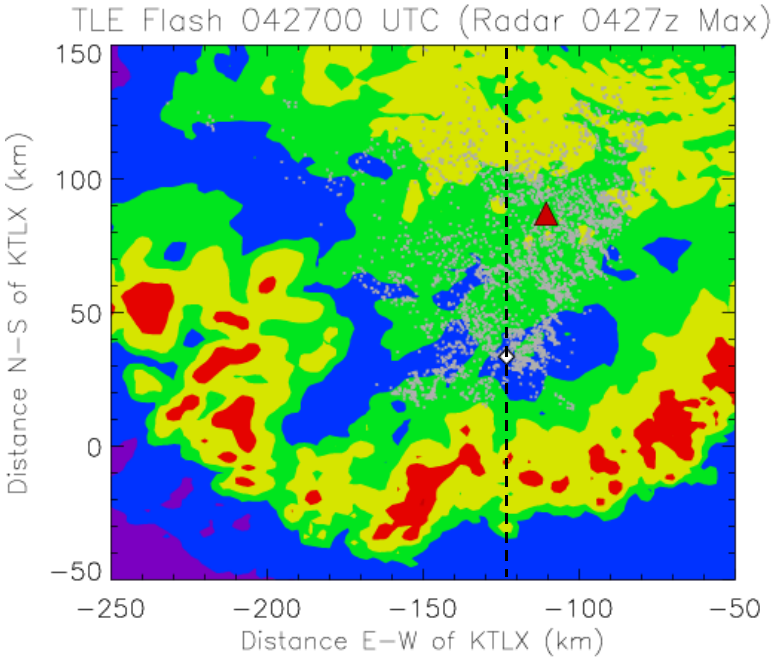
Post-TLE (9.2 km)



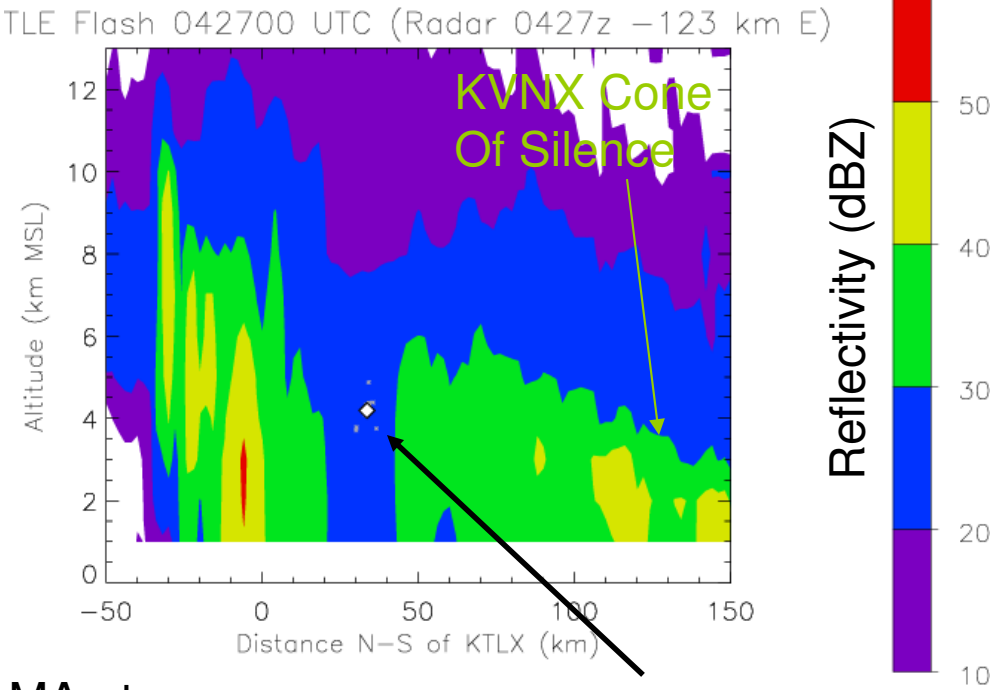
TLE (9.7 km)

TLE @ 03:59:21 UTC
Parent CG - I_p = +59 kA
iCMC = 123 C km
88 km from OK LMA
Taps upper + charge

Plan View



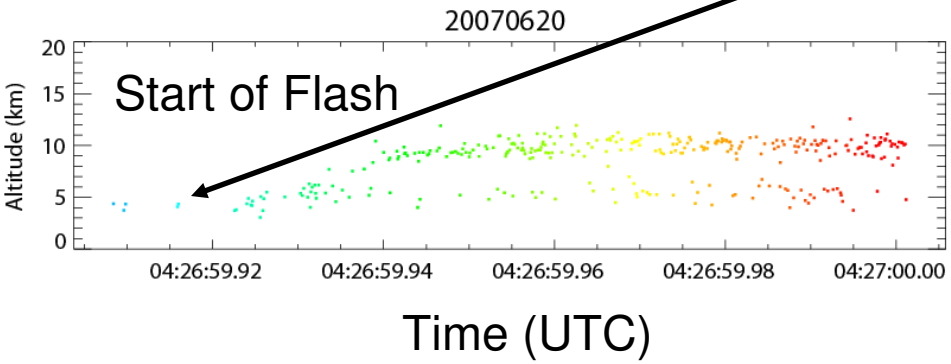
Vertical (1st 10 LMA pts)

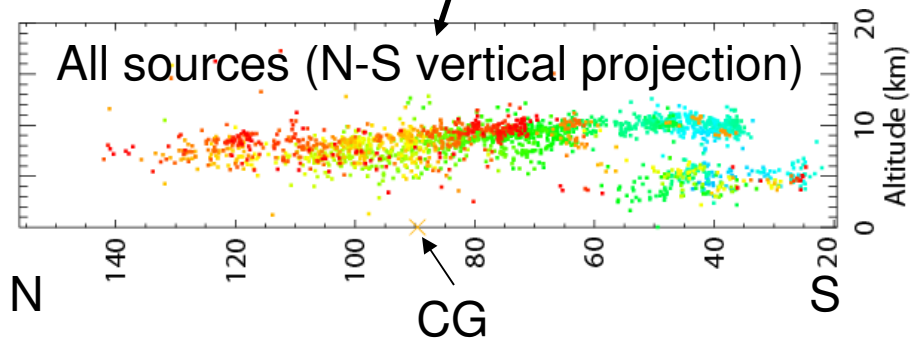


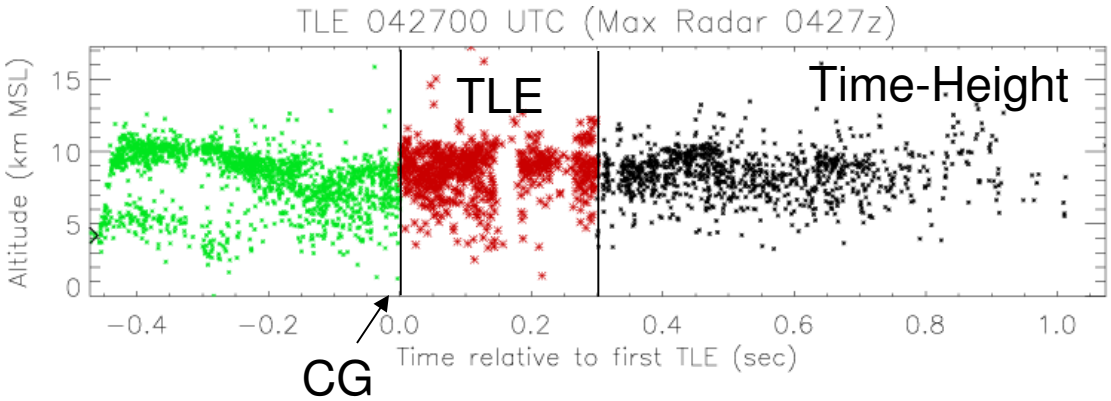
White Diamond - Mean loc of 1st 10 LMA pts
Red Triangle - SP+CG strike location
Grey Points - LMA sources

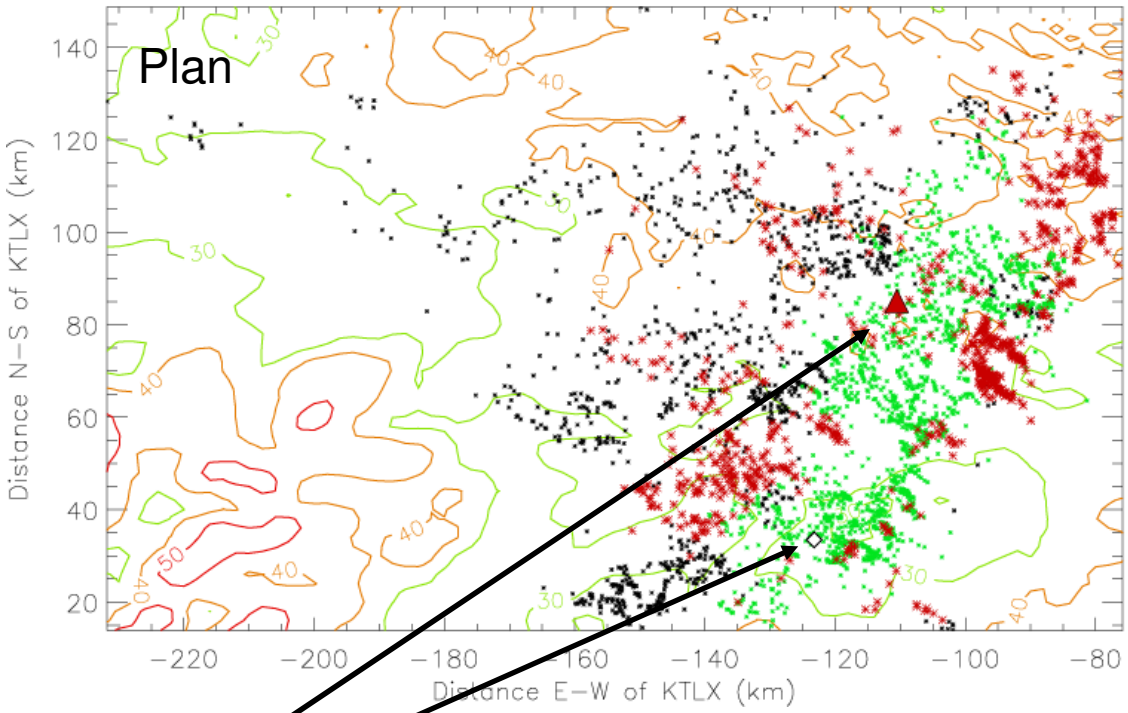
Initiation in Transition Zone
just below Freezing Level

Bi-level flash w/ sloping upper +



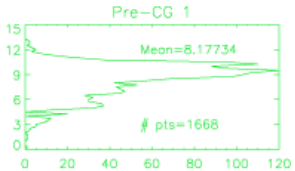




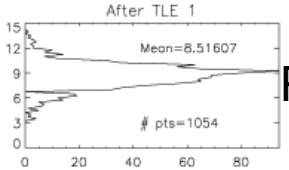


White Diamond - Mean loc of 1st 10 LMA pts
Red Triangle - SP+CG strike location

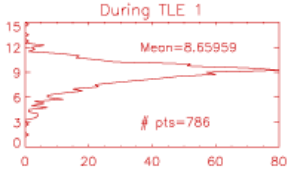
LMA Altitude Histograms



Pre-CG/TLE (8.2 km)



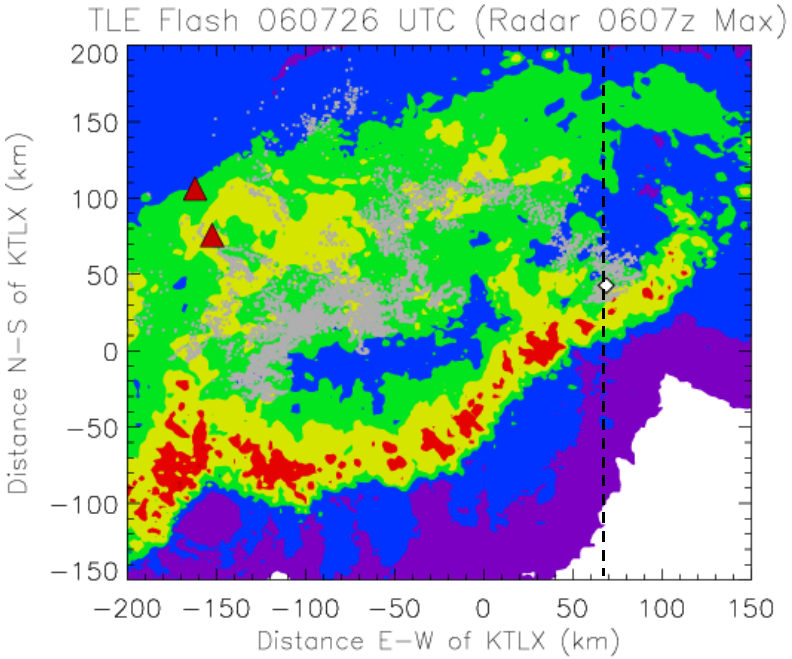
Post-TLE (8.5 km)



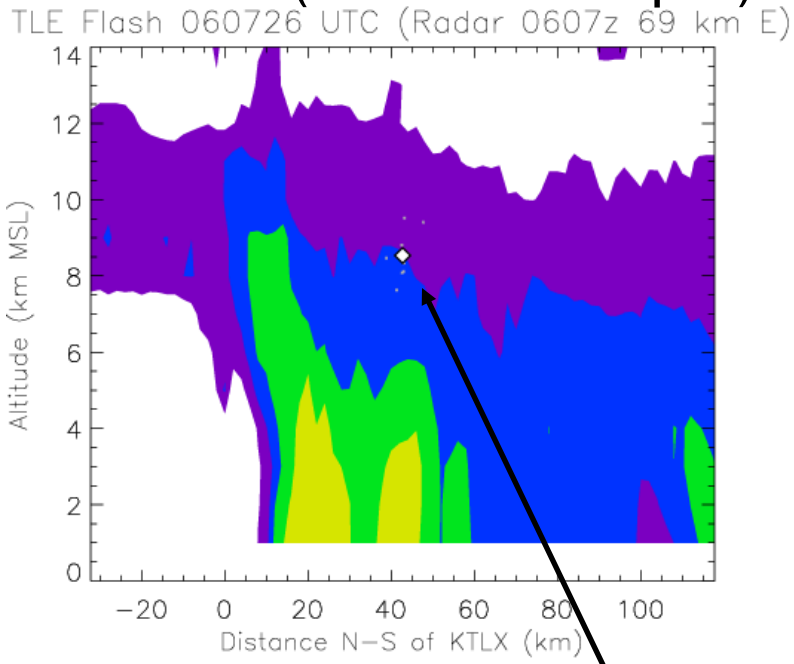
TLE (8.7 km)

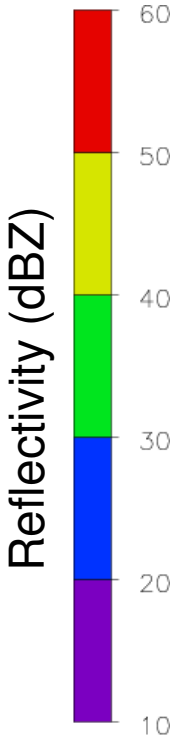
TLE @ 04:27:00 UTC
Parent CG - I_p = +92 kA
iCMC = 640 C km
98 km from OK LMA
Taps upper + charge

Plan View



Vertical (1st 10 LMA pts)

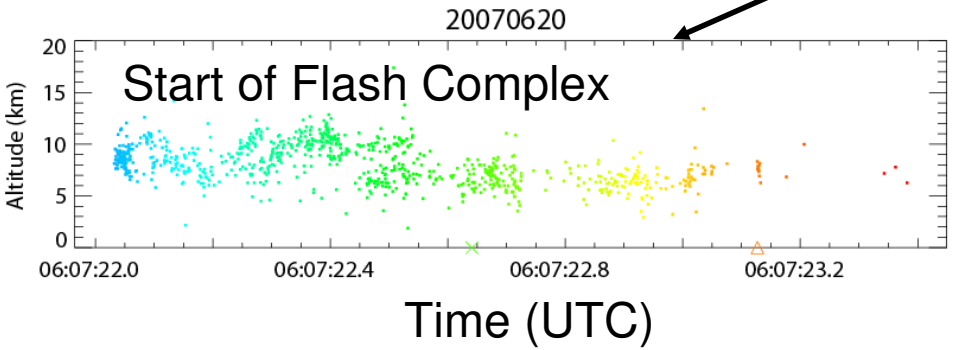


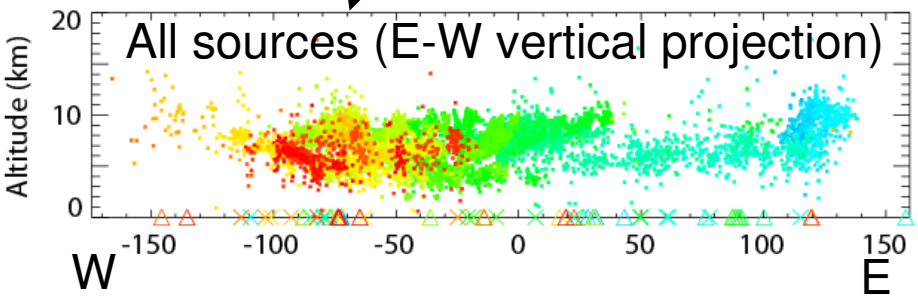


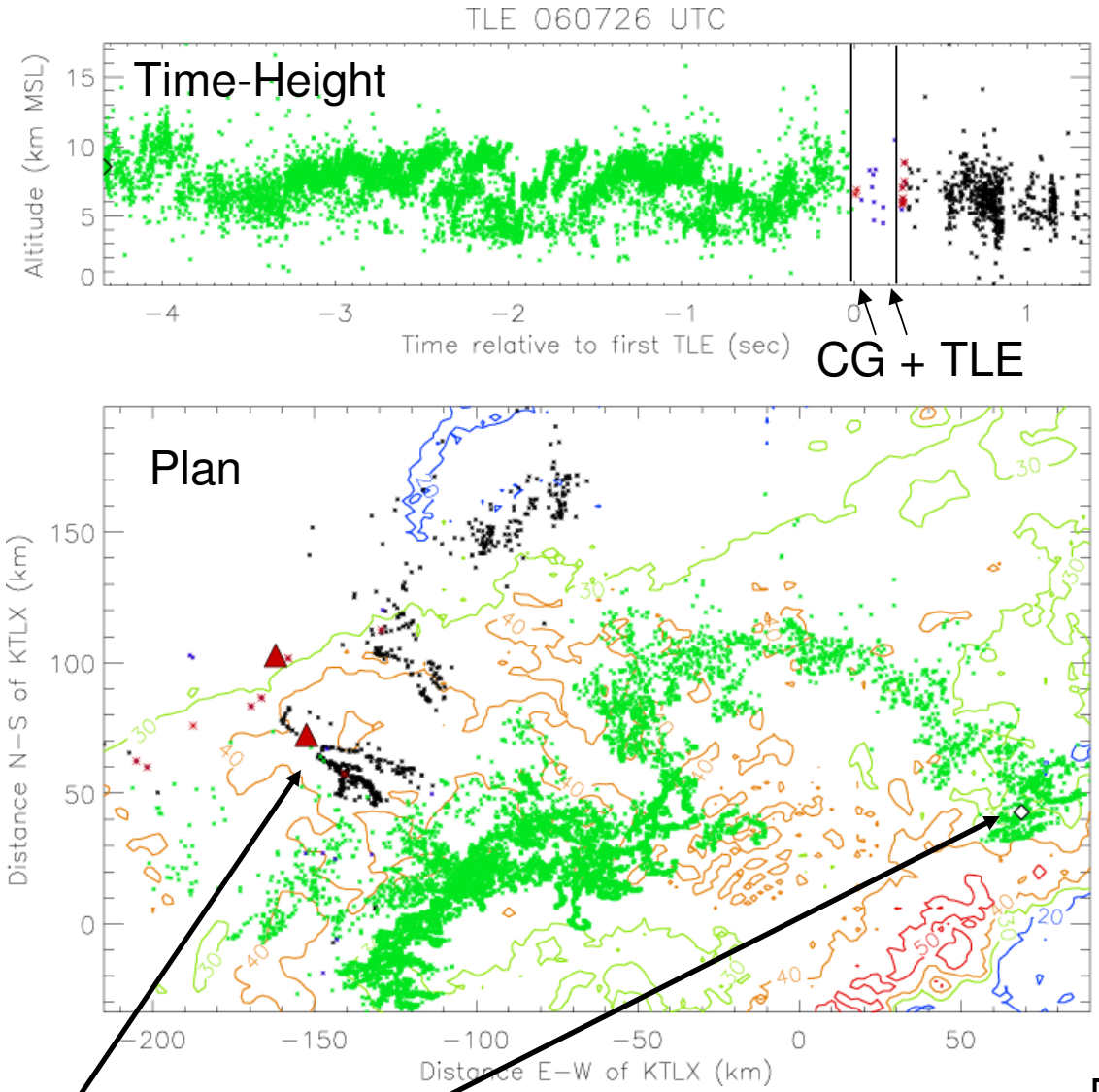
White Diamond - Mean loc of 1st 10 LMA pts
Red Triangles - SP+CG strike locations
Grey Points - LMA sources

Initiation in Decaying Convection just behind Leading Line

Complex flash behavior in vertical



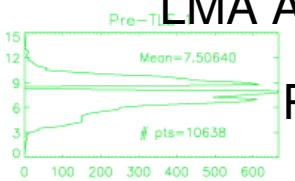




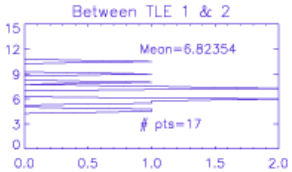
White Diamond - Mean loc of 1st 10 LMA pts
Red Triangles - SP+CG strike locations

Flash Complex ~6 s in duration

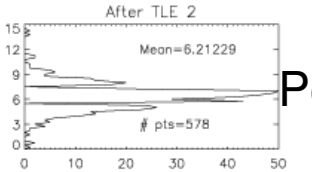
LMA Altitude Histograms



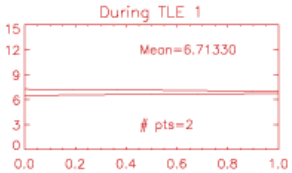
Pre-TLEs (7.5 km)

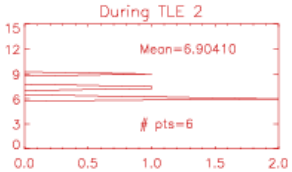


Between TLEs (6.8 km)



Post-TLEs (6.2 km)





Few points during and after TLEs - Change in physical behavior of the lightning?

Two TLEs @ 06:07:26 UTC
Parent CGs - I_p = +63, +42 kA
iCMCs = 166, 236 C km
115, 142 km from OK LMA

2007 Sprite Studies…

- LMA allows us to study details of positive cloud to ground flashes that were associated with sprites
- iCMC data are useful for isolating those storms and portions of those storms that are producing sprites
- Three sprite producing positive discharges were examined. Two began near the melting level in the transition zone and tapped upper level positive charge. The third flash initiated at high levels near the convective core and then propagated rearward and downward into the stratiform region, consistent with a sloping positive charge layer. Casual analysis of other flashes supported these two models.
- Examine more flashes, study more cases.