OBSERVATIONS OF TWO
TRANSIENT LUMINOUS EVENT-
PRODUCING MESOSCALE
CONVECTIVE SYSTEMS

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Scientific Problem

It is currently thought that discharging of large positive charge layers near 0 °C by positive cloud-to-ground (+CG) lightning can lead to transient luminous events (TLEs; Williams 1998; Lyons et. al. 2003).

But we know that other pos. layers can be active in stratiform lightning - namely, downward-sloping upper charge layers (< -20 °C) and charge layers near -10 to -15 °C (e.g., Carey et al. 2005; Lang and Rutledge 2008).

Can these other charge layers also be involved in TLE production? If so, are there intra- or inter-storm differences in the positive charge layers tapped by TLEs? Does this depend on storm structure?
THE STORMS

9 May 2007

Asymmetric Line-Parallel Stratiform MCV with Embedded Convection

20 June 2007

Symmetric Massive MCS/MCC Leading Line/Trailing Stratiform Convective Line Merger
OTHER DATA
NLDN (Stroke Data)
GOES Satellite IR
Rapid Update Cycle (RUC) Analyses
National NEXRAD MOSAICS
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)
WSR-88D NEXRAD RADARS

9 May - Oklahoma City (KTLX) only

20 June - Mosaic using NCAR REORDER and Zhang et al. (2005) weighting

KTLX
Tulsa (KINX)
Vance AFB (KVNX)
Frederick (KFDR)
Dodge City (KDDC)
Amarillo (KAMA)
Lubbock (KLBB)

Convective/Stratiform Partitioning
Yuter and Houze (1998)
Oklahoma Lightning Mapping Array (OK-LMA)

LMA Vertical Error

\[ \Delta Z \quad \text{Rng} \]

0.6 km @ 100 km
1.8 km @ 175 km

Error nearly normally distributed

Sensitive to neg. breakdown in positive charge
20 June and 9 May TLEs were mostly sprites, with some halos and elves

9 May 2007
Few Strong Neg. iCMC
25 Total TLEs ~03-05Z
9 May Radar Evolution

(a) Total (30 dBZ)  
All 30+ dBZ Vol

(b) Convective (30 dBZ)  
Conv 30+ dBZ Vol

(c) Stratiform (30 dBZ)  
Strat 30+ dBZ Vol

(d) Area (Conv - Solid, Strat - Dash)  
Echo Area

9 May Radar Evolution

TLEs
Temporal Evolution Of Lightning Sources

VHF Sources (9 May - Dash; 20 June - Solid)

20 June
(Not Whole Storm)

9 May
TLE/+CG = 3.6% (20 June), 13.7% (9 May)
TLE/Strat +CG = 16.3% (20 June), 35.7% (9 May)
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

20 June Conv TLE Flash

Vertical (1st 10 LMA pts)
Two TLEs @ 06:07:26 UTC
Parent CGs - $I_p = +63$, +42 kA
iCMCs = 166, 236 C km
115, 142 km from OK LMA

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

Flash Complex ~6 s in duration
20 June Stratiform TLE Flash

Plan View

Time-Height

Vertical (1st 10 LMA pts)

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

Initiation in Transition Zone just below Freezing Level
9 May 2007

Initiates in strong convection in southern convective line
9 May 2007
TLE-Producer
03:12:07 UTC

Initiates in weak convection near MCV core
20 June Stats

53 Total TLE +CG Parents w/in 175 km of OK-LMA
27 Stratiform-Initiated TLEs
26 Convective-Initiated TLEs

Rank Sum Non-Parametric Test on Strat vs. Conv
Significantly Different at 90%+ Confidence

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Convective</th>
<th>Stratiform</th>
</tr>
</thead>
<tbody>
<tr>
<td>Init Alt (km MSL)</td>
<td>8.1</td>
<td>7.3</td>
</tr>
<tr>
<td>Initiation Ref (dBZ)</td>
<td>39.3</td>
<td>31.5</td>
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</tbody>
</table>

Not Different
Area, Flash Altitude at Time of TLE (Z_{TLE}), Peak Current
8.4 km MSL (-25°C)
9 May Stats

22 TLEs w/ Detected +CG Parents w/in 100 km of OK-LMA
17 Initiated in/near Northern MCV Convection
5 Initiated in/near Southern Convective Line

Rank Sum Non-Parametric Test on North vs. South
Significantly Different at 90%+ Confidence

<table>
<thead>
<tr>
<th>Parameter</th>
<th>North</th>
<th>South</th>
</tr>
</thead>
<tbody>
<tr>
<td>Init Alt (km MSL)</td>
<td>5.6</td>
<td>7.5</td>
</tr>
<tr>
<td>Pk Current (kA)</td>
<td>56</td>
<td>68</td>
</tr>
</tbody>
</table>

Not Different
Area, Flash Altitude at Time of TLE ($Z_{\text{TLE}}$), Init Reflectivity
6.2 km MSL (-15°C)
## 20 June vs. 9 May Stats

20 June - 53 TLEs produced by parent flashes
9 May - 22 TLEs produced by parent flashes

Significantly Different at 90%+ Confidence

<table>
<thead>
<tr>
<th>Parameter</th>
<th>20 June</th>
<th>9 May</th>
<th>19Jul00</th>
</tr>
</thead>
<tbody>
<tr>
<td>Init Alt (km MSL)</td>
<td>7.7</td>
<td>6.0</td>
<td></td>
</tr>
<tr>
<td>Flash Area (km²)</td>
<td>23225</td>
<td>8461</td>
<td>4494</td>
</tr>
<tr>
<td>Pk Current (kA)</td>
<td>75</td>
<td>59</td>
<td>68</td>
</tr>
<tr>
<td>Z_{TLE} (km MSL)</td>
<td>8.4(-25°C)</td>
<td>6.2(-15°C)</td>
<td>5.2(0°C)</td>
</tr>
<tr>
<td>Init Ref (dBZ)</td>
<td>36.9</td>
<td>38.9</td>
<td></td>
</tr>
</tbody>
</table>

**Not Different**
None
Conclusions

TLE-parent flashes can initiate within any location of an MCS (convective line, stratiform, embedded conv), and this significantly affects the initiation altitude

Regardless of initiation point, TLE-parent lightning tends to stick to one dominant charge layer in an MCS, but this layer can vary between storms (20 June - higher layer; 9 May - lower layer) - Storm morphology may be key!

20 June produced ~6x the TLEs/hour as 9 May
Was ~2-4x larger depending on time
Had at least 2-4x the LMA sources (i.e., lightning)
Also had the higher charge layer - ~35% higher
We know CMC is likely important in TLE production
Help graduate marginal flashes into TLE parents?

*But 20 June had ~12x the stratiform +CG stroke rate!
*And 9 May was the more efficient TLE producer!
## Total CMC - 20 June vs. 9 May

Have total CMC data (RS+CC) for a select group of flashes
20 June - 7 TLE-producing flashes
9 May - 15 TLE-producing flashes
20 June set not truly random, but let's run stats anyway

<table>
<thead>
<tr>
<th>Parameter</th>
<th>20 June</th>
<th>9 May</th>
</tr>
</thead>
<tbody>
<tr>
<td>Altitudes (km AGL)</td>
<td>Higher</td>
<td>Lower</td>
</tr>
<tr>
<td>CC Duration (ms)</td>
<td>61</td>
<td>135</td>
</tr>
<tr>
<td>CC Moment (kA km)</td>
<td>26.4</td>
<td>17.3</td>
</tr>
<tr>
<td>iCMC (C km)</td>
<td>407</td>
<td>269</td>
</tr>
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**Not Different**
- Impulse Charge (~50 C)
- Total Charge (~310 C)
- CC Charge (~260 C)
- Total CMC (~2000 C km)
- CC CMC (~1700 C km)