A Lightning Mapping Array for West Texas

DEPLOYMENT AND RESEARCH PLANS

Eric Bruning
TTU Department of Geosciences
Atmospheric Science Group

Nai-Yu Wang\textsuperscript{1}, Rachel Albrecht\textsuperscript{2}, and Kaushik Gopalan\textsuperscript{1}
\textsuperscript{1}Earth System Science Interdisciplinary Center / CICS, UMD, College Park, Maryland
\textsuperscript{2}INPE, Cachoeira Paulista, SP, Brazil

2011 AMS Annual Meeting, Seattle
5MALD Paper 6.2
25 January 2010, 2:00 pm
TTU has purchased an LMA for West Texas
  - Fall 2010: Site surveys
  - Mid-2011: Install, initial obs
150 km diameter 3D mapping
  - Cloud electrification research
400 km diameter 2D mapping
  - Operational applications
    - Joins networks in OK, AL, DC, KSC, NM
    - GOES-R GLM Proving Ground
  - Covers West Texas Mesonet
West Texas LMA

- Unique regional coverage with OKLMA
  - *Studies of long-track supercells and MCSs*

- NSF proposal submitted for participation in DC3 campaign
  - *Summer 2012, joint with OU for ballooning obs and SMART-R operations*
  - *TTU Ka mobile radars also in the field*
**LMA: Hardware**

**TTU notional setup**

- 11 Stations (1 spare)
- 15 km spacing, 60 km network diameter
- Single tripod-type mount
- RF-sealed electronics enclosure in shade of solar panels
- 2-12VDC marine batteries charged by 1-2 solar panels
- 5.4 GHz wireless modem, 1/4 to 1/2 mi link to wired connection nearby
- 10 W without wireless modem, (modem adds about 5 W)

*Recent NMT installation, photo courtesy Ron Thomas*
• **5** confirmed sites; good to very good noise levels

• **2** sites ok
  - *will check adjacent farm fields*

• **4** sites yet to be surveyed
Relate electrification and lightning morphology to convective storm morphology and kinematic character *across scales*

- Exploit detailed resolution of leaders, which respond to electric potential set up by thunderstorm charge structure

- Where do flashes begin?

- Where do leaders go?

- How do the above factors relate to “large” charge transfers and optical flashing?
CHARGE STRUCTURES REFERENCED TO STORM STRUCTURE

Stolzenburg et al. (1998b), Synthesis

Wiens et al. (2005), Supercell

Stolzenburg et al. (1998a), MCS
Relate electrification and lightning morphology to convective storm morphology and kinematic character across scales

- Exploit detailed resolution of leaders, which respond to electric potential set up by thunderstorm charge structure

- Does turbulent convective mixing impact charge structure and electrification mechanisms?
  - e.g., one- vs. two-cloud lab experiments of Saunders et al. (2006)
A Possible Theoretical Approach (Ongoing Work)

- Apply meteorological idea of frontogenesis ($F$) to electric potential
  - $F =$Time rate of change of the gradient of a scalar
  - Electric potential frontogenesis is time rate of change of the electric field
  - Electric field “frontogenesis” is time rate of change of charge

- Dynamics under mass conservation contains deformation, tilting, confluence, and local source
  - Relate these processes to the formation of potential wells (flash extent) and electric field maxima (flash initiation)

- A route to link flow geometry, flash morphology, and thunderstorm turbulent dynamics?
Initial observations with TTU Ka-band radar suggest we can resolve contrasting eddy & laminar convective flows.

Next step: compare to lightning measurements from the WTLMA (planned Ka deployments through 2012)

Data courtesy John Schroeder, Scott Gunter and the TTU Ka team
Evidence for fine-scale organization of charge: mean quantities vs. large eddies and scalar field morphology

Supercell, Bruning et al. (2010, MWR)

Fig. 3. Across-line cross sections of equivalent potential temperature ($\theta_e$, in K) from weak shear simulations at 180 min using (a) 1000-m grid spacing (at $y = 45$) and (b) 125-m grid spacing (at $y = 49$ km).

Top: Inferred conceptual model of charge structure
Bottom: Observed lightning-inferred charge corresponding to top left panel.

Squall line, Bryan et al. 2003

“Stratiform” “Convective”
Sort LMA data into flashes

- 0.15 s and 3 km threshold
  - *Using McCaul et al. (2009) algorithm*
- Flash footprint: area of convex hull of (x,y) event coordinates
- Events and flash metadata written to HDF5 table for easy query with PyTables

Read, query and plot event and flash data

- Flexible Python pipeline for counting and gridding of any parameter, in any map projection
  - *https://bitbucket.org/deeplycloudy/lmatools/src*
Flash size spectrum and $\kappa^{-5/3}$ line
Squall line vertical velocity spectra and $\kappa^{-5/3}$ line (Bryan et al. 2003, Fig. A1)

Three 125 m simulations with different diffusion coefficients
Overlay of Bryan et al. (2003) and 10 June 2009
SOME REMARKS ON SIMILARITIES

Overall shape of flash size and kinetic energy spectra are very similar.

Peak in eddy energy spectrum and peak in flash size spectrum are at about the same wavelength (several km).

Ostensible $\kappa^{-5/3}$ subrange is at a 1 km or less.
22 June 2004 - Squall Line & Cellular Convection

The image shows a graph with a logarithmic scale on both axes. The x-axis represents flash width (square root of area, km), and the y-axis represents the number of flashes. The graph displays a blue line with fluctuations, and a green line indicating a trend.

The x-axis ranges from $10^{-1}$ to $10^2$, and the y-axis ranges from $10^{-3}$ to $10^3$. The graph suggests an exponential relationship between flash width and the number of flashes.