COMET Outreach

FINAL REPORT

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Name of University Researcher Preparing Report: Eric Bruning

NWS Office: Lubbock, Texas

Name of NWS Researcher Preparing Report: Steve Cobb

Partners or Cooperative Project: GOES-R Pre-Launch Products Research — Partners

Project Title: Operational Trials of Total Lightning Data and Training at the NWS Lubbock Forecast Office

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Report Date: 31 October 2012

Section 1: Summary of Project Objectives

The two core objectives of this project are to 1) deliver data from the West Texas Lightning Mapping Array (LMA) to NWS Lubbock, and use it in operations, and 2) to provide training to forecasters in the interpretation and use of the LMA data.

Section 2: Project Accomplishments and Findings

2.1 Product delivery

TTU deployed a preliminary LMA in research mode, and collected the first data in storms on 21 November 2011, followed by another storm on 3 December 2011. NWS personnel assisted TTU in deployment activities by providing contacts for field site locations and helped with site surveys and installation of some of the initial equipment. Work continued throughout late winter and early spring on real-time communication and processing infrastructure for the LMA. As of 10 April 2012, real-time data was delivered regularly to the NWS as a stream of points. Aggregated 1-minute ASCII point files, gridded flash-level products, and imagery via the web followed by 25 April 2012. Data flow is summarized in Figure 1.

The 1-min gridded products were implemented on a server at TTU using a real-time version of the McCaul et al (2009) flash-sorting algorithm. Flash extent density, mean flash area, and flash origin density gridded products were produced at 1 min, 1 km resolution. A Local Data Manager (LDM) server was installed and began providing 1-minute ASCII source data and the aforementioned gridded, AWIPS-ready products. NWS Southern Region picked up this product feed and forwarded it to NWS LUB. The feed was also picked up by the NOAA Hazardous Weather Testbed at the National Severe Storms Laboratory in Norman, OK for use in their annual Spring Program (Calhoun et al. 2013). The same product feed to Norman was also used as part of the National Lightning Jump Field Test.

The real-time stream of LMA source detections (of which there are 10s to hundreds per flash) were delivered with 1-2 second latency from flash to display in the standalone LiveLMA Java program written by New Mexico Tech. TTU and WFO LUB developed a public delivery method over an HTTP/WebSocket connection that allowed multiple users to share a single stream of points throughout the local forecast office's intranet. This method of display has been used successfully in operations, as will be detailed below, and is preferred by some forecasters, especially those with a scientific background or interest in lightning data and new technique development in general.

At some point between the processing server and the LUB office, key portions of the AWIPS grid records were scrubbed from the data files. These empty files made it impossible to test display in AWIPS. Eric Bruning, Steve Cobb, Jason Jordan, and Joe Jurecka reevaluated this strategy in June 2012, and decided to approach the NOAA HWT in Norman, OK about using their methodology for producing the same products on their robust product prototyping system. Our HWT contacts, Kristin Calhoun and Darrell Kingfield, agreed and have begun producing AWIPS-II-ready gridded flash extent and flash initiation density products. They are delivered over the SRH LDM feed and have been ingested into the AWIPS-II ADAM box and CAVE display within the Lubbock office. A sample screen shot is provided below in Figure 2.

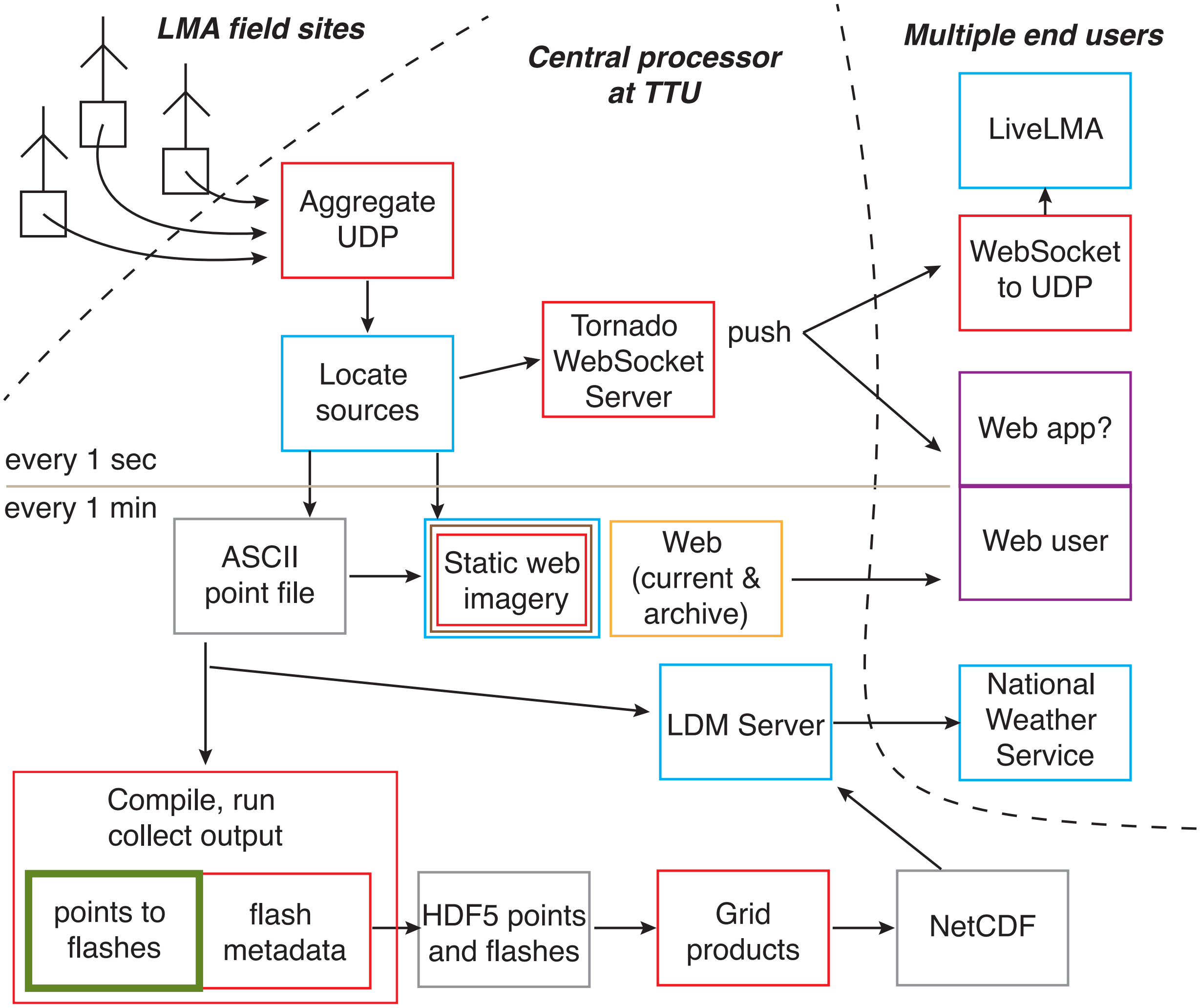
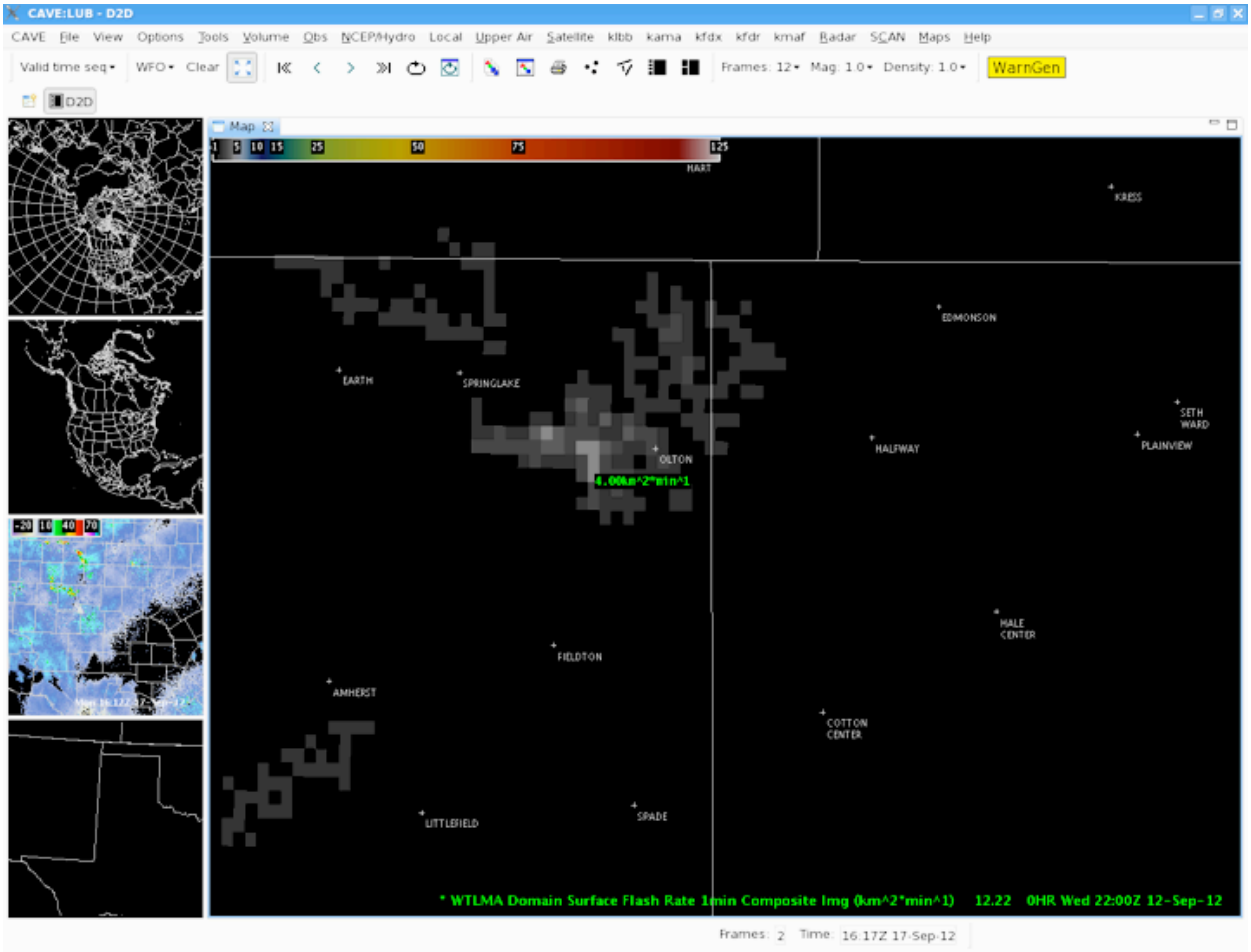


Figure 1. Technical diagram of data flow and processing for the WTLMA.



* WTLMA Domain Surface Flash Rate 1min Composite Img (km^2*min^1) 12.22 0HR Wed 22:00Z 12-Sep-12

Figure 2 West Texas LMA data displayed in the AWIPS II CAVE display for 22:00 UTC on 12 September 2012.

2.2 Training and operational utility of total lightning data

The goal of our training module development was to strengthen the ties between lightning and meteorological conceptual models through provision of lightning training materials that relate storm electrification to storm morphology, with a secondary goal of providing a solid understanding of the LMA’s characteristics when used to detect total lightning.

Formal training materials for two modules, *Storm Electrification and Total Lightning Meteorology: Storm Electrification and Signatures*, and *LMA Hardware and Data*, have been developed and reviewed by university and operational parties. Voiced narration for the modules has been recorded in the Articulate Presenter software, and the completed modules have been placed in the NWS Southern Region LMS for dissemination to forecasters. These materials were completed at the end of September 2012, which was later than expected because the student funded to develop these materials had several medical issues. The training modules have also been provided to Kristin Calhoun at NSSL for discussion and possible use within the NWS Warning Decision Training Branch as they develop total lightning training materials.

As it became clear that the WTLMA data would be available to forecasters before formal training was complete, we decided that the graduate student would continue to work on the training material while Bruning delivered oral, in-person training in early 2012 with a small core (3-5 people) of forecasters interested in the lightning data. After a few of these sessions, the forecast office requested the university develop a double-sided quick-look training summary sheet summarizing basic detection characteristics of the LMA and principles of interpretation. An initial version and an update in response to forecaster comments were delivered by TTU, and there were further tweaks by the NWS. The resulting document is attached in Appendix A. The training sheet was easily incorporated into the local workflow since a similar sheet was already in use for dual-pol data interpretation. We think a summary sheet complements intensive but fundamentally short-lived traditional training by allowing forecasters to quickly review key training principles in the middle of actual storm situations.

The LMA data were first used in real-time operations in early April 2012. Eric Bruning sat on three occasions with Steve Cobb, who served as mesocale forecaster for the events. The LMA data were used as a situational awareness tool. This method allowed traditional radar interrogation and warning operations to continue unimpeded while enabling real-time evaluation of the LMA data in a warning environment. Relevant changes in lightning trends, including new cells, rapid increases in flash rate, and changes in average flash size / compactness relative to storm structure were communicated as complementary information for assimilation in the warning decision maker's mental model of storm physics. The use of a situational awareness forecaster at the CWA scale was a helpful model for gradually integrating new products and decision-making models into workflows while not disrupting known workflows or pushing new tools. We also think this model is helpful in showing a possible role for lightning data both in high-pressure warning decision situations as well as in situations with more general thunderstorm activity that does not frequently reach severe thresholds. The latter is a role for lightning data that has not, to date, received much visibility.

In order to facilitate post-analysis of the real-time LMA data, ASCII data files were made available for download on the TTU webserver. TTU also developed a LiveLMA replay script to enable interrogation of the LMA data alongside other data.

During the project, Bruning and MacGorman (2013) submitted a new manuscript on the physical controls on flash rate and extent. The key findings of this study were that flash rate and in-cloud extent are opposed, and that the distribution of flash sizes in storms is nearly identical to the distribution of turbulent kinetic energy. This strongly suggests, and observations qualitatively support, that regions of more turbulent flow in thunderstorms, especially those near deep convective updraft, should be characterized by smaller flashes and more-frequent flash rates.

In summary a foundation was laid and demonstrated for real-time and operations-focused science R&D as a result of this project. Training is now prepared to provide a baseline on current conceptual models of lightning in relationship to storm structure and processes. Lightning flash rate trending applications and new decision support applications were identified. Formal development of new training focused on these applications, as well as new products such as average flash area discussed by Bruning and MacGorman (2013) could serve as opportunities for future work.

Section 3: Benefits and Lessons Learned: Operational Partner Perspective

This project provided NWS forecasters with a new observation tool that benefited them in the warning decision-making process and in decision support efforts. The introduction of total lightning data produced by the WTLMA has given forecasters not only a base tool for situation awareness but on average 5-10 minutes lead time in recognizing developing strong convection which may need further attention. The 1-2 second latency of the raw flash sources is advantageous in recognizing new updrafts in evolving supercell and multicell convection as well as time-rate and flash size which is important in distinguishing the relative strength of the individual cells.

On June 4, 2012 we suffered a catastrophic loss of real-time ingest of products in AWIPS during a severe episode. WTLMA data was used for a time as a primary source in warning-decisions while our backup office was getting spun up on the event. Throughout the remainder of the evening while radar data was being restored, total lightning data was used to alert the backup office of where new convection of interest was developing and to assist them in the warn-don't-warn process.

Numerous times since total lightning data has been available we have provided decision makers at outdoor events and in commercial businesses with probabilities of hazardous lightning and flash proximity information for safety purposes.

The saturation of bandwidth within the NWS external network has resulted in the need to be creative in how datasets are shared between the NWS and TTU. With the failure to successfully deliver processed netCDF lightning products directly into AWIPS a method to get the raw source data to all operational PCs was devised using a HTTP/WebSocket connection.

Section 4: Benefits and Lessons Learned: University Partner Perspective

This work benefited the University by building an initial relationship with the local NWS office in Lubbock in the area of storm electrification and lightning. In addition to relationships with the Science and Operations Officer, we were able to identify individuals in the forecast office with specific computing- and lightning-related skills and interests that should benefit future collaborations.

Consensus building and close interaction with a few interested parties in an office has been an effective way to explore new application areas while instilling comfort and confidence with a new dataset before general introduction to the office as a whole. TTU has been privileged to work with a Lubbock office that is curious while remaining focused on its operational mission. A slower pace in reaching deliverable items on our original work plan has accompanied our successful interaction model, and we plan to use the lesson of this experience to adjust the plan and scope of future work.

While the AWIPS-specific file data file format is a straightforward NetCDF file that was easy to produce at TTU, actual configuration of AWIPS to ingest this product was more challenging than expected. The

NWS in Lubbock was helpful in providing sample grid files and made a valiant attempt to integrate the products in their operational system, but in the future we would propose to work with the NOAA HWT in producing the real-time products and in configuration of AWIPS / AWIPS II for these custom products. They are also natural regional partners due to their close association with the Oklahoma Lightning Mapping Array, allowing us to prototype regional-scale products with the unique, combined regional coverage of the WTLMA and OKLMA.

Through the process of developing training materials, a graduate student has been exposed to NWS operations and forecaster needs while being given an opportunity to practice and transfer scientific thinking models learned in an academic setting. The graduate student has in turn educated the PI in practical aspects of communicating weather hazards and the needs of NWS customers. Many of the lessons learned about operational needs have informed the emphases of several student thesis projects, results of which will be presented at upcoming national meetings, as listed in Section 5. Those discussions have also served as a forum to discuss with the graduate student the scientific challenges associated with utilizing lightning data in a way that could ameliorate weather impacts on human activities.

Section 5: Publications and Presentations

5.1 Refereed journal articles

Bruning, E. C., S. A. Weiss, and K. M. Calhoun, 2012: An evaluation of inverted polarity terminology and electrification mechanisms. *Atmos. Res.*, in press, doi: 10.1016/j.atmosres.2012.10.009.

Bruning, E. C. and D. R. MacGorman, 2013: Theory and observations of controls on lightning flash size spectra. *J. Atmos. Sci.*, submitted.

5.2 Conference presentations

Bruning, E. C., 2011a: West Texas LMA: Deployment and operations update. *GOES-R Geostationary Lightning Mapper Science Meeting*, Huntsville, AL.

Bruning, E. C., 2011b: Lightning flash size spectra: Observations and theory. *Eos Trans. AGU, Fall Meet. Suppl.*, AE31A-0266.

Bruning, E. C., 2012: West Texas LMA: Operational and Research Use. *GOES-R Geostationary Lightning Mapper Science Meeting*, Sep. 19-21, Huntsville, AL.

Calhoun, K. M., E. C. Bruning, D. M. Kingfield, S. D. Rudlosky, C. W. Siewert, T. Smith, G. T. Stano, and G. J. Stumpf, 2013: Forecaster use and evaluation of pGLM data at the NOAA Hazardous Weather Testbed and GOES-R Proving Ground. *Preprints, Sixth Conference on the Meteorological Applications of Lightning Data*, AMS Annual Meeting, Austin, TX, USA., submitted

Cobb, S., J. Jordan, E. Bruning, and J. Daniel, 2012: Early results of operational use of total lightning data from the West Texas Lightning Mapping Array. *26th Conference on Severe Local Storms, Nashville, TN*, submitted

Conder, M. R., S. Cobb, G. Skwira, E. Bruning, and J. Daniel, 2012: Multi-sensor observations and analysis of the 14-15 June, 2012 heat bursts in the Texas Panhandle. *26th Conference on Severe Local Storms, Nashville, TN,* submitted

Daniel, J., E. Bruning, S. Cobb, J. Jordan, and J. W. Jurecka, 2013: Operational Trials of Total Lightning Data and Training at NWS Lubbock Forecast Office, *6th Conference on the Meteorological Applications of Lightning Data, Austin, TX,* submitted

Plourde, C. M. and E. C. Bruning, 2013: An investigation of lightning behavior during the QLCS in Northwestern Texas on March 18 & 19. *Preprints, Sixth Conference on the Meteorological Applications of Lightning Data*, AMS Annual Meeting, Austin, TX, USA., submitted

Sullivan, V. C., E. C. Bruning, D. R. MacGorman, P. R. Krehbiel, W. Rison, and H. E. Edens, 2013: A comparison of the electrical characteristics of three different storm systems during DC3. *Preprints, Sixth Conference on the Meteorological Applications of Lightning Data*, AMS Annual Meeting, Austin, TX, USA., submitted

Cobb, S., J. Jordan, E. Bruning, and J. Daniel, 2012: Early results of operational use of total lightning data from the West Texas Lightning Mapping Array. *26th Conference on Severe Local Storms, Nashville, TN*, submitted

Schultz, C. J., E. C. Bruning, L. D. Carey, W. A. Petersen, and S. Heckman, 2011: Total lightning within electrified snowfall using LMA, NLDN and WTLN measurements. *Eos Trans. AGU, Fall Meet. Suppl.*, AE12A-03.

Section 6: Summary of University/Operational Partner Interactions and Roles

TTU: Lightning Mapping Array deployment, operation, basic data processing, and product production.
NWS: AWIPS product format specification and product ingest and display on NWS systems.
TTU and NWS: Identification of training module needs and development of outline
TTU: Development of training module content,
TTU and NWS: development of operations quick-look lightning reference
NWS and TTU: Coordinate graduate student participation in lightning-related forecast activities

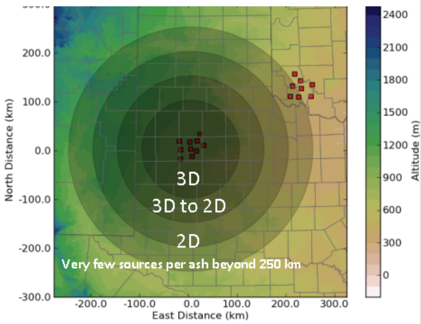
7. References

McCaul, E. W., S. J. Goodman, K. M. LaCasse, and D. J. Cecil, 2009: Forecasting lightning threat using cloud-resolving model simulations. *Weather and Forecasting*, **24 (3)**, 709–729, 10.1175/2008WAF2222152.1

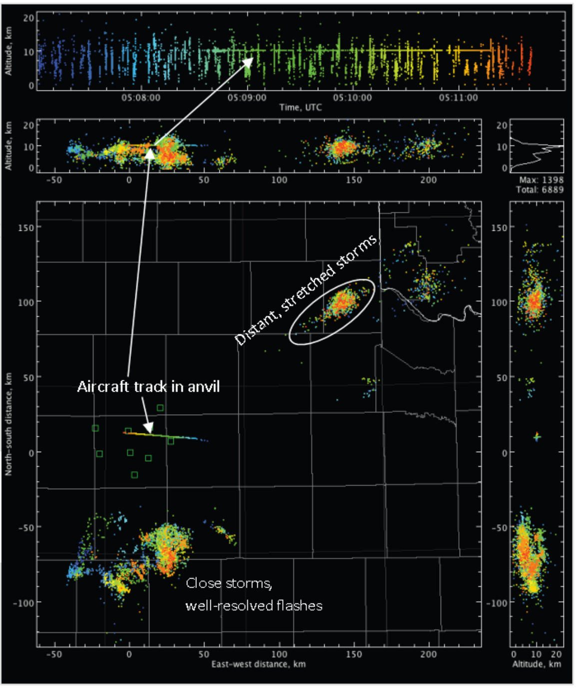
Appendix A

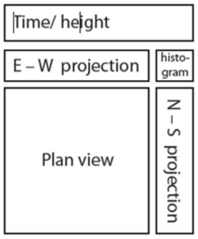
West Texas LMA Quick-Look Training Sheet (following pages)

WTLMA Coverage Area
Max range—240 km
Best within 100-150 km of LBB

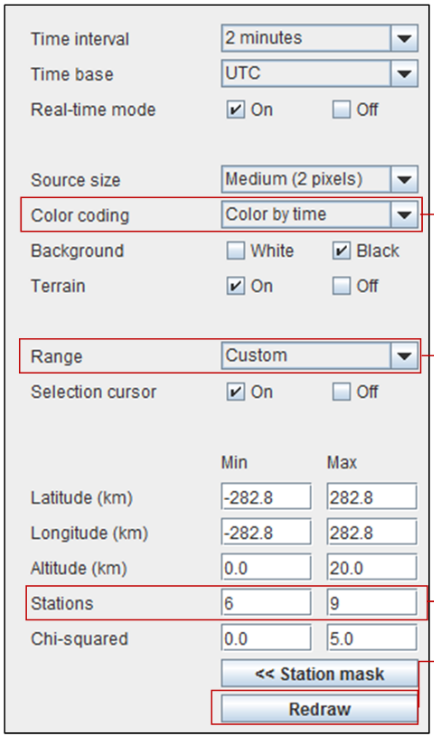


In 2D coverage, also expect:
- Increasingly large altitude errors
- Increasing minimum detectable altitude: earth curvature





Colors:
cool = earlier
warm = later



Time interval: 2 minutes
Time base: UTC
Real-time mode: ☑ On ☐ Off

Source size: Medium (2 pixels)
Color coding: Color by time
Background: ☐ White ☑ Black
Terrain: ☑ On ☐ Off

Range: Custom
Selection cursor: ☑ On ☐ Off

	Min	Max
Latitude (km)	-282.8	282.8
Longitude (km)	-282.8	282.8
Altitude (km)	0.0	20.0
Stations	6	9
Chi-squared	0.0	5.0

Log-density: good for showing cellular features
Source plots: good for seeing channel structure

Mouse scrollwheel allows you to zoom in and out
Right click + hold pans
Left click + drag allows area/ time selections in any projection

Minimum stations:
Use **5** (short range) or **6** (long range) click
Redraw to see change

Rules of thumb:
More, smaller flashes in stronger updrafts

Fewer, larger flashes in anvils or stratiform regions

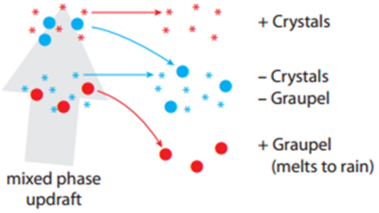
Tropical multicell: about 1 flash per minute
Supercell: >1 flash per second

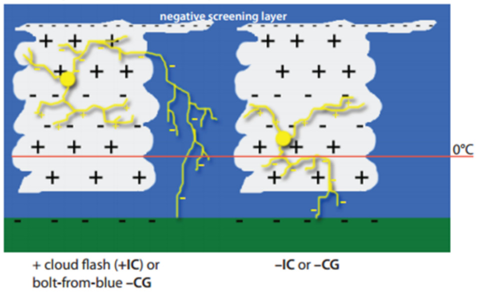
West Texas LMA Operations Cheat Sheet – front side

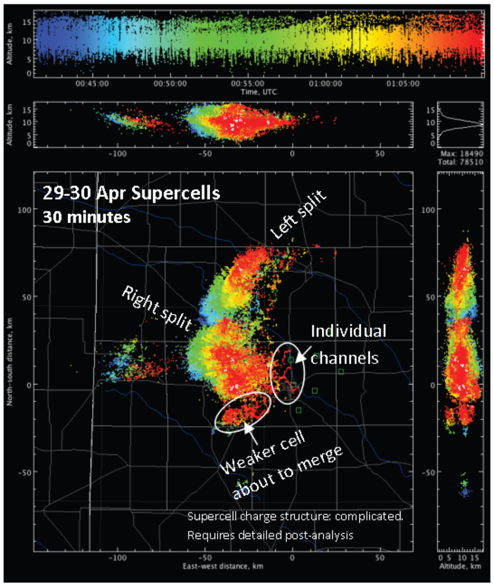
Electrification occurs in updraft mixed phase region (~-15C) -> crystal-graupel charge separation occurs -> larger graupel (net – charge) precipitates below smaller crystals (net + charge) -> km-scale charge regions

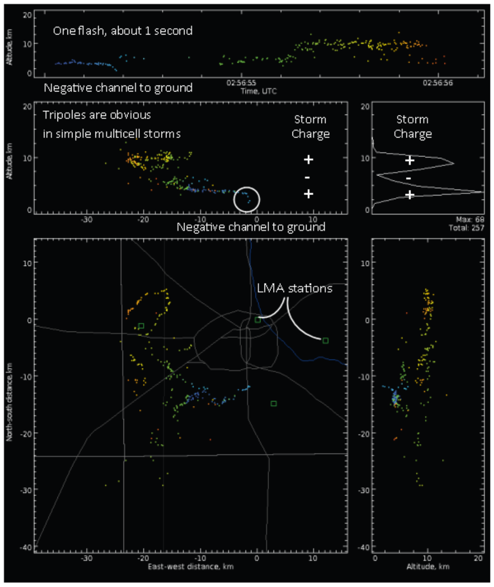
Intensifying updraft means liquid water condenses at greater rate which produces more graupel. More graupel colliding with ice leads to more charge generation and separation. The result is an increase in electrical field within and beneath cloud.

Electrification ◄———— Normal polarity tripole ————► Lightning









LMA detects VHF point sources made by lightning channel steps.

A CG's channel to ground is a tiny fraction of points detected.

Negative channels make more points, and +CGs are nearly invisible

to the LMA because positive leaders move less impulsively

West Texas LMA Operations Cheat Sheet – back side