2014
23rd International Lightning Detection Conference
18 - 19 March • Tucson, Arizona, USA
5th International Lightning Meteorology Conference
20 - 21 March • Tucson, Arizona, USA

Development of a Total Lightning Climatology for Oklahoma using the Oklahoma Lightning Mapping Array

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Abstract— **The Oklahoma Lightning Mapping Array (OK-LMA) has collected the time and location of the very high frequency (VHF) radiation sources produced by all types of lightning in central Oklahoma since the spring of 2003. To produce a useful climatology using these data, one must correct for the considerable bias with range in the minimum signal strength that can be detected across the range of OK-LMA coverage. Several methods for making this correction were attempted, and some yielded unrealistic results. A brief summary of the attempted methods and justification for the method we have chosen will be presented. Using this method, we have produced monthly, seasonal, and annual plots of the geographic distribution of lightning density in central Oklahoma with 10 km horizontal grid spacing. We also have examined how the seasonal and geographic variations in the diurnal time-series of flash rates are related to corresponding variations in the dominant mode of deep convection.**

Keywords—lightning, climatology, LMA

I. INTRODUCTION

The Oklahoma Lightning Mapping Array (OK-LMA) has collected lightning location data over central Oklahoma for over ten years. The long-term goal of this project is to reprocess the lightning data in such a way that they will be useful for comparisons to other climatological meteorological data (i.e., rainfall totals) and for evaluations for other practical applications (i.e., electrical power outages). Because the minimum radiated signal strength that can be detected by a station increases with range from the station, there is a bias of more points are collected over the network than at longer

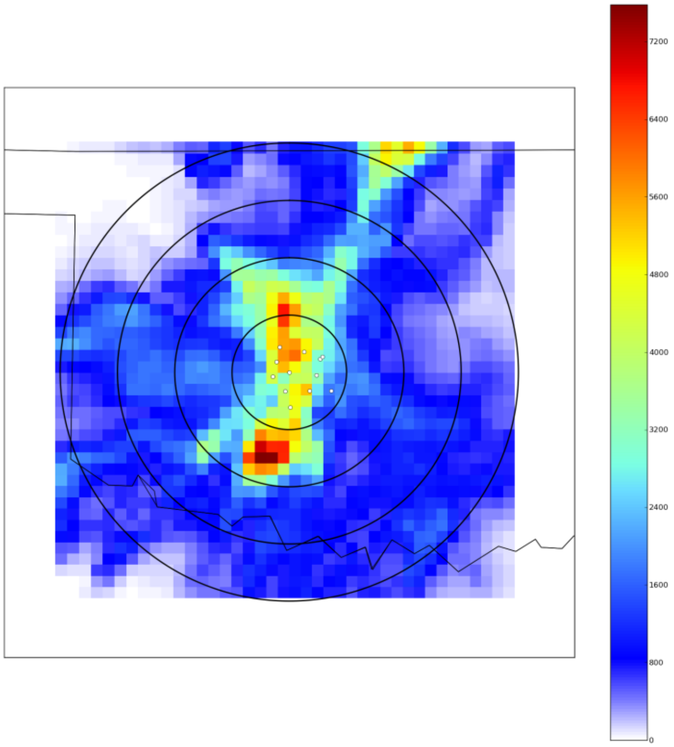

Fig. 1. Number of seconds with at least one VHF source per (10kmx10km) gridcell as denoted by the colorbar, with warm colors indicating more points. The outline of the states is shown, along with range rings every 50km centered on the OKLMA. White dots indicate the locations of individual LMA stations.

This work is sponsored by NASA Grant NNX12AC65G and NOAA/NESDIS grant L2NSR20PCF.

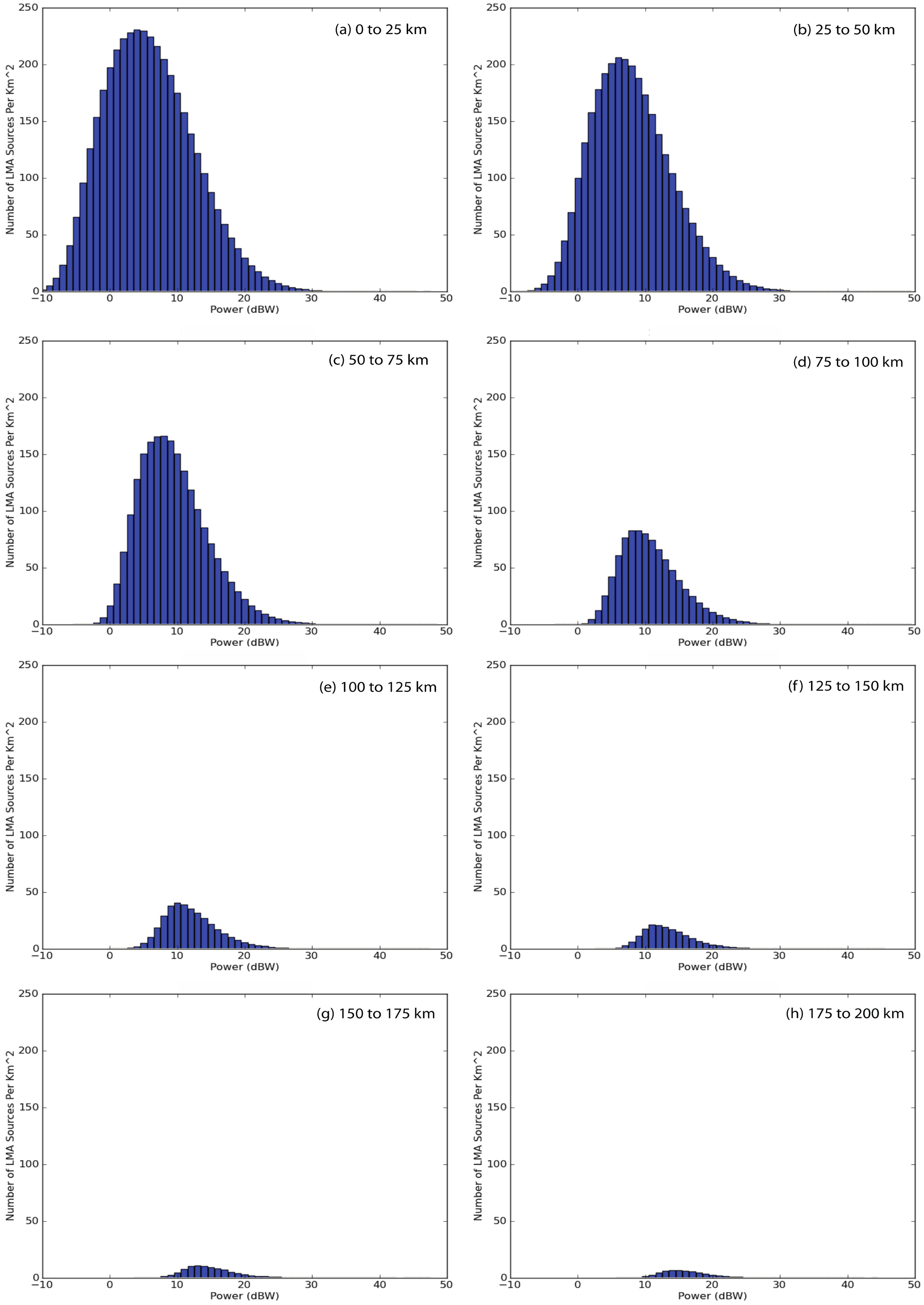

Fig. 2. Histograms of the number of LMA sources per km^2 with each power value for different ranges out to 200km, every 25km as labeled (a)-(h).

ranges [e.g., Thomas et al., 2001 and Thomas et al., 2004]. Therefore, a simple count of detected sources is biased in range. Two possible ways of correcting this bias have been explored - one in which individual radiation sources produced by the lightning are gridded and then filtered using a power and range-dependent criteria (VHF sources method) and one in which the sources are sorted into individual flashes and then gridded (lightning flashes method). Neither method provides the perfect solution, but both are presented here in order to highlight the difficulties of using large quantities of LMA data and to illustrate the pros and cons of each method. The strengths and weaknesses of each method in turn suggest further processing that might be useful in normalizing the LMA data for climatological purposes.

II. METHODOLOGY

All lightning data were pre-filtered using certain criteria no matter which range/power-correction method was used. All source points above 20km in altitude and with a χ^2 value of greater than one are disregarded. All source points must have been detected by at least six stations to be included. All final data are plotted on a 10km by 10km grid centered on the LMA stations, with a maximum distance of 200km from the center of the LMA.

A. *VHF Sources Method*

For the VHF sources method, the data are normalized such that the low power sources detected near the center of the array are removed. To determine what percentage of points with each power to remove, a subset of the data was used. The subset which was chosen consists of three highly-active lightning days in which lightning was present across the entire range of the OKLMA each day (Figure 1). The domain was partitioned by distance from the center of the array, with range rings every 25km out to a distance of 200km. A range of 150-175km was used as the distance at which to normalize, since this is far enough away from the center of the array as to have a drop off in detection of sources with low powers but still within the reliable 2-D range of the LMA network and at close to 100% flash detection efficiency [Thomas, 2004]. Histograms of the density of sources (count divided by partition area) with each power for each range are shown in Figure 2. The shape of the 150-175km histogram (Fig. 2g) was used to determine what percentage of sources were kept for each power value at each range interval. Once the data were normalized, the sources were gridded such that every grid cell that had at least one source point per second was counted one time.

B. *Lightning Flashes Method*

For the lightning flashes method, the VHF sources were sorted into flashes using the method developed by McCaul et al. [2009]. All VHF sources within 3km in space and 0.15s in time were grouped together into a flash, and all flashes with less than ten points were ignored. The flashes were counted on the same 10km by 10km grid as in the VHF sources method. The count in each grid cell was incremented for each flash that passed through it.

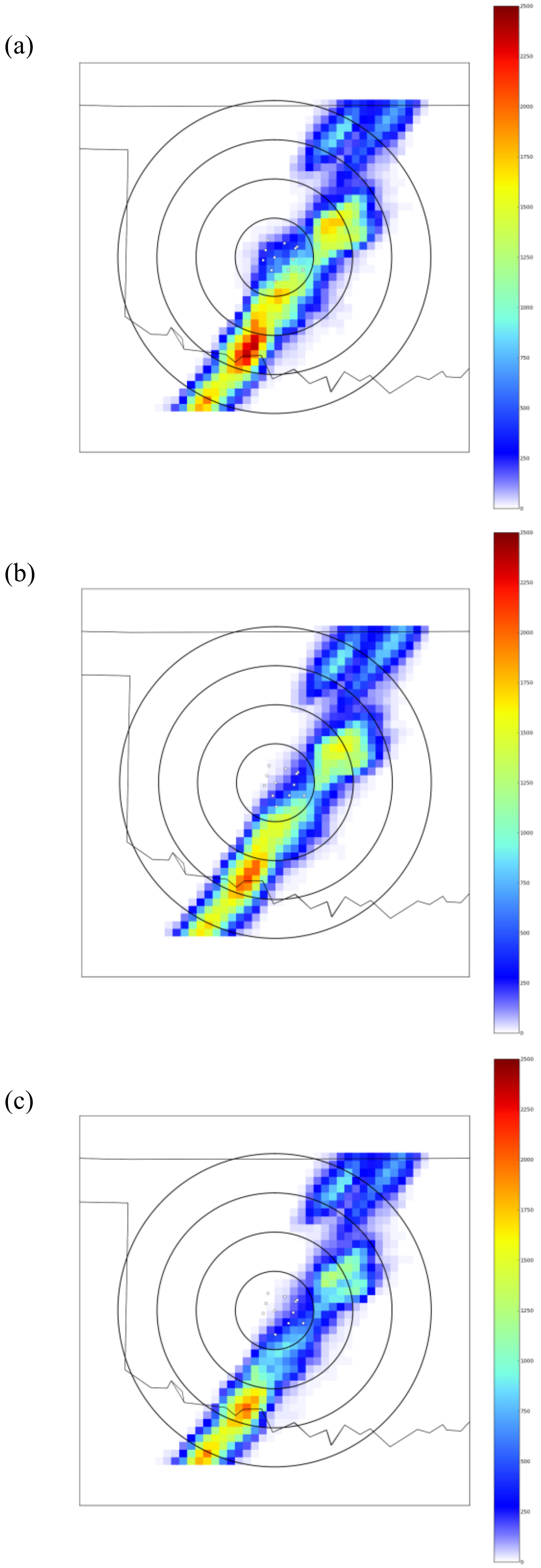

Fig. 3. (a) and (b) Number of seconds with at least one VHF source per (10kmx10km) gridcell as denoted by the colorbar, both before (a) and after (b) the normalization correction for 0300 to 0400 UTC on 6 June 2008. (c) Flash extent densities for the same time period. In all plots, the outline of the states is shown, along with range rings every 50km centered on the OKLMA. White dots indicate the locations of individual LMA stations.

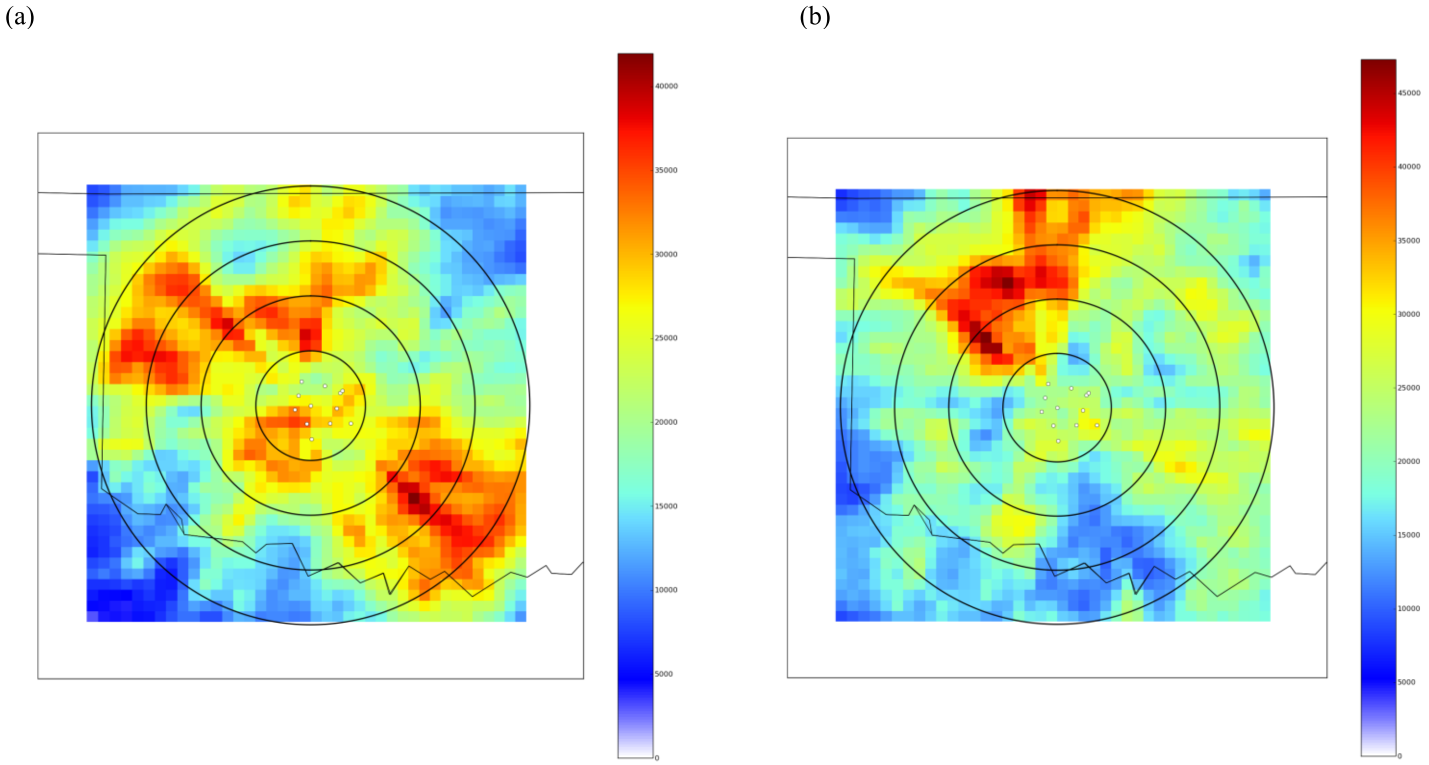

Fig. 4. Number of seconds with at least one VHF source per (10kmx10km) gridcell as denoted by the colorbar for all Mays from 2007-2011 (a) and for all Junes from 2007-2011 (b). The outline of the states is shown, along with range rings every 50km centered on the OKLMA. White dots indicate the locations of individual LMA stations. In these preliminary plots, all VHF sources with powers less than 5dBW have been disregarded.

III. COMPARISON OF THE METHODS

On 6 June 2008, a squall line with intense lightning stretched across the full range of the LMA network. Fig. 3 shows a comparison of the gridded lightning data using the VHF sources method before normalization (Fig. 3a) and after normalization (Fig. 3b), and using the lightning flashes method (Fig. 3c) for one hour of data (0300-0400 UTC). Both methods eliminated extra source points over the network and had a maximum in lightning activity in the same location. The VHF sources method eliminated more sources close to the network than the lightning flashes method.

IV. PRELIMINARY RESULTS

Preliminary monthly and seasonal plots have been created using a simplified method of bias correction in which sources with power less than 5dBW (at all ranges) have been removed from the data set. Lightning data from May (Fig. 4a), and June (Fig. 4b) of 2007-2011 (combined) are presented here. Seasonal variations in the lightning patterns for these two months seem to follow the paradigm for seasonal patterns of thunderstorm modes. For example, May is the peak month in Oklahoma for isolated supercell thunderstorms across the entire domain of the LMA; whereas in June there tend to be mostly mesoscale convective systems (MCSs) that move from the northwest to southeast across the domain. This pattern is mimicked in the LMA data. In May the lightning activity is widespread across the domain, with obvious localized maxima, but in June the lightning activity is predominately in the northwestern quadrant of the domain, where many MCSs originate.

V. DISCUSSION AND FUTURE WORK

Overall, the two methods of correcting the bias in VHF source detection efficiency with range seem comprable in this example. Each method has slight advantages and disadvantages over the other. The VHF sources method is slightly faster to run and eliminates more points over the network; however, there is concern that it is eliminating too many points close to the network. If true, this is due to the subset of data that is used for the normalization not being uniform enough in coverage. Future work needs to be done to determine if there is a different subset of usable data with more uniform coverage across the network, or if the locations of the maxima in the subset used in this example are representative of the biases in the network detection efficiency.

The lightning flashes method also eliminates the extra source points over the network. It also has the advantage of being flexible enough to use over any network, including the new southwestern stations of the OKLMA that were added in 2013, which will make for a more comprehensive climatology. However, recent examinations of the data have shown that as lightning approaches the center of the LMA, the average flash size drops dramatically while the flash rate increases, which may indicate that a large number of small flashes are being detected only over the center of the network. Further investigation needs to be done to determine if this is the case; and, if so, what can be done to correct it.

VI. ACKNOWLEDGMENTS

The authors would like to thank Paul Krehbiel, Ron Thomas, Ted Mansell, and Harold Brooks for their input and suggestions on this topic.

VII. REFERENCES

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

Thomas, R. J., P. R. Krehbiel, W. Rison, T. Hamlin, J. Harlin, and D. Shown (2001), Observations of VHF source powers radiated by lightning, Geophys. Res. Lett., 28(1), 143-146.

Thomas, R. J., P. R. Krehbiel, W. Rison, S. J. Hunyady, W. P. Winn, T. Hamlin, and J. Harlin (2004), Accuracy of the lightning mapping array, J. Geophys. Res., D14207, doi: 10.1029/2004JD004549.