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Comparison of Data from the North Georgia Lightning Mapping Array and the GOES-16 Geostationary Lightning Mapper

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***Abstract*—The North Georgia Lightning Mapping Array (NGLMA) is an array of sensors deployed by the Severe Storms Research Center (SSRC) at the Georgia Tech Research Institute. Centered on the metropolitan Atlanta area in north Georgia, the NGLMA uses 12 ground-based sensing stations to detect total lightning. In this paper, we will compare total lighting data collected in north Georgia by the NGLMA to the data detected by the GOES-16 Geostationary Lightning Mapper (GLM) over this same area for two cases in July and September of 2017. Results indicate that the GLM data is offset to the east by 0.05 to 0.1 degrees in longitude (5-9 km), with no significant latitudinal offsets found.**

Keywords—GLM, LMA, detection efficiency, lmatools, GOES-16

I. INTRODUCTION

Prior to the deployment of the Geostationary Lightning Mapper (GLM) onboard GOES-16 launched in November 2016, detecting total lightning over large regions in North and South America was not possible. Detecting total lightning, defined as the combination of cloud-to-cloud and cloud-to-ground lightning, was formerly limited to the utilization of ground-based instruments and networks. All ground-based lightning detection operations continue to provide critical data and measurements. Total lightning information specifically is advantageous in the realm of meteorology because it has demonstrated usefulness in detecting, analyzing, and forecasting severe weather. However, ground-based total lightning detection spatial coverage is restricted to the limited number and sparse distribution of networks capable of detecting total lightning. The specific ability of the GLM to collect total lightning information continuously with a large field of view spanning the Americas and adjacent ocean regions with an approximate 10 km near-uniform spatial resolution is unprecedented.

The GLM obtained operational status in December 2017 following a testing phase that involved data calibration and validation of its data by trusted ground-based total lightning sensors. One network that participated in the GLM calibration and validation efforts was the North Georgia Lightning Mapping Array (NGLMA) based in Atlanta, GA. This paper focuses on the comparison, and analyses between the data from the NGLMA and the GLM.

II. LIGHTNING MAPPING BACKGROUND

A. North Georgia Lightning Mapping Array (NGLMA)

A Lightning Mapping Array (LMA) is a system that identifies and locates, in three dimensions, the VHF radiation pulses emitted by lightning [Rison et al., 1999]. According to Goodman et al. [2005], a typical array is made up of multiple sensors, typically on the order of 10 to 12 sensors, placed throughout an area of 50 to 75 km in radius. Currently, the NGLMA is centered on downtown Atlanta and consists of 11 operational sensors. Fig. 1 shows a map of sensor locations and contours of flash detection efficiencies (FDE) for one of the dates examined later in this paper. At its farthest point, the 70% FDE contour extends about 85 km from Atlanta.

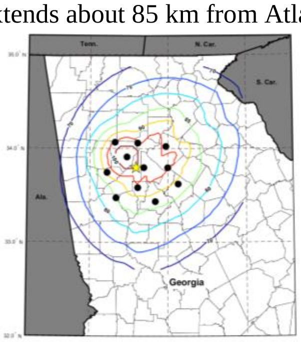

Fig. 1. Current NGLMA sensor locations (black dots) and flash detection efficiency contours. Atlanta is represented by the star.

Fig. 2 shows a typical setup of a NGLMA sensor system.

Fig. 2. NGLMA system setup, including the antenna, GPS, PC104-based processing system (in blue box), cell phone antenna, and solar panel.

A sensitive RF detector records VHF emissions from many points along an intra-cloud (IC) or cloud-to-ground (CG) lightning flash. An associated GPS receiver is used to determine the time that the signal was detected [Rison et al., 1999] to picosecond accuracy. If four or more LMA sensor locations detect a signal above a set threshold during a processing period (typically on the order of 8 to 10 microseconds), algorithms based on a time difference of arrival solution hosted on a central processing computer, can solve for the 3D location of each of these sources [Goodman et al., 2005]. These sources can then be grouped by time and space to determine which sources are associated with individual parts of an entire lightning flash (Fig. 3).

LMAs, therefore, are able to observe total lightning, which is the combination of both IC and CG lightning [Stano et al., 2015; White et al., 2013]. Since the LMA collects more extensive data, it has the benefit of giving a more complete picture of internal storm [White et al., 2013].

Because processed LMA data from the central computer updates every minute, one of the most useful applications of LMA data is its ability to perform minute-by-minute analysis of a storm and to follow and provide total lightning data on the entire lifecycle of a storm cell [Liu and Heckman, 2011].

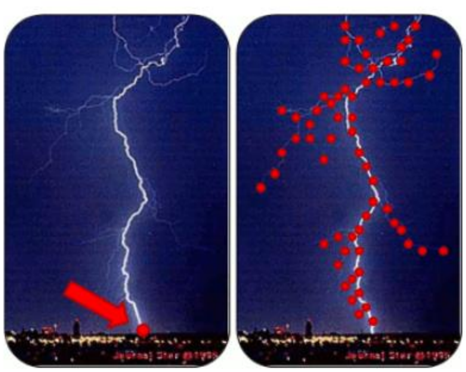

Fig. 3. Single point detection from CG network (left) versus LMA detection of sources (right). (Image courtesy of NASA SPoRT).

According to the work of Liu and Heckman [2011], utilizing LMA data alongside radar data have determined that an increase in warning times and forecast confidence can be achieved. Forecasters can look for a "lighting jump," which describes the rapid increase in the number of sources detected by the LMA. Since the LMA affords a faster update time than a typical/complete radar sweep, the NWS can potentially use the data to issue earlier and more type-specific warnings with less error. [Metzger & Nuss, 2013; White et al., 2013]. The processed NGLMA data is ingested into the AWIPS system of the NWS forecast office in Peachtree City, GA in real-time. The data is also publicly available live at http://nglma.gtri.gatech.edu/.

The objective of this paper is to use the NGLMA data from 10 July 2017 and 5 September 2017, to perform calibration and validation studies comparing the LMA data to the total lightning data from the GOES-16 Geostationary Lightning Mapper.

B. GOES-16 Geostationary Lightning Mapper

The NOAA operated GOES-16 satellite was launched on November 19, 2016 to provide meteorological measurements of the western hemisphere of Earth. It is the first geostationary weather satellite to carry a lightning detector— the Geostationary Lightning Mapper [GOES-R GLM website]. Using a single-channel, near-IR optical transient detector, the GLM detects the momentary changes in an optical scene, which indicates the presence of lightning. With a spatial resolution of about 10 km, GLM allows measurements of total lightning continuously over the Americas and the adjacent ocean regions. Analogous to the LMA network, total lightning data from the GLM can provide critical information to forecasters that affords them the ability to determine which storms may become severe based on the detection of a significant increase in lightning activity occurs. Furthermore, this critical data from the GLM allows severe weather in areas out of range of a weather radar to be tracked.

III. Methods

To perform the comparison, an hour of total lighting data from the NGLMA and GLM were compared for each of two dates: 10 July 2017 and 5 September 2017. Unprocessed and undecimated source data from each of the NGLMA stations in operation at the time were initially combined using the LMA analysis scripts and programs on the NGLMA central processing computer.

These processed combined data files, however, only show total lightning source data, as opposed to flash data. The source data were required to be converted into flash data in order to be compared to the GLM flash data. To do this, a Python library, called lmatools, reads in the NGLMA ASCII source data files and completes flash sorting and flash area calculations based on the times of arrival, location in three dimensions, and duration that are then outputted into HDF5 flash files [Bruning, 2017]. The variables used to run lmatools for the NGLMA are shown in Table 1.

TABLE 1: variables used to run lmatools for the NGLMA.

Variable Name	Value for used for NGLMA
Network's center latitude	33.8
Network's center longitude	-84.4
Network's ID	NGLMA
Minimum, Maximum number of stations allowed	5,99
Chi2 (range of allowable chi squared vales)	0,2.0
Distance: space grouping threshold	3000 m
Time threshold: time grouping threshold	0.15 s
Duration threshold: maximum expected flash duration	3 s

Once the flashes were calculated from the source data files, various filtering methods were implemented. First, any flashes comprised of less than 5 sources were filtered out from both LMA and GLM datasets. [Schultz et al., 2014; McCaul et al. 2009]. Using the individual LMA sensor thresholds valid for the time of observation, Flash Detection Efficiency (FDE) calculations were made to determine the regions where various percentages of detected lightning flashes could be reasonably expected. The data was then filtered by removing all data outside of at least the 70% FDE radii. For the cases analyzed in this paper, the majority of the NGLMA data fell within higher FDEs.

Level 2 flash data for GLM (GLM-L2-LCFA) were downloaded from the GOES-R Cal/Val Lightning Data Portal. Preprocessing of these data sets required assessing the prescribed scale factors and offsets and applying them appropriately. The GLM data could then be compared to the flash results produced from the NGLMA data sets.

Statistical analyses and visualizations were produced in MATLAB using the Mapping Toolbox. The GLM and NGLMA data sets were each separated into 0.05° latitude and longitude bins. These binned data sets were then used to calculate flash densities for each set of observations. Spatial offsets and detection efficiencies were ultimately analyzed based on the flash density maps.

IV. Results

Total lighting data collected from the NGLMA and the GLM were examined for two dates.

<u>10 July 2017</u>

On 10 July 2017, isolated thunderstorm cells moved through the Atlanta region. Data from 2300-2359 UTC was examined in an area just east of downtown Atlanta. The data from this period fell entirely within the 85% flash detection efficiency contour of the NGLMA. Comparison of the NGLMA and GLM flash data showed generally good agreement in shape and flash density (Figs. 4 and 5). However, it was determined that the maxima in each GLM cell was displaced to the east about 0.1° (9 km) relative to the NGLMA maxima with no apparent latitudinal offset. The quantity of lightning flashes displayed in the maxima of GLM cells/bins tended to be greater compared to that of the corresponding maxima of LMA cells/bins.

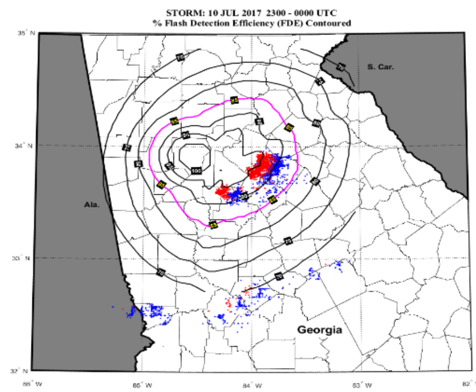

Fig. 4. GLM (blue) and NGLMA (red) flashes with NGLMA detection efficiency contours for 10 July 2017.

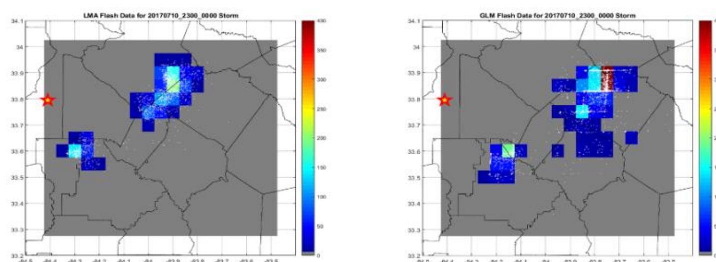

Fig. 5. NGLMA (left) and GLM (right) flash location and flash density for 10 July 2017.

<u>5 September 2017</u>

On 5 September 2017, a linear complex of thunderstorm cells moved through Atlanta. In this case, the data fell within the 75% flash detection efficiency range of the NGLMA. The lower range of detection efficiency was due to higher noise thresholds on most of the individual LMA sensor sites on this date. As with the 10 July case, the comparison of the NGLMA data to the GLM data showed good agreement in shape and flash density. The maximum in each GLM cell was similarly displaced east relative to the NGLMA maxima, although the extent of this offset was only about 0.05° to 0.1° (5 to 9 km) with no apparent latitudinal offset (Figs. 6 and 7). Furthermore, the 5 Septermber case had a comparable discrepancy in flash detection density compared to that of the 10 July case.

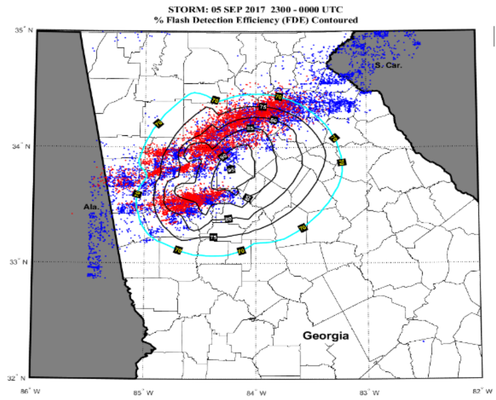

Fig. 6. GLM (blue) and NGLMA (red) flashes with NGLMA detection efficiency contours for 5 September 2017.

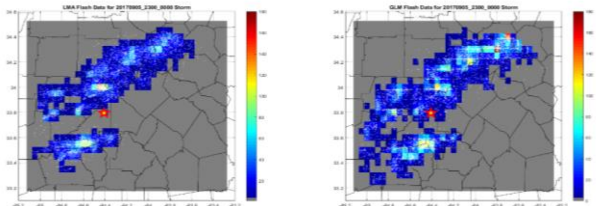

Fig. 7: NGLMA (left) and GLM (right) flash locations and flash density for 5 September 2017.

V. Conclusion

Overall, there was good agreement between the GLM and NGLMA data for the two cases we examined from 10 July 2017 and 5 September 2017. The GLM data is offset to the east by 0.05 to 0.1 ^{o} longitude, or about 5-9 km. This offset agrees with that found in Fig 8, which shows the direction and extent of the spatial offsets between the ground-based systems ENGLN and GLD360 and GLM flash detections for the period 2017-06-29 to 2017-09-06 [Virts, 2017]. No significant latitudinal offset was found.

It is important to note that, since the time that this data was collected, several updates to the GLM ground processing algorithms were made that likely corrected the offsets and discrepancies found in both cases. However, there has been minimal thunderstorm activity in the Atlanta area since early September. Comparisons of NGLMA and GLM data utilizing the improved GLM processing will be pursued when new thunderstorm data become available.

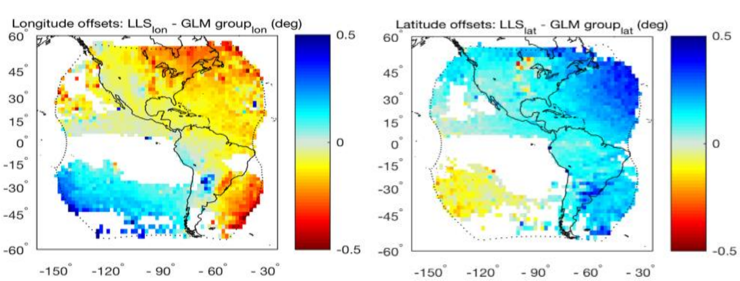

Fig. 8. Spatial offsets between ENGLN and GLD360 (ground-based systems) and GLM flash detections for period 2017-06-29 to 2017-09-06.

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