Fusing Total Lightning Data with Aviation Weather Center and Storm Prediction Center Operations during the GOES-R Visiting Scientist Program

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ABSTRACT

The NASA Short-term Prediction Research and Transition (SPoRT) center has been providing total lightning measurements to NWS forecasters since 2003. The use of these data by forecasters has resulted in enhanced situational awareness, guidance on severe weather warnings, and improved lightning safety. SPoRT has used this expertise to participate with the GOES-R Proving Ground. This led to the development of a suite of pseudo-geostationary lightning mapper (PGLM) products derived from ground-based total lightning networks. The PGLM products serve as a demonstration of space-based geostationary observations to help prepare forecasters for the geostationary lightning mapper (GLM). This particular effort, started in 2009 has been a leading activity with SPoRT's GOES-R Proving Ground activities and has been the de facto GLM training data set for the Hazardous Weather Testbed's Spring Program. The PGLM effort is resulting in training for forecasters to discuss total lightning and the GLM as well as providing a two-way dialogue on how to best integrate these observations in the operational forecast environment.

This effort has traditionally focused on collaborations with local National Weather Service Forecast Offices. The call for GOES-R visiting scientist proposals was identified as an opportunity to establish collaborations with national centers to gain their unique operational forecast perspectives. Specifically, this presentation will discuss SPoRT's initial efforts to develop collaborations using total lightning with the Aviation Weather Center (AWC) and Storm Prediction Center (SPC). Unlike SPoRT's traditional National Weather Service Forecast Office partners, the AWC and SPC have different operational perspectives and concerns. This presentation will highlight the unique forecast issues discussed during each respective visit, where future GLM observations will aid with forecasts, as well as the efforts that have been undertaken since the initial visit to collaborate with these national centers as part of the GOES-R Proving Ground.

1. Introduction

The Short-term Prediction Research and Transition (SPoRT) Center (Darden et al. 2002; Goodman et al. 2004) (http://weather.msfc.nasa.gov/sport) has been collaborating with partner Weather Forecast Offices (WFOs) since 2003. The SPoRT mission is to transition unique NASA and NOAA observations and research capabilities to the operational weather community to improve short-term forecasts on the regional scale. A major component of SPoRT's activities is the transition of total lightning data (both cloud-to-ground and intra-cloud observations) from ground based lightning mapping arrays (LMAs – Rison et al. 1999; Thomas et al. 2000; 2001; Koshak et al. 2004; Goodman et al. 2005; Krehbiel 2008; MacGorman et al. 2008; Bruning et al. 2011). This effort began with the transition of the North Alabama Lightning Mapping Array (NALMA – Koshak et al. 2004).

Since this initial effort, SPoRT is now supporting total lightning data in several partner offices thanks to collaborations with partner WFOs and LMA operators. Through evaluations and discussions with forecasters, total lightning has been used to improve situational awareness, warning decision support, lightning safety, airport weather warnings, and provide a lead time on the first cloud-to-ground lightning strike (Bridenstine et al. 2005; Goodman et al. 2005; Demetriades et al. 2008; Nadler et al. 2009; Darden et al. 2010; Stano et al. 2010; MacGorman et al. 2011; Stano 2012; White et

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al. 2012). These operational benefits are due to unique capabilities with total lightning data.

First, total lightning observes both cloud-to-ground and intra-cloud lightning as opposed to cloud-to-ground only networks like the National Lightning Detection Network (NLDN – Cummins et al. 1998; 1999). This is a major advantage as cloud-to-ground strikes make up a small percentage of all lightning activity on average (MacGorman et al. 1989; Stano et al. 2010; MacGorman et al. 2011). This provides more data than cloud-to-ground strikes alone. The additional information also provides the spatial extent of lightning activity. Figure 1 demonstrates both features. The ground-based lightning mapping arrays have a 1 to 2 minute update time, providing sub-radar volume scan time updates, providing additional information to forecasters on the evolution of a storm.

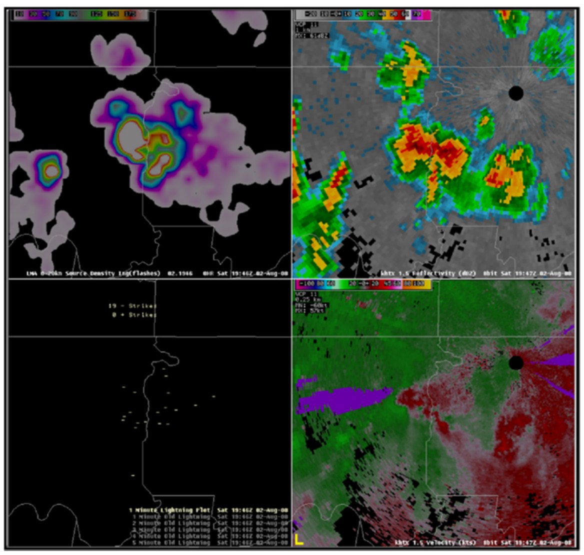

Figure 1: Total lightning source density (upper left), cloud-to-ground strikes (lower left), radar reflectivity (upper right), and storm relative velocity (lower right) as has been used in AWIPS I. Note the difference with the cloud-to-ground data

The additional information is due to total lightning's relationship to a storm's updraft. In short, total lightning is driven by the strength of the updraft in the mixed phase region of a thunderstorm. The relationship also is non-linear (Vonnegut 1963; Williams 1985; Boccippio 2002), which indicates that storms with strong updrafts have a greater potential to produce lightning. Operationally, we take advantage of this relationship by looking for rapid increases (decreases) in total lightning and use this as an indicator that a storm updraft is rapidly intensifying (weakening). These rapid increases, called lightning jumps (Schultz et al. 2009; Gatlin and Goodman 2010; Schultz et al. 2011), serve as an indicator that a particular thunderstorm may become severe.

With this background, the subsequent sections will focus on the next step in total lightning observations with the Geostationary Lightning Mapper (Section 2), the collaborative effort with the GOES-R Visiting Scientist Program and accomplishments (Section 3), as well as future activities based on the results of the visits (Section 4).

2. The Geostationary Lightning Mapper Era

With the approaching launch of GOES-R, an entirely new observation system is being prepared for use by operational forecasters. This new instrument is the Geostationary Lightning Mapper (GLM – Christian et al. 1992; 2006) and builds off of previously demonstrated instruments such as the Optical Transient Detector (OTD - Christian et al. 1996; 1999) and the Tropical Rainfall Measuring Mission's (Kummerow et al. 2000) Lightning Imaging Sensor (LIS - Christian et al. 1999; Mach et al. 2007). This instrument will be able to provide ~90% detection efficiency for both day and night conditions over the GOES-East or GOES-West field of view (Figure 2), depending on its position after launch. This is a major improvement over the ground-based LMAs which only have an effective operational radius of 250 km from the center of the network. This field of view will provide total lightning observations into several data sparse regions, such as mountainous terrain and oceanic regions. The GLM will have an 8 km resolution that will degrade to 14 km at the edge of the field of view. Furthermore, it will

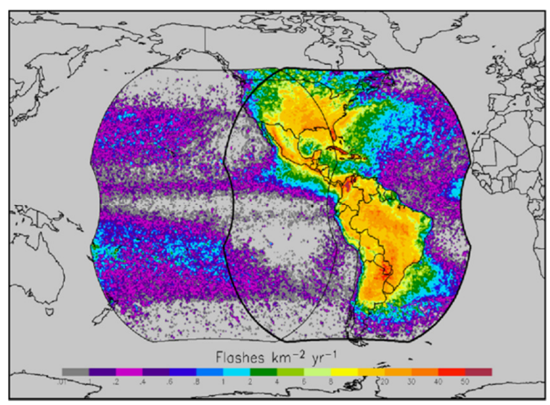

Figure 2: A lightning density map derived from 1995-2005 of OTD and LIS data that shows the GOES-East and –West fields of view of the GLM.

have a rapid temporal update. Also, unlike the OTD and LIS, the GLM instrument will be in a geostationary orbit, allowing for constant observations of storms instead of a single snapshot of lightning activity.

In preparation for GOES-R, an effort called the GOES-R Proving Ground (PG) has been established. The primary responsibility of the PG is to promote "Day 1" readiness for the new capabilities, such as the GLM, that GOES-R will provide to operational forecasters. SPoRT has been an active partner with the PG as several NASA datasets and instruments can be considered precursors to instruments on GOES-R (Stano et al. 2010). More relevant to this presentation is SPoRT's activities with total lightning in the PG.

Initially, the GOES-R Algorithm Working Group was developing a GLM proxy product from the ground-based LMAs. The product would attempt to simulate what would be observed by GLM using ground-based LMA observations with comparisons to the existing OTD and LIS data. The effort has been successful, but the proxy is not currently available in real-time. To address this, SPoRT developed a product called the pseudo-Geostationary Lightning Mapper (PGLM) product in 2009 (Stano et al. 2010; 2011; Stano and Carcione 2012). The PGLM is designed as a rough demonstration dataset that generates a GLM-resolution total lightning product. Unlike the proxy, which is created with a transformation function between ground-based LMAs and satellite-based OTD and LIS data, the PGLM only uses ground-based LMA data. While not a true proxy, it is available in real-time for any ground-based LMA and allows for training and demonstration activities. Furthermore, SPoRT has worked to ingest this into the National Weather Service's new decision support system, AWIPS II (Tuell et al. 2009 – Figure 3), to allow for forecaster evaluations on how to visualize these data and to develop new procedures. Combined with SPoRT's training modules and evaluation by SPoRT's partners and the Hazardous Weather Testbed, the PGLM provides a useful tool to prepare forecasters for the GLM era. At this point, there is one main drawback to all of the PGLM activities within the GOES-R PG. The main focus has only been on local forecast offices.

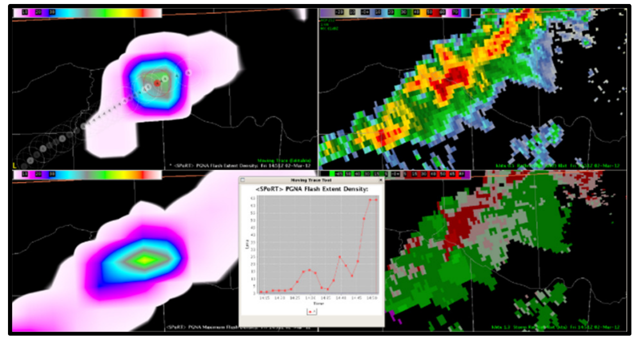

Figure 3: AWIPS II view of the pseudo GLM flash extent density with the lightning tracking tool path (upper right), 30 minute maximum flash density (lower left), radar reflectivity (upper right), and storm relative motion (lower right). The PGLM time series from the tracking tool is displayed in the inset image.

3. The GOES-R Visiting Scientist Program

In Fall 2011, the GOES-R PG solicited a call for proposals to support visits by research scientists to promote improved evaluation of PG products and capabilities with operational end users. SPoRT, in collaboration with our co-authors from the Aviation Weather Center (AWC) and Storm Prediction Center (SPC), realized that no effort had been made to include national centers in the total lightning PG efforts. All current activities were focused on local WFO warning operations, which may not be applicable to a national center's operations. A proposal was submitted and then accepted to create collaboration between SPoRT, AWC, and SPC. The proposal focused on five key points.

- Learn about AWC and SPC operations
- Learn about the operational differences from local WFOs (e.g. larger domains – Figure 4)
- Demonstrate total lightning capabilities
- Develop a plan to ingest total lightning observations into operations
- Determine how to focus on the short-ranged LMAs within the large operational domains

During the course of drafting the proposal, a major concern would be the sheer size of the operational domains. Unlike SPoRT's current collaborations with some local WFOs (blue boxes in Figure 4), the AWC and SPC have massive operational domains. While several ground-based LMAs were available, these networks would only cover a small fraction of the operational domains. It was clear that the operational perspective of AWC and SPC could be quite different from the local WFO perspective. To address this, the lead author would spend time shadowing forecasters at each location to better understand the operational needs and concerns.

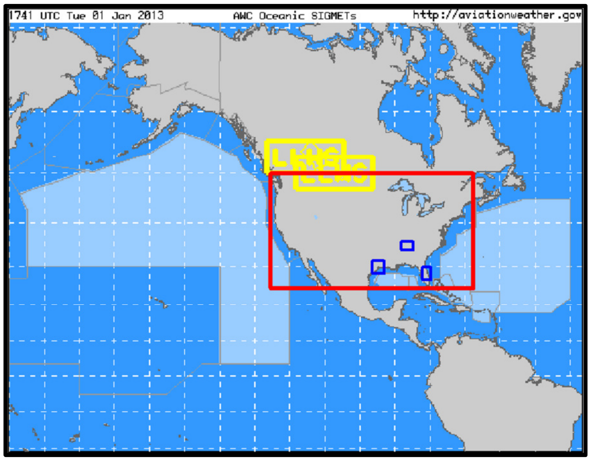

Figure 4: A subset of the Aviation Weather Center's domain (full image), the Storm Prediction Center domain (red box), and the local forecast office county warning areas of Houston, Huntsville, and Melbourne (blue boxes).

Accomplishments

By all accounts, the visiting scientist trips to AWC and SPC were successes. Much of the credit goes to the forecasters who took time out of their schedules to attend the training seminars, allow job shadowing, providing discussions and comments on how lightning is currently used operationally, and how total lightning from GLM could be used in the future.

SPoRT provided training sessions that covered several operational aspects. First, concepts of total lightning and current uses at local WFOs were described, as discussed in Section 1 above. Total lightning data were compared to observations of cloud-to-ground only data. This ranged from discussing the lead time that intra-cloud lightning can provide ahead of the first cloud-to-ground strike and regional variability (Stano et al. 2010; MacGorman et al. 2011), and the ratio of intra-cloud to cloud-to-ground data across the United States from OTD and NLDN observations (Boccippio et al. 2001). The training sessions then discussed LMAs compared to other networks, such as the NLDN or long-ranged networks like the World Wide Lightning Location Network (Dowden et al. 2002; Lay et al. 2004; Roger et al. 2004; 2005).

From there, the discussions turned to the actual Geostationary Lightning Mapper instrument and what the potential uses of these data may be at the National Centers. This served as the foundation with which to begin discussing the use of the PGLM products as well as the limitations imposed on the PGLM given the small domains of the individual ground-based LMAs. The overall feedback was very positive in wanting to incorporate these data.

In addition to SPoRT's training and overview, the AWC and SPC highlighted eight major topics of interest that each center currently applies lightning data to and would like to evaluate with total lightning data. Some would be easier to implement than others, given the short range of the individual ground-based LMAs. These topics include:

- Confirm convection in remote regions
- Aid with flight diversions

Each of these was especially important to the AWC, particularly with their trans-oceanic air routes. During the AWC visit, a major mid-latitude cyclone was in the central north Pacific. No lightning network detected lightning anywhere within the system, although had this system been in the central United States it would have been a major news event. A LIS overpass was able to detect lightning at the extreme northern limit of its field of view, subtly demonstrating the advantage GLM would have in the future. Additional topic points included:

- Monitoring the status of the cap breaking
- Modifying mesoscale discussions
- Modifying convective forecasts
- Investigating tropical systems
- Monitoring nighttime decay and morning initiation scenarios
- Applications with fire weather

Most of these topics could be evaluated in the small domains available when storms were present in these regions. The availability of the LMA in Washington D.C. and a future network in Atlanta, Georgia, is advantageous as it is part of a major flight corridor for AWC.

However, in order to begin any evaluations, these data would need to be provided in the AWC and SPC decision support system, N-AWIPS. This is a change for SPoRT as it traditionally supports AWIPS I and AWIPS II for our local WFO partners. Additionally, unlike our local partners who only need access to a single LMA, the national centers would require all available networks in a single product. The resulting effort between SPoRT and our co-authors is the PGLM Mosaic product (Figures 5 and 6), available every two minutes. This display provides the basic PGLM flash extent density product in N-AWIPS and includes range rings on each network to indicate where data would be available.

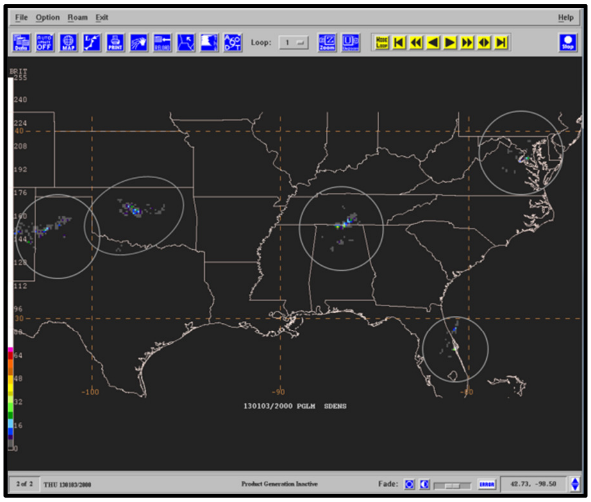

Figure 5: The PGLM Mosaic flash extent density in N-AWIPS for the five currently available networks. From west to east they are: West Texas, Oklahoma, North Alabama, Kennedy Space Center and Washington D.C.

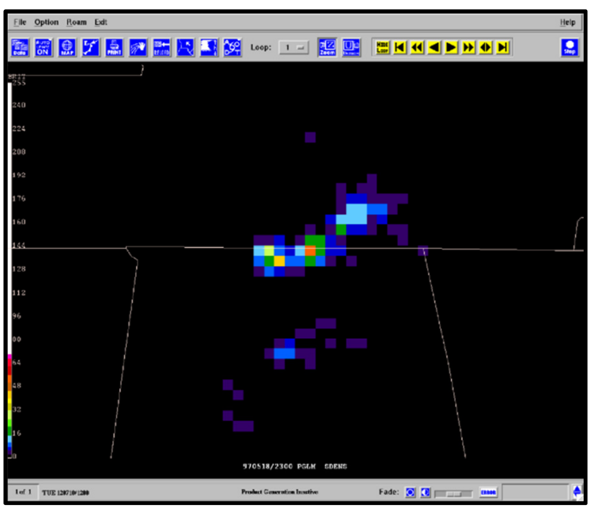

Figure 6: The same as Figure 5, but zoomed in on North Alabama

Finally, once the mosaic was created, SPoRT and AWC were able to provide these data to the AWC's summer experiment, which occurred on 4-15 June 2012. The experiment brought together the AWC, center weather service units, the FAA, Air Force Weather Agency, airline operators, and researchers. The overall emphasis was on traffic flow management, aviation weather statements, and to evaluate GOES-R products, such as the PGLM. Unfortunately, the PGLM display had a few technical glitches and then a lack of lightning activity during the experiment. Still, the PGLM product generated a great deal of interest as well as several discussions on applications.

One particular application was demonstrated 14 June 2012. Here, forecasters and air traffic managers were monitoring convection across north central Florida. Figure 7 shows the radar reflectivity at 1708 UTC with the associated flight paths. Air traffic managers were attempting to direct aircraft between several cells of convection (circled region) on their approach to Orlando International Airport. With only the radar reflectivity, the path appeared clear. However, the corresponding PGLM mosaic image (Figure 8) showed that lightning was actually occurring in the chosen path. The location of the lightning is partly dependent on the grid box chosen for the display. However, this example still demonstrates that the aircraft may have been diverted into a region of a strengthening updraft.

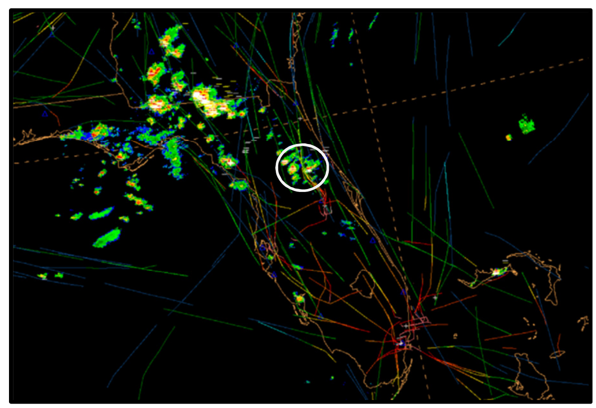

Figure 7: Radar reflectivity over Florida with flight paths across the region. Note the flight paths through the storms on approach to Orlando International Airport (circle) at 1708 UTC on 14 June 2012.

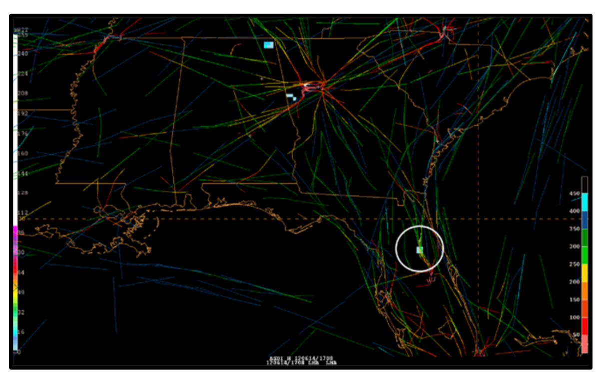

Figure 8: The PGLM Mosaic at the same time as Figure 7, noting lightning in the proposed flight path.

Even with the limited availability during the summer experiment, there was still a large amount of discussion. Because of this and forecaster interest at AWC and SPC, the PGLM mosaic continues to be produced for these centers and will be available again in the 2013 summer experiment.

4. Future Work

Overall, the initial GOES-R visiting scientist proposal was a major success. The collaboration between SPoRT, the Aviation Weather Center (AWC), and the Storm Prediction Center (SPC) has led to the development of the pseudo-geostationary lightning mapper (PGLM) product being made available in a mosaic format for N-AWIPS. By working with these centers to understand their operational concerns and issues, which have a different perspective than SPoRT's traditional local forecast office partners, SPoRT and each center are continuing to evaluate the PGLM product to prepare these centers for future Geostationary Lightning Mapper data. This is a success for the GOES-R Proving Ground as the collaboration ensures that these national centers are included in GLM preparations for GOES-R and ensure that all operational users achieve "Day 1" readiness ahead of launch.

Based on the lessons learned from the visit to AWC and SPC as well as those from the 2012 summer experiment, there are several future activities that have been outlined. In particular, SPoRT is continuing to establish collaborative ties with other ground-based lightning mapping array (LMA) operators. By doing this, SPoRT will expand the number of regions available for evaluation by AWC and SPC given the limited domains of each individual LMA network. To that end, SPoRT has successfully proposed a follow-up visiting scientist trip in 2013. This effort will be in collaboration with the Collaborative Institute for Research in the Atmosphere (CIRA), Colorado State University (CSU), and New Mexico Tech University to obtain access to the Colorado LMA (Rison et al. 2012). Additionally, SPoRT is improving the processing of the data from each network to improve product latency. Furthermore, with the initial testing that has occurred since the visit, SPoRT is working with the GOES-R satellite champions to move the PGLM mosaic product from a test dataset to a product that will be fully available on the operations floor.

SPoRT also is collaborating with the GOES-R satellite champions to create a training module of total lightning that is more suited to the national centers. This will focus on the different perspective that the national centers have compared to the local forecast offices, as seen in Figure 4. Lastly, feedback has suggested a modification to the current PGLM mosaic product so that it displays a status bar in N-AWIPS (Figure 9). This will allow forecasters to know whether or not a network is observing no lightning or if there is an issue with the network itself.

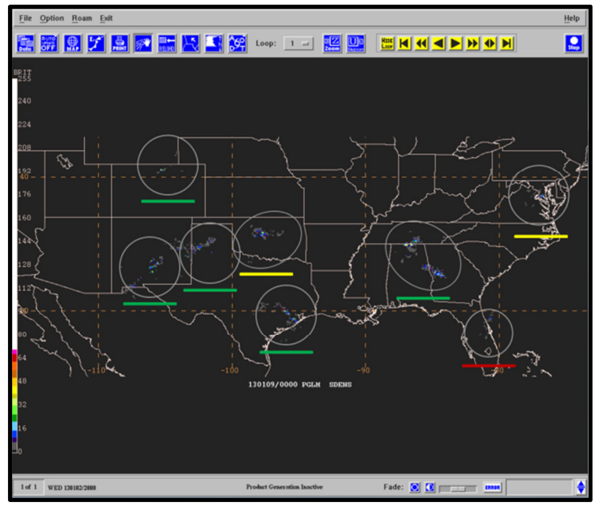

Figure 9: A demonstration of an improved PGLM Mosaic flash extent density product in N-AWIPS. Compared to Figure 5, this demonstration shows "observations" from all current and near-future networks along with a color-coded status bar to indicate the difference between no observations and a network outage.

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