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NASA SPoRT Prepares for the Geostationary Lightning Mapper

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1. NASA SPoRT and the GOES-R Proving Ground

NASA's Short-term Prediction Research and Transition (SPoRT) program (Goodman et al., 2004) (http://weather.msfc.nasa.gov/sport/) seeks to accelerate the infusion of NASA Earth science observations, data assimilation, and modeling research into weather forecast operations and decision-making. The program is executed in concert with other government, university, and private sector partners. The primary focus is on the regional and local scale and emphasizes forecast improvements on a time scale of 0-24 hours. The SPoRT program has facilitated the use of real-time NASA data and products to address critical forecast issues at a number of partner National Weather Service (NWS) Weather Forecast Offices (WFOs) and private weather entities, primarily in the southeast United States. Numerous techniques have been developed to transform satellite observations into useful parameters that better describe changing weather conditions (Darden et. al., 2002).

One of the core efforts of SPoRT is the transition of ground-based total lightning data into real-time operations. This originally involved the North Alabama Lightning Mapping Array (Goodman et al. 2005 – NALMA), but has since expanded to include networks at Kennedy Space Center and Washington D.C. Since the NALMA was first transitioned in 2003, SPoRT has been working with our partners to develop assessments, training, and improved visualizations of these data (Goodman et al. 2005; Nadler et al. 2009; Darden et al. 2010; Demetriades et al. 2008; Stano et al. 2011). The goal is to provide a product or products that enhance a forecaster's situational awareness. This will lead to improved severe weather warnings and lightning safety. SPoRT's initial efforts have led to a greater utilization of total lightning data operationally where assessments have observed improved warning lead times and situational awareness (Bridenstine et al. 2005; Goodman et al. 2005; Nadler et al. 2009). At this time, forecasters primarily rely on a lightning jump signature for their warning operations (Schultz et al. 2009; Gatlin and Goodman 2010).

SPoRT's efforts to match data to specific forecast problems, integrate products into the end user's decision support system, and product training with user feedback has created a strong working relationship with our partners. This successful collaboration with our end users is instrumental to the success SPoRT has had with its total lightning activities. This working paradigm has led to SPoRT's involvement with the GOES-R Proving Ground (PG). SPoRT's knowledge of using total lightning data in real-time operations and training modules has led to SPoRT taking an active role in preparing forecasters for the Geostationary Lightning Mapper (GLM – Christian et al. 2006).

2. Proving Ground Lightning Activities

SPoRT is involved with three specific lightning activities for the GOES-R Proving Ground. To support the PG, these activities are included in the Spring Program in Norman, Oklahoma (Kain et al. 2003). These are leveraged off of SPoRT's internal expertise in the use of total lightning data, transitioning the data in real-time to operational forecasters, and SPoRT's co-location with the lightning group at the National Space Science and Technology Center (NSSTC) in Huntsville, Alabama. The lightning group includes members of the Geostationary Lightning Mapper's Algorithm Working Group (AWG). Each activity has its own focus, but all are designed to either simulate future GLM data or demonstrate its

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potential uses to end users in advance of the launch of GOES-R.

a. Logistics, Expertise, and Training

The starting point for collaboration is to provide data. In 2010, SPoRT supplied the raw total lightning data from three separate total lightning networks via a secure local data manager. These networks were from NALMA, Washington D.C., and Kennedy Space Center. For the 2011 Spring Program, SPoRT will continue to provide data for these networks, but as a finished product and not the raw data. Additionally, SPoRT is collaborating with the Oklahoma lightning mapping array (MacGorman et al. 2008) to obtain these data in real-time and add to the finished product from the other three networks. In addition to these networks, SPoRT is actively inquiring with other total lightning network operators to obtain their real-time data for use with the Spring Program's evaluations as well as to support other SPoRT WFO partners.

Once transferred, the products need to be displayed in the decision support system of choice by the end user. For the Spring Program, and specifically the Experimental Warning Program, this will be AWIPS. The staff involved at the Spring Program utilize the same data formats and techniques to ingest real-time total lightning data as SPoRT for use with AWIPS. This allows for effective trouble-shooting of ingest or display issues. SPoRT's role to display these data will increase once AWIPS II (Tuell et al. 2009). SPoRT, in collaboration with the Huntsville WFO, now has the expertise to ingest and display total lightning data in AWIPS II via a software plug-in. When the Spring Program switches to this decision support tool, SPoRT will provide this tool.

SPoRT provides additional support through training. This is done in one of two ways. SPoRT personnel have participated directly at the Spring Program in 2009 and 2010 as the total lightning expert. In this role, the SPoRT personnel have the opportunity to provide on-site training and education about total lightning, its uses, and discuss the future Geostationary Lightning Mapper. Additionally, while serving in this capacity, SPoRT personnel have the opportunity to work directly with forecasters with their decision support activities during the numerous intensive operation periods that occur during the week involving lightning data.

Beyond on-site expertise and training, SPoRT produced a training module in 2010 for forecasters before their arrival at the Spring Program. This has been added to the NWS' own learning management system to better facilitate its use. A copy has been uploaded to SPoRT's web page for end users who may not have access to the NWS system (http://weather.msfc.nasa.gov/sport/training/). This training will be used again for the 2011 Spring Program. SPoRT will update this module as new products are selected for the PG.

b. The Pseudo GLM Product

As described above, SPoRT provided personnel to act as lightning experts about the use of operational total lightning data. In 2009 it was determined that the existing GLM demonstration product was insufficient for use by the Spring Program. In order to have any semblance to GLM data, the Spring Program required a flash based product, which was not available in 2009.

Using this feedback, SPoRT worked to develop a flash-based product that had the resolution of the GLM instrument. The result is an 8 km resolution, flash extent density product available for any ground-based total lightning network. Figures 1-4 show how this new product, the pseudo-GLM (PGLM), is produced.

The PGLM starts with the raw observations of any ground based lightning network (Figure 1). The raw data, representing the individual stepped leaders of a flash and called sources, are combined into flashes using spatial and temporal criteria (Figure 2). This is done by a flash algorithm developed by McCaul et al. (2005; 2009), which describes the process in detail. Although we have chosen to not include the details here, it is important to note that this algorithm was chosen over several others (Williams et al. 1999; Nelson 2002; Thomas et al. 2003; Wiens et al. 2005). Comparison with the Thomas et al. (2003) algorithm using NALMA data show output agreement within ~5% (Gatlin and Goodman 2010). Another reason for this selection is that the McCaul algorithm runs rapidly, even in high activity events, allowing its use in operational, real-time activities.

Next small flashes are removed before additional processing. Flashes are considered small if they are comprised of less than 10 individual sources. This is a highly simplistic way of acknowledging that a satellite-based optical instrument will not see every observation that the ground based, VHF networks will observe. This is only a rough estimate based on discussions with the GLM AWG members. This rough estimate is a major limiting factor in the use of the PGLM. In our example, all three flashes in Figure 2 have more than 10 sources.

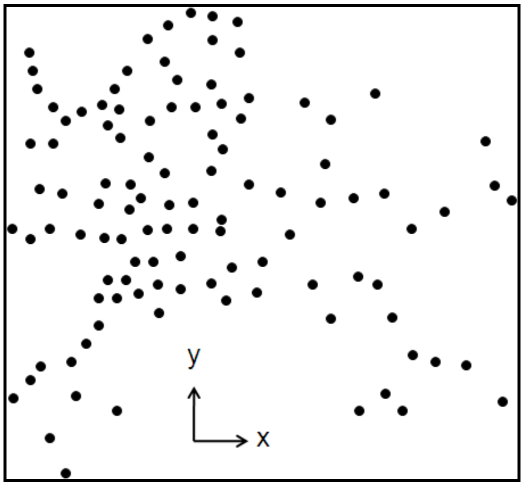

Figure 1: A demonstration example of an x-y plane view image of raw sources observed by a total lightning network.

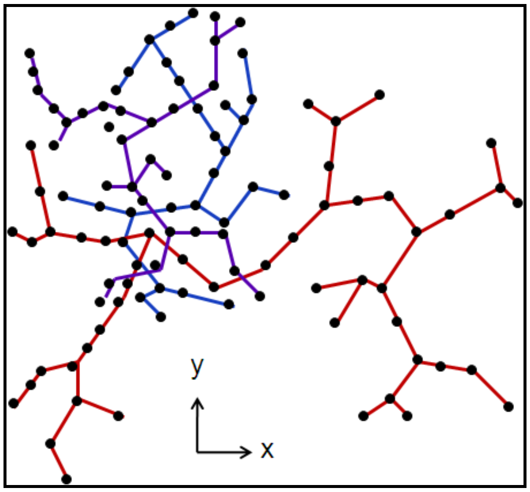

Figure 2: The same as Figure 1, but now with the sources re-constructed into 3 distinct flashes using the McCaul et al. (2005; 2009) flash algorithm.

The remaining flashes are then placed on a grid (Figure 3). For 2010, the PGLM was produced for each network on individual grids. In 2011, SPoRT will produce a "mosaic" product that will contain all of the PGLM output in one file. This will have limited utility with the current AWIPS display, but will be highly effective with AWIPS II. Regardless of the grid used, each grid box is a summation for the number of flashes that enter a specific grid box. While a single flash may enter a single grid box multiple times with different branches, the flash will only be counted once for that grid box. Conversely, a single flash can be counted in multiple grid boxes. This is seen with flashes with larger horizontal extents. With this summation, the PGLM is complete (Figure 4).

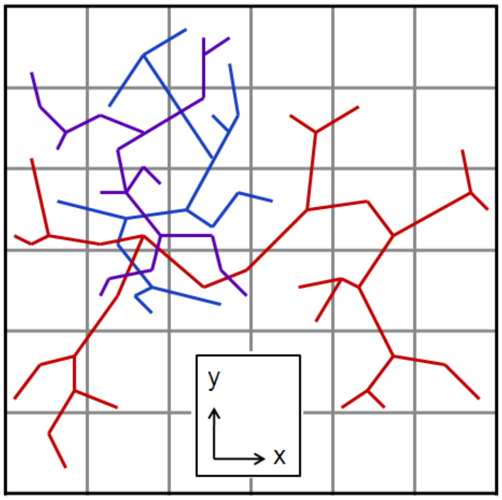

Figure 3: The same as Figure 2, but with the raw sources removed and the flashes placed on a grid.

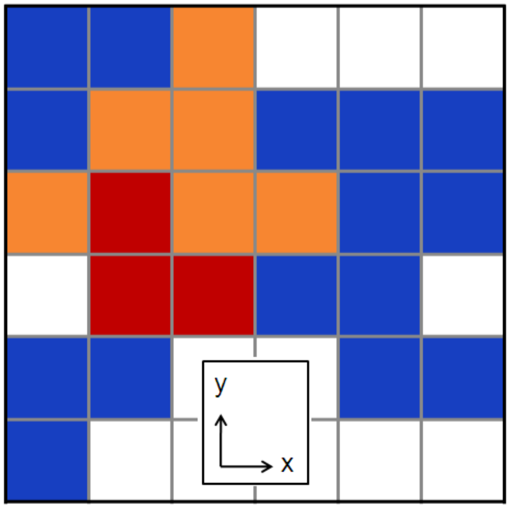

Figure 4: A demonstration example of the flash extent density for each grid point based on the raw sources observed in Figure 1 and processed in flashes on this grid (Figures 2-3). Red is three flashes, orange is two, and blue is 1. This image represents the final pseudo geostationary lightning mapper product.

Overall, the PGLM is a simple and easy to produce product and Figure 5 shows this product displayed in AWIPS II. The PGLM is a step beyond the product used in 2009.

However, the PGLM cannot be considered a true representation of what the GLM instrument will eventually observe. The PGLM can be accurately described as a flash extent density product at the GLM resolution. The reason for this distinction is that, unlike the official GLM proxy product under development by the GLM AWG, the PGLM does not attempt to utilize knowledge gained from the Lightning Imaging Sensor (LIS) aboard the Tropical Rainfall Measure Mission (TRMM) satellite.

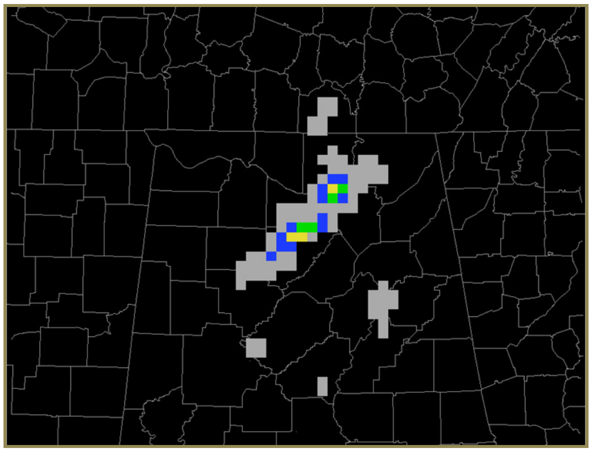

Figure 5: An actual display of the PGLM product in AWIPS II using data from the North Alabama Lightning Mapping Array.

The reason for the PGLM's existence is that the official GLM proxy is not yet ready for use by forecasters in the Spring Program. Because of this, the PGLM was selected for use in the 2010 Spring Program (Stano et al. 2010; Stumpf et al. 2010). The PGLM provides a demonstration to forecasters of the resolution of GLM lightning observations and familiarizes end users with the potential benefits the GLM once launched.

In this demonstration capacity, the PGLM serves well. The PGLM acts as a point of reference for forecasters when initiating conversations about the ability and utility of the GLM instrument's observations. The PGLM also is a valuable tool to help explain what total lightning is to forecasters and end users. This is a vital component of both the Spring Program and SPoRT's activities as GLM observations will be a new and unique operational dataset.

In addition to the base PGLM product that was used in 2010 (figure), SPoRT is developing two variant products. These variants are meant to introduce forecasters to different concepts of how to use total lightning by describing lightning jumps and emphasizing the spatial data available that cannot be obtained with National Lightning Detection Network (NLDN – Cummins et al. 1998; 1999; 2006) cloud-to-ground strike data only. The two variants are based on the new visualizations being discussed with SPoRT's collaborators for operational, ground-based total lightning data (Stano et al. 2011).

The first is the rate of change (ROC) product (Figure 6). The ROC attempts to apply the University of Alabama in Huntsville's (UAH) lightning jump algorithm (Schultz et al. 2009) to the gridded PGLM product and not by tracking individual storm cells (figure). Essentially, the ROC takes an Eulerian approach to observing lightning activity. A baseline flash rate for each grid box is computed for a 10 minute period. From there, the current flash rate derived from the most recent 2 minute PGLM value at each grid point is calculated. The current flash rate is then compared to the baseline and its standard deviation from this baseline is calculated. Standard deviations greater than 2 sigma are flagged with warm colors indicating a lightning jump and the potential for severe weather to occur. Cool colors represent sigmas of -2 or less indicating a rapid weakening, while neutral colors represent locations where lightning activity is not significantly changing. The 8 km grid boxes used by the PGLM allow for storms that are moving through the domain to affect a smaller number of grid boxes, reducing the impact of storm movement. However, the ROC still appears to be heavily affected by storm movement across the grid.

The ROC is intended to serve as a preliminary tool to discuss an automated lightning jump algorithm. SPoRT is introducing this product in 2011 to obtain feedback from end users on how to best display lightning jump information and train end users on the utility of trended total lightning data. This feedback will then be provided to the UAH researchers to assist in the real-time display of their product once the GLM proxy is available. The ROC is not intended for true operational use, but the feedback it provides will help improve the eventual display of the UAH algorithm.

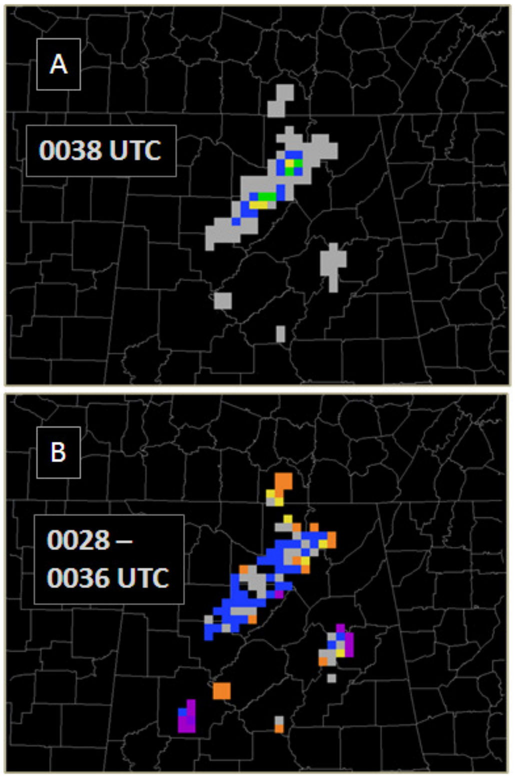

Figure 6: An example (A) PGLM flash density at 0038 UTC and (B) rate of change product using data from 0028-0036 UTC in AWIPS II from 19 April 2009. For the PGLM, brighter colors indicate a greater flash density. For the rate of change, warm colors indicate 2 (yellow) or ≥ 3 (red) sigma deviations above the baseline flash rate for each grid box, indicating a strengthening system. Cool colors indicate -2 (blue) or ≤ -3 (purple) sigma deviations below the baseline flash rate for each grid box, indicating a weakening system. Neutral colors (grey) indicate no major change in the grid box's flash rate.

The second variant is the maximum flash density product (MFD – Figure 7). Like the ROC, the MFD is a gridded product. Unlike the ROC, which uses flash rates within each grid box, the MFD plots the maximum flash density that each grid point had for the last 30 minutes. This time can be lengthened or shortened, based on forecaster feedback. The MFD product is intended to help forecasters visually monitor how lightning activity has increased or decreased over a set period of time. With this, a forecaster can compare the MFD product, which updates at the same rate as the PGLM, with the most recent PGLM product. When the two are compared, forecasters can see whether or not the region of interest has an increase, decrease, or no change in lightning activity. This provides forecasters the ability to roughly ascertain the trend in lightning activity at a glance. This is an important feature, as forecasters report that focusing exclusively on a single storm cell during warning operations is a problem. The MFD allows forecasters to quickly take in a view of the larger domain and assess if other storms cells require more detailed attention.

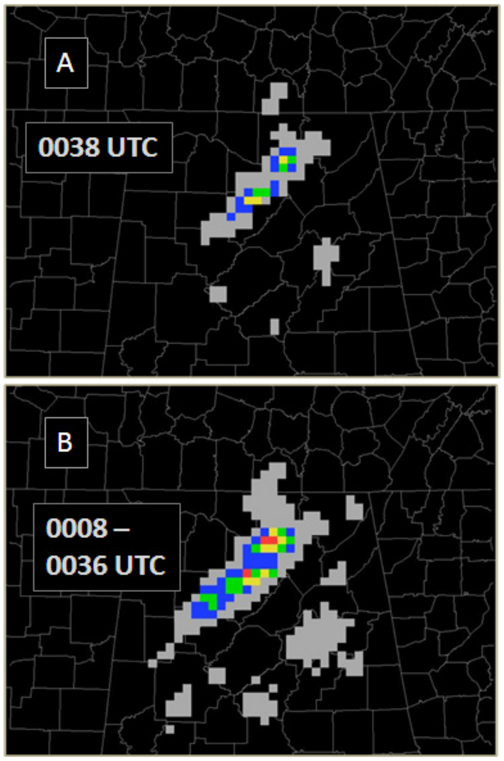

Figure 7: An example (A) PGLM flash density at 0038 UTC and (B) maximum flash density product using data from 0008-0036 UTC in AWIPS II from 19 April 2009. Each uses the same color curve with brighter colors indicating larger flash densities. Note how the two storm cores in the PGLM (A) can be seen in the maximum flash density (B), although the maximum flash density indicates that both cores had higher values at certain grid points within the past 30 min.

Beyond the ability to estimate the change in lightning activity, the MFD has another use. The MFD shows the spatial extent of all lightning activity for the past 30 minutes (in its basic configuration). This allows a forecaster to see where lightning has occurred and where the threat of lightning remains, particularly since total lightning data often observes more lightning that cloud-to-ground data alone. The caveat is that unlike the ground-based product available to the WFOs (Stano et al. 2011), the PGLM version of the MFD has 8 km grid spacing. This means that a single flash entering a grid box would indicated lightning in the entire 8 × 8 km box. This highlights one of the key assessment questions SPoRT poses during the Proving

Ground; how does the GLM's resolution impact the data's utility? Even with this question needing to be answered, the MFD represents a new tool to assist forecasters with lightning safety decisions.

Ultimately, the PGLM, ROC, and MFD are tools to initiate a dialogue with the forecaster participants at the Spring Program. The PGLM and its variants will never be used operationally, nor are they intended to be the final look of how GLM data should appear. However, the concepts they introduce to forecasters will help educate forecasters on how to use GLM data for severe weather applications as well as lightning safety and situational awareness activities. These lessons will be applied to the training and transition of the full GLM proxy and eventually the GLM itself, enabling day 1 capabilities.

c. Geostationary Lightning Mapper Proxy

The Geostationary Lightning Mapper proxy (no figure available) is under development by the GLM AWG in Huntsville, Alabama and co-located with the SPoRT program. The AWG is tasked to create the official demonstration product for before the launch of GOES-R. The major difference between the official proxy product and the PGLM is that the proxy is designed from the start to incorporate scientific characteristics and observations from the TRMM LIS instrument (Christian et al. 1992; 1999).

The GLM proxy is, simply put, a transformation function between the ground-based VHF observations of the NALMA network to the optically based lightning observations from the TRMM LIS instrument. The first phase of the GLM proxy compared ground-based observations from the NALMA network to coincident overpass observations from the TRMM LIS. This created a baseline comparison between the ground and satellite observations, since each instrument observes lightning differently. Once this initial comparison phase was completed, the GLM AWG began to develop GLM proxy data from the NALMA observations when there were no corresponding satellite observations. The algorithms developed by the AWG transform the ground-based source observations into proxy datasets of GLM events, groups, and flashes much like those described for the Optical Transient Detector (Christian et al. 1996) and the TRMM LIS (Mach et al. 2007).

SPoRT's role with the GLM proxy will be to assist the AWG in providing training for their product as well as collaborating to put the proxy data into a format that can be viewed in AWIPS (and AWIPS II) by the NWS and the Spring Program. At this time, the GLM proxy is not yet ready for use in real-time evaluations and is only available from NALMA observations. Therefore, SPoRT is collaborating with its partners to identify specific events to develop a selection of case studies using GLM proxy data. With these cases and the understanding of how to import these data into AWIPS and AWIPS II, SPoRT will work to develop Warning Event Simulator cases that can be used by the Spring Program or by individual forecasters. The feedback from these cases will be used to improve the visualization of these data and to develop training for the wider NWS in preparation for the launch of GOES-R.

3. Summary of SPoRT Lightning Activities

This conference paper serves as a brief overview of the activities and efforts the SPoRT program has undertaken to support the GOES-R Proving Ground in preparation for the launch of the Geostationary Lightning Mapper in the next several years. SPoRT's participation has evolved out of the program's expertise in providing real-time lightning data to our collaborating NWS partners and supporting that collaboration with assessments and training. Drawing on this expertise, SPoRT has focused on three activities.

SPoRT's initial efforts have been and are continuing to be focused on an advisory and support role. This has leveraged off of SPoRT's expertise and knowledge in working with total lightning data and providing these data to our WFO partners in real-time. Initially, SPoRT supplied total lightning data from three networks (Kennedy Space Center, North Alabama, and Washington D.C.) to the Spring Program in Norman, Oklahoma and provided advice on displaying these data in AWIPS. Additionally, SPoRT has provided personnel with total lightning expertise to spend a week in Norman to provide onsite training. Beyond this, SPoRT has produced a training module that explains the utility of total lightning, SPoRT's Proving Ground lightning products, and a basic description of the Geostationary Lightning Mapper. With the upcoming 2011 Spring Program, SPoRT will continue to provide these logistics, expertise, and training. SPoRT's efforts will expand to produce the various lightning products for the three networks listed as well as the Oklahoma Lightning Mapping Array and send the finished product to the Spring Program.

In addition to the data flow activities, SPoRT has developed the pseudo GLM (PGLM) that was first used in 2010 and will be used again in 2011. Also, SPoRT is introducing two variants of the PGLM to further enhance discussions with forecasters. The PGLM has been a stop-gap measure to support the Spring Program ahead of the availability of the official Algorithm Working Group (AWG) GLM proxy product. The PGLM cannot be considered a scientifically derived stand-in for GLM observations. However, the PGLM and its variants like the maximum flash density and rate of change products are useful tools to train forecasters and end users on the capabilities and resolution of the GLM. By providing forecasters with the PGLM, the training of what total lightning is and how it can be applied to real-time operations can begin and allows discussions to be focused. With this knowledge, forecasters will be ready to implement the real GLM data when available. Once the full GLM proxy is available, the PGLM will be discontinued.

While the PGLM will see use for the 2011 Spring Program, a large portion of SPoRT's lightning focus for the GOES-R Proving Ground will turn to the AWG GLM proxy product. The proxy may see limited use during the 2011 Spring Program, and SPoRT is working with the AWG to develop the necessary transition techniques and training to have this available by 2012. SPoRT with the support of the Huntsville, AL WFO has developed a plug-in to display the ground-based total lightning data in AWIPS II. This expertise can be applied to the GLM proxy. This effort will be instrumental in helping provide the GLM proxy to end users for training and evaluation in the future.

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