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NASA SPoRT GOES-R Proving Ground Activities

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1. INTRODUCTION

a. NASA SPoRT Program

The Short-term Prediction Research and Transition (SPoRT) program (http://weather.msfc.nasa.gov/sport/) (Goodman et al., 2004) seeks to accelerate the infusion of NASA Earth science observations, data assimilation, and modeling research into weather forecast operations and decision-making at the regional and local level. It directly supports the NASA strategic plan of using results of scientific discovery to directly benefit society (NASA 2006, 2007). The program is executed in concert with other government, university, and private sector partners. The primary focus is on the regional 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 15 National Weather Service (NWS) Weather Forecast Offices (WFOs) and several private weather entities primarily in the southeast United States. Numerous new techniques have been developed to transform satellite observations into useful parameters that better describe changing weather conditions (Darden et. al., 2002).

The success of the SPoRT program lies in three key components of its collaborative relationship with end users, namely, the need to 1) match data to a particular forecast problem(s), 2) integrate real time products into the AWIPS environment, and to develop a strong end user relationship to facilitate the above items and to 3) provide training, encourage product feedback, and to conduct user assessments of the products and activities. These efforts provide a strong end user advocacy for new products and raise the knowledge level of the forecasters. This collaborative effort extends to working with other entities to extend these concepts to other regions. Additionally, these collaborations better prepare forecasters for future NOAA operational satellite capabilities from the NPOESS and GOES-R instruments.

b. The GOES-R Proving Ground

The GOES-R Satellite Proving Ground (PG) project engages the NWS forecast and warning community in pre-operational demonstrations of selected capabilities anticipated from the next generation of NOAA geostationary Earth observing systems (http://cimss.ssec.wisc.edu/goes_r/proving-ground/mission_statement.html).

The GOES-R PG objective is to bridge the gap between research to operations by:

- Utilizing current systems (satellite, terrestrial, or model/synthetic) to emulate various aspects of future GOES-R capabilities
- Infusing GOES-R products and techniques into the NWS operational environment, with emphasis on the AWIPS environment
- Engaging in a two-way dialogue to provide feedback to the GOES-R product developers from the users

The intended outcomes of this project are Day-1 readiness for users of the GOES-R observing system, and an effective transition of GOES-R demonstration and eventual operational products to the weather community.

The SPoRT program is directly associated with the GOES-R Proving Ground activities in both leading and support roles. SPoRT has

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several major contributions to the PG, such as establishing a successful paradigm for transitioning and evaluating research products in an operational setting. Additionally, SPoRT is supporting efforts with the real-time demonstration of ABI proxy data as well as leading efforts with demonstrations of Geostationary Lightning Mapper (GLM – Christian, 2006) data.

c. *AWIPS II Development Program*

The Advanced Weather Interactive Processing System (AWIPS) Technology Infusion (Tuell et al., 2009), also known as AWIPS II, is a multi-phase program that will deliver a modern, robust software infrastructure to the entire NWS enterprise and will include a series of major system enhancements to allow the NWS to meet its future mission requirements. The first phase includes a re-architecture of the software infrastructure. The second phase includes extending the AWIPS II system to incorporate applications across the NWS including the migration of National Centers AWIPS (NAWIPS). The third phase includes several major enhancements that will benefit the entire enterprise.

SPoRT is creating a unique synergy between its Proving Ground and AWIPS II development efforts, with each program supporting the other. The SPoRT program is actively involved with AWIPS II with access to the early development systems. This access has allowed SPoRT to maintain its mission by collaborating with the NWS Huntsville WFO to create a plug-in to produce unique NASA products made in McIDAS viewable within the NWS' next generation decision support system. This effort also will result in new and improved product / data visualization techniques in the future. Similarly, SPoRT is leading efforts to transition total lightning data to AWIPS II.

2. SPoRT Proving Ground Activities

SPoRT is involved with three product suites for the GOES-R Proving Ground. These are leveraged off of SPoRT's internal expertise in the use of MODIS data from the Aqua and Terra satellites as well as total lightning data, primarily, but not limited to, the North Alabama Lightning Mapping Array (NALMA). Each product suite addresses real-time forecast issues with data designed to simulate GOES-R data and to be viewable in the NWS' next generation AWIPS II decision support system.

a. *Hybrid MODIS-GOES Imagery*

One of the largest product suites transitioned by SPoRT comes from the MODIS instrument. Products range from high resolution visible and infrared imagery, to false color composites showing snow cover, to a four times per day 1 km resolution sea surface temperature composite (Haines et al., 2007). The MODIS instrument serves as an excellent proxy to the future ABI, sharing such positive features as high resolution and similar spectral channels.

Currently, SPoRT transitions the MODIS data as independent swaths when the instrument passes within the field of view of the direct broadcast stations in Madison, Wisconsin and at the University of South Florida (Figure 1). This can be viewed in AWIPS and provides forecasters a high resolution snap shot of current conditions. However, feedback from SPoRT's partners has indicated that this narrow swath data is inherently limited. As shown in Figure 1, there are no data outside the swath. Additionally, since MODIS is a polar orbiting instrument the temporal resolution is on the order of one image approximately every six hours for a given location. This limits the utility as forecasters have indicated that if they cannot have a high frequency loop the data in AWIPS, it is less likely to be used.

SPoRT has addressed this feedback with the creation of a Hybrid MODIS-GOES product. The advantage of this product (Figure 2) is the availability in real-time. Unlike the traditional MODIS swaths, the hybrid uses standard GOES imagery when and where there are no MODIS data. When a MODIS pass is available, these data replace the GOES imagery within the appropriate swath area while leaving the GOES imagery in place outside the swath. The result, as Figure 2 shows is still a swath of high resolution data, but it is now provided with temporal and spatial continuity. This allows a forecaster to loop the data, while simultaneously having regular access to MODIS imagery, and therefore ABI proxy data. In addition to supporting GOES-R PG activities, the Hybrid MODIS-GOES product will be tested with our partners involved in the Standardized Configuration for AWIPS II Testing (SCAT) program.

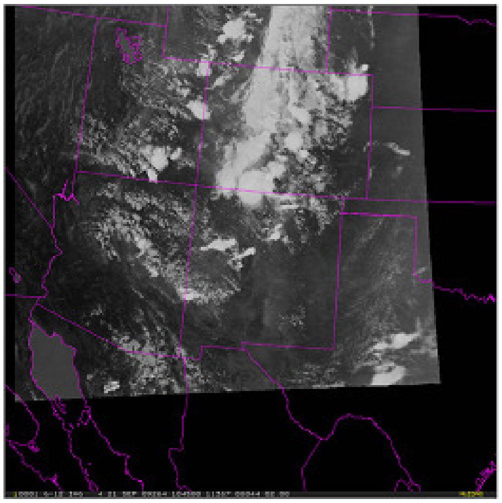

Figure 1: An example 1 km IR MODIS swath as it would be seen in AWIPS II at 1045 UTC 21 September 09. The resolution is very good, but there are no corresponding satellite observations surrounding the MODIS swath.

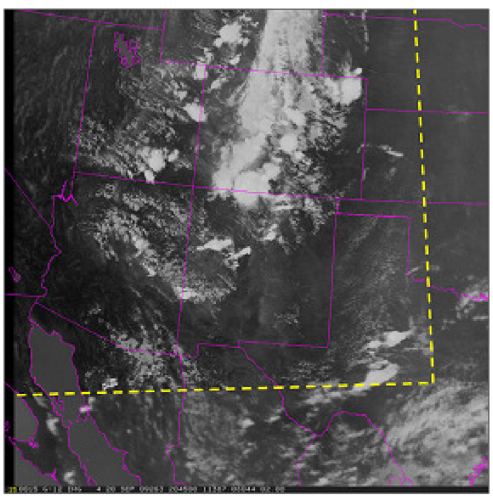

Figure 2: An example of the Hybrid MODIS-GOES IF product at the same time as Figure 1. This product embeds the high resolution MODIS swath with the lower resolution (4 km) GOES data. The yellow dashed line marks the boundary between the two observations with MODIS being above and to the left and GOES being below and to the right.

This product serves as a Proving Ground contribution demonstrating future ABI capabilities, and as a showcase for the capabilities of MODIS. The hybrid complements the Weather Event Simulator case study for the ABI developed by the Cooperative Institute for Meteorological Satellite Studies (CIMSS) at the University of Wisconsin. Where the simulator provides ABI resolution data for a static case study, the SPoRT hybrid is provides real-time exposure to ABI proxy data.

Another enhancement is the correction of the “bow-tie” effect (Figure 3a). This effect is a result of the scanning strategy of the MODIS instrument. This creates a re-sampling of data at the edges of a MODIS swath resulting in previous observations being displayed over the proper observation. The resulting degradation reduces the utility of the data near the edges of the swath. SPoRT has initiated a correction to remove this feature (Figure 3b), allowing the MODIS data, and therefore the hybrid product, to be used for the entire swath.

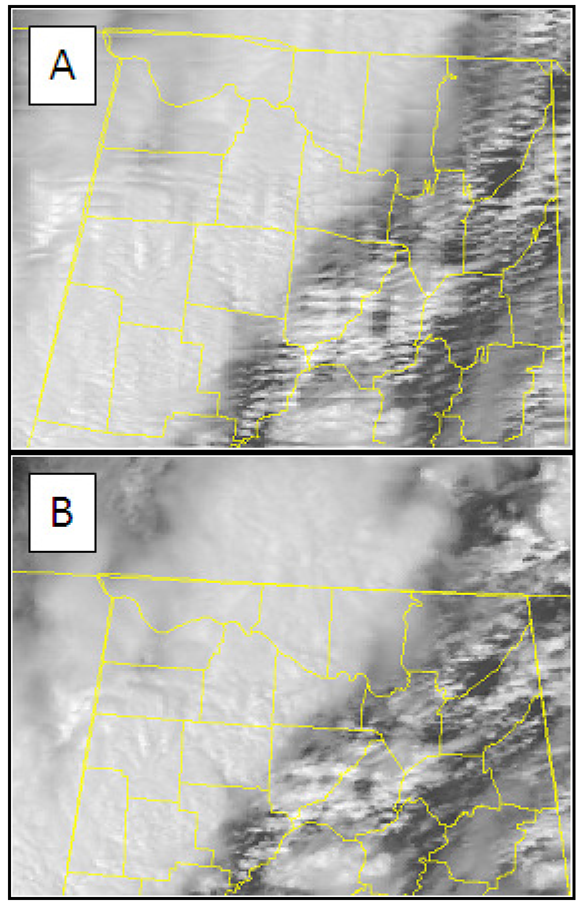

Figure 3: An example of the “bow-tie” effect (A) of a visible MODIS swath over northern Alabama where the sampling technique causes observations to be repeated near the edge of the swath. Image (B) shows the same MODIS data but with the correction applied that provides a superior image.

The hybrid product has been well received in discussions with SPoRT’s WFO partners. The feedback has focused on the ability to provide MODIS data to forecasters that is more readily accepted within the operational environment. With this positive feedback, SPoRT is expanding this effort by developing the hybrid for multi-spectral channels, such as the 11-3.9 µm channels for fog detection.

b. Lightning Threat Forecasts

Beyond efforts with MODIS as an ABI proxy, SPoRT is has a leading role in the transition, training, and use of total lightning for warning decision support operations. SPoRT has transitioned data from the NALMA in Huntsville, Alabama to five NWS offices, starting with WFO Huntsville in 2003. These observations, in part relying on a lightning jump signature (Gatlin, 2006; Schultz), have been successfully used operationally to improve warning lead times and forecasters' situational awareness (Goodman et al., 2005; Nadler et al., 2009). Beyond the most recognizable use with severe weather, total lightning data also have been used to not issue a warning when radar may suggest such an action (i.e. decreasing the false alarm rate), anticipate the first cloud-to-ground strike, and improve lightning safety in general.

SPoRT has more recently been involved in developing derived products from the ground based NALMA data (Buechler et al., 2009). One is the lightning threat product (McCaul et al., 2009). This effort uses the WRF model to produce a quantitative, short-term forecast of lightning threat. Two approaches and a blended combination have been developed. According to McCaul et al. (2009), these methods are distinctive in that they are based entirely on the ice-phase hydrometeor fields generated by regional cloud-resolving numerical simulations. The results have been justified with comparisons of total flash rates from the NALMA network.

The first method (Threat 1) is based on the upward fluxes of the precipitating ice hydrometeors in the mixed-phase region at the -15℃ level. Using this graupel flux to help determine the updraft makes this method more capable of capturing the temporal variability in the lightning threat. Threat 2 is based on the vertically integrated amounts of ice hydrometeors in each model grid column. Unlike the first method, this option is more capable predicting the areal coverage. Both methods use the output as a proxy for total lightning activity. Lastly, a final Threat 3 is produced that blends the two techniques.

For comparison, two figures are presented. Figure 4 plots the actual radar and lightning activity for 0400 UTC on 30 March 2002. The lightning is shown as a flash extent density, where a grid space is counted if any part of a lightning flash is observed within it. This provides the verification for the blended (Threat 3) example shown in Figure 5.

Figure 5 presents a sample, blended Threat 3 output field for the same time as the observations shown in Figure 4. This depicts the flash origin density in flashes per 5 min per km. Unlike the flash extent, the flash origin density only bins the initiation locations of each lightning flash. As can be seen in Figure 5, the model output is internally consistent with the locations of radar and flash origins. The forecast's main drawback is the imperfection in the timing and location of the convection.

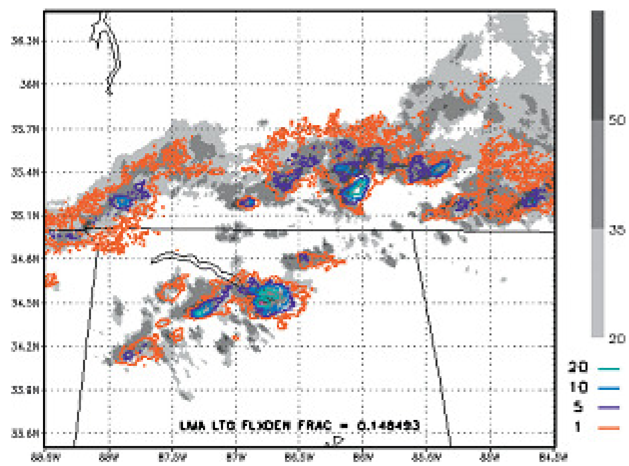

Figure 4: Low-level radar reflectivity from the KHTX Doppler radar at 0400 UTC 30 March 2002 (gray shades), and the Lightning Mapping Array-derived flash extent density (color contours) for a 5 min period at the same time. Flash extent density is depicted for clarity, although all calibrations and predictions of lightning threat are based on observations of flash origin density. Courtesy McCaul et al. (2009).

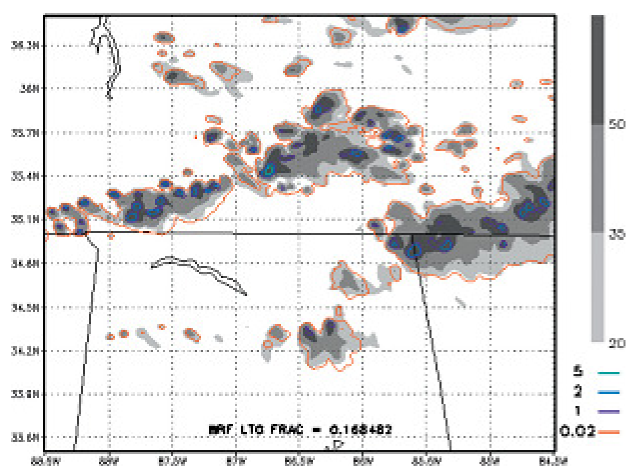

Figure 5: A sample image of the WRF-derived reflectivity at the -15℃ level at the same time as Figure 5 (gray shades), and the WRF-predicted flash origin density using the blend of the Threat 1 and Threat 2 (Threat 3, color contours) for the same time period.

With the preliminary success, the work in McCaul et al. (2009) is being applied to 2008 cases from the Center for the Analysis and Prediction of Storms (CAPS) to test ensemble capabilities. Additionally, this product has been requested to participate with the GOES-R PG. The overall objective of this work is to better characterize the microphysics and storm environment in modeling for improved convective forecasts. Ultimately, these model efforts can be applied to GLM proxy data and eventually the GLM itself. This work will be applied to the ABI simulation case to test its impact with high resolution ABI data available for model runs. In addition, the lightning threat output will be available for evaluation with the 2010 Spring Program in Norman, Oklahoma (Kain et al., 2003).

c. Pseudo Geostationary Lightning Mapper

SPoRT's final lead activity with the GOES-R PG also draws on the program's expertise with total lightning data as described in section 2.c. SPoRT is involved with preparing the user community for the eventual deployment of the Geostationary Lightning Mapper (Christian, 2006). In this effort, SPoRT is both a developer and subject matter expert for developing transition techniques and training.

This initially started with developing the required expertise in transitioning ground based total lightning data to the AWIPS II decision support system. The effort has grown to incorporate the development and distribution of the pseudo GLM product. During the 2009 Spring Program, it was determined that a flash-based GLM demonstration product was needed. The product used at the Spring Program was essentially a low resolution version of the ground based source density product. The resolution was correct, but the output had not relation to what the GLM instrument may eventually observe.

In response to the need for a more realistic GLM product, SPoRT has produced the pseudo GLM demonstration (Figure 6). This takes the raw observations seen by the NALMA or any of the other total lightning networks SPoRT has access to (Washington DC and Kennedy Space Center), and recombines the raw data into individual lightning flashes. The procedure removes any flashes with a small number of raw observations, or sources. This is a simplistic approach to address the fact that the GLM will not observe every feature that the ground based networks will observe. This is due to the fact that GLM is an optical, space based platform while the ground based networks rely on very high frequency (VHF) electromagnetic detections.

These flashes are then binned to an 8 km grid in two ways. The first is the flash extent density (Figure 6). Here, whenever a flash is observed in a grid cell during the current observation time (every one or two minutes), the value for that grid cell is increased by one. The flash extent is very good at indicating the total spatial coverage of storm electrification as well as highlighting intensifying cells. The second method is the flash origin density. Here only the initiation points of each flash are binned. This creates a product that focuses almost exclusively on the cores of individual storms. Current forecaster feedback indicates that the flash extent density is the desired product. Beyond these two methods, other visualizations can be created, such as a time since the last flash grid, to help forecasters know which storms may be decaying and possibly lessening in the lightning threat.

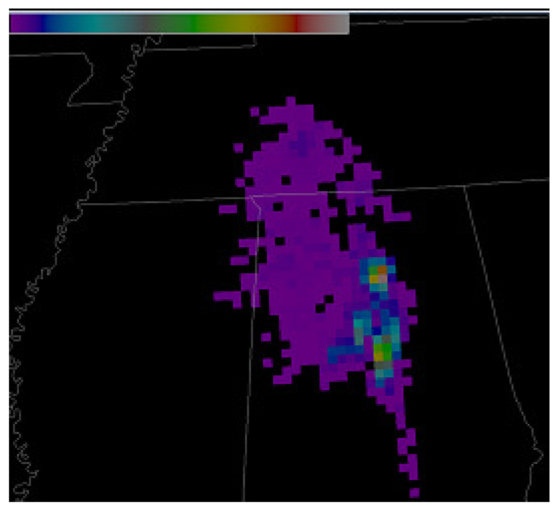

Figure 6: An AWIPS II screen capture of SPoRT's pseudo GLM flash extent density at 8 km resolution from 14 June 09 over northern and central Alabama. The brighter colors indicate locations of the main updrafts while the cooler colors extending to the northwest indicate lightning flashes extending back through the stratiform region of precipitation.

One item that must be noted is that the SPoRT pseudo GLM is intended as a "first look" product. Co-located with the SPoRT program is the GLM AWG. The AWG is tasked with creating the more robust GLM proxy product. The pseudo GLM only uses ground based VHF electromagnetic observations and does not incorporate optical data. The AWG is developing a conversion algorithm to convert the VHF observations of the ground based networks, such as the NALMA, into what the optically based GLM will observe by using the Lightning Imaging Sensor (LIS) (Christian et al., 1999) aboard the Tropical Rainfall Measuring Mission satellite. This sensor is the closest analogy to the future GLM instrument. The GLM AWG is developing a proxy product to capture all three categories of GLM observations. These include events, which are individual pulses of visible light, groups that are clusters of events, and flashes that are created from combinations of groups. Both the AWG proxy GLM and SPoRT's pseudo GLM are limited to the domains of the current ground based networks.

Until the AWG proxy is available, the SPoRT pseudo GLM will serve as a stand-in. The advantage of the pseudo GLM is that it can be easily processed for any total lightning networks. In addition, while it is a far more simplistic product than the AWG proxy, it maintains the same spatial resolution of binned flashes and a slightly lower temporal resolution (1 min versus 20 s). The other advantage is that the pseudo GLM introduces a wide range of forecasters to a demonstration of GLM's potential capabilities. Already, the GOES-R PG and the Spring Program will be implementing the pseudo GLM in their operational testing during the spring of 2010.

This feedback generated by SPoRT's partners and the Spring Program allows SPoRT the ability to begin developing ways to display the eventual AWG GLM proxy in AWIPS II ahead of the proxy's release. Once the AWG GLM proxy is available, SPoRT will be responsible for transitioning this product to AWIPS II. The efforts with the pseudo GLM will reduce the time required to begin assessing the AWG GLM proxy. This lead time will give the GOES-R PG, with SPoRT's assistance, more time to assess the operational capabilities of the GLM ahead of launch, thus promoting Day-1 readiness.

3. Summary of SPoRT Efforts

This conference papers serves as a brief overview of the activities and efforts the SPoRT program has undertaken to support both the GOES-R Proving Ground and the AWIPS II development efforts. SPoRT's participation with each of these activities ensures SPoRT's continued success in transitioning unique NASA data to the operational weather community. These efforts have been focused on two key areas of SPoRT expertise; operational uses of MODIS observations as proxies for the Advanced Baseline Imager (ABI) as well as total lightning applications that can be applied to demonstration products for the Geostationary Lightning Mapper (GLM). Beyond these products, SPoRT will support the Proving Ground with its unique paradigm of training and assessment techniques.

SPoRT has developed a Hybrid MODIS-GOES product to act as a proxy for the ABI. This product complements the case study work developed by CIMSS to simulate an entire day's worth of ABI resolution data. Unlike the ABI simulation, the SPoRT hybrid embeds high resolution MODIS data into a standard GOES image. This allows an ABI proxy to be displayed in the AWIPS II environment in real-time. This has the benefit of exposing forecasters to both MODIS and future ABI capabilities in a daily fashion in their native decision support system. Feedback for this has already been positive using a longwave infrared hybrid. The positive feedback has led to continued efforts to create additional and multi-channel hybrid products.

While less directly tied to the PG, SPoRT is leading efforts with collaborations with the Jet Propulsion Laboratory to create an enhanced sea surface temperature (SST) composite. This updates SPoRT's original MODIS SST composite (Haines et al., 2007) by incorporating passive microwave observations from AMSR-E and a background analysis to fill-in where appropriate. These enhancements maintain the original products benefits of a 1 km SST composite product available four times per day, but with far less latency due to cloud cover and extending the domain from regional to global. The primary use for this product will be in modeling efforts using GOES-R resolution data. Already, several assessments using the Haines et al. (2007) data have shown promise (Case et al., 2008; LaCasse et al., 2008) and has been incorporated into version three of the Weather Research and Forecasting Environmental Modeling System model (Case et al., 2009).

The next two activities involve SPoRT's expertise with total lightning and the SPoRT program is acting as both a developer and subject matter expert. First is the lightning threat forecast by McCaul et al. (2009). Here short-term forecasts using the WRF model are produced based on graupel flux and integrated ice content as proxies for total lightning activity. These forecasts provide operational users insight into the location and intensity of lightning activity, although the output is constrained by the limits of the individual model runs. However, with positive results, efforts are underway to generate ensemble forecasts and the technique will be applied in the 2010 Spring Program in Norman, Oklahoma. The ultimate goal is to develop a technique to better quantify the mircophysics and storm environment for improved convective forecasts. The effort will be modified to incorporate information from GOES-R proxy data.

The second total lightning activity is the pseudo GLM product. This was SPoRT's response to the Proving Ground's need for a flash-based GLM demonstration product that could be applied to multiple total lightning networks in advance of the GLM Algorithm Working Group's (AWG) more robust GLM proxy. The SPoRT pseudo GLM can be applied to any ground based total lightning network and provides forecasters with insight into the resolution and capabilities of the GLM instrument. In addition, the efforts to transition the pseudo GLM to AWIPS II will speed the transition of the final AWG GLM proxy, when it is ready. This product has been selected for use in the 2010 Spring Program.

The final point with the GOES-R Proving Ground efforts is that this is a synergistic project with SPoRT's AWIPS II development activities. SPoRT is working to provide all of these products in AWIPS II, which is the next generation decision support system for the National Weather Service. SPoRT's early involvement with the AWIPS II project will assist in the real-time assessment and evaluation of the GOES-R proxy products, enhancing the final products, and provide training in the use of the observations that will be available once GOES-R is operational.

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