

## NASA SPoRT GOES-R Proving Ground Activities

Geoffrey T. Stano<sup>1</sup>, Kevin K. Fuell<sup>2</sup>, Gary J. Jedlovec<sup>3</sup>

### ABSTRACT

The NASA Short-term Prediction Research and Transition (SPoRT) program is a partner with the GOES-R Proving Ground (PG) helping prepare forecasters understand the unique products to come from the GOES-R instrument suite. SPoRT is working collaboratively with other members of the GOES-R PG team and Algorithm Working Group (AWG) scientists to develop and disseminate a suite of proxy products that address specific forecast problems for the WFOs, Regional and National Support Centers, and other NOAA users. These products draw on SPoRT's expertise with the transition and evaluation of products into operations from the MODIS instrument and the North Alabama Lightning Mapping Array (NALMA).

The MODIS instrument serves as an excellent proxy for the Advanced Baseline Imager (ABI) that will be aboard GOES-R. SPoRT has transitioned and evaluated several multi-channel MODIS products. The true and false color products are being used in natural hazard detection by several SPoRT partners to provide better observation of land features, such as fires, smoke plumes, and snow cover. Additionally, many of SPoRT's partners are coastal offices and already benefit from the MODIS sea surface temperature composite. This, along with other surface feature observations will be developed into ABI proxy products for diagnostic use in the forecast process as well as assimilation into forecast models.

In addition to the MODIS instrument, the NALMA has proven very valuable to WFOs with access to these total lightning data. These data provide situational awareness and enhanced warning decision making to improve lead times for severe thunderstorm and tornado warnings. One effort by SPoRT scientists includes a lightning threat product to create short-term model forecasts of lightning activity. Additionally, SPoRT is working with the AWG to create GLM proxy data from several of the ground based total lightning networks, such as the NALMA. The evaluation will focus on the vastly improved spatial coverage of the GLM, but with the trade-off of lower resolution compared to the NALMA.

In addition to the above tasks, SPoRT will make these data available in the NWS' next generation display software, AWIPS II. This has already been successfully completed for the two basic GLM proxies. SPoRT will use these products to train forecasters on the capabilities of GOES-R and foster feedback to develop additional products, visualizations, and requirements beneficial to end users' needs. These developments and feedback will be made available to the GOES-R Proving Ground for the upcoming 2010 Spring Program in Norman, Oklahoma.

<sup>1</sup> NASA Short-term Prediction Research and Transition program / ENSCO, Inc., Huntsville, Alabama

<sup>2</sup> NASA Short-term Prediction Research and Transition program / UAH, Huntsville, Alabama

<sup>3</sup> NASA Marshall Space Flight Center, Huntsville, Alabama

*Corresponding author address:*

Geoffrey Stano or Kevin Fuell

Short-term Prediction Research and Transition Program

320 Sparkman Drive, Huntsville, AL 35805

email: [geoffrey.stano@nasa.gov](mailto:geoffrey.stano@nasa.gov) and [kevin.fuell@nasa.gov](mailto:kevin.fuell@nasa.gov)

## 8.2

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Geoffrey T. Stano<sup>1\*</sup>, Kevin K. Fuell<sup>2</sup>, Gary J. Jedlovec<sup>3</sup>

<sup>1</sup>ENSCO Inc. / Short-term Prediction Research and Transition (SPoRT), Huntsville, Alabama

<sup>2</sup>University of Alabama / SPoRT, Huntsville, Alabama

<sup>3</sup>NASA Marshall Space Flight Center / SPoRT, Huntsville, Alabama

#### 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 NPOESS and GOES-R instruments.

##### b. The GOES-R Proving Ground

The Geostationary Operational Satellite (GOES-R) Satellite Proving Ground (PG) project ([http://cimss.ssec.wisc.edu/goes\\_r/proving-ground/mission\\_statement.html](http://cimss.ssec.wisc.edu/goes_r/proving-ground/mission_statement.html)) 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.

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 (PG) activities

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\*Corresponding author address: Geoffrey Stano,  
320 Sparkman Dr, Huntsville, AL 35805  
email: [geoffrey.stano@nasa.gov](mailto:geoffrey.stano@nasa.gov)

in both leading and support roles. SPoRT has several major contributions to the PG. These include 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 enterprise 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 create a plug-in to produce unique NASA products 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 four 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 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. 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. This limits the utility as forecasters have indicated that if they cannot have a high frequency loop the data in AWIPS, it is generally 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.

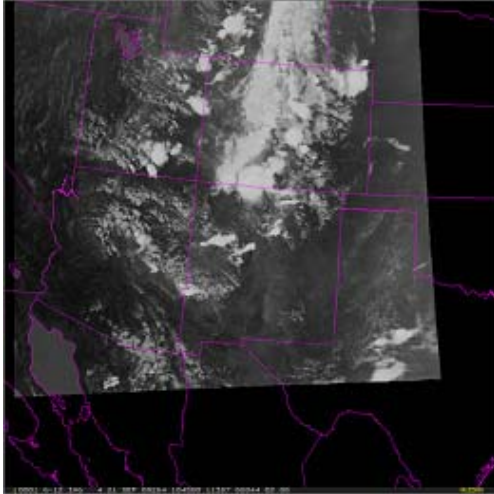


Figure 1: An example 1 km IR MODIS swath as it would be seen in AWIPS II at 1045 UTC 21 September 09. The resolution is very good, but there are no corresponding satellite observations surrounding the MODIS swath.

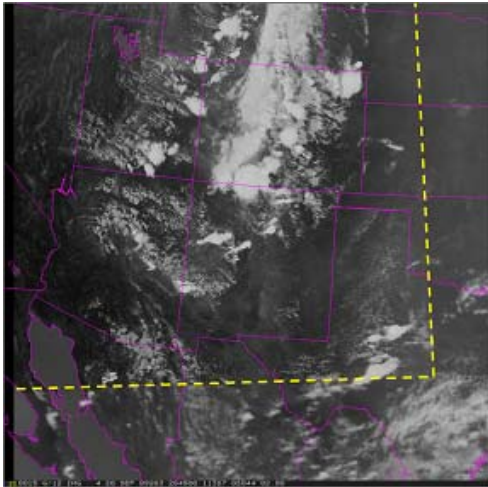


Figure 2: An example of the Hybrid MODIS-GOES IF product at the same time as Figure 1. This product embeds the high resolution MODIS swath with the lower resolution (4 km) GOES data. The yellow dashed line marks the boundary between the two observations with MODIS being above and to the left and GOES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

This product serves both as a Proving Ground contribution demonstrating future ABI capabilities, and as an improved way to showcase the capabilities of MODIS. This product will serve to complement 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 designed to provide real-time exposure to ABI proxy data during forecast operations.

Another enhancement is the correction of the “bow-tie” effect (not shown). 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. SPoRT has initiated a correction to remove this feature, allowing the MODIS data, and therefore the hybrid product, to be used for the entire swath.

The Hybrid MODIS-GOES product has been well received in discussions with SPoRT’s WFO partners. Most of the feedback has focused on the ability to provide MODIS data to forecasters in a format 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  $\mu\text{m}$  channels for fog detection.

#### *b. MODIS Sea Surface Temperature Composites*

Another product with dual use as an operational MODIS product and an ABI proxy is the sea surface temperature (SST) composite (Haines et al., 2007). This product, developed by SPoRT, updates four times a day at 1 km resolution. The composite takes the three most recent observations for each pixel and averages the two warmest observations to create a continuous SST field. This approach helps eliminate cloud contamination. The four times per day updates allow for the capture of diurnal changes in the SST field. For comparative purposes the MODIS SST composite at 1 km resolution (Figure 3a) is shown with the half degree resolution Real Time Global (RTG – Thiébaux et al., 2003) (Figure 3b).

With higher resolution than existing SST products, SPoRT has begun providing the SST composite for use in the Weather Research and Forecasting (WRF) Environmental Modeling System (EMS) model and is available as the default ocean surface boundary option to users of version 3 of the software (Case et al. 2009). Assessments (Case et al., 2008; LaCasse et al., 2008) have shown promising results. This is due to the improved resolution of SST gradients to better resolve surface energy fluxes. The MODIS SST composite has resulted in better representation of the marine boundary layer and more realistic fluxes of heat and moisture from the ocean to the atmosphere. A recent example was with WFO Mobile in their local model runs

for Tropical Storm Claudette. Figure 4 shows the forecast difference between the MODIS SST composite and the RTG SST model runs for the 6-hr forecast. The MODIS run shows an elongated region of enhanced convergence/cyclonic flow, coincident with a high/low couplet of mean sea level pressure differences on the order of a few tenths of a millibar. This run more accurately resolved the circulation and location of Tropical Storm Claudette than the model runs without the MODIS data.

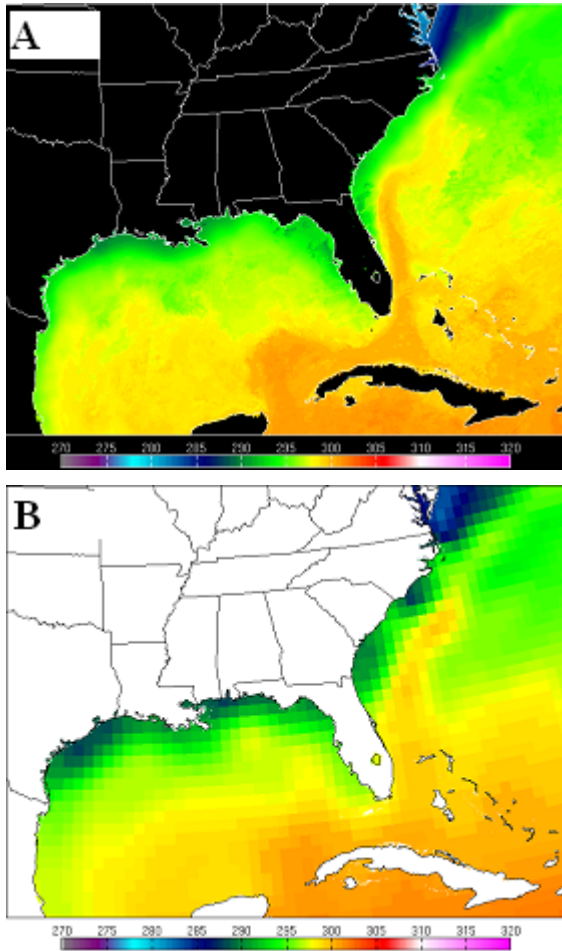


Figure 3: A comparison between the (A) MODIS SST composite from 16 December 09 showing the high 1 km resolution and (B) the RTG SST analysis from the same date at a half degree resolution. Note the enhanced view of the Gulf Stream Current off of Florida's east coast and the southerly extent of the cooler shelf waters.

With this success, the MODIS SST composite is being enhanced (Figure 3a) in a collaborative effort with the Jet Propulsion Laboratory to include Advanced Microwave Scanning Radiometer – Earth Observing System (AMSR-E) data. The inclusion of AMSR-E passive microwave data allows for a reduction of

data latency that is present when persistent cloud cover prevents new MODIS SST retrievals. Lastly, the enhanced SST composite incorporates a global SST analysis product to fill in areas where MODIS and AMSR-E data are either missing or highly latent. Testing is presently ongoing to evaluate which SST analysis is most appropriate. The full product uses a latency-weighted averaging scheme to draw on the strengths of each individual observation system to produce a product with the same temporal cycle and resolution as the original MODIS SST composite, but with dramatically reduced latency.

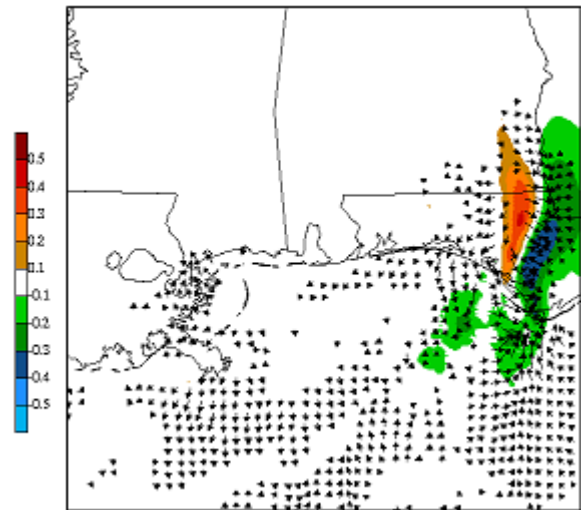


Figure 4: A difference in the WRF forecast (MODIS – RTG) mean sea level pressure (mb - shaded) and vector difference (arrows) of the 10 m winds for the 6 hr forecast valid at 0900 UTC 17 August 2009.

### c. Lightning Threat Forecasts

Beyond SPoRT's efforts with MODIS as an ABI proxy, SPoRT is taking a leading role in the transition, training, and use of total lightning data for warning decision support operations. SPoRT has transitioned data from the North Alabama Lightning Mapping Array (NALMA) in Huntsville, Alabama now 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 in an operational environment 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, the 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) and to anticipate the first cloud-to-ground strike.

SPoRT has more recently been involved in developing derived products from the ground based NALMA data (Buechler et al., 2009). One such project with application to the Proving Ground 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  $-15^{\circ}\text{C}$  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 in 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 5 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 6.

Figure 6 presents a sample, blended Threat 3 output field for the same time as the observations shown in Figure 5. 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 6, 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. Still, the model forecast shows promising results.

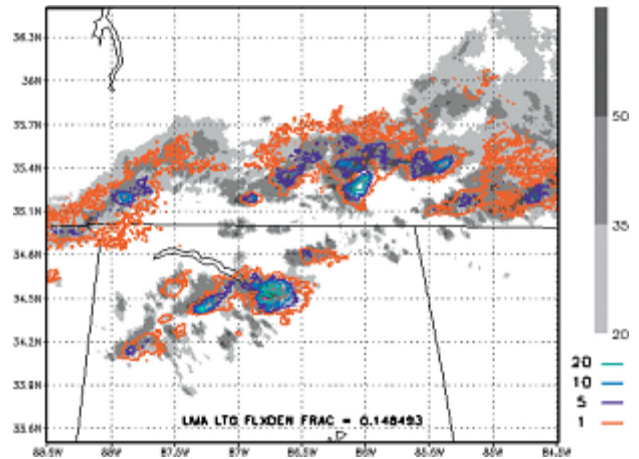


Figure 5: Low-level radar reflectivity from the KHTX Doppler radar at 0400 UTC 30 March 2002 (gray shades), and the Lightning Mapping Array-derived flash extent density (color contours) for a 5 min period at the same time. Flash extent density is depicted for clarity, although all calibrations and predictions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

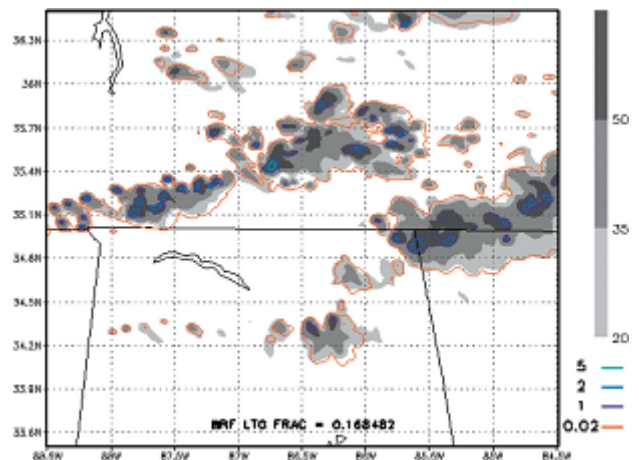


Figure 6: A sample image of the WRF-derived reflectivity at the  $-15^{\circ}\text{C}$  level at the same time as Figure 5 (gray shades), and the WRF-predicted flash origin density using the blend of the Threat 1 and Threat 2 (Threat 3, color contours) for the same time period.

With the preliminary success, the work in McCaul et al. (2009) is now 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. 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).

*d. 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. This 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. This is not what the GLM instrument will see.

In response to this need, SPoRT has produced the pseudo GLM demonstration product (Figure 7). This takes the raw observations seen by the NALMA or any of the other total lightning networks SPoRT has access to (Washington DC, Kennedy Space Center, and White Sands Missile Range), 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 see every observation that the ground based networks will observe.

These flashes are then binned to an 8 km grid in two ways. The first is the flash extent density. 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.

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 in Huntsville, Alabama is the GLM AWG. The AWG is tasked with creating the more robust GLM proxy product. The pseudo GLM only uses ground based very high frequency (VHF) electromagnetic observations. However, the GLM will be a visible light optical detector. 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. Both products are still limited to where the current ground based networks are located.

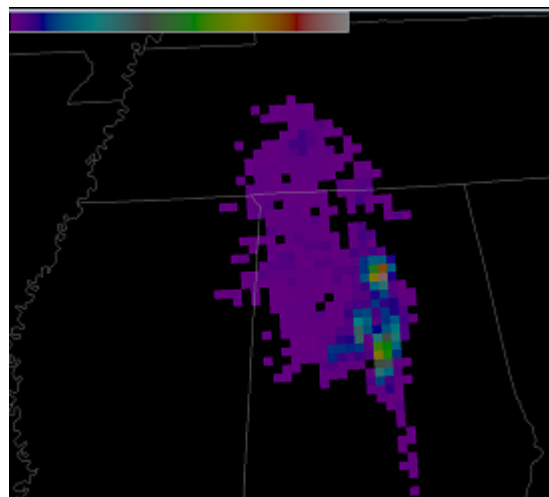


Figure 7: An AWIPS II screen capture of SPoRT's pseudo GLM flash extent density at 8 km resolution from 14 June 09 over northern and central Alabama. The brighter colors indicate locations of the main updrafts while the cooler colors extending to the northwest indicate lightning flashes extending back through the stratiform region of precipitation.

The GLM includes three categories of observations. The first are events, which are simply detected pulses of visible light. The next are groups, which are clusters of events. Finally, groups will be combined into flashes. The AWG is basing its algorithm on comparisons between ground based VHF networks and the Tropical Rainfall Measuring Mission's Lightning Imaging Sensor (LIS). The LIS is an optical detector and is the closest analogy to the future GLM sensor.

Once the AWG GLM proxy is available, SPoRT will be responsible for transitioning this product to AWIPS II. 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 of the four total lightning networks SPoRT has data

access to and could be applied to the remaining three 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 unique 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. This 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 product 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. Feedback for this

has already been positive using a longwave infrared hybrid, which has led to focusing on additional and multi-channel hybrid products.

SPoRT is leading efforts with collaborations with the Jet Propulsion Laboratory to create the enhanced sea surface temperature (SST) composite. This updates SPoRT's original MODIS SST composite 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 at four times per day, but with far less latency due to cloud cover and extending the domain from regional to global.

The next two activities involve SPoRT's expertise with total lightning and the SPoRT program is acting as both the 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 now underway to generate ensemble forecasts and the technique will be applied in the 2010 Spring Program in Norman, Oklahoma. The final advantage of this technique is that it can 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 network SPoRT and the Proving Ground have data access to and provides forecasters with insight into the resolution 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 that the National Weather Service is beginning to switch to. 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 that will be available once GOES-R is operational.

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