3A.2 RESULTS FROM THE GOES-R PROVING GROUND PORTION OF THE 2014 HWT SPRING EXPERIMENT

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1. INTRODUCTION

Geostationary Operational Environmental Satellite R-series (GOES-R) Proving Ground demonstrations in the National Oceanic and Atmospheric Administration (NOAA) Hazardous Weather Testbed (HWT) provide users with a glimpse into the capabilities, products and algorithms that will be available with the future geostationary satellite series, beginning with GOES-R, which is scheduled to launch in early 2016. The education and training received by participants in the HWT helps to ensure day-1 readiness for the use of GOES-R data.

The HWT provides a unique opportunity for product developers to interact directly with end-users and to observe baseline and enhanced-capability GOES-R algorithms being used alongside operational datasets in a simulated operational forecast and warning environment (research to operations, or R2O). This interaction helps the developers to understand how forecasters use their products, and what improvements might increase the product usability in an operational environment. Feedback received from participants during past HWT experiments has proven invaluable to the continued development of GOES-R algorithms (operations to research, or O2R). Furthermore, the Experimental Warning Program (EWP) of the HWT allows for the testing of satellite-based products in the second generation Advanced Weather Interactive Processing System (AWIPS-II) data visualization system.

This report summarizes the activities and results from the GOES-R Proving Ground demonstration at the 2014 Spring Experiment, which took place at the NOAA HWT in Norman, OK, from May 5 to June 6. The Proving Ground activities were focused in the EWP which ran for 4 weeks, with informal demonstrations taking place in the Experimental Forecast Program (EFP) of the HWT which ran for 5 weeks. A total of twelve National Weather Service (NWS) forecasters representing four NWS regions and an additional four broadcast meteorologists evaluated nine experimental GOES-R products, capabilities and algorithms in the real-time simulated short-term forecast and warning environment of the EWP using AWIPS-II. Many visiting scientists also attended the EWP over the four weeks to provide additional product expertise.

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2. PARTICIPANTS AND DAILY ACTIVITIES

This year, the EWP was conducted during the weeks of May 5, May 12, May 19, and June 2, with three NWS forecasters participating each week. One of the twelve NWS participants was a Center Weather

Service Unit (CWSU) forecaster. Additionally, in an effort to extend Proving Ground knowledge and participation to the broader meteorological community, and recognizing the critical role played by the private sector in communicating warnings to the public, one broadcast meteorologist per week participated alongside the NWS forecasters. Each week participants arrived in Norman on a Sunday, worked 8-hour forecast shifts Monday-Thursday and a half-day on Friday before traveling home Friday afternoon. Training modules (in the form of Articulate Power Point presentations) for each demonstration product were completed by participants prior to their arrival in Norman.

Much of Monday was a spin-up day that included a one hour orientation, familiarization with the AWIPS-II system, and one-on-one hands-on training. The Tuesday, Wednesday and Thursday “flex shifts” had a start time anywhere between 9 am and 3 pm, depending on when the most active convective weather was expected to occur. The half-day on Friday consisted of a weekly debrief and preparation and delivery of the “Tales from the Testbed” webinar. The decision on when and where to operate each day was partially based off of input from the daily EFP weather briefing and EFP 1- and 3-hour probabilistic severe forecasts.

Shifts typically began a couple of hours before convective initiation was expected to occur, as many of the products demonstrated this year have their greatest utility in the pre-convective environment. Forecasters, working in pairs, provided experimental forecasts for the given County Warning Area (CWA) via blog posts. Early in the shift, these were primarily mesoscale discussions highlighting what the applicable demonstration products were showing. Once convection began to mature, one forecaster in the pair would switch to issuing experimental warnings for their CWA while the other forecaster would continue to monitor the mesoscale environment. Blog posts regarding the use of demonstration products in the warning decision-making process were composed during this period along with continued posts about the mesoscale environment. If severe convective activity in a CWA ceased or was no longer expected to occur, the pair of forecasters would be moved to a more convectively active CWA.

At the end of each week, the four forecasters participated in the “Tales from the Testbed” webinar, broadcast by the Warning Decision Training Branch (WDTB). These 22-minute presentations gave participants an opportunity to share their experience in the HWT with over 30 offices each week, including NWS Headquarters, NWS Weather Forecast Offices (WFOs), and product developers, providing widespread exposure for the GOES-R Proving Ground products. Topics for each of the four webinars were chosen based on the particular week's weather. Sixteen minutes were allowed afterward for questions and comments.

Feedback from the forecasters came in several forms. During the experimental short-term forecast and warning shifts, participants blogged their forecast/warning decisions along with feedback they had regarding the products under evaluation. Over 350 GOES-R related blog posts were written during the four weeks of the experiment by forecasters, developers, and the HWT Satellite Liaison. At the end of each Monday-Thursday shift, participants completed a survey covering all of the demonstrated products. The Tuesday-Thursday shifts began with a "daily debrief" in which participants discussed their use of the demonstration products during the previous day's activities. On Friday morning, a "weekly debrief" allowed product developers an opportunity to ask the forecasters any final questions, and for the forecasters to share their final thoughts and suggestions for product improvement.

3. RESULTS

3.1 NSSL-WRF GOES-R ABI Synthetic Imagery

Synthetic satellite imagery demonstrated in the HWT was produced from the NSSL-WRF convection-allowing Numerical Weather Prediction (NWP) model at spectral bands that will be available with the GOES-R Advanced Baseline Imager (ABI). After the NSSL-WRF cycle is complete, model output is fed into the Community Radiative Transfer Model (CRTM) to produce the synthetic imagery. The imagery is generated daily from the 0000 UTC model cycle as a 13-36 hour forecast valid from 1300 UTC on the current day to 1200 UTC on the next day. This year, the GOES-R ABI 10.35 um longwave window channel and 6.95 um IR midlevel water vapor channel were available to the forecasters. The purpose of this demonstration was to expose forecasters to GOES-R ABI channels, evaluate synthetic imagery as an additional means of viewing model data, and test a real-time NWP model forecast evaluation technique (Bikos et al. 2012).

The synthetic satellite imagery provided participants with an alternative method for viewing model data in 4-dimensions. The integrated images allowed forecasters to use their experience interpreting satellite imagery to more quickly comprehend the model information. More specifically, the imagery helped to increase situational awareness on timing and location of features such as shortwaves, convective initiation and dissipation, fog and low stratus clouds, high cirrus clouds and general cloud cover. Several forecasters noted that current sky cover forecast guidance is lacking, and that this tool could certainly help to fill that void. The synthetic imagery provided forecasters with more detailed insight into how the day's weather might unfold.

Through side-by-side comparisons between the synthetic imagery and observed GOES imagery of a similar spectral band, users were able to easily spot errors present in the model forecast (Fig. 1). Participants speculated the effects that displacements early in the forecast cycle might have on the rest of the model forecast. In general, they found that the synthetic satellite imagery was a useful and unique tool for evaluating a particular model forecast cycle.

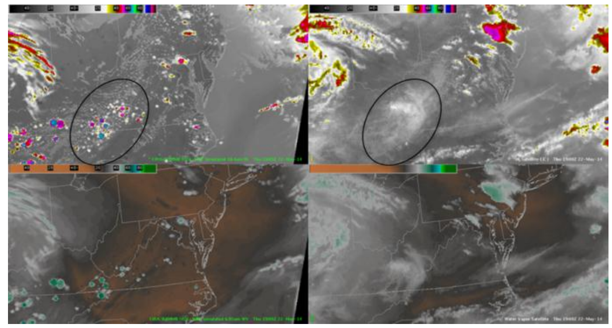

Figure 1: On left, 22 May 2014 00 UTC NSSL-WRF 19 hour forecast valid at 19 UTC for 10.35 µm IR (top) and 6.95 µm IR (bottom). On right, 22 May 2014 19 UTC observed GOES-East 11 µm IR (top) and 6.7 µm IR bottom. From blog post "Simulated Satellite WRF. Cirrus/Insolation issues leading to convection".

Overall, participants from all weeks agreed that the synthetic imagery would be useful to have in their forecast offices, and would like to see it produced with other high-resolution convection-allowing models. It provides them with an alternative method for visualizing model output and a relatively easy way to spot errors in the model forecast.

3.2 NearCast Model

The NearCast model was designed to increase the utility of GOES moisture and temperature retrievals. The model uses a Lagrangian approach to dynamically project GOES sounding data forward in space and time at multiple layers of the atmosphere that are consistent with the observing capabilities of the GOES instrument. The technique preserves fine details present in the full-resolution (10-12 km) observations such as gradients, maxima, and minima, which often provide the focus for convective development. The multi-layer NearCast products are used to help determine where and when convective development is more or less likely to occur in the near (1-9 hour forecast range) future (Petersen et al. 2013). In the GOES-R era, the NearCast model will utilize Legacy Vertical Temperature and Moisture Profiles, which are baseline GOES-R products. These sounding products will provide comparable quality to those from the current GOES sounder (Schmit et al. 2008).

Available to forecasters in the HWT for the 2014 Spring Experiment were analyses and 1-9 hour forecasts of: low- (centered around ~780 mb) and mid- (centered around ~500 mb) layer theta-e, vertical theta-e difference (mid-low), low- (~900-700 mb) and mid-

(~700-300 mb) layer precipitable water (PW), and vertical PW difference (low-mid). The theta-e difference instability field was especially well-received by the forecasters, garnering an average rating of 4.41 out of 5 from participants when asked how useful its addition would be to their forecast office.

Part of this year's NearCast demonstration included the evaluation of NearCast analysis animations to determine whether they might help a forecaster gain a better understanding of how the atmosphere has evolved to its current thermodynamic state. Forecasters were encouraged to load a 4-panel NearCast procedure which included low and mid-layer theta-e, theta-e difference, and low layer PW. This enabled the forecaster to view the past several hours of NearCast analyses leading up to the present, followed by the latest Nearcast forecast. Additionally, by overlaying IR satellite, visible satellite, or radar imagery, forecasters could see how convective activity has evolved with respect to the NearCast fields (Fig. 2). 87% of survey respondents found that analysis loops of NearCast fields at least "somewhat" (i.e., greater than or equal to 3 on a scale of 1-5) improved their situational awareness at the beginning of the shift.

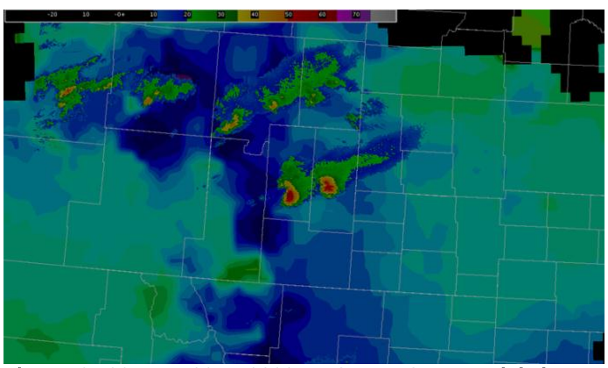

Figure 2: 20 May 2014 2200 UTC NearCast model theta-e difference analysis with Multi-Radar/Multi Sensor (MRMS) composite reflectivity overlaid. From blog post "NearCast Supports Weakening".

Evaluating the degree to which the 1-9 hour NearCast forecasts helped to increase confidence in near future atmospheric moisture and stability evolution, 88% of forecasters responded at least "somewhat". In particular, the forecasts helped increase situational awareness to where ongoing convection was more likely to continue to progress, and where new convection was more likely or less likely to develop.

The NearCast analyses and short-range forecasts were the primary ways that forecasters used the GOES moisture and temperature soundings in their forecast process. The NearCast products were especially effective in increasing situational awareness to where convection was more and less likely to develop in the 0-6 hour forecast range, as well as how on-going convection was likely to evolve. In particular, instability and moisture gradients and maxima depicted in the NearCast fields were often the focus for convective development.

Forecasters across all weeks integrated NearCast products effectively into their forecast decision-making process, primarily in assessing the current and predicted state of the thermodynamic environment. Although data gaps are often present in the NearCast fields in areas of prolonged cloud cover, participants understood why they exist and most were not bothered by them. They appreciated having high-resolution (horizontally and temporally), observation-based information about near-future atmospheric moisture and stability changes that is otherwise limited, but highly desired.

3.3 GOES-R Convective Initiation

The GOES-R Convective Initiation (CI) data fusion algorithm combines various GOES convective cloud properties and Rapid Refresh model environmental fields in a logistic regression framework to produce probabilities of imminent convective initiation (Mecikalski et al., 2014). The output is a 0-100% probability that a given cloud object will achieve a 35 dBz reflectivity echo at the -10C level in the ~0-2 hour forecast range. Some modifications to the algorithm since last year's experiment include improved detection of cumulus clouds at night and a significant increase to the GOES-West validation database. For product display in AWIPS-II, default procedures overlaying the CI algorithm on visible and IR imagery were set up for and utilized by the participants. The main goals of this demonstration were to gauge the real-time performance of the GOES-R CI algorithm and to assess its impact on operational nowcasts and forecasts.

54% of survey respondents felt that the CI algorithm had "some" impact in the operational nowcast/forecast process, while 19% believed it had a large or very large impact. There were situations where the product helped to increase forecaster confidence on where convection was more and less likely to develop in the near future (Fig 3). The probabilities helped to focus attention to particular areas of interest and away from less favorable ones. Furthermore, forecasters found that trends in the probabilities as well as relative probabilities were often just as valuable (if not more) to the forecaster as the exact probability values.

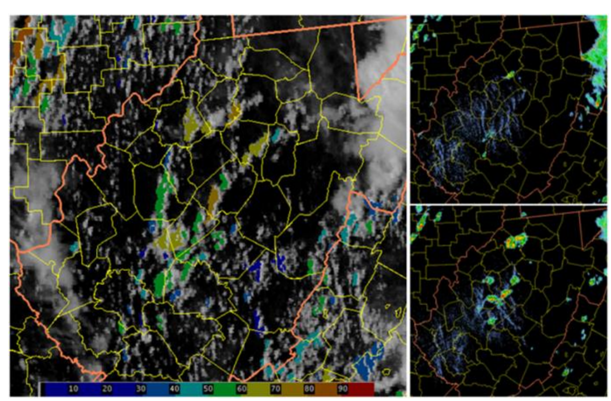

Figure 3: 14 May 2014 2100 UTC GOES-R CI, visible satellite imagery (left), 2100 UTC radar reflectivity (top right), 2145 UTC radar reflectivity (bottom right). From blog

post "GOES-R Convection Initiation Nails Developing Storms in Wonderful West Virginia".

Participants did, however, note several deficiencies present in the algorithm. The probabilities were often inconsistent, sometimes giving <10% probabilities where convection developed, or high probabilities where nothing occurred. The lead-time to CI was also quite inconsistent, spanning anywhere from negative lead-time to two hours. Such inconsistencies often made it difficult for participants to identify specific thresholds to look for a given situation. Finally, participants mentioned that the product display was often very noisy with probability values exhibiting considerable variability from image to image. To help alleviate this problem, participants made a variety of suggestions for product visualization, often implementing changes themselves.

Forecasters also mentioned specific situations where the product's performance was exceptionally poor. The probabilities changed drastically and became much less useful at night, when the spatial resolution is purely IR-based (4 km vs. 1 km) and a much more simplified cloud mask is used. Also, discrepancies between GOES-East and West probabilities (where they overlapped) confused forecasters and decreased their confidence in the product in those areas. Participants agreed that the algorithm performed much better when the satellite was in Rapid Scan Mode versus routine mode, indicating that the higher temporal resolution, in addition to the improved spatial and spectral resolutions, of the GOES-R ABI will have a positive impact on the algorithm.

3.4 Probability of Severe Model

New to the HWT this year was the ProbSevere model. This observation-driven statistical model produces a probability that a developing storm will first produce any severe weather in the next 60 minutes (Cintineo et al. 2014). The data fusion product merges NWP-based instability and shear parameters, satellite vertical growth and glaciation rates, and radar-derived maximum expected size of hail (MESH). The model updates approximately every two minutes (with MRMS) and is displayed as contours colored by probability and overlaid on radar imagery. Data readout is available by mousing over the probability contour, revealing the probability of severe along with the model predictor values (Fig. 4). The main purpose of this demonstration was to determine if the ProbSevere model output could be used to increase confidence and/or lead-time for severe thunderstorm and/or tornado warning issuance. Additionally, feedback regarding the product display and readout was desired.

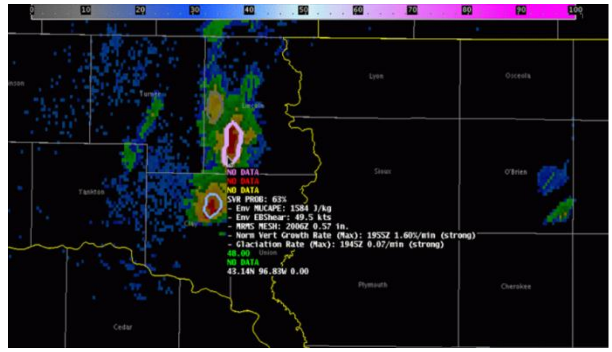

Figure 4: 08 May 2014 2006 UTC MRMS composite reflectivity and ProbSevere model probability contour and readout. From blog post "Storms develop further southwest along dryline".

The vast majority of participants agreed that the ProbSevere Model did indeed have a positive impact on their warning decision-making. It often pushed the forecaster in a particular direction when on the fence between issuing a warning or not. In fact, when asked if the ProbSevere model helped to increase their confidence in issuing severe thunderstorm and tornado warnings, 78% of respondents answered "yes". This was true for decisions to issue a warning and for the decisions to not issue a warning. Additionally, almost half of the respondents (47%) answered that the model increased lead-time to warning issuance. When asked if they would use the product during warning operations at their home WFO if available, 98% of respondents answered "yes".

Forecasters found value in monitoring trends in the probabilities in addition to the values themselves. For example, many noted that significant upward trends in probabilities would lead them to take a closer look at a particular storm, and possibly issue a warning. Several emphasized, however, the importance of seeing sustained high probabilities before issuing a more confident warning. Similarly, although the product provides probabilities that the storm will first produce severe weather in the next 60 minutes, forecasters did at times find it useful for monitoring convective maintenance and weakening (beyond 60 minutes). There were several cases when the decreasing trends in probabilities provided confidence in letting warnings expire.

The display was one of the favorite aspects about the ProbSevere model, as 93% of respondents found the probability contours and readout to be unobtrusive and intuitive. The contour color scheme worked well for most participants, and the gradual increase in contour size with probability generally was also a positive. Many felt that this display was successful in drawing the user's attention to a particular cell, and most liked having the lower probabilities plotted because it was useful to see the progression. Participants really valued the ability to sample the contour for the exact probability value as well as the predictor values. It provided a quick and easy way to get information about the storm and its surrounding environment, increasing situational awareness while informing the user of what is impacting the probability.

The algorithm was found to perform best with discrete cells and when hail was the primary hazard, likely owing to using MESH as an input. The probabilities became less reliable after storms became organized and when wind was the primary severe threat (as was covered in the training). Many suggestions were provided throughout the four weeks for how the algorithm and its display could be improved and enhanced.

3.5 Overshooting Top Detection

The Overshooting Top Detection (OTD) algorithm uses satellite-observed spatial gradients in the infrared window channel, GFS tropopause temperature, and satellite brightness temperature thresholds to identify and determine the magnitude of OTs (Bedka et al. 2010). The product offers continuous day/night detection capability and can be produced where sufficient satellite coverage is available. OTs signifiy the presence of deep convection with an updraft strong enough to vertically penetrate the tropopause into the lower stratosphere. Convection with OT signatures is often associated with nearby hazardous weather conditions such as frequent lightning, heavy rainfall, and severe weather (Dworak et al. 2012). The product provides a means for users to quickly identify OTs in animations of satellite imagery, which is especially important during busy nowcast situations (Fig. 5). In response to Proving Ground feedback, the algorithm is currently being improved via GOES-R Risk Reduction, namely to incorporate more NWP and to eliminate fixed thresholds.

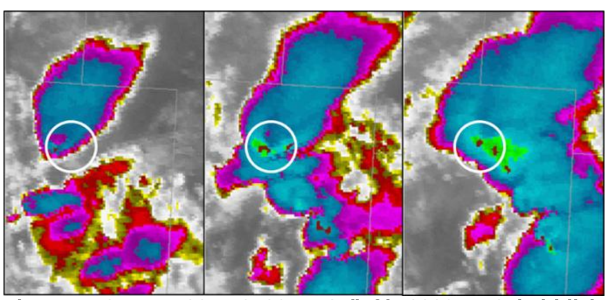

Figure 5: 21 May 2014 2130 UTC (left), 2230 UTC (middle), 2330 UTC (right) Overshooting Top Detection's (red fill) and GOES-East IR brightness temperature. Locations within white circle received over one inch of rainfall from these storms. From blog post "Over-Shooting Top and Heavy Rain".

One of the main foci of this year's OTD demonstration was to evaluate the usefulness of trends in OTDs and their relationship to overall storm evolution. Recent demonstrations have revealed that the presence of a persistent OT feature can signify an especially long-lived and potential hazardous weather-producing storm. Similarly, decreasing trends in previously persistent and abundant OTs may indicate the thunderstorm or convective system is weakening. There were indeed a few examples of forecasters successfully using the product to monitor mature convective evolution. They used it to help identify where the strongest updrafts were moving, and to help identify cells that were experiencing weakening trends.

As expected, instances occurred where OTs suspected in the visible imagery (owing to visual identification of storm tops) were not detected by the algorithm. When missed detections were suspected, the HWT Satellite Liaison would interrogate the feature with the forecaster, revealing why it was not detected by the algorithm. The feature was either an OT that did not meet the brightness temperature thresholds of the algorithm, or was misclassified as an OT by the forecaster. It became clear to forecasters how the higher spatial resolution of the GOES-R ABI will improve the OT algorithm's detection accuracy.

Forecasters felt that this product in particular suffers from the current 15 minute scan intervals, and will have increased value with the more rapid imagery updates in the GOES-R era. With increased temporal resolution, trends in the OTs will become more valuable as misses between updates will decrease.

Participants agreed that the OTD product had utility in increasing situational awareness and confidence to where hazardous weather was likely occurring or would soon occur, sometimes confirming what they already knew. The display was non-obtrusive, and helped to draw the user's attention to noteworthy storms.

3.6 GOES-14 Super Rapid Scan Operations for GOES-R 1-minute Imagery

For the first time during a HWT Spring Experiment, GOES-14 was out of storage mode and able to provide Super Rapid Scan Operations for GOES-R (SRSOR) 1-minute satellite imagery. The daily-changing approximately 1500x2000-km sector of 1-minute imagery was available in AWIPS-II for EWP participants to view from May 8-24. Additionally, the EFP utilized the imagery in NAWIPS during daily operations. GOES-14 SRSOR data collection during parts of 2012 and 2013 is summarized by Schmit et al. (2013; 2014).

GOES-14 SRSOR demonstrates a capability of the GOES-R ABI when in "flex mode" scan strategy, which will include 30 second imagery over one 1000x1000 km sector, or two 1000x1000-km sectors of 1-minute imagery. The 1000x1000-km domain refers to the size at the satellite sub-point. In addition to familiarizing users with a future ABI capability with respect to its temporal resolution, this evaluation sought to understand how 1-minute imagery might benefit users in operational environments. Acknowledging that 1-minute satellite data will likely play an important role as part of future data-fused products, this demonstration focused on the potential utility of the imagery itself.

Similar to what has been observed in previous demonstrations, forecasters quickly appreciated the benefit of 1-minute satellite imagery over current 5-30 minute imagery. When asked if 1-minute imagery provided additional value compared to 5- or 15- minute imagery, *all* respondents answered "yes". Some of the most commonly experienced improvements to forecaster situational awareness and nowcasting included quicker and more confident identification of boundaries, improved lead time to confidence that convective initiation is occurring, more value in identifying overshooting tops and other cloud top features and their trends, and enhanced ability to differentiate between stronger and weaker updrafts.

No major AWIPS-II performance issues were experienced when loading and viewing the 1-minute imagery. The only related concern was the 64-frame limit currently in AWIPS-II, as forecasters often wanted to view more than just one hour of imagery. It didn't take long for forecasters to appreciate the value that 1-minute satellite imagery adds to a variety of forecast situations, acknowledging the complete benefit would be discovered through longer-term use.

3.7 PGLM Total Lightning

To help prepare users for the total lightning (in-cloud and cloud-to-ground lightning) detection capability of the GOES-R Geostationary Lightning Mapper (GLM) instrument (Goodman et al. 2013), a pseudo-GLM (PGLM) product has been developed which utilizes total lightning data from various Lightning Mapping Array (LMA) regional research networks around the United States. The 8-km resolution PGLM updates every 1-2 minutes, depending on the LMA. The products available to forecasters in the HWT included the Flash Extent Density (FED), Flash Initiation Density (FID) and Maximum Flash Extent Density (MFED). The regional LMA's utilized in this year's experiment included: Oklahoma, Northern Alabama, Washington D.C., Colorado, and West Texas.

With the PGLM being restricted to LMA regional domains, opportunities to evaluate it were limited, though participants across all weeks had at least some exposure to the data. In addition to familiarizing users with total lightning data, the trends in total lightning and their relationship to storm evolution were evaluated.

Almost 60% of respondents had "High" or "Very High" confidence in using the total lightning data throughout the experiment. This led to participants using the total lightning data effectively in experimental operations, with over 50% responding that it had a "High" or "Very High" impact for an event. Much of the positive impact was due to the high refresh rate of the product, often providing lead time over radar data to the initiation, strengthening, and dissipation of storms. Additionally, the total lightning magnitudes and trends were helpful in highlighting the most noteworthy storms in particularly complex convective situations. Finally, when comparing the PGLM to cloud-to-ground (CG) lightning data, forecasters appreciated that the total lightning data provides a significantly more complete picture of the lightning activity within a storm (Fig 6).

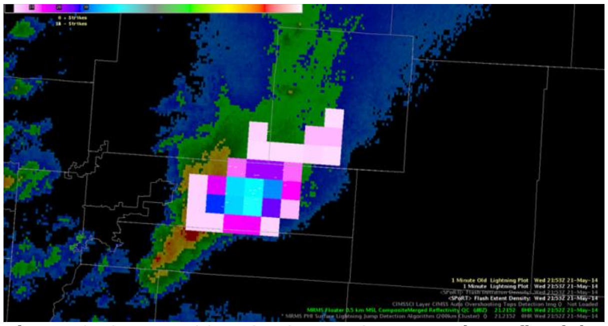

Figure 6: 21 May 2014 2152 MRMS composite reflectivity (underlay), PGLM total lightning FED (overlay), and National Lightning Detection Network (NLDN) CG strikes (minus signs). Note that the total lighting extends into the storm anvil, while CG strikes are concentrated within the highest reflectivity areas. From blog post "Anvil Flashes in PGLM".

Participants often had recommendations for improvement to the display of the PGLM products. While some users liked being able to interpolate the data in AWIPS-II, most preferred the standard gridded look. Forecasters requested the ability to color contour the lightning data, which would allow for a non-obtrusive overlay on other products such as radar and satellite imagery. Overall, forecasters appreciate the unique information total lightning data added to the forecast process, and look forward to its availability with GOES-R.

3.8 Lightning Jump Algorithm

Taking advantage of the total lightning detection capability of the GOES-R GLM, the Lightning Jump Algorithm (LJA) has been developed to highlight storms that experience significant increases in total lightning activity, or "lightning jumps". Previous studies have shown that lightning jumps often precede the occurrence of severe weather at the surface by as much as tens of minutes (Schultz et al., 2009). The LJA indicates when an updraft is strengthening or weakening on timescales that are shorter than radar and satellite. This helps forecasters in identifying where the potential for hazardous weather has increased, aiding their warning decision-making. Similar to the PGLM, the current algorithm utilizes total lightning data from multiple LMAs. The display of the LJA was a gridded storm object colored by the degree of the "jump", or standard deviation (sigma), for that time period.

Similar to what was found with the PGLM total lightning products, participants appreciated the rapid update of the LJA (1-min), updating between radar scans. This often helped provide lead-time and confidence to the issuance of severe warnings. The simplicity of the display was also acknowledged by participants, making the product easy to understand and use during busy warning situations. Finally, forecaster confidence in the tool was increased when lightning jumps were detected at the same time or were followed by increases in radar intensity.

Participants suggested that the LJA be included as a predictor in other algorithms such as the ProbSevere model. This would help to reduce the amount of products a forecaster must view while still taking advantage of the information contained in the LJA. Forecasters most often viewed the LJA in multi-panel displays with other observational data such as PGLM total lightning and radar reflectivity (Fig. 7).

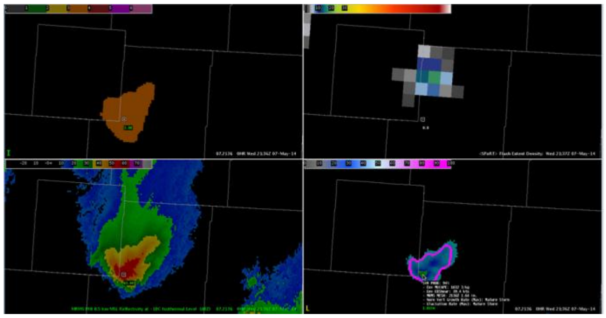

Figure 7: 07 May 2014 2136 UTC. Top Left: LJA – 3-sigma level shown. Top right: pseudo-GLM flash extent density. Bottom left: Reflectivity at -10 C. Bottom right: MESH and ProbSevere model.

3.9 Total Lightning Tracking Tool

The Total Lightning Tracking Tool (TLTT) allows forecasters to manually generate an object-oriented time series of PGLM total lightning products in real-time (Fig. 8). The product has received many updates since the 2013 experiment, including the capability to track fields other than total lightning such as satellite products, radar products, and NWP data. Under evaluation this year was the timeliness for implementing the tool, effectiveness of the generated time series, ease of use, and the effectiveness of the tool on observations beyond the PGLM.

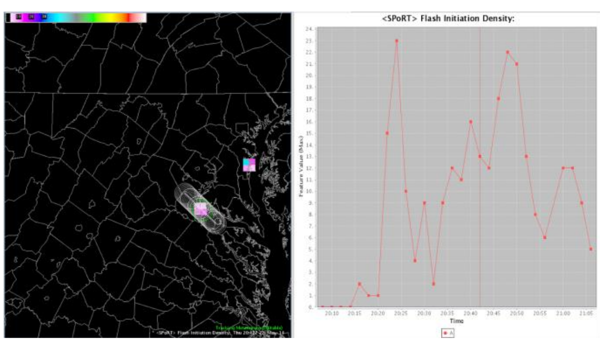

Figure 8: 22 May 2014 PGLM total lightning FID (left) and corresponding TLTT meteogram (right). From blog post "Tracking Tool, Lightning Jumps and Storm Evolution".

Forecasters generally appreciated the ability to visualize trends in various meteorological fields, and found the TLTT to be fairly intuitive when working correctly. They liked being able to track numerous storms at once, with the graphical interface allowing for simple comparisons between storms. Participants also took advantage of the ability to track fields other than total lightning, often examining and comparing several fields with one storm. Particular fields tracked by forecasters in the HWT included PGLM total lightning products, LJA, radar reflectivity and velocity, dual pol products, and MRMS products. In fact, 86% of respondents who evaluated the tracking tool used it with radar fields. Over 60% of respondents found the tool to be "somewhat" or "very easy" to implement, while over 70% agreed the tracking tool had an effective (unobtrusive) AWIPS-II display.

Although most participants saw great potential in this tool, there were far too many technical issues holding it back from operational readiness. Using the product as they would in a normal operational environment, participants were easily frustrated as it constantly slowed or crashed AWIPS-II (owing to system memory issues), had meteograms multiply or disappear, and generally exhibited odd behavior. There were instances when data would not plot, even though it was available, causing gaps to appear in the graph. The TLTT was consistently poor with its first guess track, and at times users experienced temporal mismatches when tracking multiple fields. Many of the problems experienced were most apparent or enhanced when multiple fields and/or objects were being tracked at the same time, something desired by the participants. The abundance of issues led many to believe the TLTT would not be useful in an operational environment in its current state, especially during critical warning operations.

Even when the tool was working properly, participants generally did not believe they would use it during busy warning operations. This was in large part due to the manual nature of the tool and resulting length of time it took to create a meteogram of significance. Rather, this tool might be more appropriate for a warning coordinator or mesoscale analyst, alerting radar operators to significant trends. Many more participants agreed that the product would have its greatest benefit after the event, for research purposes. Throughout each week, participants suggested many improvements that would help increase the value of the tool in an operational environment.

4. SUMMARY

Feedback from GOES-R product demonstrations during the 2014 HWT Spring Experiment was abundant and came in several forms, including daily surveys, daily debriefs, weekly debriefs, 358 blog posts, informal conversations in the HWT and the weekly "Tales from the Testbed" webinars. Common feedback included suggestions for improving the algorithms, ideas for making the displays more effective for information transfer to forecasters, best practices for product use, and situations in which the tools worked well and not so well.

Participants agreed the side-by-side comparisons between the synthetic satellite imagery and observed imagery is a valuable means of evaluating the latest model forecast in real-time, requesting the synthetic imagery be produced with additional NWP models. The total lightning products (PGLM and LJA) and

ProbSevere model were also found to have significant use in the experimental operational environment, providing lead time and confidence to experimental warning issuance. Many forecasters expressed a desire to see the NearCast analyses and forecasts in their home offices, finding the observation-based instability and moisture fields to be unique and successful in highlighting regions of increased and decreased convective potential. Participants found that the OTD algorithm was helpful when monitoring mature convective evolution and decay as it highlights where particularly strong updrafts and potential hazardous weather is occurring. The CI algorithm at times provided lead-time to initial convective development, but was often too erratic and inconsistent for forecasters to use confidently. The TLTT software needs substantial improvements as the tool was often slow and performed erratically, with users agreeing its greatest impact would be in post-event, research settings. Finally, participants experienced many situations in which the 1-minute satellite imagery provided operationally significant information not captured in current 5-15 minute imagery. Participants acknowledged the increased utility of these products in the GOES-R era given the higher spatial, spectral and temporal resolutions of the ABI.

Additional feedback and case examples from the GOES-R demonstrations at the 2014 HWT Spring Experiment can be found on the GOES-R Proving Ground HWT blog: www.goesrhwt.blogspot.com.

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References

Bedka, K., J. Brunner, R. Dworak, W. Feltz, J. Otkin, and T. Greenwald, 2010: Objective satellite-based detection of overshooting tops using infrared window channel brightness temperature gradients. *J. Appl. Meteor. Climatol.*, **49**, 181–202.

Bikos, D., D. T. Lindsey, J. Otkin, J. Sieglaff, L. Grasso, C. Siewert, J. Correia Jr., M. Coniglio, R. Rabin, J. S. Kain, and S. Dembek, 2012: Synthetic satellite imagery for real-time high-resolution model evaluation. *Wea. Forecasting*, **27**, 784–795.

Cintineo, J. L., M. J. Pavolonis, J. M. Sieglaff, and D. T. Lindsey, 2014: An empirical model for assessing the severe weather potential of developing convection. *Wea. Forecasting*, **29**, 639–653.

Dworak, R., K. Bedka, J. Brunner, and W. Feltz, 2012: Comparison between GOES-12 overshooting-top detections, WSR-88D radar reflectivity, and severe storm reports. *Wea. Forecasting*, **27**, 684–699.

Goodman, S. J., R. J. Blakeslee, W. J. Koshak, D. Mach, J. Bailey, D. Buechler, L. Carey, C. Schultz, M. Bateman, E. McCaul Jr., and G. Stano, 2013: The GOES-R Geostationary Lightning Mapper (GLM). *Atmos. Res.*, **125–126**, 34-49.

Mecikalski, J. R., J. K. Williams, C. P. Jewett, D. Ahijevych, A. LeRoy, and J. R. Walker, 2014: Probabilistic 0–1 hour convective initiation nowcasts that combine geostationary satellite observations and numerical weather prediction model data, *J. Appl. Meteorol. Climatol.*, In press.

Petersen, R. A., W. Line, R. Aune, W. Straka and R. Dworak, 2013: Improving very-short-range forecasts of the pre-convective environment using clear-air SEVIRI products. EUMETSAT Meteorological Satellite Conference and 19th American Meteorological Society (AMS) Satellite Meteorology, Oceanography, and Climatology Conference, September 16-20, Vienna, Austria.

Schmit, T.J. , J. Li, J. J. Gurka, M. D. Goldberg, K. J. Schrab, J. Li, and W. F. Feltz, 2008: The GOES-R Advanced Baseline Imager and the continuation of current sounder products. *J. Appl. Meteor. Climatol*., **47**, 2696–2711.

Schmit, T.J., and Coauthors, 2013: GOES-14 super rapid scan operations to prepare for GOES-R. *J. Appl. Remote Sens.*, **7 (1)**.

Schmit, T.J., and Coauthors, 2014: Rapid refresh information of significant events: preparing users for the next generation of geostationary operational satellites. *Bull. Amer. Meteor. Soc*,. accepted.

Schultz, C. J., W. A. Petersen, and L. D. Carey, 2009: Preliminary development and evaluation of lightning jump algorithms for the real-time detection of severe weather. *J. Appl. Meteor. Climatol.*, **48**, 2543–2563.