Hazardous Weather Testbed – GOES-R Proving Ground Final Evaluation

Project Title: 2013 Spring Experiment - Experimental Warning Program

Organization: NOAA's Hazardous Weather Testbed (HWT)

Evaluator(s): National Weather Service (NWS) Forecasters, Storm Prediction Center, National Severe Storms Laboratory (NSSL)

Duration of Evaluation: 7 May 2013 – 24 May 2013

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Submitted Date: 2 July 2013

Final Approval Date: 30 September 2013

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1. Executive Summary

The following report summarizes the activities and results from the 2013 GOES-R Proving Ground Spring Experiment, which took place at NOAA's Hazardous Weather Testbed (HWT) in Norman, OK. Owing to a vacancy in the Storm Prediction Center (SPC)/HWT GOES-R Proving Ground Liaison position, there was a large reduction in Proving Ground activities in the Experimental Forecast Program (EFP) jointly run by the SPC and NSSL. Subject matter expertise and coordination of satellite activities in the Experimental Warning Program (EWP) were provided by Amanda Terborg (UW-CIMSS/NOAA AWC), Chad Gravelle (UW-CIMSS/ NWS OPG), and Kristin Calhoun (OU-CIMMS/NSSL). This report focuses on Proving Ground demonstration activities conducted in the EWP.

Budget restrictions forced the EWP experiment to run only three weeks and included 9 visiting scientists and 18 NWS forecasters. As in previous years, these individuals participated in real-time forecasting and warning exercises using a variety of experimental GOES-R products within the simulated short-term forecast and warning environment of the EWP.

2. Introduction

During the Spring Experiment, forecasters and developers work together in a simulated operational environment while participating in forecast and warning generation exercises that use new and emerging satellite tools. The ability to explore these new tools within this setting not only allows forecasters to familiarize themselves with the new tools and provide in-depth evaluation and feedback (operations to research interaction or O2R), but also gives the developers the unique opportunity to view their latest research to operations (R2O) transfer from the perspective of end users. During the 2013 experiment, operational forecasters from both the National Weather Service (NWS) and the Air Force Weather Agency evaluated products and provided feedback on GOES-R products in the HWT.

This year, GOES-R baseline and risk-reduction products (Table 1) generated from current satellite-based, land-based, and numerical model-based datasets were demonstrated within a real-time AWIPS II framework within the HWT, and included cloud-top cooling (CTC) observations, convective initiation (CI) nowcasting, total lightning detection, 'airmass' Red-Green-Blue (RGB) imagery, and numerical model-simulated cloud and moisture imagery. Additionally, analyses and 1-9 hour forecasts of stability products from the NearCast model were available, demonstrating the utility of satellite data in combination with other datasets to provide unique fused decision aids. Forecasters and participants provided feedback on these products via real-time blogging throughout the experiment, online surveys, daily debriefings, and weekly webinars. The feedback, gathered and discussed in detail below, is essential in identifying potential product improvements, product utility, and product training needed prior to their deployment when GOES-R becomes operationally available.

The most significant change to this year's experiment was the effort put into stimulating interactions with the diverse user groups within the HWT and the broader weather community.

Most notable was the collaboration between EWP warning activities and EFP forecasting activities. Each afternoon, participants from the EWP joined those from the EFP for a collaborative discussion regarding current and expected hazardous convection. Such discussions strengthened the relationship between the two programs and maximized the Operations-to-Research feedback received from forecasters.

To provide a more efficient spin-up to experimental activities during the week of their visit, forecasters were provided with all training material prior to their arrival and were asked to complete this during an 8-hour administrative shift at their home office. This material included an assortment of articulate material (typically a recorded PowerPoint or VISITView session limited to 30-minutes in length for each product being demonstrated) and a Weather Event Simulator (WES) case. The WES case allowed forecasters to interact with the experimental products in an AWIPS environment. Each product came with an associated 'job sheet' that included a list of steps to load each product, as well as simple tasks that allowed forecasters to familiarize themselves with the products, how they are displayed, and how they are intended to be used.

Forecasters evaluated each product in real-time in the HWT. Comments were captured in real-time by asking forecasters and visiting scientists to post to the NOAA EWP's Blog, with relevant GOES-R posts copied to the GOES-R HWT Blog during the daily activities (links are at the end of this document). In addition, post-event forecaster comments were collected via online survey tools immediately following the close of daily activities.

Lastly, with the assistance of the Warning Decision Training Branch (WDTB), participants were asked to provide three weekly webinars to their peers within the NWS community. This year the topics for each webinar were pre-chosen and organized into three areas; (1) GOES-R Applications, (2) Nowcast Applications using EFP probabilistic outlooks, the OUN-WRF model, and the LAPS Analysis system (focused on the 15 May 2013 northern Texas outbreak with inclusion of multiple GOES-R applications), and (3) Warning Applications using the Multiple-Radar Multiple-Sensor (MRMS) and the Hail Size Discrimination Algorithm (HSDA). Forecasters were asked to present on these topics, discussing potential uses of the products within actual NWS operations as well as the current limitations and successes. These webinars were presented via GoToMeeting to product developers, NWS Headquarters and NWS WFOs nationwide, providing a great opportunity for widespread exposure for the GOES-R Proving Ground products across the NWS organization.

3. Products Evaluated

Table 1. List of products demonstrated within the 2013 Hazardous Weather Testbed Spring Experiment

Demonstrated Product	Category
Simulated Cloud and Moisture imagery	Baseline
Total Lightning Detection	Baseline
Convective Initiation	Future Capabilities
Cloud-Top Cooling	GIMPAP
NearCast Model Atmospheric Stability Indices	GOES-R Risk Reduction
RGB Airmass Product	GOES-R Risk Reduction
Category Definitions: **Baseline Products** - GOES-R products that are funded for operational implementation **Future Capabilities Products** - New capability made possible by ABI **GOES-R Risk Reduction** – New or enhanced GOES-R applications that explore possibilities for improving AWG products. These products may use the individual GOES-R sensors alone, or combine data from other in-situ and satellite observing systems or models with GOES-R **GIMPAP** – The GOES Improved Measurement and Product Assurance Plan provides for new or improved products utilizing the current GOES imager and sounder	

3.1 Simulated Cloud and Moisture Imagery – University of Wisconsin Cooperative Institute of Meteorological Satellite Studies (UW-CIMSS) and Cooperative Institute of Research in the Atmosphere (CIRA)

The original intent of the generation and dissemination of the simulated satellite imagery was to prepare forecasters for the additional spectral bands that will be available with the GOES-R Advanced Baseline Imager (ABI). However, the forecasts have become a popular pre-storm situational awareness tool about the predicted evolution of the environment and convective storm evolution from a convection-allowing model. Generated from the NSSL-WRF 00Z 4-km model run and provided daily via the LDM feed from CIRA within the HWT AWIPS II system, the GOES-R ABI infrared window band 14 (10.35 μm) and the ABI water vapor band 8 (6.95 μm) were available for forecaster evaluation at the EWP (Fig. 1).
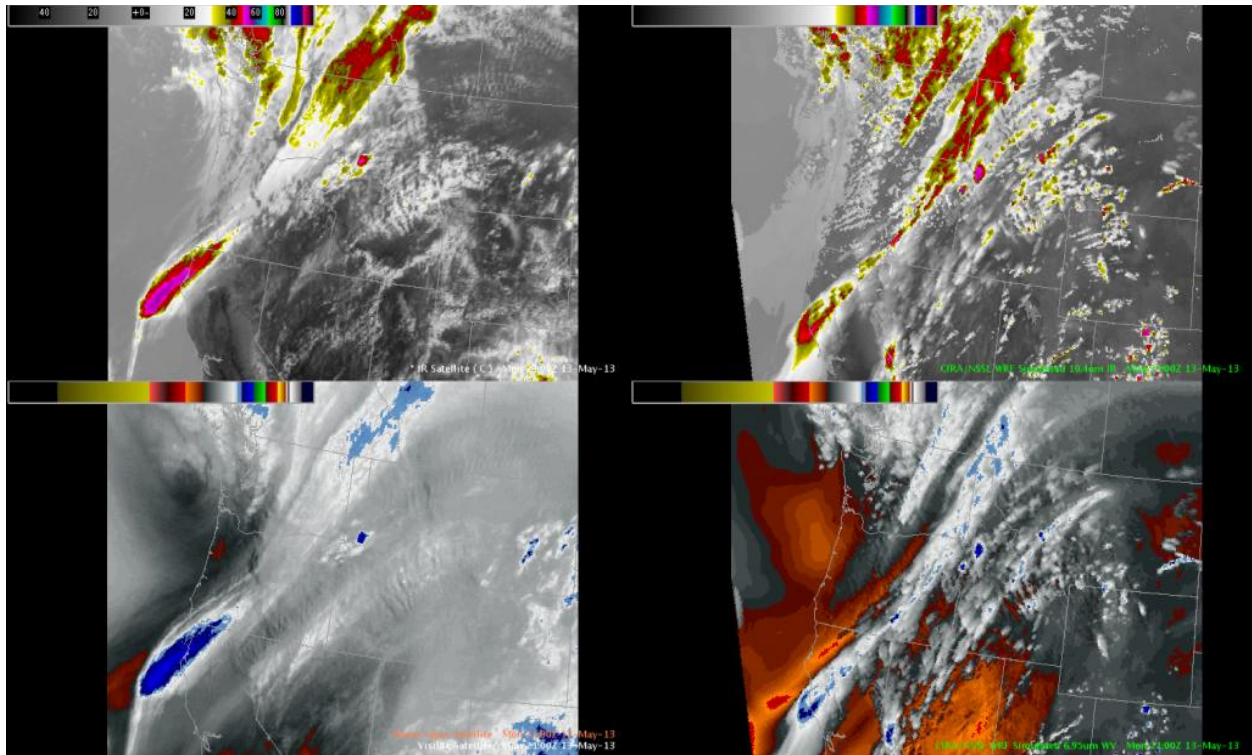
Figure 1. CIRA/NSSL-WRF ABI IR (top right) and WV (bottom right) compared with real time IR (top left) and WV (bottom left) from 2100Z on May 13th, 2013, during West Coast convection (See GOES-R HWT Blog).

Since 2011, the simulated satellite imagery has been disseminated to more than 20 WFOs across the Contiguous United States (CONUS) and is being used to aid in forecast operations in these locations. In fact, several of the forecasters who attended the EWP this year mentioned the benefits of having this information available in their local WFO. The remaining forecasters who were new to the imagery voiced their excitement about receiving these data in their own offices. In the simulated operational environment of the EWP, the majority of participants found the imagery to be particularly useful in two ways; (1) as a situational awareness tool within the model predicted pre-storm environment and (2) to gauge model performance and gain confidence while using other forecast parameters such as CAPE/CIN fields.

The most popular application of this simulated imagery was as a near-term forecast tool, particularly for the forecasters providing experimental mesoscale forecasts. Having a simulated satellite image, even though subject to the limitations inherent to using any model parameter, was found to be very beneficial as a 'big picture' of the predicted environment and how convective systems may evolve. Once convection had begun to initiate, the forecasts were replaced in favor of Convective Toolkit nowcasting tools such as CI and CTC. However, it was found to be of particular use in assessing the evolution of the model-predicted pre-storm environment. Some of the forecaster comments are shown below:

"Even though the 20+ hour forecasts are bound to fail at some points, the imagery gives a likely scenario for how situations are set to evolve. It will be up to me to change my thinking in mesoscale-heavy situations, but this data is a great first guess."
NWS Forecaster, Post-Event Surveys

"It was useful to initially get an idea of where storms would be most likely to initiate first and how they would behave."
NWS Forecaster, Post-Event Surveys

"I felt the IR forecasts were impressive…there was a single line of convection with good placement and it was remarkably similar to what was going on. This was a 23-h fcst."
NWS Forecaster, 5/20/13 Daily Debriefing*, HWT GOES-R Blog*

One case where the model guidance performed well occurred on May 9th in Central Texas. The simulated imagery indicated storms initiating over the San Angelo County Warning Area (CWA) and subsequently, more storms developing over Lubbock along the outflow boundary associated with the eastern complex (Fig. 2). Actual GOES imagery showed the situation unfolding similarly to what the simulated satellite imagery had predicted.
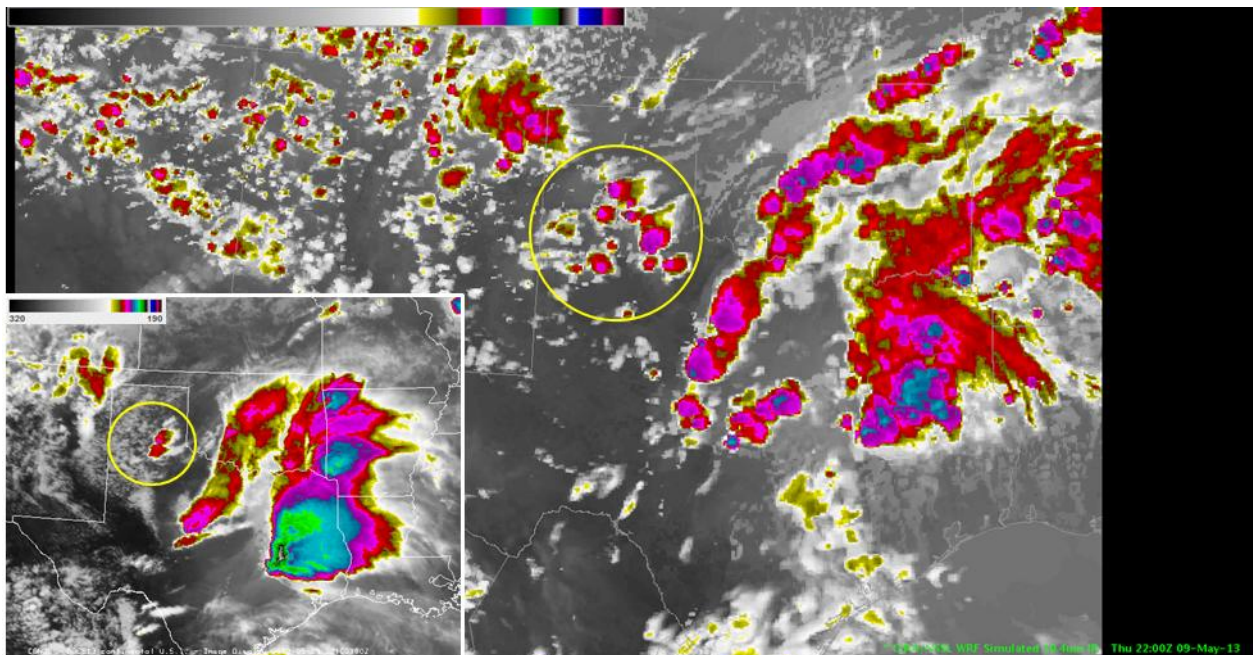

Figure 2. 2200 UTC Simulated Satellite forecast on May 9th. Note the cluster of cells over Lubbock, just west of the main complex. Actual IR imagery (inset) valid at the same time showed that a very similar situation occurred.

The simulated imagery was also used to get an idea of how well the NSSL-WRF model performed; which features it struggled with, which it picked up consistently, how it presented broader convective systems or smaller mesoscale circulations, etc. By comparing the simulated imagery to the real-time GOES imagery, forecasters were able to gain or lose confidence in how

the model ran as a whole and subsequently how other convective-related parameters were performing.

> "I used it to confirm where models may have been under or overestimating CAPE by comparing cloud cover in real and simulated."
> *NWS Forecaster, Post-Event Surveys*

> "We'd used it as a comparison to the actual IR to see what was influencing the model later. It didn't seem to handle anvils very well at all, but that may be a good thing; with the simulated imagery you could see where storms are developing without the anvil obscuring them."
> *NWS Forecaster, "Week 2 debrief", HWT GOES-R Blog*

Overall, forecasters were very impressed with the performance of the simulated imagery and appreciated how realistic the imagery looked. The main benefit of these forecasts was reaped at the mesoscale desk as an overall glimpse into the model predicted behavior of convective systems. These data will continue to be available for demonstration on the AWIPS II workstations within the HWT.

3.2 Convective Toolkit

3.2.1 Convective Initiation – University of Alabama in Huntsville (UAH) and NASA Short-term Prediction Research and Transition Center (SPoRT)

In previous years, the University of Alabama in Hunstville (UAH) has provided the SATellite Convection and Analysis and Tracking (SATCAST) product, which was based strictly on IR satellite interest fields (Walker et al. 2012) for demonstration at the HWT Spring Experiment. This year, given the Proving Ground efforts to move away from satellite-only products and integrate model data, UAH, in a collaborate effort with NOAA's Earth System Research Laboratory (ESRL) and CIMSS, provided a fused approach to forecast convective initiation typically 0-2 hours before occurrence. In this approach, the satellite interest fields defined by Mecikalski and Bedka (2006) and Walker et al. (2012) will be assimilated into the ESRL Rapid Refresh (RAP) model. A new GOES-R CI nowcasting algorithm in development, based on the heritage of the SATCAST, was provided for the HWT Spring Experiment. This product provides a probability of a cloud object achieving a 35 dBZ value using satellite observations and a number of RAP model fields. This product was available for both the GOES-E and GOES-W domains (Fig. 3).
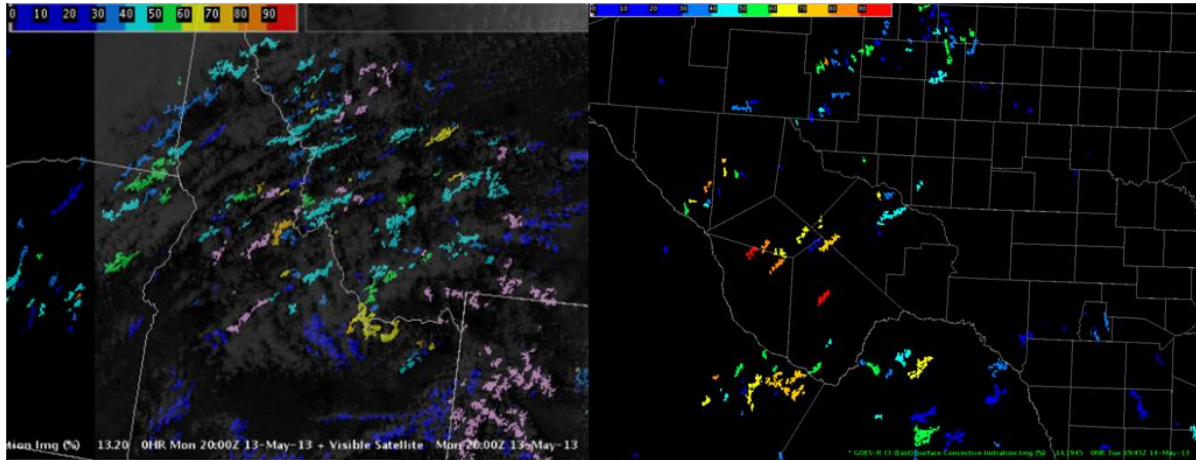
Figure 3. UAH Convective Iniation "Strength of Signal" display for GOES-W (left) and GOES-E (right). Like SATCAST, the fused CI outputs a strength value of 1-100, but also includes a snow cover contamination mask (colored in pink).

Feedback for the new fused probabilistic product was generally positive, with 84% of forecasters noting that the probability value of the cloud objects increased in the regions of observed convective initiation. Many were pleased with its performance, particularly for areas in the Central U.S.

> "The CI product was much more accurate in Western Texas then it had been previously in the Northwest U.S."
> *NWS Forecaster,* 5/15/13 Daily Debriefing*, HWT GOES-R Blog*

> "I thought it did extremely well. We were looking at a decent sized cu field and it seemed to pinpoint on specific cu very well."
> *NWS Forecaster* 5/15/13 Daily Debriefing*, HWT GOES-R Blog*

> "The CI product seemed to be much more in its element today than on the previous day. I was able to follow consistent identifications along the cold front and monitor how the CI probabilities were changing along a line of developing cumulus."
> *NWS Forecaster* 5/15/13 Daily Debriefing*, HWT GOES-R Blog*

> "Today I did not have very high confidence in it; however, it was far from a typical set-up/location so this was not a surprise to me."
> *NWS Forecaster, Post- Event Surveys*

As noted from these comments, the algorithm did not perform nearly as well for convective events that lacked identifiable surface boundaries and were weakly forced. However, performance improved for events in which there was a well-defined dryline or outflow boundary, with forecasters noting the occurrence of CI with a probability of 50-60% or higher. Additionally, for higher-value signals that resulted in successful convective initiation, the algorithm generally provided a lead time of 15 minutes or greater to the development of 35+ dBZ

echoes. One example occurred on May 15th with a tornado outbreak in northern Texas (Fig. 4 and 5).
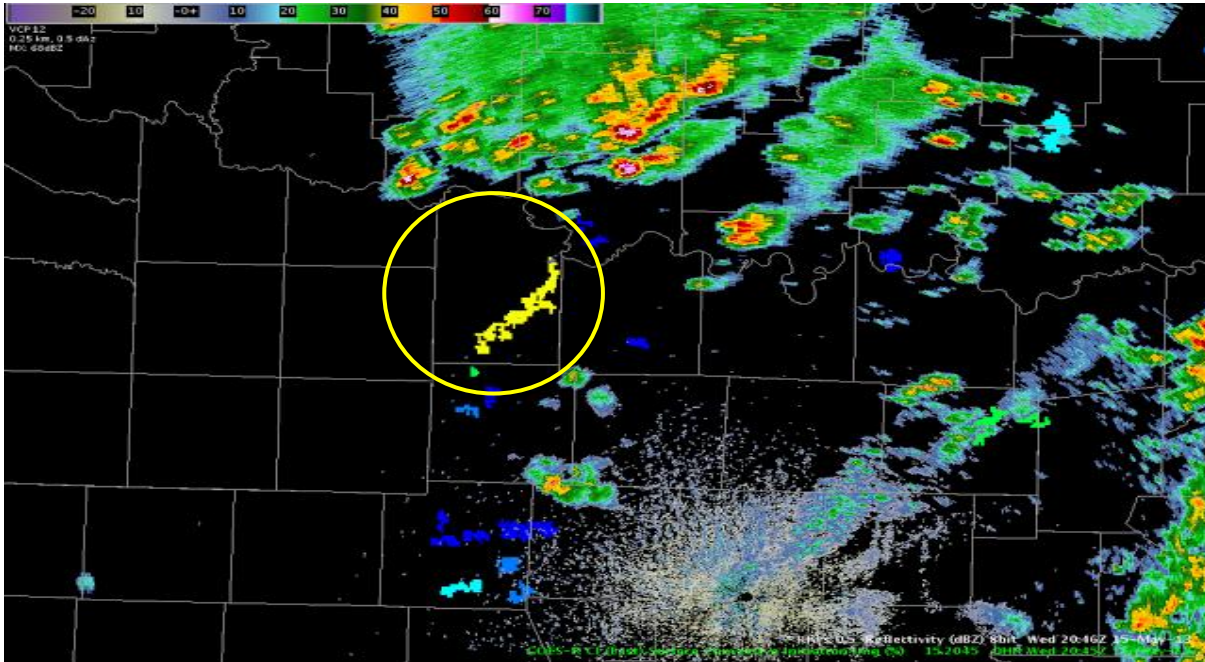

Figure 4. UAH CI and radar imagery for the Dallas/Ft. Worth CWA on May 15th at 2045 UTC. Note the areas of yellow indicated a signal of 50-60%.
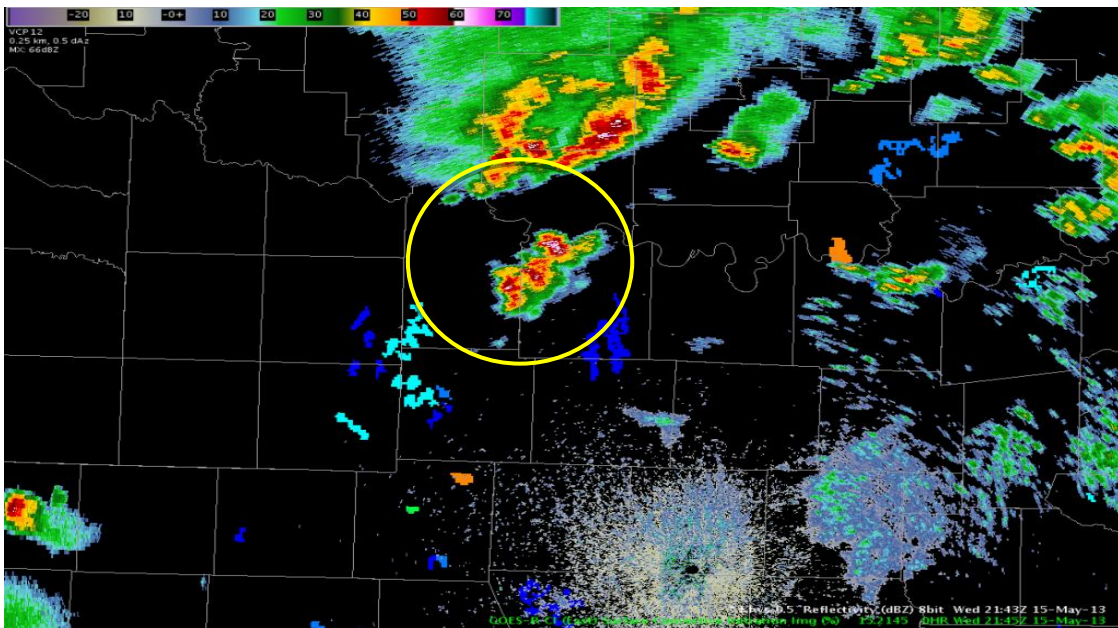

Figure 5. UAH CI and radar imagery for the Dallas/Ft. Worth CWA on May 15th at 2245 UTC. Note the fairly strong convective cores in the areas previously indicated by the 50-60% CI signal.

> "The product detected a 60% yellow area at 2045 UTC. By 2115, a thunderstorm had developed in this area. This storm strengthened and prompted the issuance of a warning by 2205. Baseball size hail was reported at 2212 UTC, and a tornado was observed around 2242 UTC."
> *NWS Forecaster,* GOES-R CI Confirms Severe Thunderstorm Initiation near Red River*, GOES-R HWT Blog*

In cases like the May 15th one, forecasters often used the GOES-R CI in conjunction with the University of Wisconsin's Cloud-Top Cooling algorithm, particularly in the transition from nowcasting to warning operations. Generally, it was found that the combination of high CI probabilities (upwards of 80-90%) with CTC cooling rates of 10 K or more per 15 minutes was associated with observed CI. Having this extra information not only increased the confidence of using these products, but also provided more details of the entire convective initiation process.

> "The UAH CI product was persistent in depicting 90+% probabilities of CI while the CTC product indicated 10 to 15 degrees of cooling over a 15 minute interval."
> *NWS Forecaster,* CI/CTC Identifying Developing Convection in a Favorable Environment*, GOES-R HWT Blog*

> "The CI product had an 80-90% signal showing initiation potential… about 30 minutes later the CTC product showed a modest signal of -15K/15min. "
> *NWS Forecaster,* CTC and CI Provide Lead Time on Texas Storms*, GOES-R HWT Blog*

There were some forecasters who, while pleased with the CI product's performance with events such as the Texas tornadoes, had a lack of confidence in the product given the 'noisy' and 'jumpy' nature of the instantaneous display.

> "The (CI) algorithm was very overwhelming. There was a lot of convection identified and the screen was quite cluttered."
> *NWS Forecaster, Post-Event Surveys*

This cluttering concern refers to the 'confetti-like' display of the algorithm, where there are a large number of signals, typically of low values, all within a very small area. Some forecasters, as noted by the above comment, saw a large number of signals as detrimental to its use in forecast operations and suggested filtering out any values less than 50%. However, others saw it as an advantage to have those values included, particularly in a broad cumulus field. In these cases, forecasters did not focus on the specific probabilities, but instead observed the trend.

> "The CI didn't help with individual elements; that is, it was noisy and there were a wide range of values in a small area. However, in backing out and taking a broader look, it gave a general idea of where I could start to expect things to occur."
> *NWS Forecaster,* 5/8/13 Daily Debrief*, HWT GOES-R Blog*

Fortunately, the flexibility of the AWIPS II software allows forecasters to adapt the display to meet their own needs. This provides them with the ability to customize how the CI product is

displayed. As forecasters all have their own unique product display procedures, this flexibility allows them to have some control over how they view the information.

One particular improvement of the new fused version of the product is the inclusion of the snow contamination mask. Signals that may be misidentified by the cloud-typing portion of the algorithm due to snow cover are located using the NOAA NWS Operation Hydrologic Remote Sensing Center SNOw Data Assimilation System (SNODAS) and displayed in pink. Forecasters found this useful in convective situations in the Rockies (see Fig. 3 above). In these areas, many mountaintops remain snow covered for much of the severe weather season and in previous years have caused confusion given the erroneous signals. However, having these signals clearly identified and comparing them to the current visible imagery was very beneficial during EWP warning operations.

> "I find it neat that one can use the GOES-R CI in concert with the visible image to discern the real signals from the snowy noise."
> *NWS Forecaster,* Using GOES-R CI in the NW U.S*., GOES-R HWT Blog*

Although many forecasters seemed to respond positively to the algorithm, only 52% indicated that they believed the CI product would have significant or at least some value within the operational or nowcast process, while the remaining ~40% indicated it would have small value. By in large, these relatively low scores were due to the high number of false alarms (i.e., clutter) in the product. It is true that the algorithm performed well in events with an obvious severe weather setup and well-defined forcing mechanisms (dryline, etc.). However, for low risk days and situations when the forcing mechanisms and environmental conditions may not have been so obvious (ie. Pacific NW), the number of false alarms was much higher, leading forecasters to have less confidence in the product.

> "My initial thought today was that the CI product was a little too "busy" in appearance (due to the numerous low CI chances). Perhaps this can be improved? However, we were also looking in a mountainous region with snow cover appearing on visible satellite so I can understand the complexity of the situation detracting from the product."
> *NWS Forecaster, Post-Event Surveys*

In regards to training, generally forecasters were able to grasp the concept of the CI algorithm fairly easily. The product was provided within the in-depth WES training prior to their arrival at the HWT, and during the experiment they had a quick guide at their disposal to use as a reference. Both of these materials were very beneficial in building a better understanding of the product itself and its uses for forecast operations.

This product will continue to be available on the AWIPS II workstations within the HWT for further demonstration and use.

3.2.2 Cloud-Top Cooling – University of Wisconsin's Cooperative Institute for Meteorological Satellite Studies

The University of Wisconsin's Cloud-Top Cooling (CTC) Algorithm was designed to provide a satellite-based tool for diagnosing convective cloud growth. Using IR brightness temperatures and AWG cloud phase information, the algorithm (Sieglaff et al. 2011) identifies immature convective clouds that are growing vertically, and hence cooling (K/15 minutes). Once these clouds begin to glaciate (determined via cloud phase), the algorithm will shut off. This algorithm was developed as a future capability of GOES-R and is meant to take advantage of the 5-minute-updating imagery the ABI will provide. However, at the moment it utilizes the current GOES imager which often impedes the overall value of the product given the 15-minute (and longer during full disk mode) interval between scans.

Though no significant developments have been made to the algorithm over the previous year, the main focus remained on the use of the CTC rates as a prognostic tool for NEXRAD Maximum Expected Size of Hail (MESH) and composite reflectivity, and on using the relationships between these parameters (as described and validated in Hartung et al. 2012) to increase warning lead-time for severe thunderstorms.

Forecasters were asked to explore the relationship between the CTC and NEXRAD fields by evaluating the lead time provided for severe storms (i.e., those with a 60 dBZ echo and/or 1.0" inch MESH). Responses varied between 15 - 90 minutes, though the majority indicated a lead-time of 30 - 45 minutes (See Fig. 6). However, it was also noted that, by in large, these lead times occurred during events in which isolated robust cores developed in a generally cloud-free area. Comments to this effect are listed here:

> "There is good potential for the CTC in relatively clear environments while awaiting initiation."
> *NWS Forecaster, Post-Event Surveys*

> "Earlier in the week it struggled, but today it performed well where there was clearing."
> *NWS Forecaster, Post-Event Surveys*

> "The CTC is a good tool when convection begins within virtually clear skies, if there is a well-defined cu field within a thin/moderate shield of stratus over the region the CTC struggles or does not indicate cooling at all."
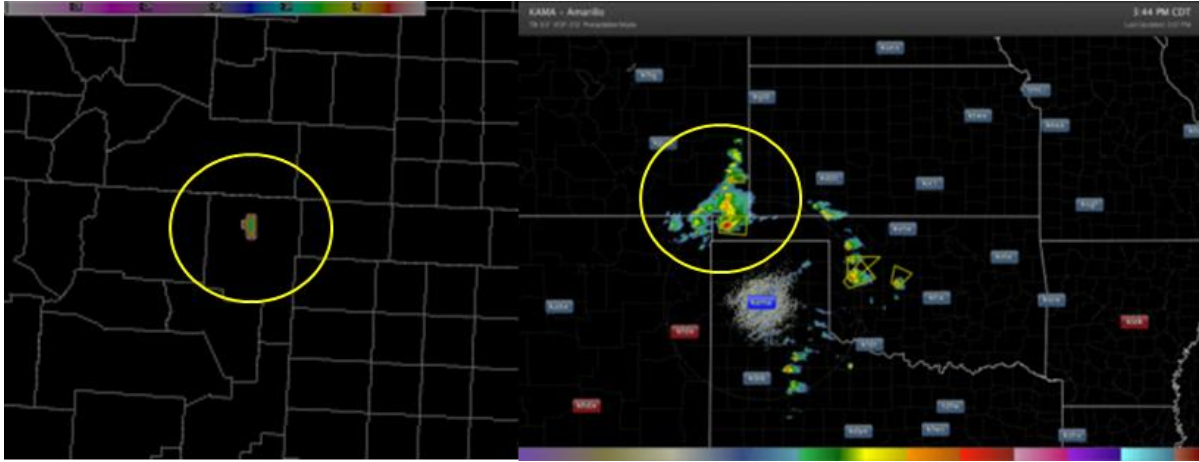> *NWS Forecaster, Post-Event Surveys*

Figure 6. The UW-CTC on May 8th at 1825 UTC (top) and KAMA radar imagery at 2044 UTC. The CTC showed a signal of ~-10 K/15 minutes at 1825 UTC in northeastern New Mexico, then increased to -15 K/15 min by 1832 UTC. By 2044 UTC, the storm had matured and a severe warning was issued. In this case the CTC provided roughly 38 minutes lead-time over the operational warning that was issued.

In cases where the focus was on isolated supercells, forecasters were very pleased with the performance of the algorithm. Many used it as a way to increase situational awareness by identifying certain cells that may have had the potential to produce severe weather. It was also shown to aid in situations where there was a cap, when the CTC rates seemed to jump around erratically for some time before finally cooling consistently. Once this consistent rate was seen, it could be assumed that the cap was beginning to erode (Fig. 7). Again, it provided situational awareness.

> "We were issuing warnings with greater confidence using cloud top cooling."
> *NWS Forecaster,* Week 2 debrief*, HWT GOES-R Blog*

> "For situational awareness the CTC is a big thing. It identifies which storms to watch."
> *NWS Forecaster,* Week 2 Debrief*, HWT GOES-R Blog*

> "The CTC did a nice job of showing that convection was really trying to break out. There were numerous cloud-top cooling signatures beginning at 20Z and the first echo reached the ground at 2145Z. So it took awhile, but eventually the storms overcame the cap and became severe.
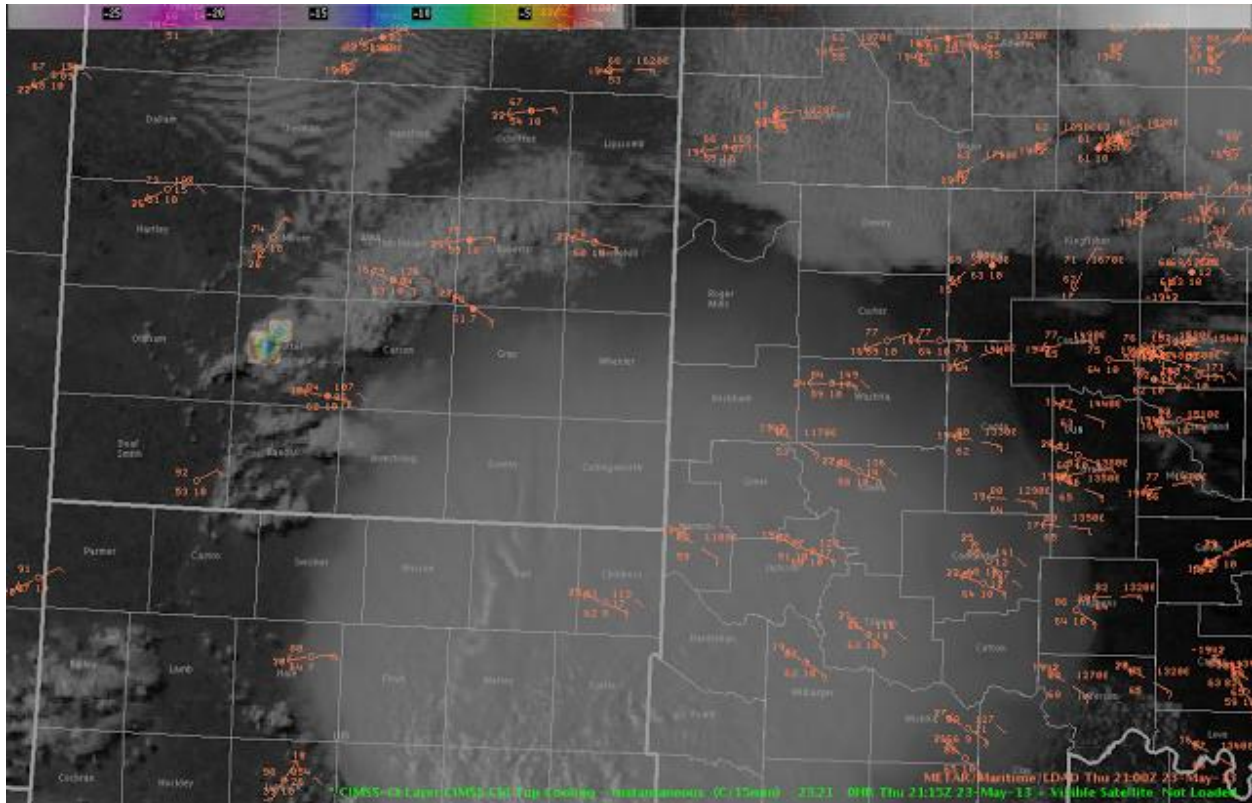> *NWS Forecaster,* Storms Close to Amarillo Radar*, HWT GOES-R Blog*

Figure 7. Cloud Top Cooling on May 23rd at 2115 UTC. CTC signals began to show around 2000 UTC but were not consistently cooling until around 2100 UTC. This indicated that the cap was finally beginning to erode.

Forecasters stressed that it was important to know the convective environment. This is especially true given the behavior of the CTC when in the presence of cirrus clouds. In the post event surveys, forecasters were asked to explore the probability of detection (POD) and false alarm rate (FAR) of the CTC and found that while the POD was very good for robust cores, there were still a number of FARs that occurred. Due to this observation, many forecasters said that they would not use the product as a standalone; instead, using it as an additional tool in the Convective Toolkit when diagnosing a severe weather situation.

> "From my experience today… the CTC algorithm cannot be used as a standalone tool as in some instances the tool missed rapidly developing storms that were very apparent on visible satellite imagery. But… it does provide more confidence to the forecaster trying to identify potential severe convection when it does show a strong detection."
> *NWS Forecaster, Post-Event Surveys*

> "I believe the UW-CTC algorithm can increase forecast confidence that a thunderstorm is developing quickly and could be severe shortly. On the other hand, it may have some false alarms. I would not be confident to issue a severe warning on the UW-CTC algorithm alone without looking at radar data."
> *NWS Forecaster, Post-Event Surveys*

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"There still appear to be enough false alarms that would prevent me from using the CTC alone for a longer term warning. However, I believe it would be very beneficial as a situational awareness and decision support air for aviation interests and also for large venues.
NWS Forecaster, Post-Event Surveys

"The initial convection was captured well and the product would be best used with other environmental data… know your environment."
NWS Forecaster, Week 3 Debrief*, HWT GOES-R Blog*

"The CTC did a good job yesterday, but it's still very important to know your environment. We saw strong signals, but as mentioned not all initiated because of other environmental factors."
NWS Forecaster, 5/15/13 Daily Debrief*, HWT GOES-R Blog*

As mentioned earlier, the 15-minute interval between GOES imager scans can impede the performance of the CTC algorithm, particularly during full disk mode when the interval stretches to over 30 minutes during which an increased number of false alarms can be seen. One potential possibility noted by forecasters that may be able to work around this issue is Rapid Scan Operations (RSO). When the GOES satellites are placed in RSO mode, the amount of images per hour doubles and the scan interval shrinks to roughly 7 minutes. If the HWT was able to request RSO mode for at least some duration during the Spring Experiment, forecasters would be able to better utilize the CTC data within experimental warning operations.

The GOES-R CTC will continue to be available within the AWIPS II workstations at the HWT for further use and demonstration.

3.3 NearCast Model Atmospheric Stability Indices - University of Wisconsin's Cooperative Institute for Meteorological Satellite Studies

The NearCast model is a Lagrangian trajectory model that uses RAP modeled wind and height fields to dynamically project satellite temperature and moisture retrieval data forward in space and time at multiple levels of the atmosphere. The multi-level output is used to determine where and when convective development is most (and least) likely to occur in the near future (1-9 hour forecast range), filling the information gap that exists between observation-based nowcasts and longer-range (beyond 12 hours) numerical forecasts. The technique preserves fine details present in the full-resolution (10-12 km) observations such as gradients, maxima, and minima. By merging ten hours of previous observations in its analysis and forecast products, the NearCast model is able to provide stability information in areas even after the IR satellite observations become cloud contaminated. The NearCast products were delivered to the HWT via the University of Wisconsin LDM and displayed within the EWP AWIPS II systems.

Within the NearCast suite are a number of products, each based on a particular parameter typically used in forecasting atmospheric instability (or stability). This year, individual layer precipitable water (PW) and theta-e, layer differences of PW and theta-e , the convective available potential energy (CAPE) field, and the long-lived convection index were available on

the AWIPS II workstations within the HWT. Similar to last year, forecasters tended to migrate towards the more conventional parameters: the PW and theta-e difference fields.

> "…I looked at the theta-e and PW values…there were no high PW values and so it made sense why the storms there weren't growing. The storms on Wednesday formed right on the low-level maximum of theta-E, so it did very well."
> *NWS Forecaster,* Week 2 Debrief, *GOES-R HWT Blog*

Most often, forecasters used the NearCast products during the nowcasting period, just prior to their transition into warning operations. Evidence of this was noted in the post event surveys where roughly 77% indicated these parameters to be of use in the 1-3 hour forecast period, while 67% indicated use also during the 3-6 hour forecast period. It was during these time periods that forecasters used the various products to identify areas of potential convective instability and assess how any developing convection would behave (Fig. 8).

> "The [NearCast] product showed enhanced chances for convection all the way to the Lubbock area. Especially the theta-e difference product as it placed a tongue of mid-level unstable air just where high based thunderstorms finally evolved… the product helped a lot to focus on the anticipated area of initiation."
> *NWS Forecaster,* Nearcasting and High Based Thunderstorms, *HWT GOES-R Blog*

> "The theta-e difference showed unstable air. When the storms entered this unstable air they did strengthen quite a bit, several becoming severe."
> *NWS Forecaster,* 5/14/13 Daily Debrief, *HWT GOES-R Blog*

> "The initial development to the west was associated with marginal moisture [as indicated by the PW fields], but just to the east there was more moderate moisture and as soon as that development moved into the area it lit up like a Christmas tree."
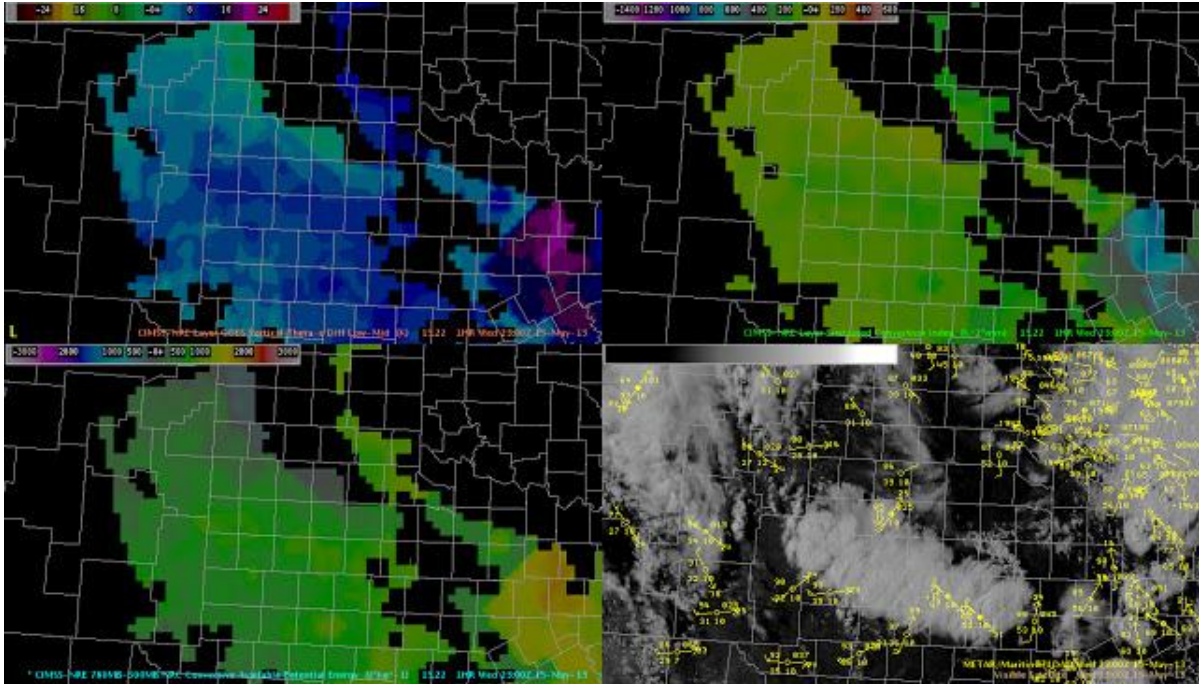> *NWS Forecaster,* 5/8/13 Daily Debrief, *HWT GOES-R Blog*

Figure 8. The May 15th, 2300 UTC Vertical Theta-E Difference (top left), Sustained Convection Index (top right), CAPE (bottom left), and visible imagery (bottom right). In this case the forecaster was looking at the tongue of mid-level instability in the Lubbock area. Later in the day, though surface dewpoints were in the mid 30s, high-based convection developed in this area.

Forecasters also used the NearCast Model to make predictions about the environment into which already developed convection was moving, and whether or not that environment would support further convective growth. For areas in which the model showed higher convective instability and increased low-level moisture, forecasters noted that storms would experience further development (Fig. 9). Similarly, those storms that encountered convectively stable air and a decrease in low-level moisture were noted to experience little or no growth, or dissipation.

> "The theta-e difference showed stable air moving into the area, and along with the simulated imagery, was used in the forecasting of the dissipation of storms."
> *NWS Forecaster,* 5/07/13 Daily Debrief*, HWT GOES-R Blog*

> "While waiting for stuff to get going, I really enjoyed the PW difference. There was cu in the area of low-level moisture and as soon as they moved into an area of higher moisture they fired."
> *NWS Forecaster,* 5/08/13 Daily Debrief*, HWT GOES-R Blog*

> "The GOES vertical theta-e difference product highlighted the moist and unstable air mass nicely. In fact, the thunderstorms really increased in strength when approaching and eventually crossing that plume of unstable air."
> *NWS Forecaster,* Nearcast Vertical Theta-E Difference with Ongoing Strong Storms*, HWT GOES-R Blog*

"The NearCast instability products showed that instability was really increasing ahead of the southern Mississippi Valley line between 00-06Z last night…which suggested a prolonged event. The squall lie kept going through the southeast and wind damage ended up occurring into central MS."

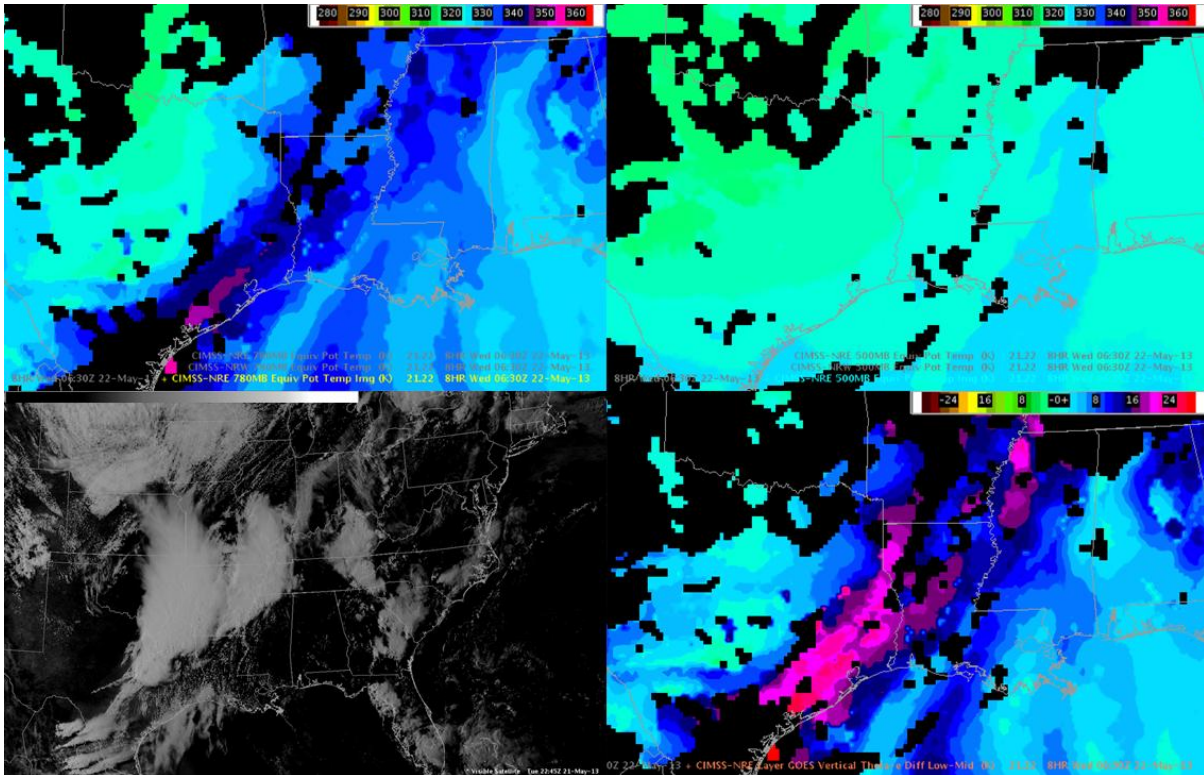*NWS Forecaster,* 5/21/13 Daily Debrief, *HWT GOES-R Blog*

Figure 9. NearCast Model May 21, 2200 UTC 8.5 hr forecast valid May 22, 0630 UTC. Low-level theta-e (top left), upper-level theta-e (top right), vertical theta-e difference (bottom right) and visible imagery valid at 2300 UTC on May21 (bottom left). This NearCast Model cycle forecasted a relatively dry and cool upper-level airmass (low theta-e) to move above a low-level plume of much warmer and moister air (high theta-e) over the lower Mississippi Valley between 2200 and 0700 UTC, correlating to increasing convective instability ahead of the ongoing line of convection. This provided forecasters with confidence that the environment would continue to support the convection as it advanced eastward through the evening. See forecaster comment "5/21/13 Daily Debrief" above.
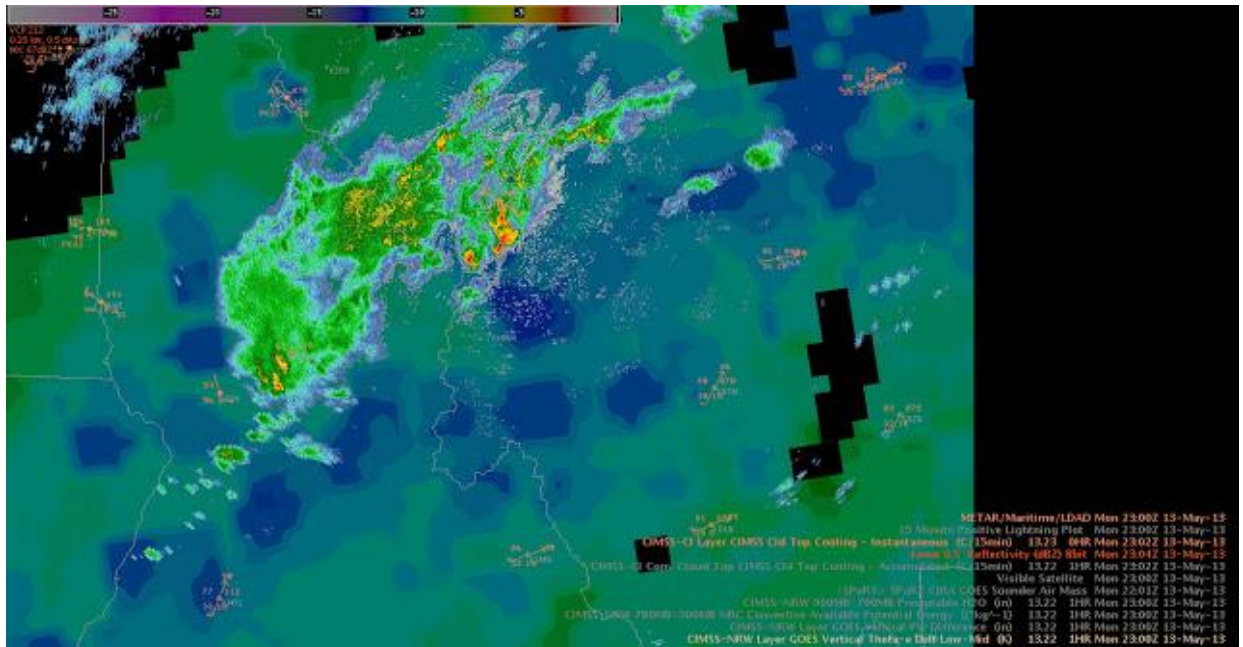
Figure 10. NearCast Vertical Theta-E difference overlaid with radar imagery. Note the complex of storms moving into an area of higher convective instability (denoted by the darker blues). These storms increased in strength as they moved into the more convectively unstable region. See forecaster comment "Nearcast Vertical Theta-E Difference with Ongoing Strong Storms" above.

Overall, forecasters were pleased with the performance of the NearCast products, particularly in diagnosing the behavior of ongoing convective activity. However, one forecaster suggested improvement during a case in which the product was used in the center of the country. Given the domain, the forecaster overlapped the GOES-E and GOES-W imagery. The result was an overlap over the center of the U.S., not necessarily detrimental except that the east and west images in that overlap did not match and this created some confusion about which was correct or more accurate. If possible, it may be beneficial to provide a merged view of the NearCast that covers the entire continental U.S.

The NearCasting products will continue to be available on the AWIPS II workstations at the HWT for further demonstration and use.

3.4 Total Lightning Detection– NASA's Short Term Prediction, Research, and Transition Center (SPoRT), NOAA National Severe Storms Laboratory (NSSL), and the University of Oklahoma Cooperative Institute for Mesoscale Meteorological Studies (OU/CIMMS)

Multiple products were created and displayed within the NWS operational AWIPS II framework to represent total lightning data from the Geostationary Lightning Mapper (GLM; Goodman et al., 2013). These psuedo-GLM (pGLM) products were created using total lightning data from six Lightning Mapping Array (LMA) networks and one Lightning Detection and Ranging (LDAR) network. The seven domains were located in: Oklahoma (central and southwest), West

Texas, Northern Alabama, Washington DC, Houston, TX, Northern Colorado, and Kennedy Space Center, Florida. Before the lightning data was ingested into AWIPS II, the VHF data from the LMA / LDAR systems was sorted into flashes and gridded at roughly 8-km resolution to match the expected GOES-R GLM resolution using software available at NASA-SPoRT (flashes from the SPoRT algorithm used a minimum threshold of 25 VHF points per flash based on previous satellite – LMA flash comparisons) and also Warning Decision Support System – Integrated Information (WDSS-II) system (data from this system was primarily for backup in 2013; the WDSS-II flash algorithm used a minimum threshold of 10-points per flash as documented in previous literature, e.g., Weins et al., 2005).

The following pGLM products were available for forecaster evaluation during 2012 real-time operations in the HWT: 1 min Flash Extent Density, 1 min Flash Initiation Location / Density, 60 / 120 min Flash Accumulation Tracks, and 60 / 120 min Maximum Flash Rate Tracks.

In addition to the real-time operations within the HWT, all forecasters completed a WES archive case from central Oklahoma on 24 May 2011. The WES case was used as an introduction and training on the lightning data for the forecasters prior to their arrival at the HWT.

The forecasters were able to examine the pGLM lightning data during nine different events during the Spring Experiment primarily over the West Texas and central Oklahoma domains for a variety a storm modes. The most often used product was the 1-min Flash Extent Density (FED) as it provided the forecasters quick evidence of the location of the most vigorous convection (Fig. 11). Similar to previous feedback in the HWT, forecasters found the data useful for situational awareness and more informative than cloud-to-ground data alone.

> "The lightning data was very beneficial in linear modes to decipher which storms were the most severe within the line."
> *-NWS Forecaster, Post-Event Survey*

> "I found the FED to be extremely useful, especially with the sub-severe convection it offered a glimpse in the storms intensity between volume scans and offered a way to monitor their growing intensity."
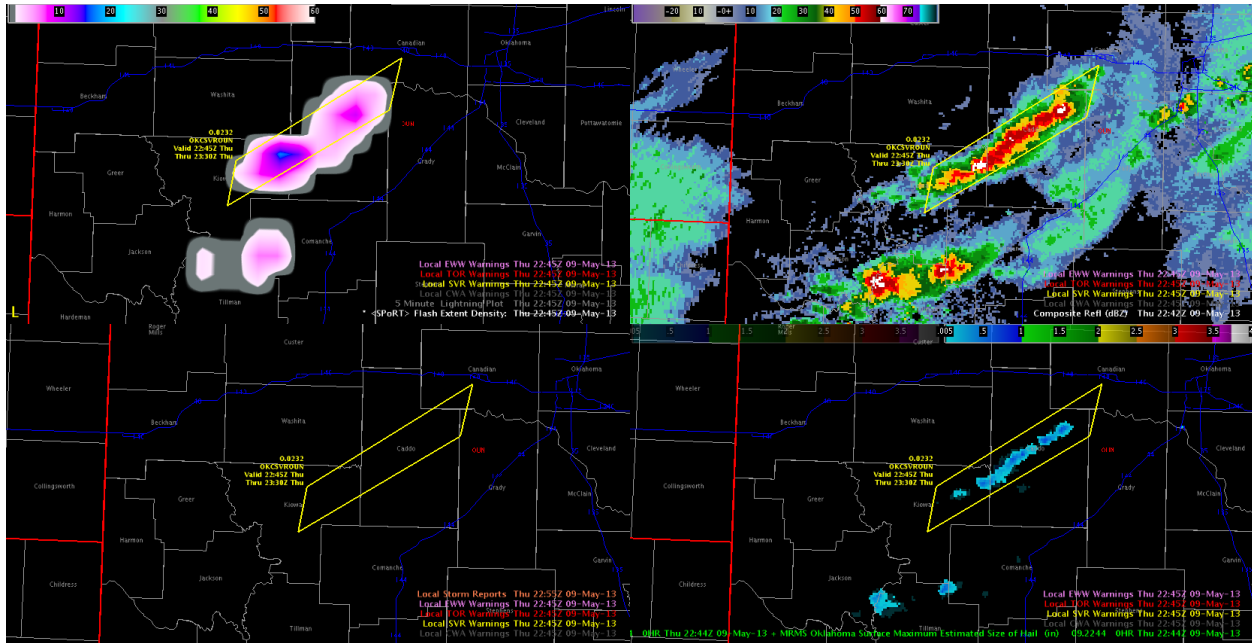> *-NWS Forecaster, Post-Event Survey*

Figure 11. Forecaster AWIPS II screenshot of pGLM FED (top left), radar reflectivity composite (top right), and MESH (bottom right) on 13 May 2013 in west-central Oklahoma. Overlaid on all images is the forecaster issued experimental severe warning polygon (yellow).

New to forecasters in the 2013 Spring Experiment was the total lightning tracking tool developed by NASA-SPoRT. This tool addressed one of the primary requests from forecasters in previous evaluations: generating a time series trend of pGLM data in real-time. The total lightning-tracking tool utilized a direct interface with the forecaster, requiring manual selection of cells and storm track. Feedback on the tool was mixed, most forecasters appreciated the ability to examine lightning trends and the extra information it can provide when determining storm severity, but found the tool to be too labor intensive to use effectively in real-time operations:

> "[*The lightning tracking tool is*] Not likely something I would use during a busy event, but I could see the value of this product for decision support services to outdoor events where lightning is the primary concern and when severe weather is not a major concern. At the current time I feel there are more effective ways to interrogate severe weather."
> *-NWS Forecaster, Post-Event Survey*

Once created by the forecaster, the time series visualization from the lightning-tracking tool provided a way for forecasters to examine "lightning jumps" and correlate to other multi-radar/multi-sensor (MRMS) fields such as vertically integrated ice, the maximum expected size of hail (MESH), and reflectivity at -10C. A forecaster derived trace of lightning associated with a storm near Ratliff City, OK on 15 May 2013 is shown in Fig. 12. For this particular event, the forecaster noted on the EWP/HWT blog the rapid increase of flash rate prior to 1910 UTC, providing 17 min lead time to the 1-inch hail report at 1926 UTC.
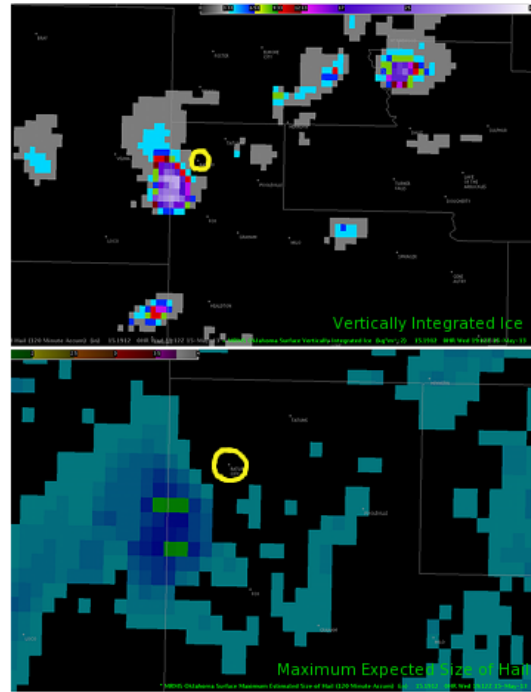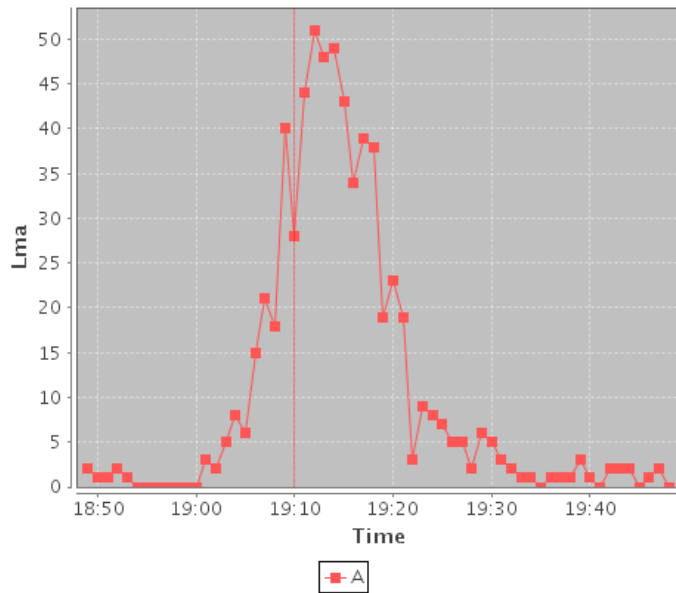
Figure 12. Forecaster AWIPS II screenshots of cell-based total lightning flash rate from the NASA-SPoRT lightning tracking tool (left), vertically integrated ice at 1912 UTC (top right), and MESH at 1912 UTC (bottom right) on 15 May 2013 in south-central Oklahoma. The rapid increase in flash rate was noted by forecaster prior to increases in radar proxies and the severe hail report at 1926 UTC in Ratliff City, OK (location of severe hail noted by yellow circle in right images).

3.5 RGB Airmass - NASA's Short Term Prediction, Research, and Transition Center (SPoRT) and the Cooperative Institute for Research in the Atmosphere

The RGB Airmass imagery was provided by CIRA and NASA SPoRT for demonstration within the AWIPS II workstations at the HWT 2013 Spring Experiment. This product creates a Red-Green-Blue composite by stretching several channels or channel differences into one image; a water vapor difference for red, ozone difference for green, and upper-level water vapor for blue. The various contributions from each create a display from which forecasters can discern various airmass characteristics (i.e., warm or cold, moist or dry, jet streaks). This product has been used extensively over Europe via the Meteosat Second Generation satellite, which has similar bands to what will be available on the GOES-R ABI. While the current GOES imager bands do not have the ability to generate this product, a proxy has been developed using the GOES sounder bands. Due to the nature of the sounder, the product only comes in once every hour and has much coarser resolution than will be available with the ABI.

During the Spring Experiment, this product was not used extensively with only 30% of forecasters responding that they had utilized it in EWP operations. Generally when it was looked

at, it was used at the beginning of the day in mesoscale outlooks to get a broad look at the large-scale environment. However, once in warning operations, forecasters found it of less use, relying mainly on the CI products.

> "The air mass RGB was helpful in identifying large-scale air mass changes, and especially in seeing areas of stratospheric intrusion / dry air aloft / jet streaks. However, it was not necessarily something that I feel could be used as much of an input into individual convective warnings. For watches and mesoscale analysis, it could definitely be of use."
> *NWS Forecaster, Post-Event Surveys*

> "I liked the RGB as an overview, especially when you first sit down to see where airmasses are setting up. Once you start getting into the nitty gritty though, you look at it less and less."
> *NWS Forecaster,* Week 2 Debrief*, HWT GOES-R Blog*

Those who did use it were very pleased with its performance, particularly for monitoring larger scale features and their potential impacts on convection later in the day. For example, on May 15th forecasters used it to watch an advancing shortwave over central TX that eventually played a part in the evolution of the system that produced the tornadoes near Dallas (Fig 13 and 14).

> "The [RGB] at 19 and 20 UTC respectively depicted an area of drier air, most likely associated with a short wave on the back side of a mid/upper low over SW Oklahoma. This wave seemed to be enhancing cloud top cooling and convection generation over west Texas."
> *NWS Forecaster,* RGB Depicts Shortwave and Developing Convection in W TX*, HWT GOES-R Blog*
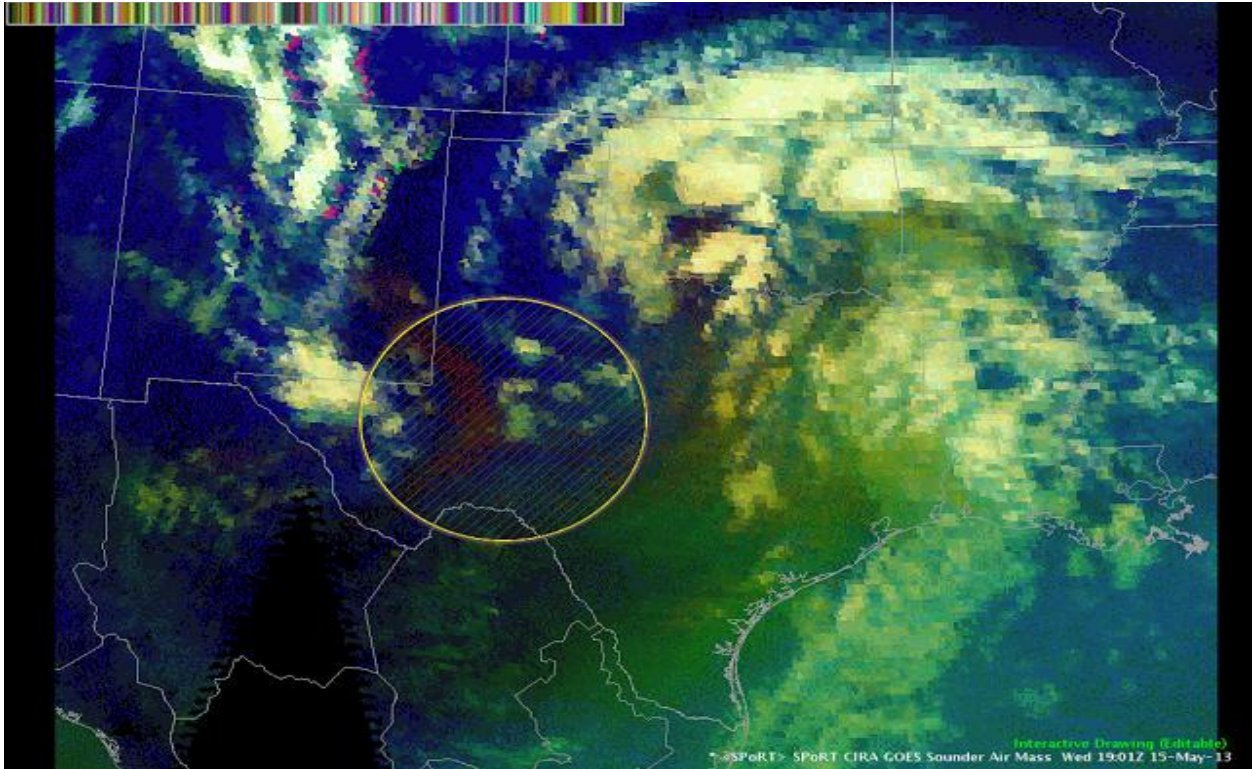
Figure 13. RGB Airmass from May 15th at 1901 UTC. Note the area of dry air indicated within the yellow circle. Forecasters monitored this feature and its eventual affect on the evolution of convection.
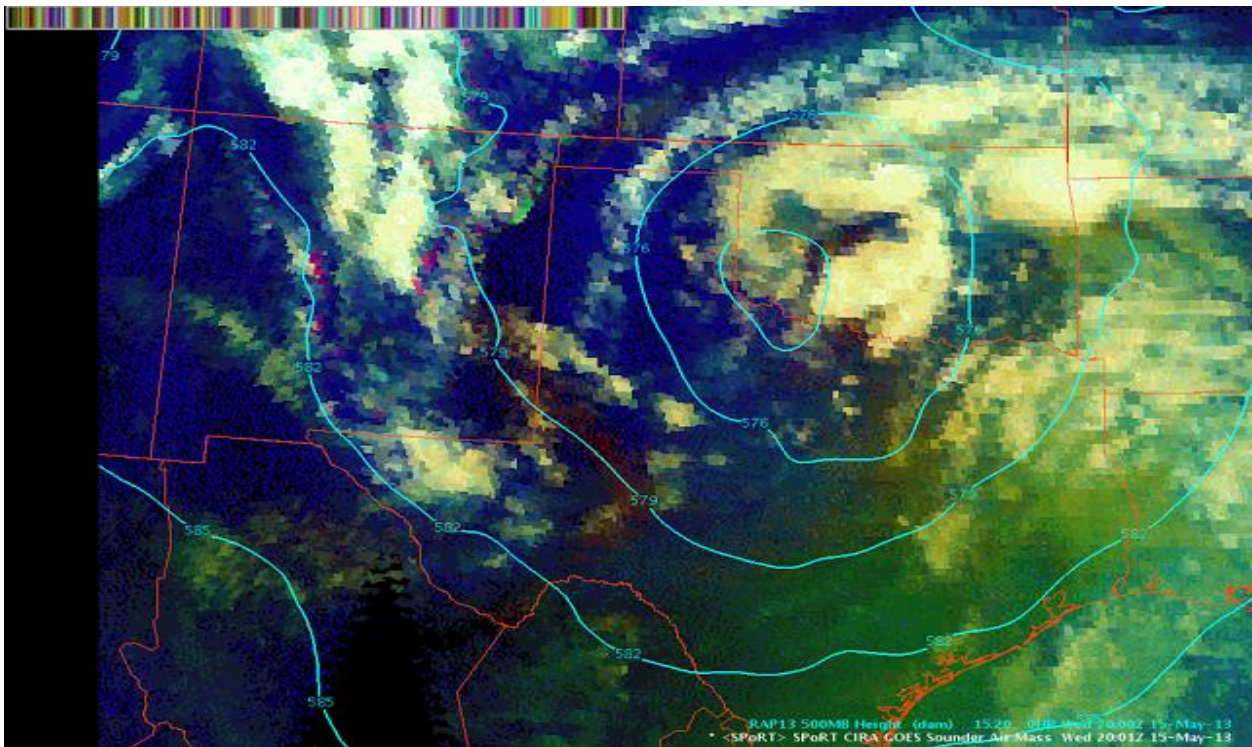

Figure 14. RGB Airmass from May 15th at 2001 UTC. Note the shortwave associated with the dry air indicated in the 1901 UTC image

Forecasters mentioned that one reason for the limited use of the product was due to the insufficient training. Forecasters were provided a WES case to work through prior to their arrival at the HWT, but given the complexity of the product's design, some found the training limited and not very intuitive.

> "I didn't have an opportunity to use the RGB airmass product… unfortunately the training material was limited on this product."
> *NWS Forecaster, "Week 3 debrief", HWT GOES-R Blog*

More in-depth training may be one solution to this problem. Additionally, forecasters would benefit from the use of a quick guide during EWP operations. These guides, also used for the CI, CTC, and lightning products, provide short summaries of each product, explanations of the display, and various suggestions for proper product use. Quick references have been particularly useful at the beginning of each week when the forecasters are spinning up. This would be particularly beneficial for the RGB Airmass imagery as its concept tends to be far less intuitive than for the CI or CTC.

The RGB Airmass imagery will continue to be available via the AWIPS II workstations within the HWT for further use and demonstration.

4. Summary and Conclusions

The 2013 HWT EWP Spring Experiment, though slightly smaller and shorter than in previous years to due budget restrictions, proved very beneficial. Despite only having 18 NWS forecasters in attendance, there were still 108 real-time blog posts, 3 weekly webinars, and the post-event surveys. To prepare for their experience, forecasters were provided with training material in the form of WES cases and articulate presentations prior to their arrival. During the three-week period, forecasters were able to interact not only with the various visiting scientists, but also with participants in the EFP component of the HWT during the daily collaborative weather briefings. Finally, at the end of their week, in conjunction with WDTB, forecasters were provided the opportunity to share their experiences using the experimental products through the weekly webinars.

Forecasters seemed to be very pleased with the GOES-R product training, with most preferring to receive the training material prior to their arrival at the HWT. This not only gave them a chance to familiarize themselves with the products before using them in a simulated operational environment, but it also allowed for shorter spin-up time during their first experimental shift. With the exception of the RGB Airmass imagery, forecasters found the training material appropriate and informative. One suggestion to improve and further solidify these training efforts is the inclusion of quick guides for each product. There were several provided by various project investigators this year, all of which were very beneficial for forecasters to use as a reference if they found themselves needing further clarification during activities.
After some consideration to last year's feedback, there was a more concentrated effort to create more interaction between the EWP and EFP participants. While this is still difficult given that the EFP has not yet transitioned over to AWIPS II, some collaboration did occur during a

number of weather discussions at the beginning of the EWP shift following the daily debriefings. During this period, participants from the EFP outlined their forecasts for the afternoon and were able to engage in discussion and exchange information with EWP participants. For days on which significant severe weather was forecast, there were additional briefings later in the afternoon. While more cross-participation is planned for future years, the interactions between the EFP and EWP this year were a very successful step towards reaching the goal of developing an end-to-end forecast generation/discussion, from outlook to mesoscale discussion, watch, and warning.

Overall, participant feedback was generally positive. NWS forecasters were eager to explore the new satellite products and capabilities that will be available once GOES-R is launched. In post event surveys, participants were asked how comfortable they felt with each product and if they believed the products would have an impact on their WFO operations. Roughly 70% indicated they would use the Simulated Satellite imagery, most of which indicated they would utilize it most in the pre-storm period. Similarly, about 78% indicated the benefit of having the NearCast data available within the 1 to 3 hour forecast period, while 67% also reported that it was useful in the 3 to 6 hour period. 53% reported at least some to large impact of the CI product during the experiment, roughly 70% used and were comfortable with the CTC, and nearly 80% found the pGLM useful. Lastly, only 40% reported that they would be comfortable using the RGB Airmass product in operations. This low percentage is likely due to the less intuitive nature of the product and the above-mentioned lack of in-depth training materials.

More detailed feedback and case examples from the 2013 Spring Experiment EWP can be found on the GOES-R Proving Ground HWT blog at:
http://goesrhwt.blogspot.com

Archived weekly webinars can be found here:
http://hwt.nssl.noaa.gov/ewp/

More details on the baseline algorithms and optional future capabilities can be found at:
http://www.goes-r.gov/resources/docs.html

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