Hazardous Weather Testbed – Final Evaluation

Project Title: 2012 Spring Experiment

Organization: NOAA's Hazardous Weather Testbed (HWT)

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

Duration of Evaluation: 7 May 2012 – 15 June 2012

Prepared By: Chris Siewert (OU-CIMMS / NOAA SPC) and Kristin Calhoun (OU-CIMMS / NSSL)

Contents

1. Executive Summary

This report summarizes the activities and results from the 2012 GOES-R Proving Ground Spring Experiment, which took place at NOAA's HWT in Norman, OK. This year 16 visiting scientists and 28 NWS forecasters participated in real-time forecasting and warning exercises using a variety of experimental GOES-R products within the Spring Experiment's Experimental Forecast Program (EFP) and Experimental Warning Program (EWP) hosted by NSSL, SPC and the Norman, OK Weather Forecast Office (WFO). Chris Siewert (OU-CIMMS / NOAA SPC) provided overall project management and oversight for the GOES-R Proving Ground efforts at the HWT and SPC. Kristin Calhoun (OU-CIMMS / NSSL) provided coordination for the GOES-R Proving Ground's efforts within the EWP.

2. Introduction

Baseline and risk-reduction products (see Table 1) generated from current satellite-based, land-based and numerical model-based datasets such as cloud top cooling (CTC) observations, convective initiation (CI) nowcasting, total lightning detection, 'airmass' Red-Green-Blue (RGB) imagery, numerical model-simulated satellite cloud and moisture imagery and associated band differences helped demonstrate GOES-R capable products to operational forecasters and the broader scientific community. Derived stability products including a 0-9 hour differential theta-e, precipitable water, and CAPE 'Nearcasts' also helped demonstrate the utility of satellite data in combination with other datasets to provide unique fused decision aids. Forecasters and participants provided feedback via weekly webinars, daily briefings, online surveys and real-time blogging throughout the experiment. The feedback gathered and discussed below was essential in identifying potential improvements and uses of the GOES-R products, as well as training prior to their deployment once GOES-R becomes operationally available.

There were many significant improvements made to the Spring Experiment demonstration itself this year, including utilizing AWIPS II as the primary decision support tool within the EWP to demonstrate the products listed above. Much work was done by Darrel Kingfield (OU-CIMMS / NSSL) to get the AWIPS II system operational within the HWT, which included a parallel operational data feed from the NWS Norman WFO to simulate an operational environment as closely as possible, as well as have the ability to compare these experimental products to those already available within NWS operations. Utilizing AWIPS II helped the product developers prepare for the display of GOES-R and other experimental products within the NWS' next-generation decision support tool. A lot of work goes into developing experimental products in a new decision support system, and much of that work has now been completed for the GOES-R Proving Ground products demonstrated during the Spring Experiment.

In addition, all training material was provided to the participants prior to their arrival, which provided a quicker spin-up to operations during the week of their visit. Each forecaster participant was asked to take an 8-hour administration shift prior to his or her arrival to review all of the training material. This training material included an assortment of articulate material (usually a recorded PowerPoint or VISITView session), which was limited to 30-minutes in length for each product being demonstrated. A Weather Event Simulator (WES) case was also included with the training material that allowed the forecasters to interact with the experimental products in an AWIPS environment at their leisure from their forecast office or at home. Each product had an associated 'job sheet' that included a list of steps to load each product, as well as simple tasks that helped the forecasters become familiar with how the product is displayed and what features they should look for.

Each product was evaluated by forecasters during real-time operations in the HWT. Forecaster comments were captured in real-time by asking forecasters and visiting scientists to post to the GOES-R HWT Blog (http://goesrhwt.blogspot.com) while the products were being evaluated. In addition, daily post-event forecaster comments were captured using online survey tools immediately following forecast operations.

Finally, with the assistance of the Warning Decision Training Branch (WDTB), forecaster participants were asked to provide 5 weekly webinars to their peers within the NWS community. Forecaster participants were asked to champion a product that they found particularly interesting through the week of their visit and discuss the potential uses of that product within operations, as well as their current limitations and successes. These webinars were presented via GoToMeeting to NWS headquarters and NWS WFOs nationwide. Up to 56 WFOs would call in weekly, which provided a great opportunity to get widespread exposure for the GOES-R Proving Ground products across the NWS field. (WDTB Archived Webinars)

3. Products Evaluated

Demonstrated Product	Category
Lightning Detection	Baseline
Simulated Cloud and Moisture Imagery	Baseline
Convective Initiation	Future Capabilities
Cloud Top Cooling	GIMPAP
Nearcast 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 as part of the ground segment base contract.
Future Capabilities Products - New capability made possible by ABI as option in the ground segment contract. Option 1 in the ground segment contract will provide reduced product latency.
GOES-R Risk Reduction - The purpose of Risk Reduction research initiatives is to develop new or enhanced GOES-R applications and to explore possibilities for improving the 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

Table 1 – List of products demonstrated during the 2012 Hazardous Weather Testbed Spring Experiment.

3.1 Lightning Detection – OU-CIMMS/NSSL and NASA SPoRT

In order to prepare forecasters for the availability of total lightning data via the GLM instrument, multiple Pseudo-Geostationary Lightning Mapper (PGLM) products were created and displayed within the NWS operational AWIPS II framework for the 2012 EWP in the HWT. These PGLM products were created using total lightning data from four Lightning Mapping Array (LMA) networks and one Lightning Detection and Ranging (LDAR) network. The five domains are located in: Oklahoma (central and southwest), West Texas, Northern Alabama, Washington DC and Kennedy Space Center, Florida. Before the lightning data were 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 the Warning Decision Support System – Integrated Information (WDSS-II) system. It is important to note the actual GLM instrument will be detecting total lightning optically while the LMA systems detect very high frequency radiation emitted as lightning leaders propagate.

The following PGLM products were available for forecaster evaluation during 2012 real-time operations in the EWP:

- 1 min Flash Extent Density (see Fig. 9)
- 1 min Flash Initiation Location / Density
- 60 / 120 min Flash Accumulation Tracks
- 60 / 120 min Maximum Flash Rate Tracks (see Fig. 1)

In addition to the real-time operations within the EWP, 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 total lightning data for the forecasters prior to their arrival at the HWT.

During the 2012 experiment, a lack of active weather in LMA/LDAR domains resulted in few opportunities to review the data compared to previous years. The majority of the events examined were marginally severe, short-lived storms that occurred over the Washington DC and Florida domains. However, 21 individual surveys were still completed regarding the PGLM data; the survey results combined with discussion with forecasters during events provided useful feedback and suggestions on future development and display of lightning data in operations. The majority of direct quotes referenced below come from the post-event surveys completed by NWS forecasters.

In terms of operational utility, forecasters noted that the total lightning data (as viewed from the 1-minute flash extent density) showed “good correlation” with updraft intensity” and was typically seen “well ahead of the first CG” (cloud-to-ground) flash (Fig. 1). Additionally, the total lightning data “pulled focus to individual storms” of interest. This was particularly useful during days that the weather was marginally severe with numerous storms across the county warning area of operations.

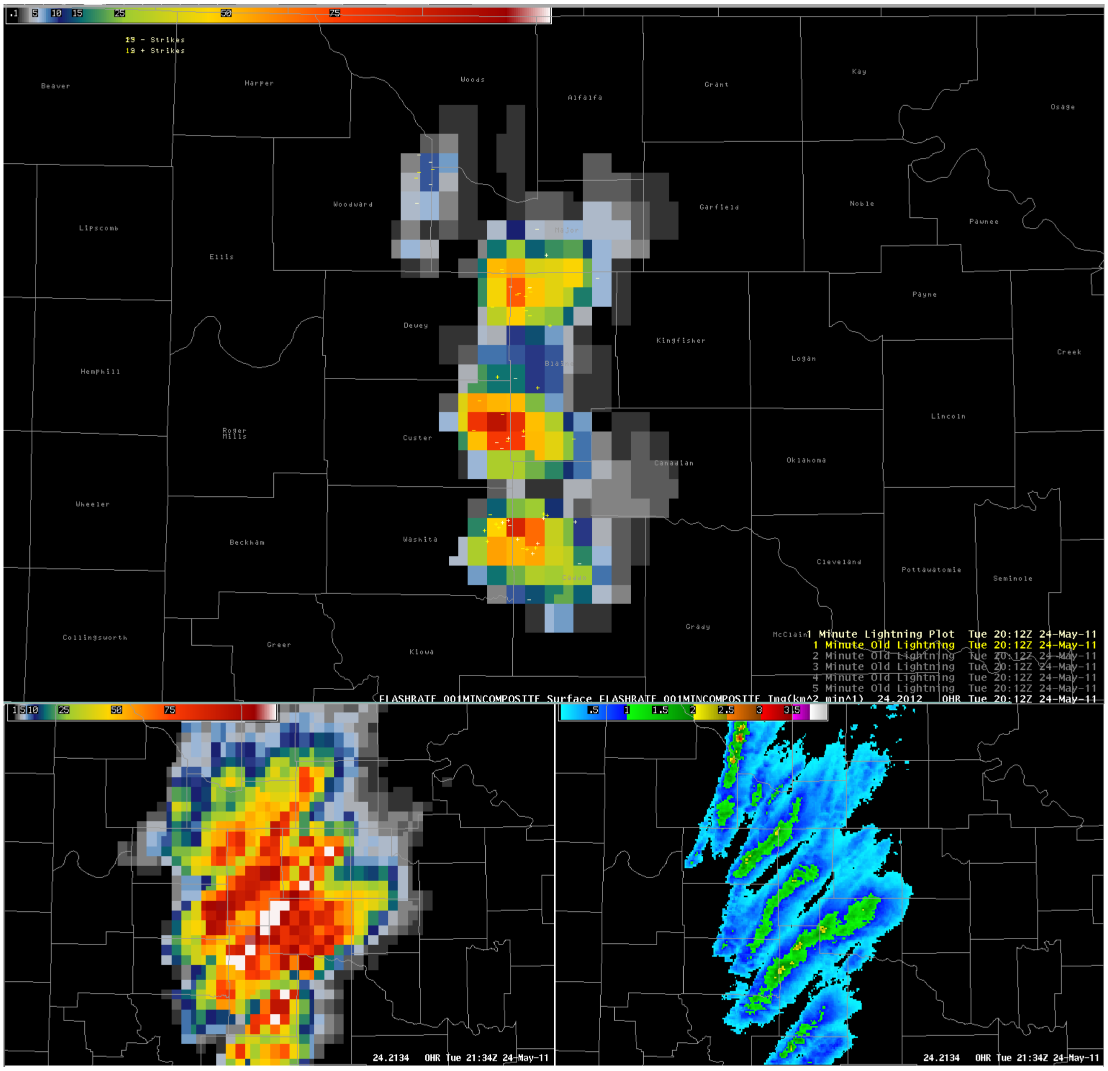


Figure 1 – *Top:* PGLM (total flashes per box per min) and NLDN (+/- ground strike locations and polarity) for 1-minute period ending 2012 UTC on 24 May 2011. *Bottom:* 60-minute tracks (max value) for PGLM flash density (left) and MESH (right) on 24 May 2011.

In evaluating the individual products, forecasters commented the flash extent density was "very useful in determining which storms were stronger," while the 60-minute tracks were "useful to illustrate storm trends." Overall, the display of 120-minute tracks showed little value and provided little utility to forecasters, particularly for the typical storm modes seen during operations this spring.

The forecasters also provided feedback regarding visualization of the data. While the majority of forecasters thought the color table was appropriate and useful at quickly diagnosing stronger storms, multiple comments were given regarding the difficulty of distinguishing individual (or first) flashes relative to the black background of AWIPS II. Further development should tweak the lower end of the color table from dark gray to light gray or white.

With the understanding that a sharp increase in the total flash rate (or lightning jump) may be indicative of rapid storm growth, multiple forecasters noted that it was difficult to see if there was a "significant increase in flash rate from one time step to another" and suggested integrating a time series view of the flash rate for individual storm cells into the forecaster display. While that capability does not currently exist in the AWIPS II platform, this would be an ideal way to integrate the actual lightning jump display.

Another change suggested was to have a readout or display of the number of flashes over a region (or scaled display). This would serve two valuable goals: (1) ease the transition from NLDN ground strike data to total lightning as current lightning display includes the number of flashes over the viewed region and would provide a comparison between the two and (2) would allow for view of flash rate trends without the need to pull up a separate table for forecasters that want it integrated in a single display.

While the forecasters appreciated 1-minute updates, it was also suggested that the products be available at 5- and 15-minute increments. In addition to matching time periods currently available for radar and satellite data, this would allow the user to go back more than 1-hour into the storm history as AWIPS II limits the display to 64 frames.

The PGLM continues to be available for demonstration within the HWT on the AWIPS II workstations and is now currently flowing into SPC non-operations N-AWIPS workstations in real-time.

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

In order to prepare forecasters for the additional spectral bands available from GOES-R ABI, simulated imagery generated from the NSSL-WRF 00Z 4km model run was provided within the HWT AWIPS II and N-AWIPS systems by UW-CIMSS and CIRA for the 2012 Spring Experiment. GOES-R ABI IR bands and band differences from the 12-36 hour forecast times were provided daily via LDM feed from CIRA within AWIPS II for the EWP, and via McIDAS ADDE server from UW-CIMSS within the N-AWIPS workstations for the EFP (see Fig. 2). This year was the first attempt to display the simulated cloud and moisture imagery within AWIPS II in the EWP (see Fig. 3). Forecasters in the EWP were provided with the GOES-R ABI infrared window band 14, as well as the ABI water vapor band 8. In addition, the 10.35-12.3 micron band difference was provided for demonstration within AWIPS II. Neither channel is currently available on our operational GOES satellites, but will be available from ABI. The 10.35 micron channel is a very clean window, and thus is very sensitive to surface temperature. The 12.3 micron channel however is sensitive to low- and mid-level water vapor. As moisture moves into a clear pixel area, the 12.3 micron brightness temperature will decrease, whereas the 10.35 micron temperature should stay the same. When this occurs, the channel difference will become strongly positive and indicates areas of moisture convergence or pooling, which can lead to destabilization and subsequent convective initiation.

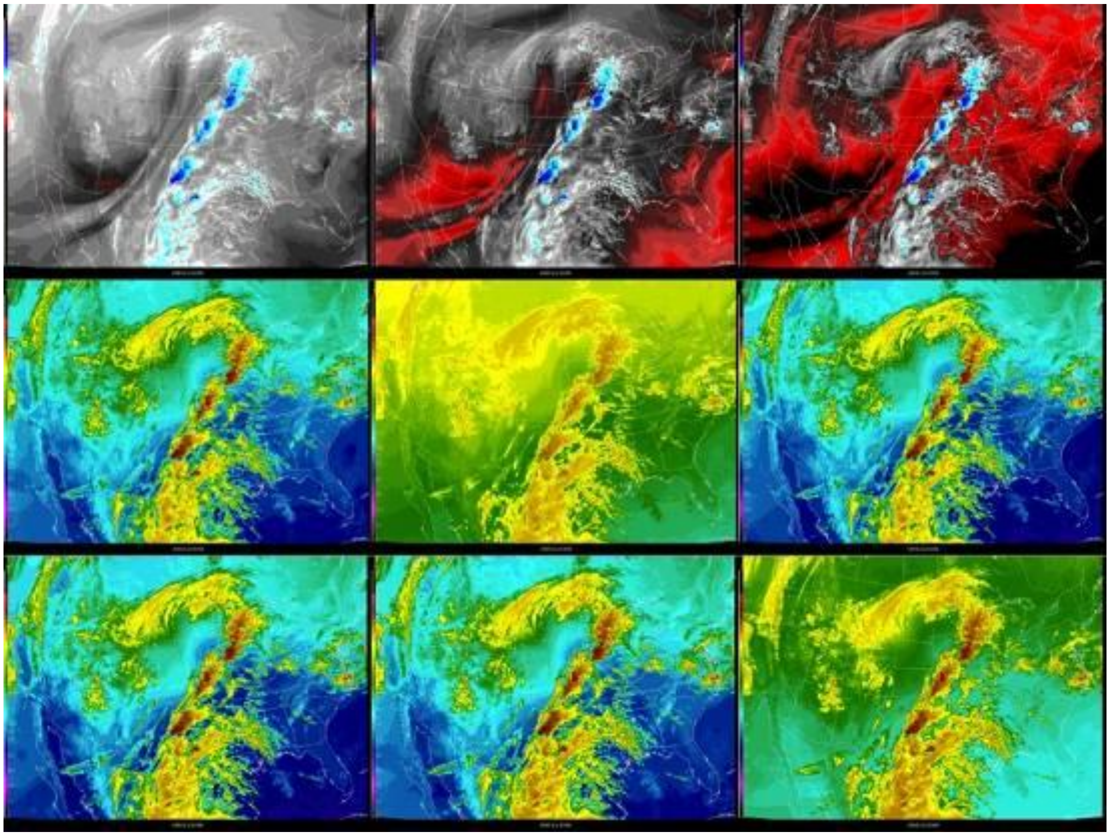


Figure 2 – UW-CIMSS NSSL-WRF simulated GOES-R ABI IR imagery. All 9 non-solar bands can be produced from the NSSL-WRF and are provided within the HWT and SPC N-AWIPS workstations.

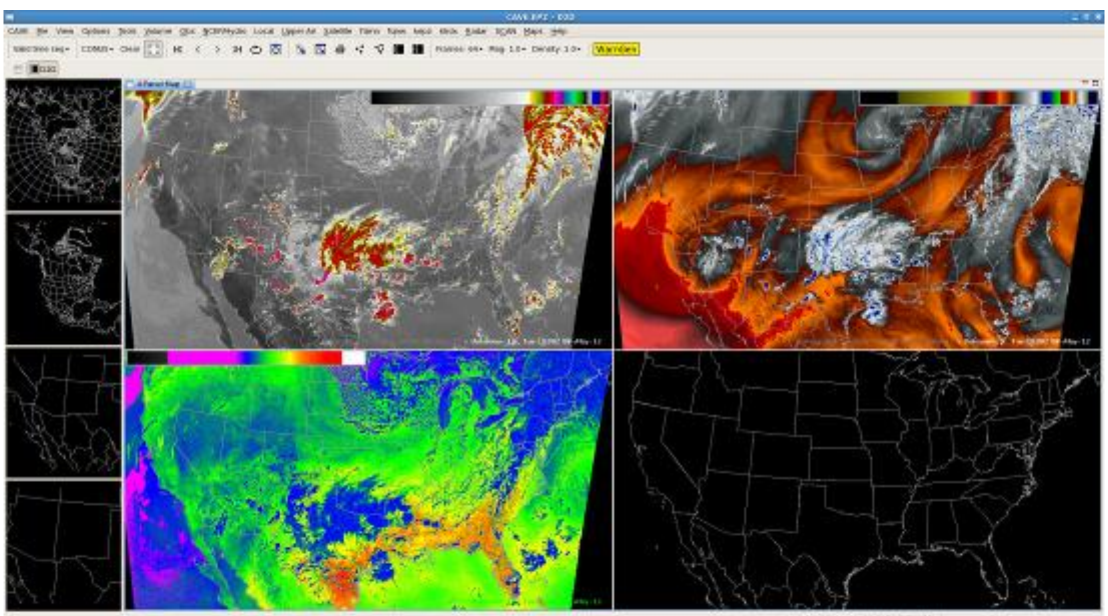


Figure 3 – CIRA NSSL-WRF simulated ABI IR window (top left), WV (top right) and 10.35-12.3 micron band difference (bottom left) in AWIPS II. (See GOES-R HWT Blog)

In general, forecasters were very excited about the simulated satellite imagery and would like to have it provided within their operations. In fact, at this moment, many of the visiting NWS forecasters have already worked to bring this product into their forecast offices. Forecasters expressed particular interest in bringing in the simulated satellite products within their GFE systems for sky coverage forecasts, which is currently not being done. While the standard IR window and WV bands are not necessarily 'GOES-R-specific' products, it is a step towards fused service capabilities as an outgrowth of the popularity of satellite-NWP integrated products. By providing this product it opens up the door for forecasters to begin using additional bands and band differences that are specific to ABI, which gives the GOES-R Program the opportunity to begin training forecasters on more advanced satellite imagery techniques. Below are some forecaster comments regarding the simulated satellite imagery.

> "I was really impressed on how well it picked up on the whole pattern, convective initiation and location... the purpose is to get a whole 3D representation and I liked that aspect."
> *NWS Forecaster, "EWP daily debrief 5/9", GOES-R HWT Blog*

> "Synthetic WRF imagery can enhance forecasts by providing model data in a familiar satellite format which makes model analysis, model comparison to obs and model forecast projections easier to visualize and understand."
> *NWS Forecaster, "Tales From the Testbed" Webinar, 11 May 2012*

The biggest change for this year was the decision to adjust the color table for the 10.35-12.3 micron channel difference. Previous years have used the standard IR RGB color table, which forecasters found difficult to see the areas of interest since it blended in the with rest of the background. This year CIRA worked to provide a color table that accentuated the areas where the band difference is indicating increased convective instability (see Fig. 3). Forecasters this year liked the new color table, saying that areas of convective instability were very easy to pick out. Forecasters stated that they would like some more training on band difference products, and admitted that they are generally not familiar with a lot of material regarding radiative transfer and the weighting functions that drive band differences and derived products from satellite imagery. Below is a comment regarding the band difference imagery.

> "I can see the channel difference being very useful in briefing non-mets about where the dry/moist air is and it's a quick way to pick out those areas."
> *NWS Forecaster, "EWP end of week 2 debrief", GOES-R HWT Blog*

The simulated satellite imagery and band differences from the NSSL-WRF continue to flow into SPC operations and are available for demonstration within the HWT AWIPS II workstations.

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

In order to prepare forecasters for potential new capabilities available from GOES-R ABI, the University of Alabama in Huntsville (UAH) has developed a proxy product similar to the one they had produced for the GOES-R Algorithm Working Group (AWG) official convective initiation (CI) algorithm (ATBD found here) called SATellite Convection Analysis and Tracking (SATCAST). Beginning in late 2008 through 2009, UAH developed an object tracking methodology (Alternative 1 from the GOES-R Aviation AWG Critical Design Review), based on an overlap methodology that will exploit the high temporal resolution from GOES-R. Since current GOES does not have the temporal resolution of GOES-R, the GOES-R CI algorithm cannot operate optimally with the current GOES instrument's 15-minute refresh rate. In order to provide more accurate object tracking, a combination of overlap and mesoscale atmospheric motion vectors (Zinner et al. 2008) methodologies have been employed. The addition of the Zinner et al. methodology allows for accurate object tracking with up to a 15-minute and, sometimes, 30-minute temporal resolution. The advantages of an object-based CI product is that it can monitor object sizes down to 1 pixel, and track cloud objects between consecutive satellite scans for validation purposes.

Previous versions of SATCAST have produced "binary" yes/no forecast output regarding the potential of CI for tracked cloud objects. As a result of HWT forecaster feedback, the algorithm has undergone an enhancement that provides forecasters with a "Strength of Signal" forecast output. This method applies a linear regression approach to combine information from all available GOES IR channels into a single numerical value on a scale from 0 to 100%, giving a sense for how strong the satellite-retrieved signal is for the development of cloud objects between the previous two GOES satellite scans. The new system was deployed at the HWT Spring Experiment on the AWIPS II workstations via LDM feed from SPoRT. New data arrived within a few minutes from the most recent satellite image scan time.

The forecasters were pleased with the new probabilistic output from the CI product (Fig. 4), with 100% of the forecasters responding "yes" in the survey when asked if they preferred a probabilistic approach to a binary yes/no approach. In addition, multiple forecaster comments were gathered during weekly debriefs.

> "It was a great move to go with the strength of signal... it provided information instead of the yes or no... you can compare it to your level of confidence in terms of development."
> *NWS Forecaster, "EWP end of week 1 debrief", GOES-R HWT Blog*

> "The (CI) strength of signal is a huge improvement."
> *NWS Forecaster, "EWP end of week 2 debrief", GOES-R HWT Blog*

> "The probabilistic CI will be really useful for aviation purposes since we're not looking at just severe convection."
> *NWS Forecaster, "EWP end of week 3 debrief", GOES-R HWT Blog*

> "There were a couple instances where the (CI product) would have a lot of 'confetti', but there weren't any really strong signals... it really showed the utility of having the strength of signal instead of a yes/no."
> *NWS Forecaster, "EWP week 4 debrief", GOES-R HWT Blog*

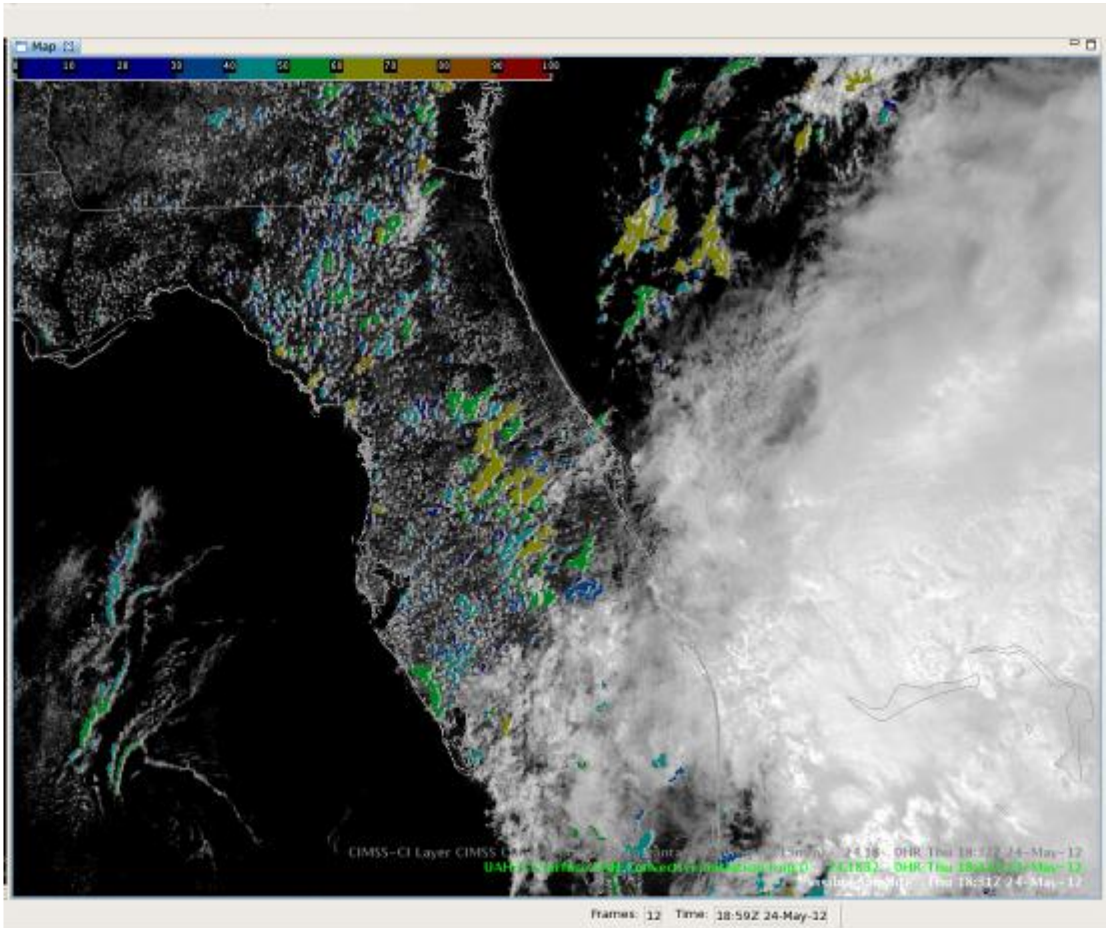


Figure 4 – CI "Strength of Signal" nowcast overlaid on visible satellite imagery displayed within HWT AWIPS II workstations at 1832 UTC on 24 May 2012 over much of Florida. Increasing potential for CI is shown as warmer colored cloud objects, yellow colors indicate probability of CI reaching near 70%. (See GOES-R HWT Blog)

The comment above mentions a topic that was brought up multiple times by forecasters throughout the experiment regarding the occurrence of what they called "confetti", or a large amount of cloud objects with varying strength of signals (often low) in a small area. In some cases, like the comment above, this was not necessarily seen as detrimental to the product's performance. Some forecasters thought that there was simply too much 'signal', and would prefer to see less of it by cutting off the display of the signals that were less than a certain percent probability. Fortunately within AWIPS II it is very simple to change your color tables on the fly and save them for future use. This allows an individual forecaster to customize the display to their preferred level of strength of signal that they want displayed. In either sense, providing them with the additional information, even if there is a low confidence of CI, allows the forecasters to have the maximum amount of information while still being flexible to customize the output to suit their needs.

Throughout the length of the experiment, post-event survey responses indicate that forecasters used the CI product during 83% of their warning operations within the EWP. In addition, the majority of forecasters reported that they saw increased strengths of signal preceding convective initiation. Typical values reported within the post-event survey indicate strengths of signal of 50-70% are sufficient for successfully forecasting convective initiation in the future. In addition, when asked if the probabilities corresponded well to the actual occurrence of CI (i.e. 70% meaning CI would occur 7 out of 10 times), the forecasters responded that it generally did, but would like more experience with it before they gave a definitive answer.

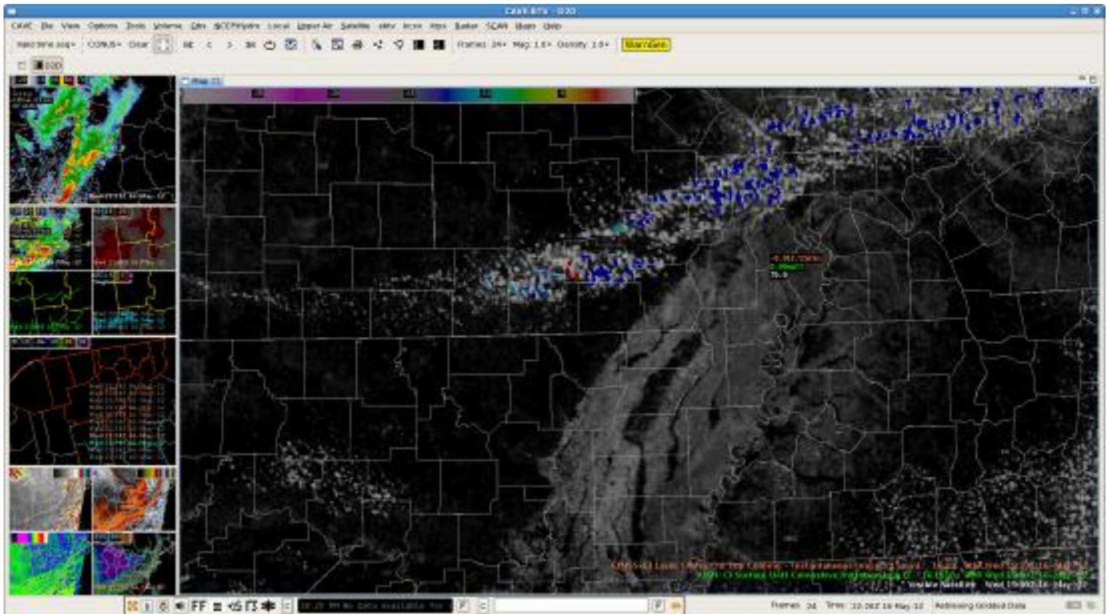
Generally the CI product would indicate the possibility (low probabilities) for CI 5-15 minutes before the cloud-top cooling rates were detected from the University of Wisconsin's Cloud-top Cooling Rate algorithm (CTC, see Section 3.4), at which point the CI strength of signal would generally increase as well. Forecasters used the two products in tandem to get an end-to-end picture of convective initiation, determining the relative strength of the convection and possibility of severe weather that would subsequently develop from the cloud-top cooling rates (see Fig. 5). When CI forecasts were successful, forecasters generally noticed increased CI strength of signal (usually about 50-70%) 30-60 minutes prior to the occurrence of CI signals on radar or first lightning, with the potential for longer lead-times on the occurrence of severe weather.

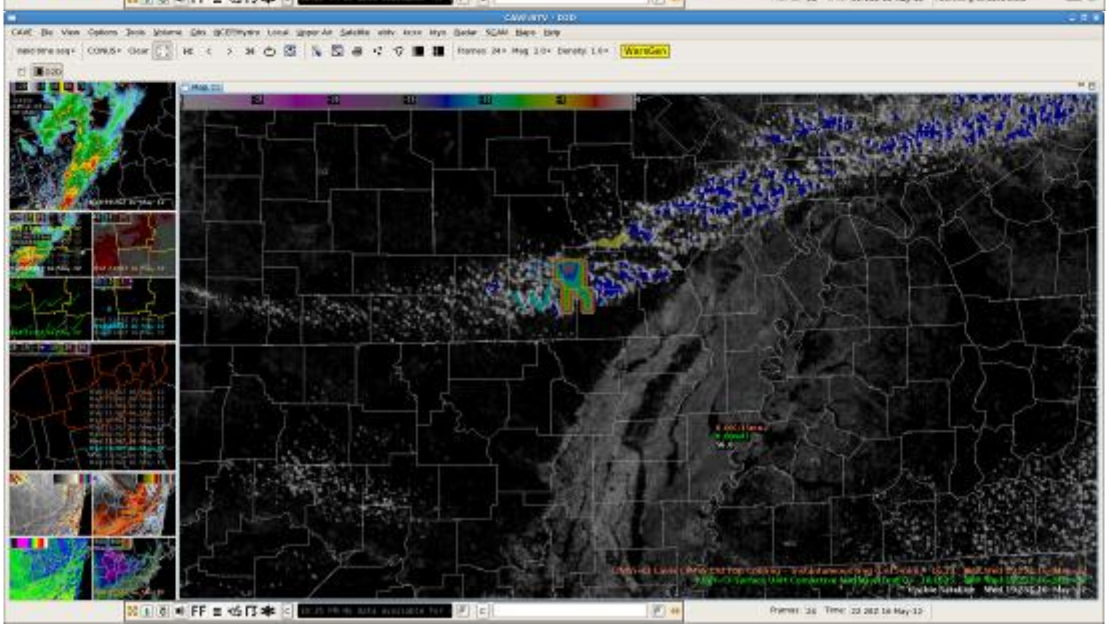
> "In this case, the strong (CI) signal (1615 UTC) preceded the CTC signal (1645 UTC) by about 30 minutes. By 1715-1730 UTC, 30-45 minutes later, deep-moist convection did indeed form as evidenced by the numerous CG strikes. We've seen this all week… (The CI product) gives us a heads up that general convection is initially building, then a short time later CTC typically picks up on the stronger convection building. Given a strong cap isn't present and instability is sufficient, deep-moist convection typically develops 30-60 minutes thereafter."
> *NWS Forecaster, "UAH-CI Signal Precedes CTC signal… Both Precede Convective Initiation", GOES-R HWT Blog*

> "Roughly 30 min before reflectivity at -10C isothermal level revealed first signs of development, the CI product highlighted both counties with 50-60% probabilities."
> *NWS Forecaster, "CI product over E-Nebraska", GOES-R HWT Blog*

> "The (CI) algorithm displayed two areas with high strength of signal values (64 and 92) across southern Cumberland and western Sampson counties on the 1702z image. These cells intensified quickly into two thunderstorms and a report of penny sized hail was received from the eastern storm at 1823z, more than an hour after the algorithm first detected these thunderstorms."
> *NWS Forecaster, "CI algorithm successes over North Carolina", GOES-R HWT Blog*

> "Small area of cumulus developing over higher terrain in west Texas shows high strength of signal value (>80%) on the (CI) product at 1730z… This area continued to develop into a mature CB, with the first cloud to ground lightning detected by NLDN at 1945z – a 2 hour lead time from the first CI signal to the initial cloud to ground lighting activity."
> *NWS Forecaster, "West Texas CI", GOES-R HWT Blog*





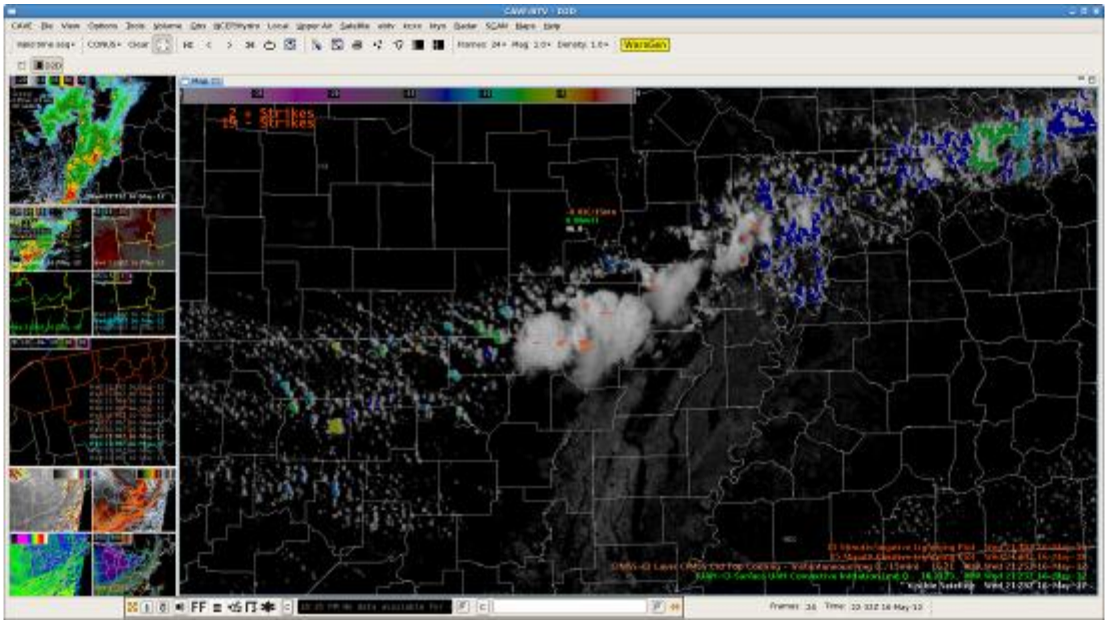


Figure 5 – CI and CTC products overlaid with visible satellite and NLDN ground strikes for 1910 (top), 1925 (middle) and 2125 UTC (bottom) on 16 May 2012. Series of images showing how the CI and CTC products can be used in tandem to pinpoint rapidly developing convection. (See GOES-R HWT Blog)

Generally, forecasters noticed an increase in false alarm rate over areas of high terrain (such as just east of the Rocky Mountains), where the probabilities would not be indicative of the actual occurrence of CI due to the likelihood of the developing convection to be elevated in nature and not able to tap into the near-surface moisture and instability. This was also apparent in the CTC product described in Section 3.4. It is possible that this is a common limitation with current satellite based CI products and should be communicated in the training material.

The CI product also makes use of the visible data within its cloud mask when available to aid in identifying small growing cumulus clouds. During the day, this is extremely beneficial, but since visible data is not available at night, the product is unable to make such high spatial identifications of growing clouds (see Fig. 6). This clearly shows the benefit of having 2 km IR data like that which will be available on GOES-R's ABI during all times of the day, not only for imagery, but for derived products and decision support tools as well. Below is a comment from a forecaster regarding this issue from the survey.

> "Once the algorithm tripped to the night/IR detection, it clearly struggled more to identify 'real' objects to track (ie it tracked a plume of cirrus/ice clouds). This isn't an issue, just something to filter out mentally."
> *NWS Forecaster, Post-Event Survey*

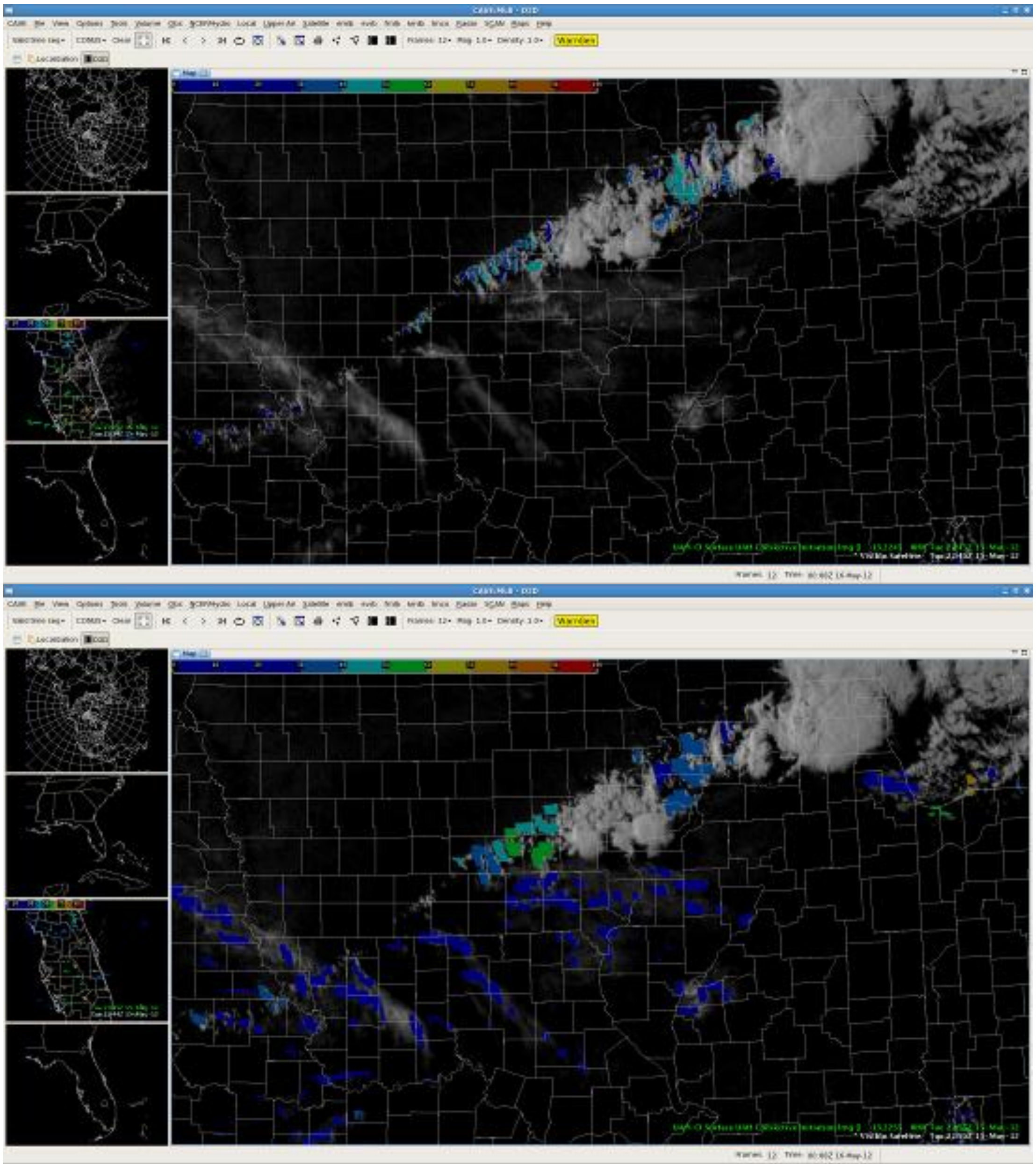


Figure 6 – CI product overlaid on visible satellite imagery at 2245 UTC (top) and 2255 UTC (bottom) on 15 May 2012. The first image (2245 UTC) shows output from CI product in daytime mode, which utilizes the high-resolution visible data to track cloud objects. The second image shows output from the CI product in nighttime mode. Notice the spatial resolution changes and increased false alarms (widespread low strength of signal over high-level clouds) when the product switches from daytime mode to nighttime mode. (See GOES-R HWT Blog)

In general, forecasters responded that they felt comfortable using the CI product in warning operations following the training that they received and that it worked as expected, with 88% reporting being comfortable using the product within the post-event surveys. In some occasions, forecasters mentioned that they would like to see some additional training material and display changes to help them understand some of the background data going into the CI forecast. The first issue can be simply addressed by providing the forecasters with a short write-up explaining the individual interest fields that the CI product uses, or providing them with a reference to a peer-reviewed paper where these fields are discussed, such as Mecikalski and Bedka, (2006) or Walker et al., (2012). The display issue mentioned by several forecasters involves providing them with readout of the individual interest field values when they interrogate a cloud object within their AWIPS II display. This could be a complicated task since, in its current state, AWIPS II would require each individual field to be loaded and displayed with the nowcast, which would cause increased load times and data flow via LDM.

The CI product continues to flow within the SPC non-operational N-AWIPS workstations and is available for the HWT AWIPS-II systems for any additional experiments.

3.4 Cloud Top Cooling – UW-CIMSS

In order to prepare forecasters for potential future capabilities available from GOES-R ABI, the University of Wisconsin's CTC algorithm is an experimental satellite-based decision aid used to diagnose IR brightness temperature cloud-top cooling rates (K / 15 minutes) and to nowcast CI (Sieglaff et al, 2011). The CTC algorithm uses GOES imager data to determine immature convective clouds that are growing vertically and hence cooling in infrared satellite imagery (see Fig. 7). Additionally, AWG cloud phase information (ATBD found here) is utilized to deduce whether the cooling clouds are immature water clouds, mixed phase clouds or ice-topped (glaciating) clouds.

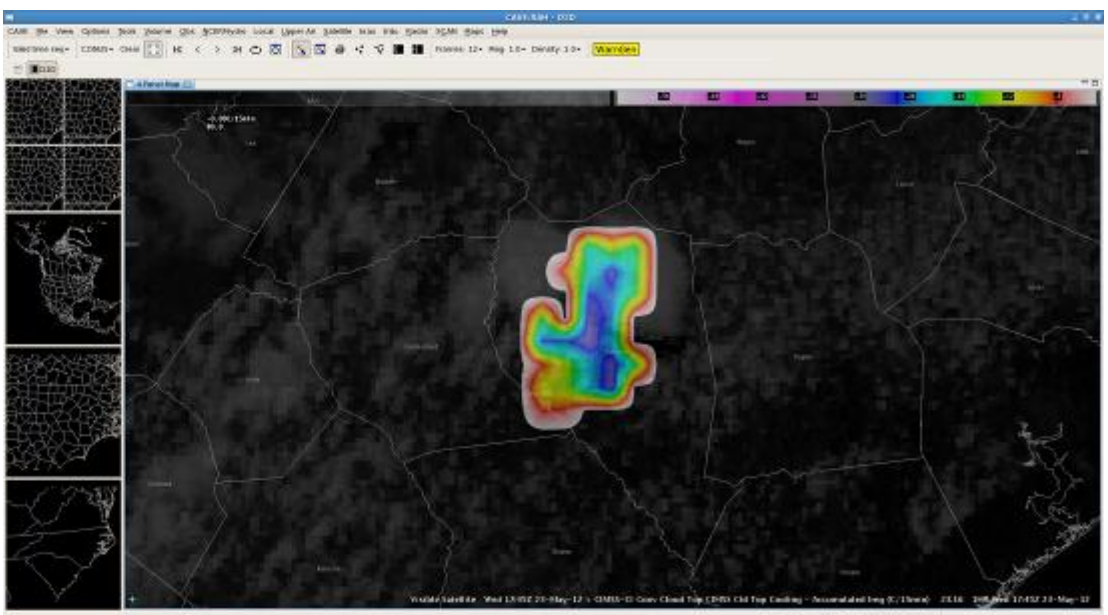


Figure 7 – CTC signal overlaid with visible satellite data within AWIPS II at 1745 UTC on 23 May 2012. (See GOES-R HWT blog)

New for 2012, based on previous HWT forecaster feedback, the CTC algorithm was improved to operate in areas of thin cirrus clouds during daytime hours by including GOES cloud optical depth retrievals. Additionally, for 2012 the focus included using the CTC rates as a prognostic tool for NEXRAD composite reflectivity and Maximum Expected Size of Hail (MESH). The goal was to show how the relationships of the NEXRAD-based validation of the CTC rates performed by Hartung et al., (2012) could potentially be used to increase severe thunderstorm warning lead-time ahead of NEXRAD-only guidance.

Forecasters were asked to use the CTC product in tandem with the CI product to get an end-to-end picture of the CI process, from initial reflectivity signal on radar (as nowcast by the CI product), to rapid intensification (as nowcast by CTC), in an attempt to increase their warning lead-times on the occurrence of severe weather versus using radar alone (see Fig. 5). Forecasters were also encouraged to evaluate the CTC as an additional warning decision support tool, where strong cooling rates (generally -20 C / 15 minutes or less) have been shown to have some correlation with the occurrence of severe hail (see Hartung et al., 2012).

Forecasters reported during their post-event surveys that they used the CTC product during 89% of their warning operations. When forecasters were asked whether the CTC product provided signals beneath non-opaque cirrus clouds, the results were mostly positive. There were some occasions where the cirrus was just too thick and no cooling rate retrievals could be made. In other situations, forecasters reported that there was no cirrus over the area at all, so they could not determine the effectiveness of the CTC product where thin cirrus was present. Overall, the forecasters expressed that they would like more time to evaluate the product in their operations. Forecasters were asked in their post-event survey how much lead-time the CTC product provided over the first occurrence of 60 dBZ composite reflectivity and 1.0” MESH. Responses varied from 10-90 minutes, but were most commonly around 30 minutes.

Forecasters were also asked if the CTC product provided any additional confidence in their warning decision-making or if they issued a warning earlier than if they had NEXRAD data alone (see Fig. 8).

> “CTC did enhance confidence/lead time for a severe warning. A warning was probably issued one scan before I would have without CTC, after seeing -20C/15 min rates.”
> *NWS Forecaster, Post Event Survey*

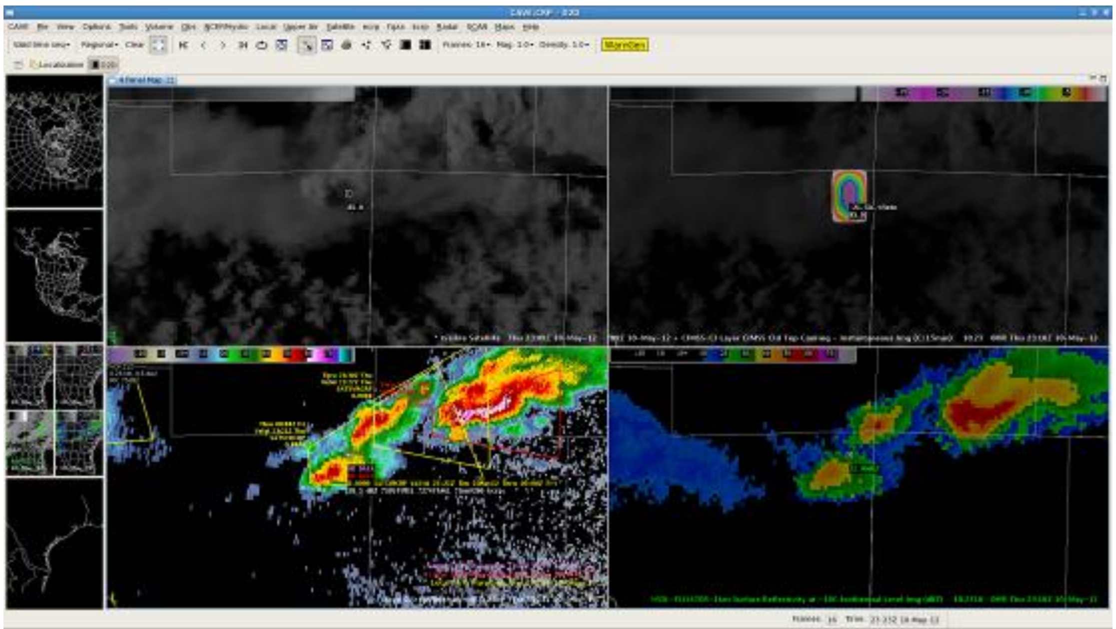
> “The CTC rates exhibited greater than -35C/15 min for a particular storm on the southern extent of a broken line. The reflectivity aloft peaked with this storm about 45-60 minutes after the CTC signature, and a strong core of +45kt (near the surface) was observed around 30 minutes after the peak as well.”
> *NWS Forecaster, Post Event Survey*

> "If you looked at the day where there were the Dallas supercells, I found it really useful... I actually warned on the CTC and it worked out well... It preceded the 60 dBZ and 1" mesh by about 20-30 minutes."
> *NWS Forecaster, “Final EWP weekly debrief”, GOES-R HWT Blog*

"Yesterday in Hastings we had a -34 C / 15 mins signal early on... there were some weaker storms ongoing at that time and it seemed like the stronger convection formed a little south of there afterwards... it definitely clued us in that something was going on."
NWS Forecaster, "Final EWP weekly debrief", GOES-R HWT Blog

"Based on the environment and the ongoing supercell activity, I issued the warning as soon as I saw the CTC... Without the CTC product, I may have issued the warning a scan or two later... which lead to a greater warning issuance lead time."
NWS Forecaster, "Tales from the Testbed" Webinar, 11 May 2012

"Every storm that went severe yesterday in MO had a -30 C/15 min and every signal that strong lead to a severe storm, so it was a complete success."
NWS Forecaster, "EWP End of Week 3 Debrief", GOES-R HWT Blog



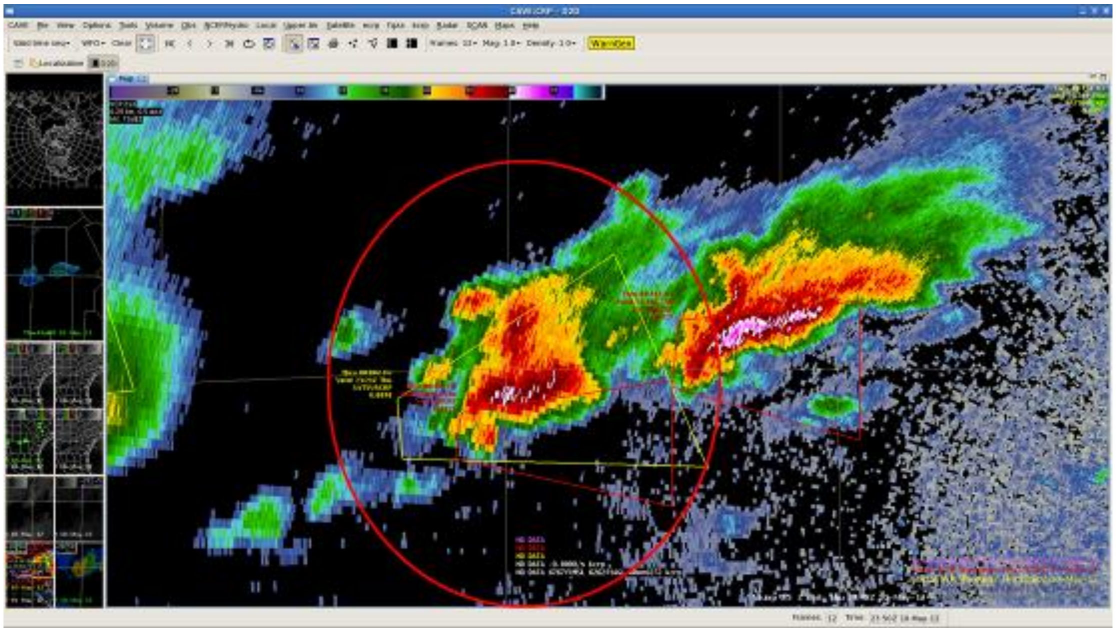


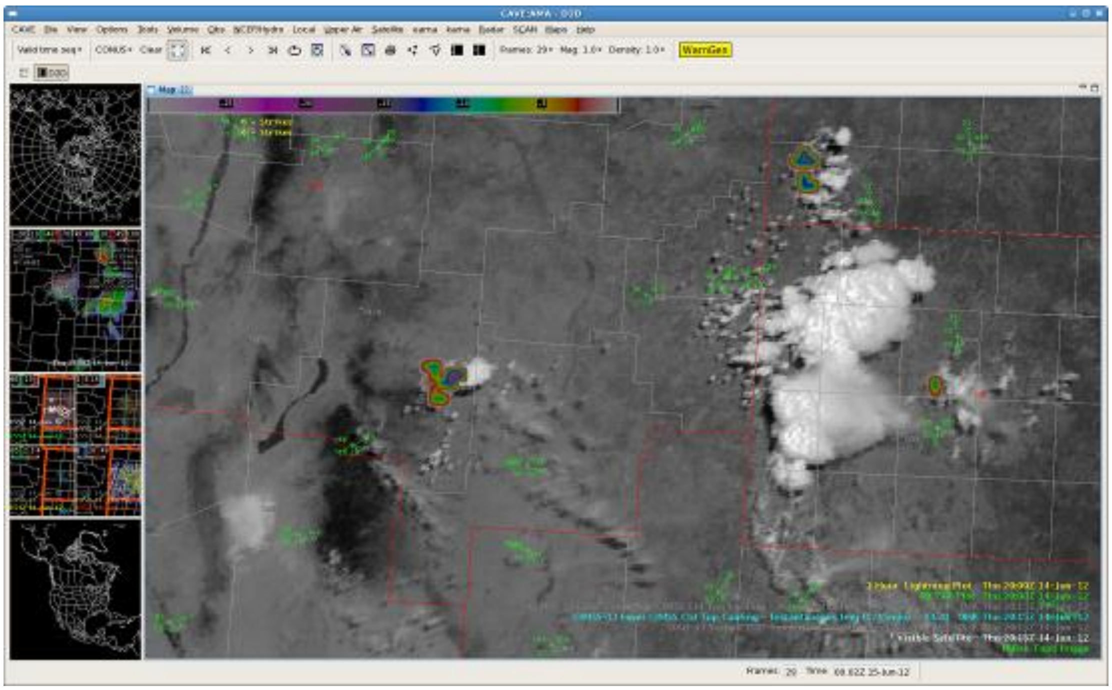
Figure 8 – *Top:* CTC product (upper right panel), valid at 2310 UTC, with visible satellite imagery (upper left panel), 0.5° base reflectivity (lower left panel), and reflectivity at the -10°C isothermal level (lower right panel). The CTC rate of ~ -20 K / 15 min combined with the environmental conditions and previous thunderstorm development in the vicinity allowed an NWS forecaster to issue an EWP experimental severe thunderstorm warning (lower left panel). At 2340 UTC the radar (not shown) estimated just over 1.00" hail (severe hail threshold); a 30 minute lead-time for CTC. *Bottom:* 0.5° base reflectivity valid at 2350 UTC. The NWS forecaster had upgraded the severe thunderstorm warning to an EWP experimental tornado warning, 40 minutes after the intense CTC signal. The radar estimated hail size has increased to 1.40". The red circle highlights the storm of interest. (See GOES-R HWT Blog)

Forecasters mentioned that it was important to be aware of the surrounding environment before you could make a warning decision based on the CTC product. Often if there was ongoing supercell activity, a forecaster would warn solely on the appearance of the CTC signal exceeding about -20 C / 15 minutes. In addition, it was important for forecasters to be aware of the overall likelihood of CI from the surrounding environment. A common occurrence that both the CI and the CTC exhibited was that high terrain would often force convective development that would be flagged by the algorithms, but could not be sustained due to lack of moisture or instability. It was quite common for orographically enhanced 'convection' to have significant cooling rates (see Fig. 9) where surface dewpoints would be in the teens. Obviously it would be difficult for surface-based convection to maintain in such an environment, so forecasters can easily be aware of potential false alarms by simply overlaying surface observations in these situations. Below are some comments regarding the effect of terrain on the CTC product.

> "In ABQ's area, the CTC product did show some enhanced cooling along the higher terrain. However, we did not warn based on previous problems with terrain and the CTC. Glad we did not since the storm died as it moved off the higher terrain."
> *NWS Forecaster, Post Event Survey*

"Once again, we are seeing strong CTC signals off the terrain in NM with little or no convective development… Take home point — this is a great product, however forecasters need to know their environment to use this product in enhanced warning ops and beware of times that the convection is being forced by the terrain. Case in point, although the CTC product showed -20 to -25 C/15 min cooling values over higher terrain areas in SE NM, the sfc dwpts were in the teens and lower 20s. Almost no way convection could develop with this dry air."

NWS Forecaster, "ABQ: CTC + Situational Awareness = Great Fcst", GOES-R HWT Blog



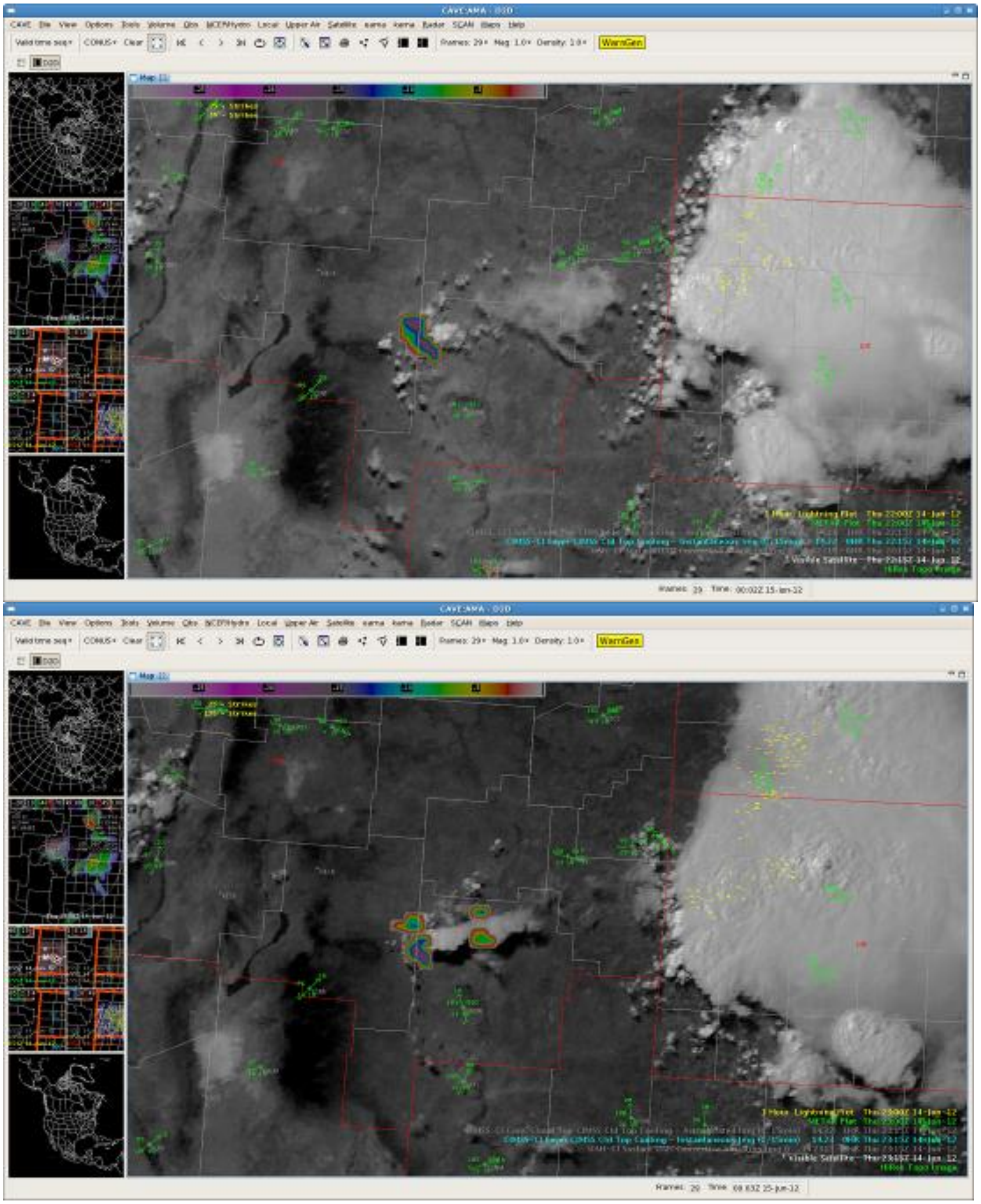


Figure 9 – Series of three CTC signals overlaid with visible satellite, lightning and surface observations over high terrain at 2015 (top), 2215 (middle) and 2315 UTC (bottom) on 14 June 2012. None of these cells developed into anything sustained due to low dewpoints in the upper teens to low twenties. It is important for forecasters to be aware of the environment in which cooling rates occur. (See GOES-R HWT Blog)

In general, forecasters responded that they felt comfortable using CTC in warning operations following the training that they received and that it worked as expected, with 93% reporting being comfortable using the product within the post-event surveys. Forecasters would like more time to evaluate product to determine the appropriate cooling rate values that are associated with the occurrence of severe weather. They would also like more research done and solid statistics on the same topic. Forecasters are excited to see this product provided with higher temporal and spatial resolution. On occasion their lead-times were only limited by the time between satellite scans.

CTC continues to flow into the SPC non-operational N-AWIPS workstations and is available for additional demonstration within the HWT in AWIPS II.

3.5 Nearcast Atmospheric Stability Indices – UW-CIMSS

In order to demonstrate potential data-fusion activities between AWG Legacy Atmospheric Moisture Profile, Legacy Atmospheric Temperature Profile, Total Precipitable Water, and Derived Stability Indices (ATBD found here) with NWP, a Nearcast model that assimilates full resolution information from the current 18-channel GOES sounder and generates 1-9 hour "nearcasts" of atmospheric stability indices was provided within the 2012 HWT Spring Experiment. The system fills the 1-9 hour information gap, which exists between radar nowcasts and longer-range numerical forecasts. The Nearcast system uses a Lagrangian approach to optimize the impact and retention of information provided by GOES sounder. It also uses hourly, full resolution (10-12 km) multi-layer retrieved parameters from the GOES sounder. Results from the model enhance current operational NWP forecasts by successfully capturing and retaining details (maxima, minima and extreme gradients) critical to the development of convective instability several hours in advance, even after subsequent IR satellite observations become cloud contaminated. The Nearcast products were delivered to HWT within the Spring Experiment in GRIB2 format via the University of Wisconsin LDM for display within the EFP N-AWIPS and EWP AWIPS II systems (see Fig. 10).

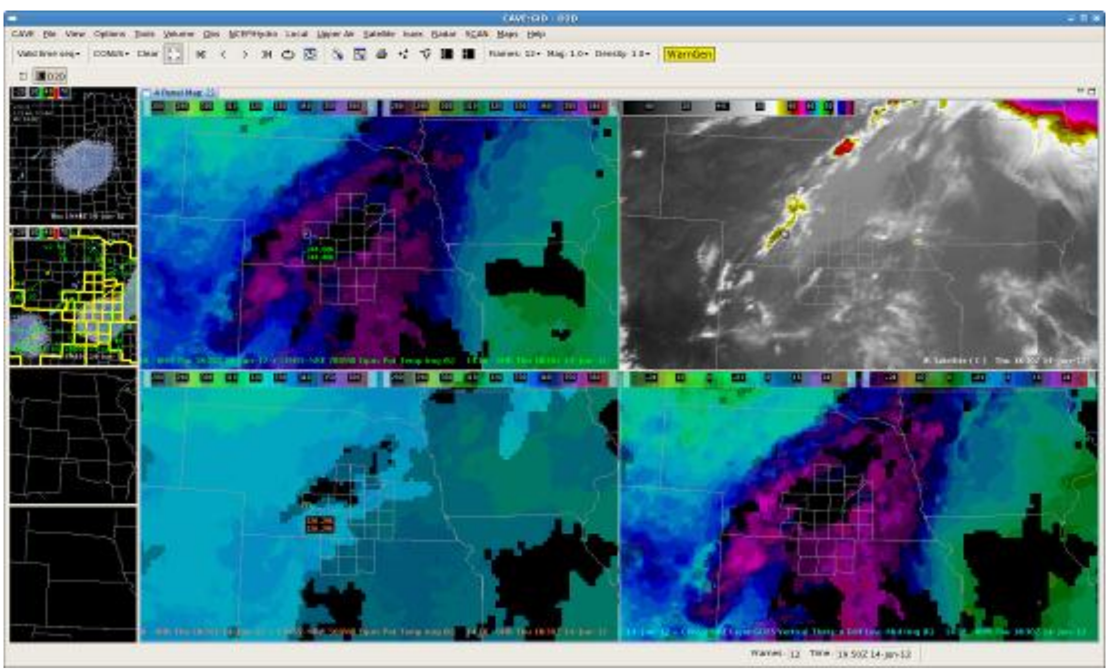


Figure 10 – GOES-E and GOES-W Nearcast low-level theta-e (top left), GOES-E observed IR (top right), mid-level theta-e (bottom left) and theta-e difference (bottom right) displayed within HWT AWIPS II workstations at 1830 UTC on 14 June 2012. (See GOES-R HWT Blog)

The Nearcast product contains a suite of fields, including precipitable water (PW) levels and difference, theta-e levels and difference, long-lived convection parameter, and the newly developed convective available potential energy (CAPE) field (see Fig. 11), which was provided to the HWT during week 2 of the Spring Experiment. According to post event surveys, forecasters reported using the Nearcast product in their warning operations 70% of the time. In addition, forecasters were asked which fields (other than the long lived convective parameter and CAPE) helped delineate areas of convective development, inhibition and the relative strength of convection. In each instance, forecasters responded that the theta-e difference was the most useful, gaining more than 70% of the responses in each category. In each category, the low-level theta-e field had the second most responses.

Forecasters found the instability fields from the Nearcast products particularly useful in determining convective maintenance.

> "I found it to be useful when I was in the HUN area... the instability kept showing up to the SE and I had some confidence that the storms would continue to maintain as they moved through the area."
> *NWS Forecaster, "Final EWP weekly debrief", GOES-R HWT Blog*

> "It was telling us that the axis of instability was going all the way to the coast (and it did) and that would be a huge thing to know, whether the convection would continue or die."
> *NWS Forecaster, "EWP daily debrief 6/12", GOES-R HWT Blog*

> "It was an overall helpful tool... not necessarily picking out where severe occurred, but where convection would occur."
> *NWS Forecaster, "EWP daily debrief 5/17", GOES-R HWT Blog*

Forecasters did notice a lack of observations due to cloud cover on occasion, especially during later forecast hours. Some suggestions from the forecasters include adding model data to fill the gaps.

> "The problem I had with this was the expansion of the 'black holes'... it came to be that after about 3 hours it became limited in usefulness... if there was some way to fill that in, I think it would be more useful."
> *NWS Forecaster, "Final EWP weekly debrief", GOES-R HWT Blog*

> "Instead of seeing the holes from cloud cover... maybe you could add in some model data to fill the gaps."
> *NWS Forecaster, "EWP end of week 1 debrief", GOES-R HWT Blog*

"Tried to look at it, but it wasn't too beneficial because there was a lot of missing data due to ongoing convection."
NWS Forecaster, "EWP Daily Debrief 5/9", GOES-R HWT Blog

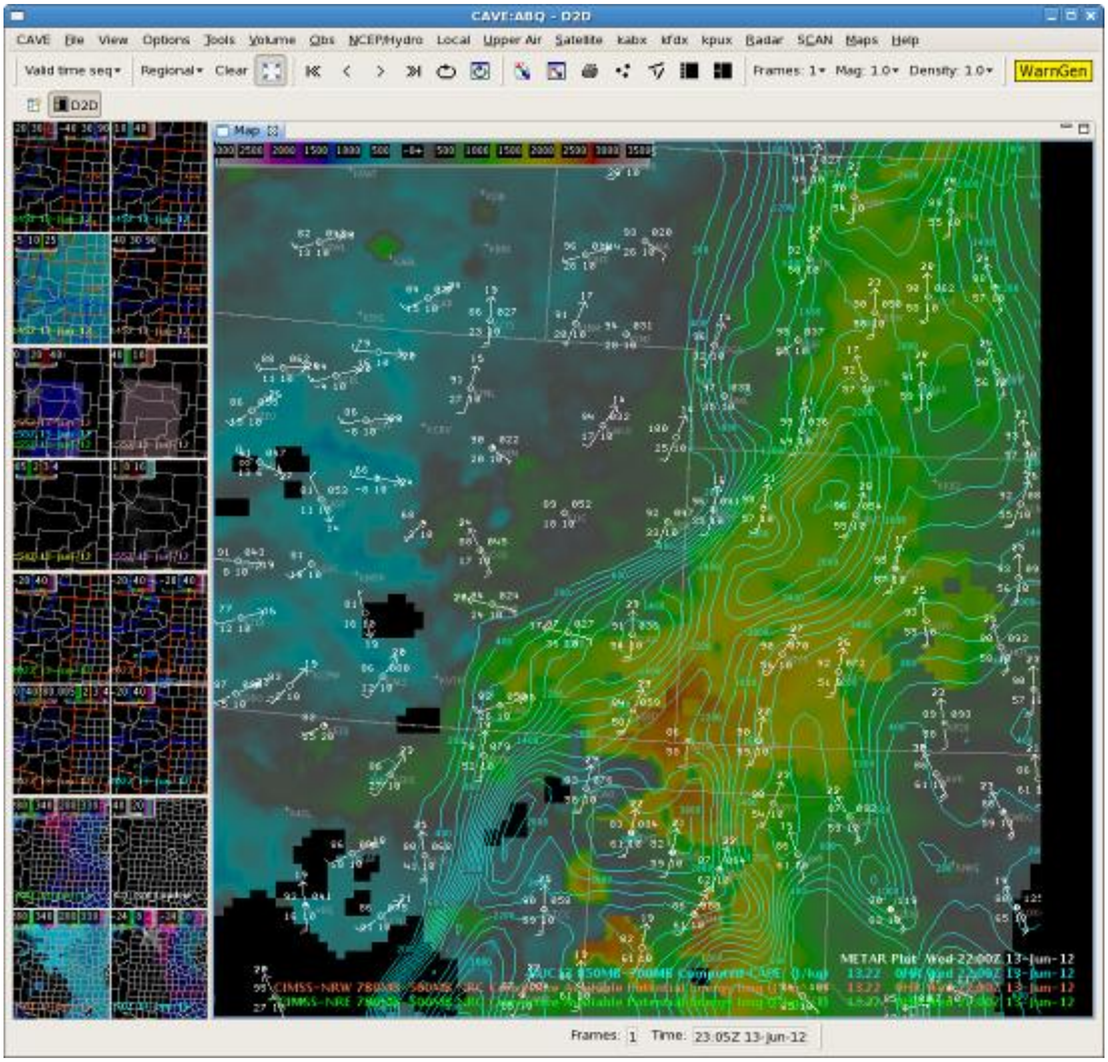


Figure 11 – Nearcast 780-500 mb layer CAPE analysis overlaid with RAP 850-700 mb layer CAPE analysis in AWIPS II at 2200 UTC on 13 June 2012. The Nearcast CAPE and RAP analysis show a similar pattern in instability coverage. (See GOES-R HWT Blog)

New for this year was the addition of a CAPE field to the Nearcast product suite. Forecasters found that this product was easier to understand conceptually than the theta-e and PW difference fields. In addition, forecasters spent some time comparing the Nearcast CAPE fields to model-based CAPE analysis fields (see Fig. 10). In general, forecasters found that the locations were very similar, but the values were slightly different. This is due to many factors, including the fact that Nearcast is making an actual satellite observation and that the levels at which the satellite observes are not constant, especially over high terrain, and thus aren't directly comparable to model levels available in AWIPS II.

> "I wanted to see how the model based CAPE analysis compared to the Nearcast CAPE and they matched (at least in pattern) pretty well... I usually have to go to the web to get those analyses, so it would be nice to have something to compare to that. Having a forecast component to it as well was nice to have."
> *NWS Forecaster, "Final EWP weekly debrief", GOES-R HWT Blog*

The Nearcast product is delivered separately for GOES-E and GOES-W retrievals. Therefore, forecasters established a display for the Nearcast products in AWIPS II that combine both the east and west domains of the Nearcast products in the same panel (see Fig. 10). While this helped the spatial coverage issue, forecasters noticed that there was no continuity between the west and the east domains (ie – retrievals moving off the eastern edge of the GOES-W domain were not retained on the western edge of the GOES-E domain). This resulted in potentially large differences in theta-e, PW and CAPE fields where the two domains overlapped (see Fig. 12), as well as expanded the black 'data void' regions throughout the forecast time period. On occasion the differences between the GOES-W and GOES-E domains were quite substantial, exceeding 1000 J/Kg where the two domains overlap. This caused some concern with the forecasters as they were unsure which value to believe since both of the retrievals are on the edge of their respective domains.

> "It was nice that you could use the GOES-E and GOES-W and overlap them to give you the complete picture... the values were a little different where they overlapped, but it still gave you a good picture."
> *NWS Forecaster, "EWP week 4 debrief", GOES-R HWT Blog*

> "On the boundary of the GOES-E and GOES-W domains, it would be nice to have some continuity from one product to the other."
> *NWS Forecaster, "Final EWP weekly debrief", GOES-R HWT Blog*

Discussions between the forecasters and product developers during the experiment suggested that a single CONUS-scale Nearcast product that utilizes both retrievals and retains information from one domain to the other would be extremely beneficial. In addition, this would help aid in reducing dataflow, since only one product would need to be delivered.

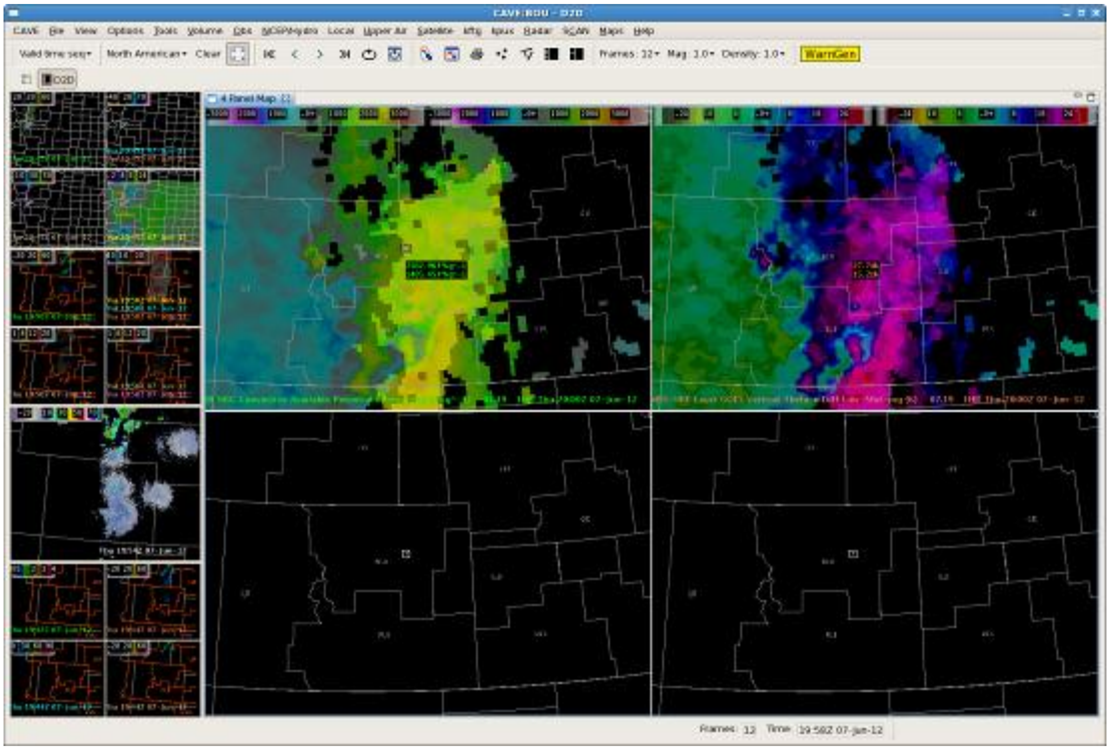


Figure 12 – Nearcast CAPE (top left) and theta-e difference (top right) from the GOES-W and GOES-E retrievals overlaid at 2000 UTC on 7 June 2012. An area where the west and east retrievals are overlapped is sampled. CAPE values range from 1405 to 2562 J/Kg and theta-e difference values range from 15 to 27 K in the area of overlap. (See GOES-R HWT Blog)

The Nearcast product continues to be delivered within the SPC and HWT N-AWIPS workstations and is still available for demonstration in HWT AWIPS II systems.

3.6 Airmass RGB Product – NASA SPoRT and CIRA

The Airmass RGB product from the current GOES sounder was provided to the HWT by CIRA and NASA SPoRT within the HWT AWIPS II and N-AWIPS workstations (see Fig. 13). RGB simply stands for Red-Green-Blue, which is a composite image created by combining three separate channels or channel differences into one image. This technique helps us identify specific features in the atmosphere without the use of complex derived products. The Airmass RGB is a combination of thermal infrared, water vapor and ozone channels that help us identify regions of warm and moist versus cold and dry air masses, spin in the atmosphere and jet streaks. The Airmass RGB has been used extensively over Europe using the Meteosat Second Generation satellite, which has similar spectral channels to what will be available on the GOES-R ABI. Current GOES imagers do not contain the spectral bands necessary to generate this product, but we are able to simulate the RGB using the GOES sounder, which does have some similar channels to the ABI. Unfortunately this data only arrives once hourly from the sounder and is in coarser resolution, but when GOES-R is launched, we will be able to create this high resolution product every 5 minutes over the continental US.

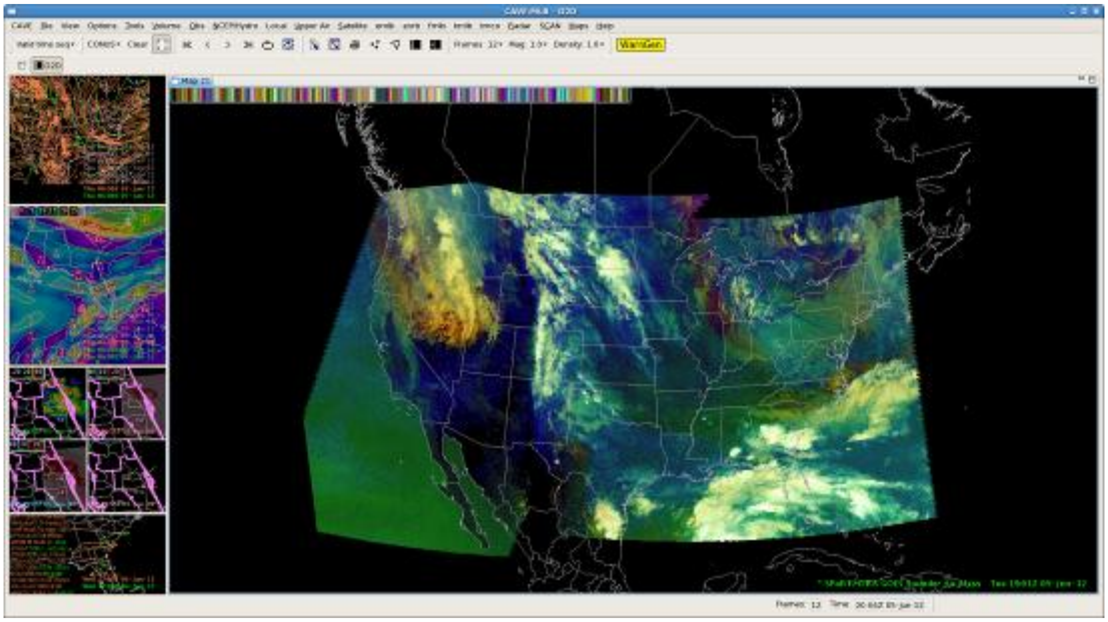


Figure 13 – GOES sounder RGB Airmass product displayed on HWT AWIPS II workstation at 1901 UTC on 5 June 2012. (See GOES-R HWT Blog)

The demonstration of the RGB Airmass product was somewhat limited during the 2012 HWT Spring Experiment since the product was not available within AWIPS II until the beginning of the 3rd week of the 5-week experiment. However, some one-on-one demonstration did occur throughout the remaining weeks. Forecasters found the product generally useful in providing them with a quick look at the synoptic scale atmosphere, as well as an innovative way to display satellite imagery outside of the typical visible, water vapor and infrared displays.

> "It would definitely be useful in a synoptic sense."
> *NWS Forecaster, "Final EWP weekly debrief", GOES-R HWT Blog*

> "It was interesting to see the initiation occurred along the sharp moisture gradients that were associated with the strong shortwave troughs... as well as being very useful for picking out the jet maximum... I really love this product."
> *NWS Forecaster, "EWP end of week 3 debrief", GOES-R HWT Blog*

> "Looping this product can show airmass movement and jet position/structure. This can be useful as a check against NWP models."
> *NWS Forecaster, "MLB: Checking out the RGB Airmass GOES Sounder product", GOES-R HWT Blog*

The RGB Airmass product continues to flow into SPC non-operational N-AWIPS workstations in real-time, and is also available for demonstration within the HWT in AWIPS II.

4. Results

The 2012 Spring Experiment continued the previous years' interactions with the EFP forecast and the EWP warning operations. These interactions proved fruitful over past years and continued this year with valuable feedback gathered via direct visiting scientist interaction with forecasters, as well as 109 online post-event surveys, 5 weekly webinars and 225 real-time blog posts. This year the GOES-R Proving Ground enhanced the interactions within the Spring Experiment's EWP by providing forecasters with interactive training material via WES case and articulate presentations prior to their arrival. In addition, with the assistance of WDTB, forecasters were provided the opportunity to share their experiences with the experimental products through the weekly webinars. Both of these interactions helped to greatly increase the exposure of the GOES-R Proving Ground products within the experiment and to the broader user community.

Forecasters commented that having the training material prior to the experiment was very useful in familiarizing themselves with the products prior to using them in real-time. It also helped them spin up during their visit much quicker. Having an informal hands-on approach to training with the provided WES case was very beneficial in allowing the forecasters to get familiar with how the products should be displayed. The procedures set up in the WES training case were also made available to the forecasters during their visit, which made finding and loading the products much easier. In general, the forecasters found that the amount and styles of material was appropriate and very informative. There were a few forecaster comments that some of the articulate training material exceeded the 30-minute time limit per product, which they would like reduced to avoid information overload.

EFP and EWP participants would also like to have more collaboration with each other throughout the day. We attempted some cross-participation previous years with a joint EFP-EWP discussion period, as well as having some of the EWP forecasters participate at an EFP desk in the morning. However, some additional planning is needed for this to work given the different rigid daily timetables of each of the programs. With the inclusion of AWIPS II expected to occur in 2013 or 2014 within the EFP, it may be possible to have more opportunities to exchange information between the two programs. This could aid in the development of an end-to-end forecast generation/discussion, from outlook to mesoscale discussion, watch, and warning.

Overall, participant feedback was positive. NWS forecasters and visiting scientists from the non-satellite community were excited by the potential of the demonstrated capabilities that will be available on GOES-R once it launches. NWS forecasters were generally pleased with the training and experience they received using the GOES-R Proving Ground products in real-time forecast and warning operations. 88% of participants reported being comfortable using the CI product in their operations following their experience in the HWT, with 93% reporting similarly for the CTC product. 73% of EWP participants reported being comfortable with the Nearcast product, a great improvement from previous years. 36% of the forecasters responded being comfortable with the PGLM product, however, this is most likely due to the lack of events demonstrated since "N/A" received 41% of the responses. In particular, forecasters reported that they would like to see these products in their operations so they could get more time with them in real-time situations.

More detailed feedback and case examples from the 2012 Spring Experiment can be found on GOES-R Proving Ground HWT blog at:
http://goesrhwt.blogspot.com

Archived weekly webinars can be found here:
http://www.wdtb.noaa.gov/resources/HWT-EWP/

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

5. References

Hartung, D. C., J. M. Sieglaff, L. M. Cronce, and W. F. Feltz, 2012: An Inter-Comparison of UWCI-CTC Algorithm Cloud-Top Cooling Rates with WSR-88D Radar Data. *Submitted to Wea. Forecasting.*

Mecikalski, J. R. and K. M. Bedka, 2006: Forecasting Convective Initiation by Monitoring the Evolution of Moving Cumulus in Daytime GOES Imagery. Mon. Wea. Rev., 134, 49-78.

Sieglaff, J. M., L. M. Cronce, W. F. Feltz, K. M. Bedka, M. J. Pavolonis, and A. K. Heidinger, 2011: Nowcasting convective storm initiation using satellite-based box-averaged cloud-top cooling and cloud-type trends. *J. Appl. Meteor. Climatol.*, **50**, 110–126.

Walker, J.R., W.M. MacKenzie, Jr., J.R. Mecikalski, and C.P. Jewett, 2012: An Enhanced Geostationary Satellite-based Convective Initiation Algorithm for 0-2 Hour Nowcasting with Object Tracking. J.Appl.Meter.Climatol. In Press.

Zinner, T., H. Mannstein, and A. Tafferner, 2008: Cb-TRAM: Tracking and monitoring severe convection from onset over rapid development to mature phase using multi-channel Meteosat-8 SEVERI data, Meteorol. Atmos. Phys., DOI 10.1007/s00703-008-0290-y.