Project Summary Report

for the
GOES-R Proving Ground
portion of the
Storm Prediction Center 2009 Spring Experiment

Final report by:
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The Spring Experiment activity at the Storm Prediction Center (SPC) in Norman, OK provides the GOES-R Program with an operational environment in which to deploy data and algorithms associated with its next-generation geostationary satellite remote sensing facility. These products include both baseline products and operational readiness trials of products transitioning from GOES-R Risk Reduction and the Algorithm Working Group. The availability of GOES-R products demonstrate, pre-launch, a portion of the full observing capability of the GOES-R system, subject to the constraints of existing data sources to emulate the satellite sensors.

The SPC receives early exposure to these next-generation products. Operational use of these new or improved data streams provides SPC with the opportunity to critique and improve the products relatively early in their development. In the first year, the SPC expected to lay foundational relationships and develop test methodologies that would lead to optimal testing of suites of products in subsequent years. The products available for 2009's Spring Experiment included a 0-1 hour Convective Initiation (CI) Nowcast and 15-minute Cloud-top Cooling (CTC) Rate from the University of Wisconsin's Cooperative Institute for Meteorological Satellite Studies (UW-CIMSS), a 0-1 hour Severe Hail Probability from the Cooperative Institute for Research in the Atmosphere (CIRA), and a 10-km Total Lightning Source Density GLM proxy from NASA's Short-term Prediction Research and Transition Center (SPoRT) and the National Severe Storms Laboratory (NSSL).

Participants

This year's participants were mainly limited to individuals from the three main GOES-R Proving Ground product developers (UW-CIMSS, CIRA and SPoRT) in order to focus on product delivery and display within the SPC's NAWIPS system. Due to the myriad of activities within the Hazardous Weather Testbed (HWT), participation in 2009's activities was limited to 2-3 individuals each day, including those attending for an entire week. The number and spectrum of participants will increase in future years as the Proving Ground activities become better integrated into the HWT and throughout the operational community. There are many products competing for the attention of the SPC (and WFO) forecasters. This past year focused mainly on product data flow and interaction between the product developers, as well as optimizing product presentation and robustness so that we could position ourselves favorably for forecaster interactions with the products in the years to come. This strategy provided the best chance of maximizing the Operations-to-Research feedback that is one of the Proving Ground goals. Below is a list of the 13 participants and their affiliations from this year's Spring Experiment:

Kris Bedka (UW-CIMSS)
Eric Bruning (UMD / CICS)
Lee Cronce (UW-CIMSS)
Wayne Feltz (UW-CIMSS)
Kevin Fuell (NASA SPoRT)
Jordan Gerth (UW-CIMSS)
Steve Goodman (GOES-R Program Office)
Jim Gurka (GOES-R Program Office)
Dan Lindsey (CIRA)

Bob Rabin (NSSL / UW-CIMSS)
Justin Sieglaff (UW-CIMSS)
Bill Sjoberg (NWS)
Gary Wade (STAR / NESDIS)

Daily Operations

At the beginning of the Spring Experiment, daily operations began at 10am with a morning post-mortem session that examined the previous day's activities and events with respect to GOES-R Proving Ground product performance. The daily schedule was adjusted to include a 2-hour period prior to the morning post-mortem in which the participants interacted with the EFP during their morning forecast period at 8am. Without this early interaction by the GOES-R Proving Ground participants with the EFP, it was difficult to include participants in the EFP activities as their morning forecasts drove the conversation throughout the day. Following the post-mortem, a daily report was written by Chris Siewert covering everything discussed about the previous day's weather and product performance, at which point the Proving Ground participants would engage in further interaction with the EFP. In cases where early afternoon initiation was occurring, or on days where significant weather was expected to occur, this time period was used for forecasting activities to maximize testing of the GOES-R Proving Ground products.

Because the day started relatively early, real-time forecasting activities became limited on some days when initiation wouldn't take place until late in the afternoon. Also, the early start made interaction with the Experimental Warning Program (EWP) difficult because the EWP began its operations late in the afternoon. Towards the end of the Spring Experiment the day was extended a couple hours to include some interaction with NWS forecasters and people from the warning community through the EWP. A possible remedy for this issue would be to alternate days for which the focus would be shifted between the other two HWT programs. Closer coordination on planning will take place for this year's EWP, EFP and Proving Ground activities.

Final Daily Operations Plan

EFP Participation (8 – 10 AM)
Discussion within the EFP familiarized Proving Ground participants with the daily weather situation as a lead-in to forecasting activities, and connected the Proving Ground to this long-running activity that has traction within SPC operations (Kain et al., 2003: Collaboration between Forecasters and Research Scientists at the NSSL and SPC: The Spring Program, *BAMS*, vol. 84, Issue 12, pp.1797-1806). These discussions also facilitated future applications of GOES-R data in next-generation operationally oriented numerical weather prediction models.

Morning post-mortem (10 AM – 12 PM)
Feedback captured by Chris Siewert with the following emphases:

1. Summary of previous day's weather

2. Utility of the Proving Ground products relative to currently available model and observational datasets
3. Successes, failures, and needed tweaks to each product
4. Summary of Proving Ground group discussion, providing critical evaluation
5. Relevant imagery for the day
6. Action Items

These daily summaries (see APPENDIX) were made available to Proving Ground participants and leadership for their perusal and real-time experiment evaluation.

EFP Participation / Lunch (1 – 3 PM)

HWT Map Briefing (3 – 4 PM)
Proving Ground participants joined other HWT participants for a discussion of the weather situation, and cross-pollination of ideas and products among groups. Group discussion of the day's activities, including lessons learned and demonstration of GOES-R Proving Ground products to the modeling community.

Forecasting exercises (4 – 6 PM)
Testing of GOES-R Proving Ground products occurred during real-time forecasting activities. The late afternoon period was chosen to maximize the opportunities for observing convective initiation and convective maintenance.

EWP Participation (6 – 8 PM)
Proving Ground participants engaged in interaction and testing of a variety of products during the early part of the EWP's daily operations, including GOES-R Proving Ground products. This provided interaction with NWS forecasters and the warning community.

Real-time Forecasting Exercises

The goal of the real-time forecasting exercises during the GOES-R Proving Ground Spring Experiment was mainly to provide quality feedback on the usefulness of GOES-R Proving Ground products in realistic operational situations. The feedback provided from these exercises provides product developers with information needed to improve their product prior to launch. The information learned during the use of these products in real-time forecasting operations also plays a valuable role in developing training and education materials that introduce products to the forecasters. Knowledge on the limitations and successes of each product prior to operational implementation is essential for usage within the operational community.

At the beginning of this year's Spring Experiment only the CI and CTC products were being delivered routinely, which limited our options for real-time forecasting exercises. Therefore, this year's Spring Experiment real-time forecasting exercises were designed around forecasting convective initiation. Once the other products became fully available later in the Spring Experiment, the limitations of the scope of the exercises became evident as the new products were not applicable. It is therefore necessary to design experiments to test the wider spectrum of GOES-R Proving Ground products for the coming years.

Products

Cloud-top Cooling Rate / Convective Initiation Nowcast

The 15-minute CTC and 0-1 hour CI products from UW-CIMSS are provided regularly day and night within the SPC's NAWIPS workstations. The 15-minute CTC product is the backbone of the 0-1 hour CI nowcast. The CI nowcast product uses more stringent microphysical requirements in order to reduce false alarms to make a yes/no nowcast of the first occurrence of 35 dBZ within a growing cumulus cloud. Both products were available at the start of the Spring Experiment and were the basis of the design of the real-time forecasting exercises. At the beginning of the Spring Experiment the products were being provided as 60-minute accumulated NAWIPS image formats only. This meant that the products could not be overlaid on any other products, such as satellite imagery or radar reflectivity. Because they were 60-minute accumulated fields, an instantaneous view of the products' output was also not possible. Suggestions made by participants through the real-time forecasting exercises quickly concluded that an instantaneous NAWIPS grid format for each of the products would be more useful. This would provide a snapshot view that could be overlaid on satellite visible or IR imagery. Further on during the Spring Experiment it was again suggested by participants that a transparent contour fill would be valuable for forecasters to determine the cloud type for which each signal was associated with. All of these suggestions were implemented and an example of the products' current display within NAWIPS can be seen in Figure 1.

Figure 2 shows an example of the CTC dryline convection over Texas from early on during the Spring Experiment. The CI product removes many false alarms seen in the CTC product due to mature cumulus expansion which were not associated with any new convective growth. Thirty minutes after the nowcasts were made explosive development took place over most of the nowcast locations. The products also operates well during nighttime convective situations (seen in Figure 3) as well as rapid scan operations, which is similar to scanning rates for GOES-R. An example where the CTC/CI product may be directly useful to SPC operations can be seen in Figure 4. Twenty minutes prior to issuance of a severe thunderstorm watch, strong CTC signals occurred over the area of interest, associated with first severe thunderstorm that occurred in the area. Overall, throughout the Spring Experiment successful nowcasts that were made tended to have a 15-30 minute lead time prior to convective development.

Through constant interaction within the Spring Experiment by the product developers during real-time forecasting exercises, a few limitations in the CTC/CI were discovered. Having a-priori knowledge of product limitations significantly reduces the risk of users rejecting the product at first use. For example, it was discovered that during 30-minute full-disk scans every 3 hours the CTC/CI products' performance degrades as it is required to re-sample 30-minute data into 15-minute fields. This leads to an increase in false alarms due to overestimated CTC values. It was also noticed that the CTC/CI products tend to be diagnostic in high CAPE/extremely moist environments (see Figure 5), such as over much of the southeastern US. The CTC/CI products also tend to create false alarms near expanding cloud edges and in situations where thin cirrus overruns small cumulus, creating false observations of cooling (see Figure 6). These effects are somewhat reduced by the CI products stricter microphysical requirements, but is still present. It is expected that improved spatial and spectral information will help greatly reduce these false alarms.

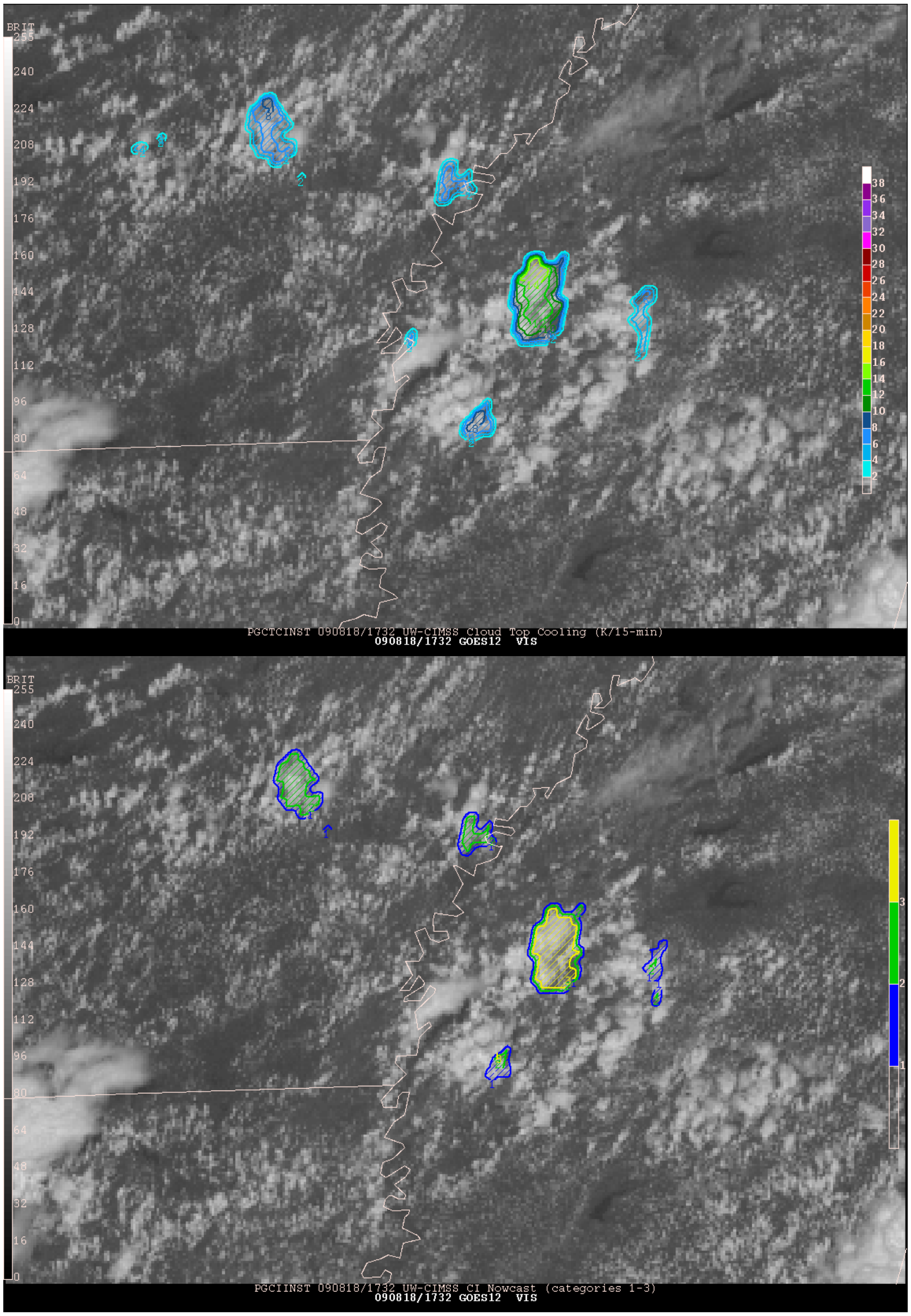

Figure 1 – Example of the cloud-top cooling rate (top) and convective initiation nowcast (bottom) products within SPC's NAWIPS workstations on 18 August 2009 at 1732 UTC. Stipple-filled contours allow forecasters to examine cloud type for which the signals are associated.

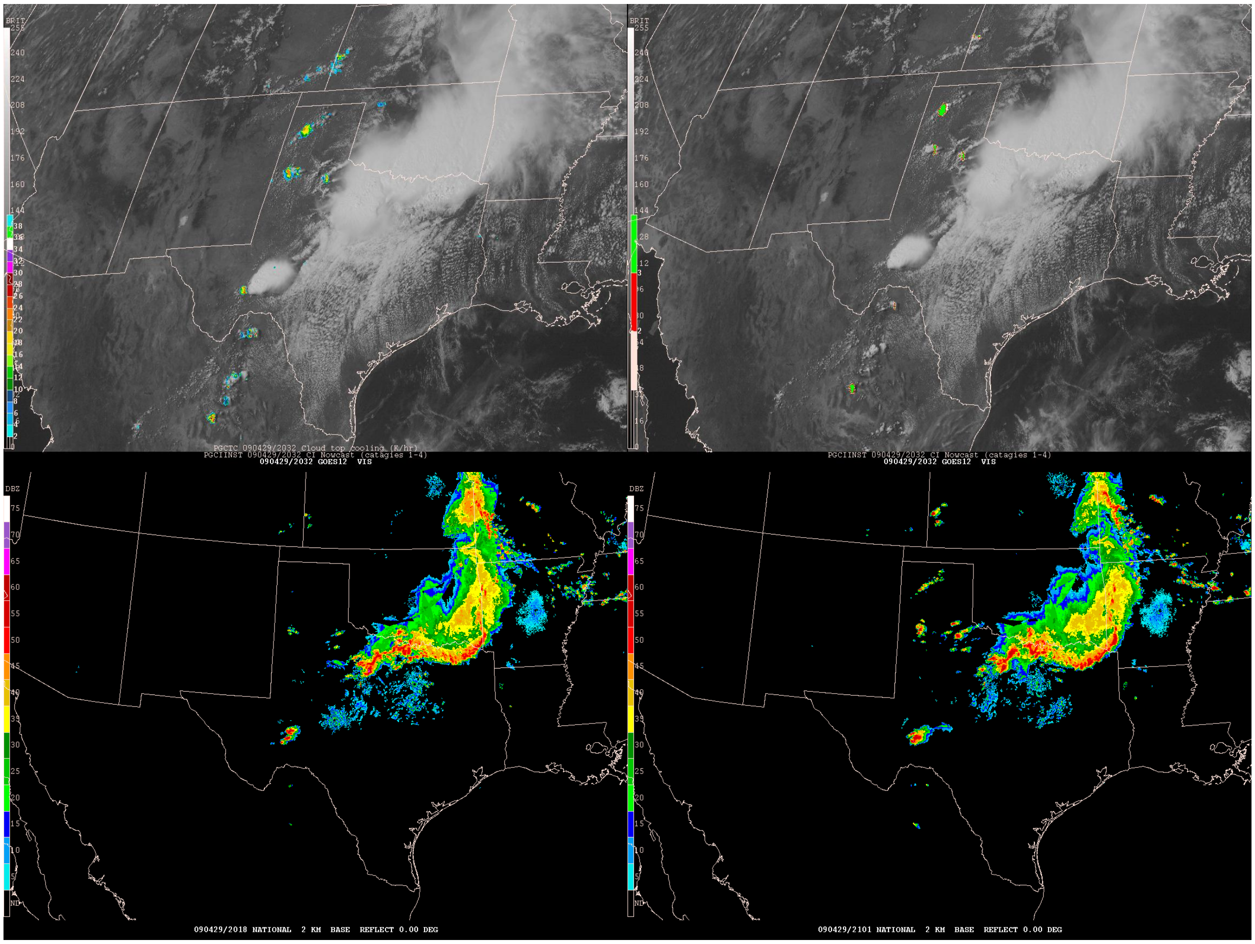

Figure 2 – Example of the CTC (top left) and CI (top right) for dryline convection on 29 April 2009 at 2032 UTC and radar base reflectivity at 2018 (bottom left) and 2101 (bottom right) UTC.

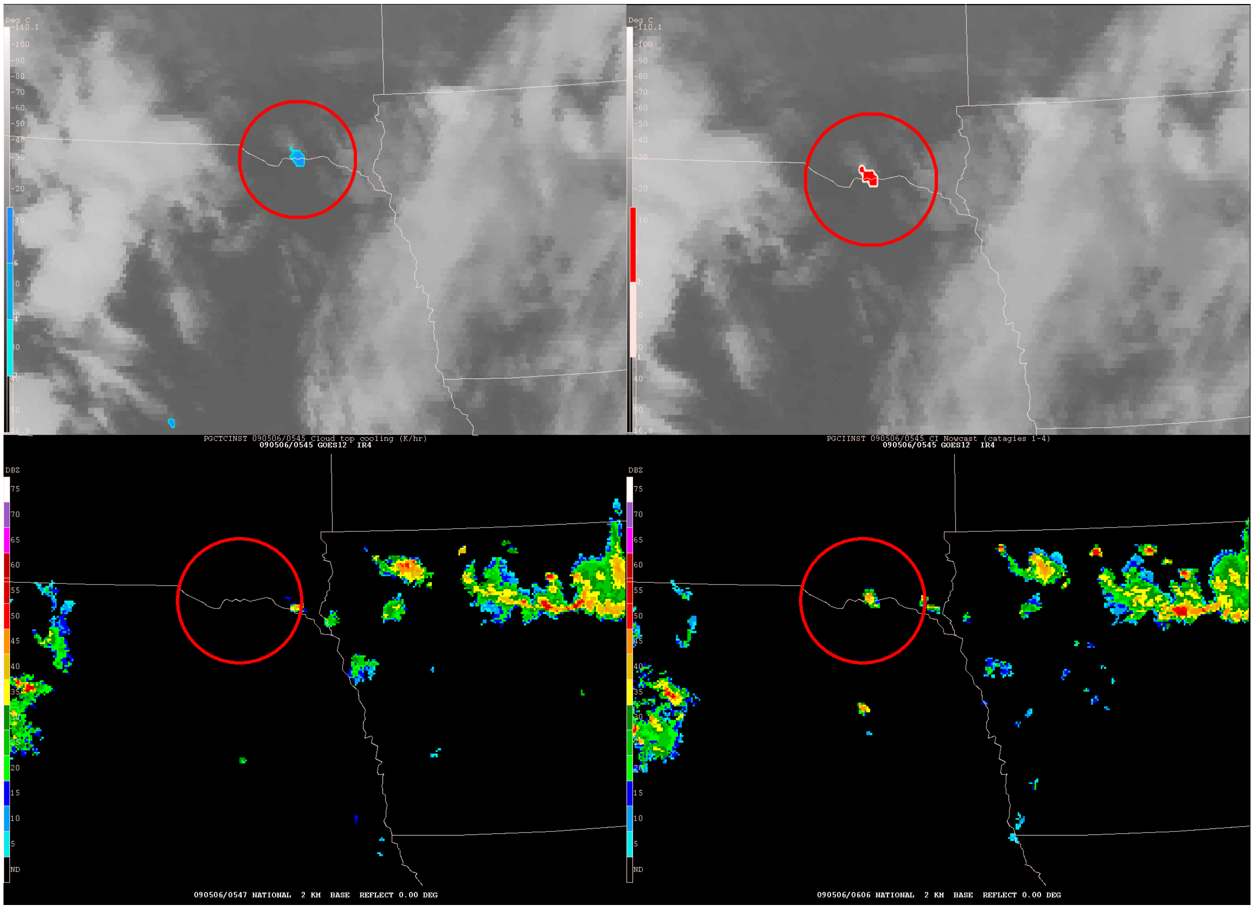

Figure 3 – Example of the CTC (top left) and CI (top right) for nighttime convection on 6 May 2009 at 0545 UTC and radar base reflectivity at 0547 (bottom left) and 0606 (bottom right) UTC.

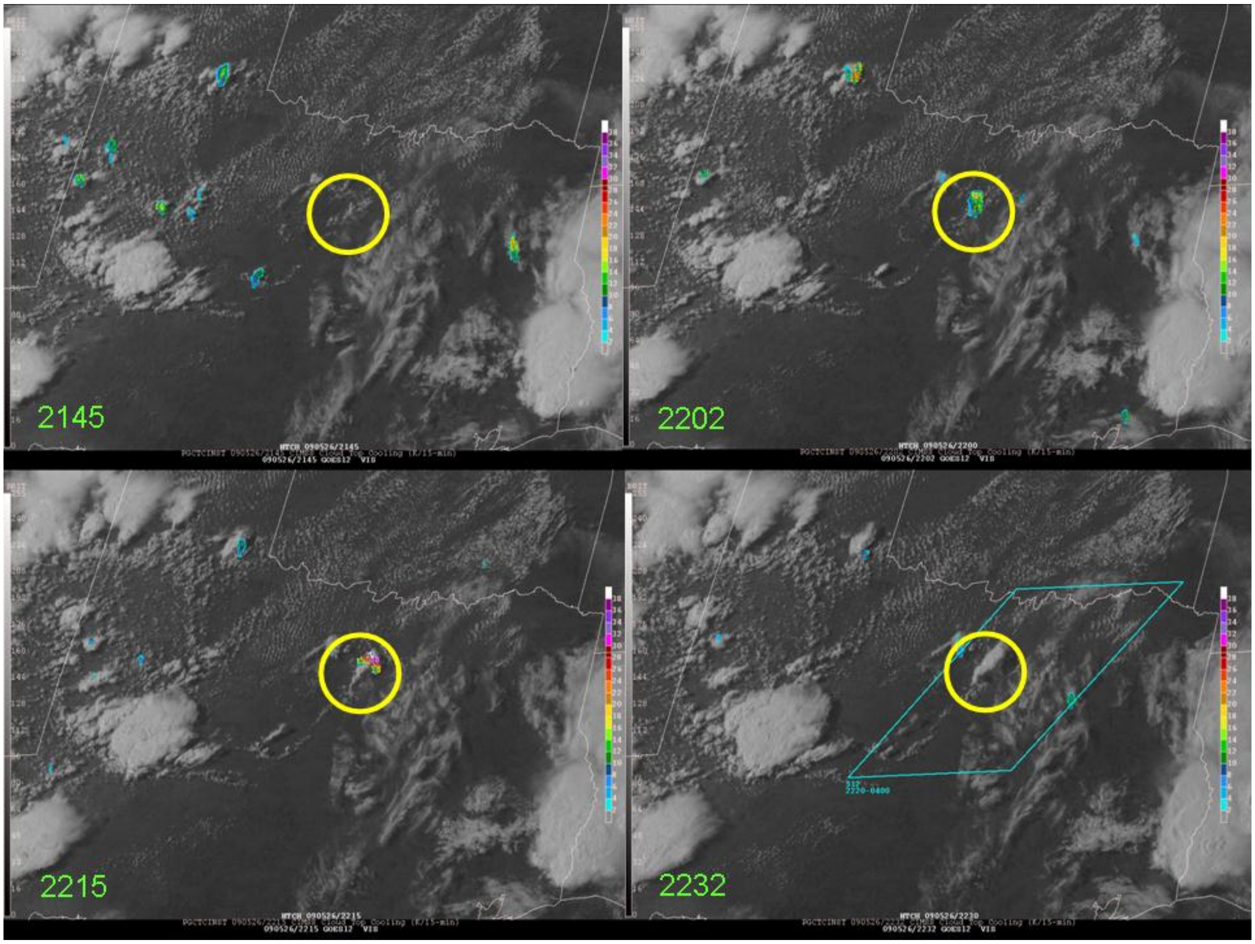

Figure 4 – 1-hour time-series of CTC product from 2145 to 2232 UTC on 26 May 2009 prior to severe thunderstorm issuance at 2220 UTC near Dallas, TX.

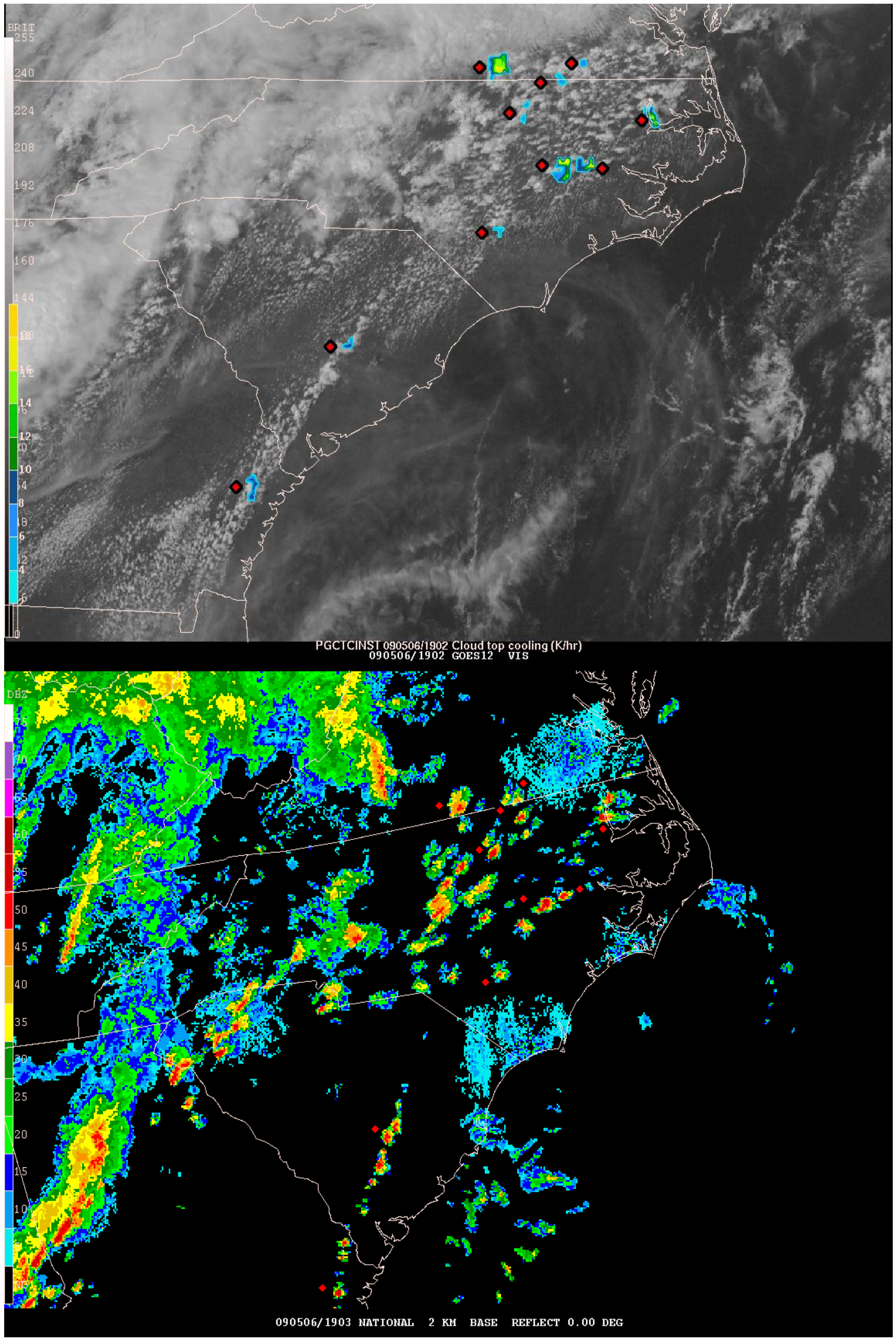

Figure 5 – CTC product at 1902 UTC (top) and radar base reflectivity at 1903 UTC (bottom) during a high CAPE, extremely moist event over the eastern US on 6 May 2009. Red dots are place markers to reference CTC and reflectivity signals between the two images. During these environmental situations the CTC/CI products are diagnostic in nature.

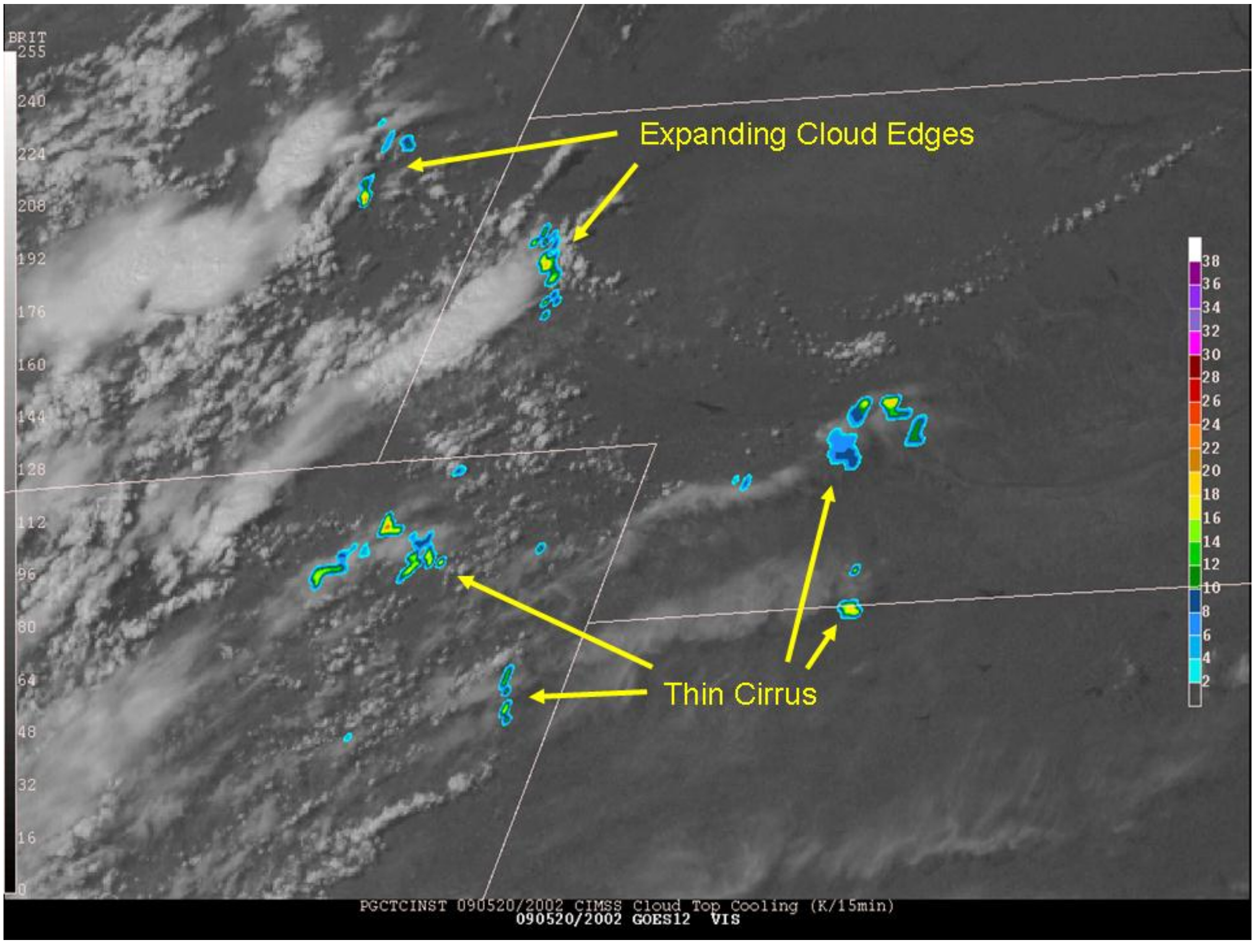

Figure 6 – Example of expanding cloud edge and thin cirrus false alarms seen in the CTC/CI products at 2002 UTC on 20 May 2009.

Severe Hail Probability

The 0-1 hour Severe Hail Probability product provided by CIRA is the first installment of a more robust 0-6 hour severe weather (wind, hail and tornado) probability product. The product began arriving at the SPC in the final weeks of the Spring Experiment, so real-time experimental testing of the product was somewhat limited. At that point the product was very early in its development and use within the Proving Ground was mainly for initializing product data flow, display and collaboration between CIRA and the SPC.

The product aims to provide a probability of severe hail occurrence (hail size > 0.75") out to 1-hour in the future through the use of Rapid Update Cycle model analysis fields conducive to hail growth, as well as satellite IR cloud-top brightness temperature to locate sufficiently cold cloud tops where hail may be possible in the future. The product developer expressed plans to include more satellite information in order to expand upon or even take the place of some of the model analysis fields in the future.

An example of the product output from an NAWIPS workstation at the SPC can be seen in Figure 7. In general, the product bounds areas where severe hail reports are seen (shown as a blue 'a' in Figure 7). However, quite often reports are seen prior to any probabilities being forecast (see Figure 8). This is mainly due to the fact that we are only limited to a 1-hour forecast at the moment and because the product uses cloud-top temperatures to locate regions to make its forecast it is subject to the limitations of the current GOES imager. Often it was seen that hail would occur for a specific cloud feature that was too small for the product to detect (see Figure 9). This was due both to the spatial resolution limitations of the current GOES imager as well as full-disk scans causing the product to use older imagery to make its forecast.

Through examination within the Spring Experiment it was seen that the product currently provides probabilities of severe hail occurring within that pixel space up to a maximum of about 10% for a 1-hour forecast. It is expected that once the product is expanded out to 6 hours these probabilities may become very low, which may mislead forecasters that the probabilities are not significant. Also, as the forecast period expands, the role of satellite data will play a smaller role. Possible uses of satellite data beyond 2-3 hours should be examined. It should be noted that, due to computational requirements, the product does not arrive at the SPC until half past the hour, which makes the usefulness of the 0-1 hour forecast limited. This latency issue will be worked on, but it should not be an issue for longer forecast periods.

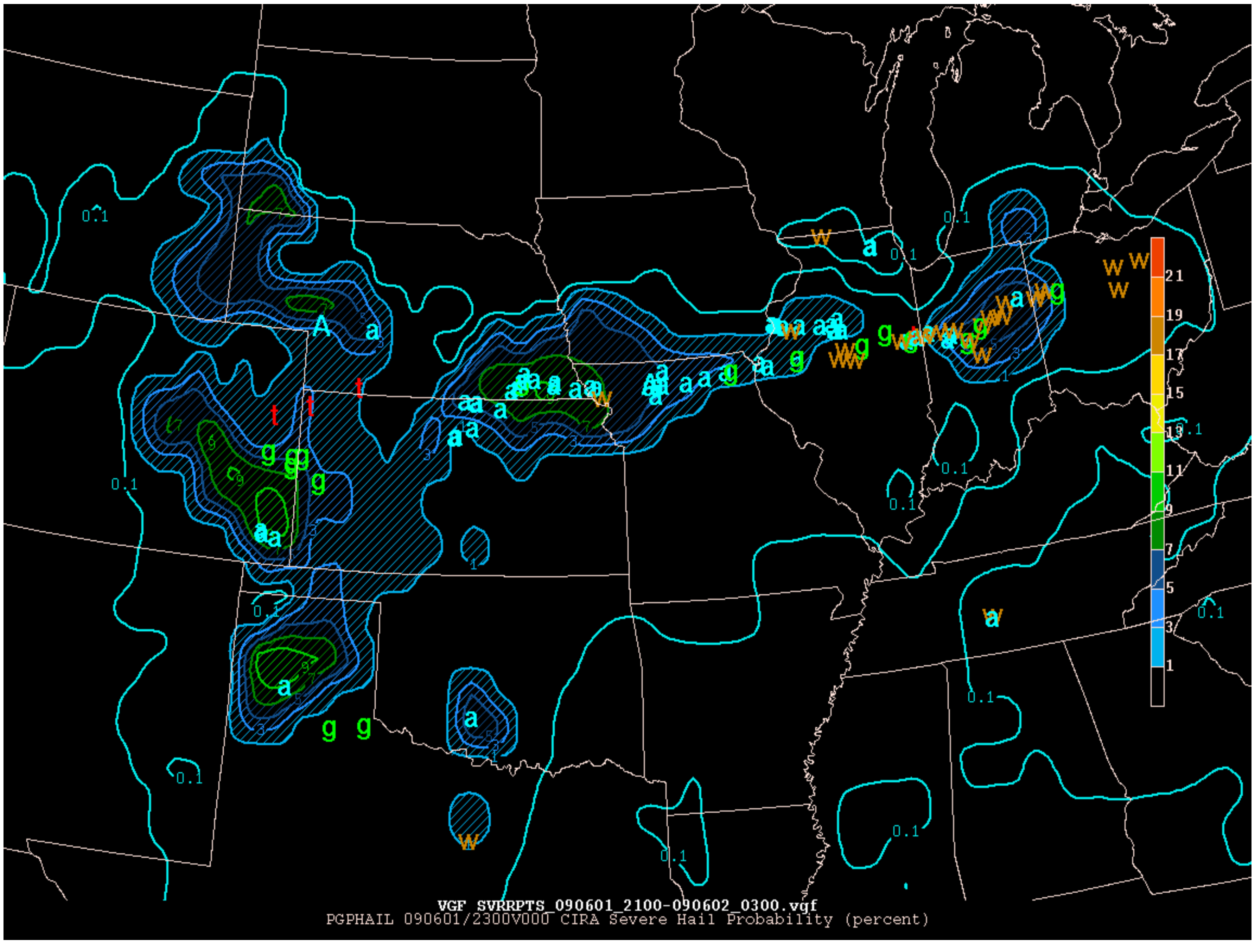

Figure 7 – Example of the 0-1 hour severe hail probability product at 2300 UTC on 1 June 2009 provided by CIRA displayed on NAWIPS workstations within the SPC during the 2009 Spring Experiment. Blue ‘a’s indicate locations where severe hail was reported. Probabilities do not exceed 10% for all cases seen thus far.

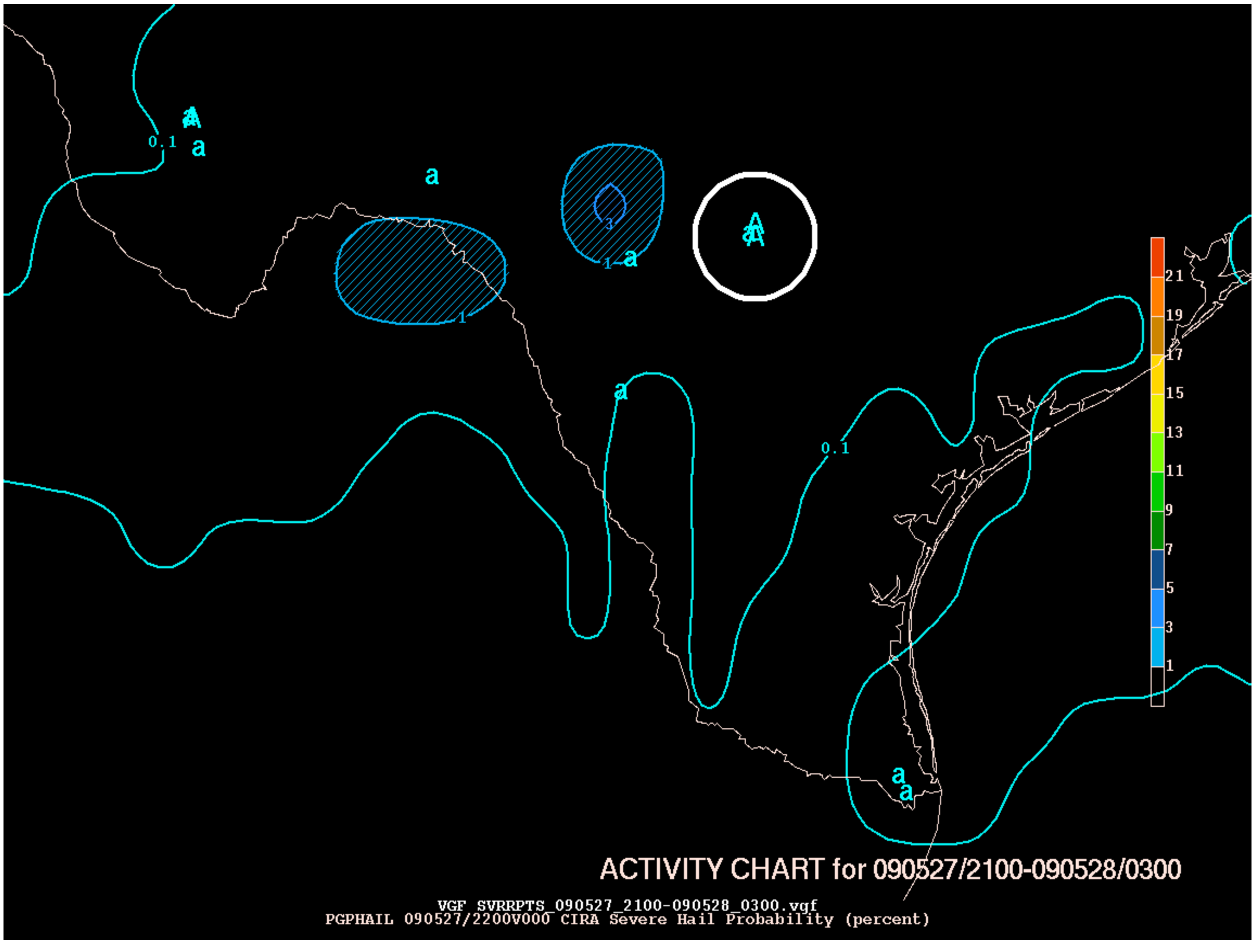

Figure 8 – CIRA's 0-1 hour severe hail probability forecast on 27 May 2009 at 2200 UTC. Blue 'a's within the white circle indicate reports of severe hail during the forecast period where no probabilities were seen.

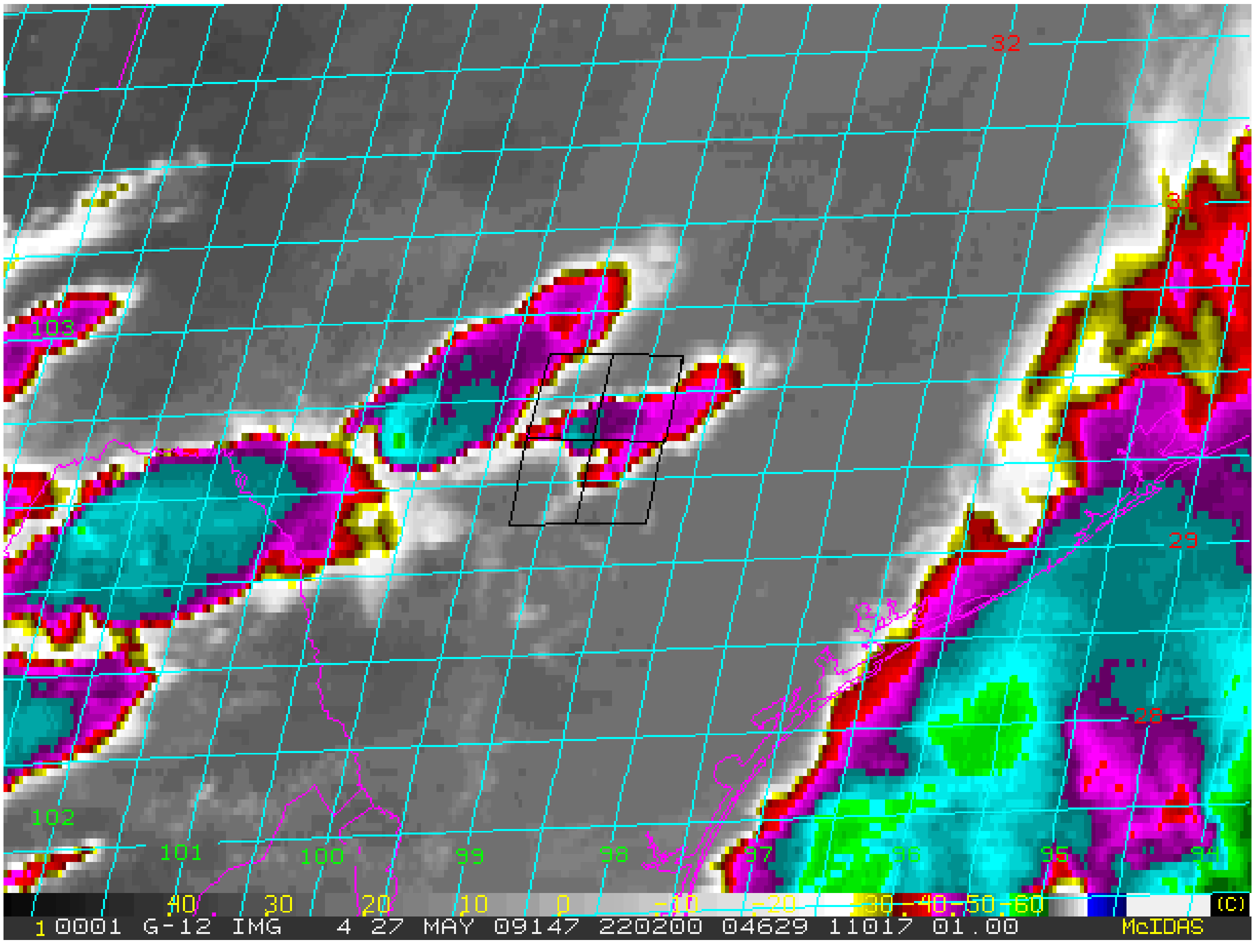

Figure 9 – McIDAS IR image for 27 May 2009 at 2202 UTC showing the grid boxes for CIRA's severe hail probability product (black boxes). Notice that the cold cloud top covers only ~25% of one grid box and was therefore not used for a forecast because the cold cloud top threshold was not met despite severe hail being reported within the next hour (Figure 8).

10-km Total Lightning Source Density

Currently the SPC receives total lightning source density data from three LMA networks across the country (Norman, OK, Huntsville, AL and Washington DC). Plans to expand dataflow with other LMA networks are currently being worked towards for next year's Spring Experiment. The data arrives in near real-time and is re-sampled to a 10-km (nominal GLM resolution) LMA source density in NAWIPS image and grid formats. The data were examined during the Spring Experiment at the SPC by both the GOES-R Proving Ground and the EWP. Comparisons between the GLM proxy 10-km and the natural 1-km data were done through a warning perspective within the EWP and somewhat within the GOES-R Proving Ground. LMA data did not arrive consistently within the Proving Ground due to local hardware and software issues until about halfway through the Spring Experiment. Once again, the main focus for this year was to solidify dataflow and display, as well as build the foundation for future expansion of the evaluation of GLM proxy products within the GOES-R Proving Ground.

The first conclusion drawn from the use of the total source density product is that in order to provide the best possible GLM proxy product, flash data rather than source data are needed since the GLM will detect flashes. LMA sources can be sorted into flashes in near real-time and this is being worked towards for the next Spring Experiment. Display of the 10-km and 1-km total source density in NAWIPS image format within the SPC is shown in Figure 10. In general there is good agreement within the spatial extent of the lightning activity. However, because the 10-km product re-samples data to a 10-km grid, some smaller areas of lightning activity can be missed (see right half of Figure 10). It was also noticed that the source counts in the 10-km product were less than those in the native 1-km image. Again this was expected since averaging over the 10-km area is occurring as the data re-sampled. Next year, comparisons of products will be made prior to the experiment start date to ensure that the flash-based LMA product at degraded resolution will in fact solve the display quality problems identified in 2009.

During real-time forecasting exercises where LMA data was available, the timing at which jumps in total source density counts were seen was compared between the 10-km and 1-km products. It was noticed that the 10-km product tends to lag behind the 1-km product when jumps occur on average of 2 minutes (or one scan period). This can be due to the fact that since the 10-km box's total source density is averaged it needs a larger jump in source densities over the entire box area to signal a significant increase.

Forecasters within the EFP, EWP and the SPC suggested providing the 10-km product as an NAWIPS grid product so that it could be overlaid on other products within NAWIPS, such as satellite imagery or radar data. This was provided by Bob Rabin and imported into the local NAWIPS workstations for evaluation (see Figure 11). Unfortunately however, hardware and software limitations only allowed for 5 hours of the gridded product to be stored at any one time within the SPC. This made examination of the product during the morning post-mortems difficult, but observations were still made during real-time forecasting exercises. Because of the nature of the grid products within NAWIPS, they have to be manually updated. Since the GLM proxy data is provided in 2-minute intervals, updating can be quite tedious. Forecasters also mentioned an interest in having a map of weak detection areas within the LMA networks to assist them while they evaluate the use of these products.

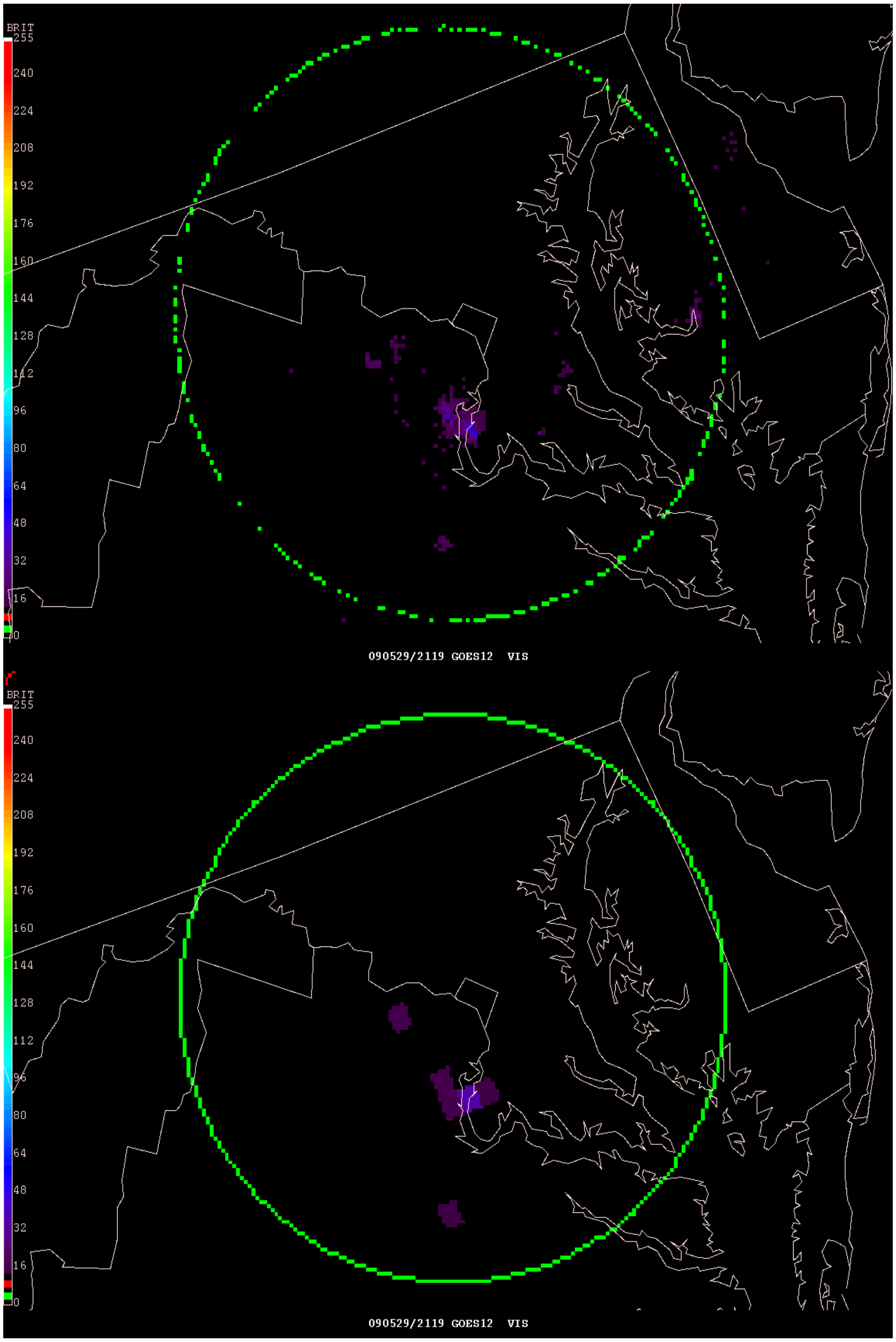

Figure 10 – Example of the 1-km (top) and 10-km (bottom) total lightning source density product displayed on NAWIPS workstations within the SPC during the 2009 Spring Experiment over Washington DC for 29 May 2009 at 2119 UTC. The 10-km product provides good agreement with locations of lightning activity and areas of maximum source densities. Some areas of small source counts are averaged out in the 10-km product. Also, source density values are generally weaker in the 10-km image due to averaging over the 10-km grid boxes.

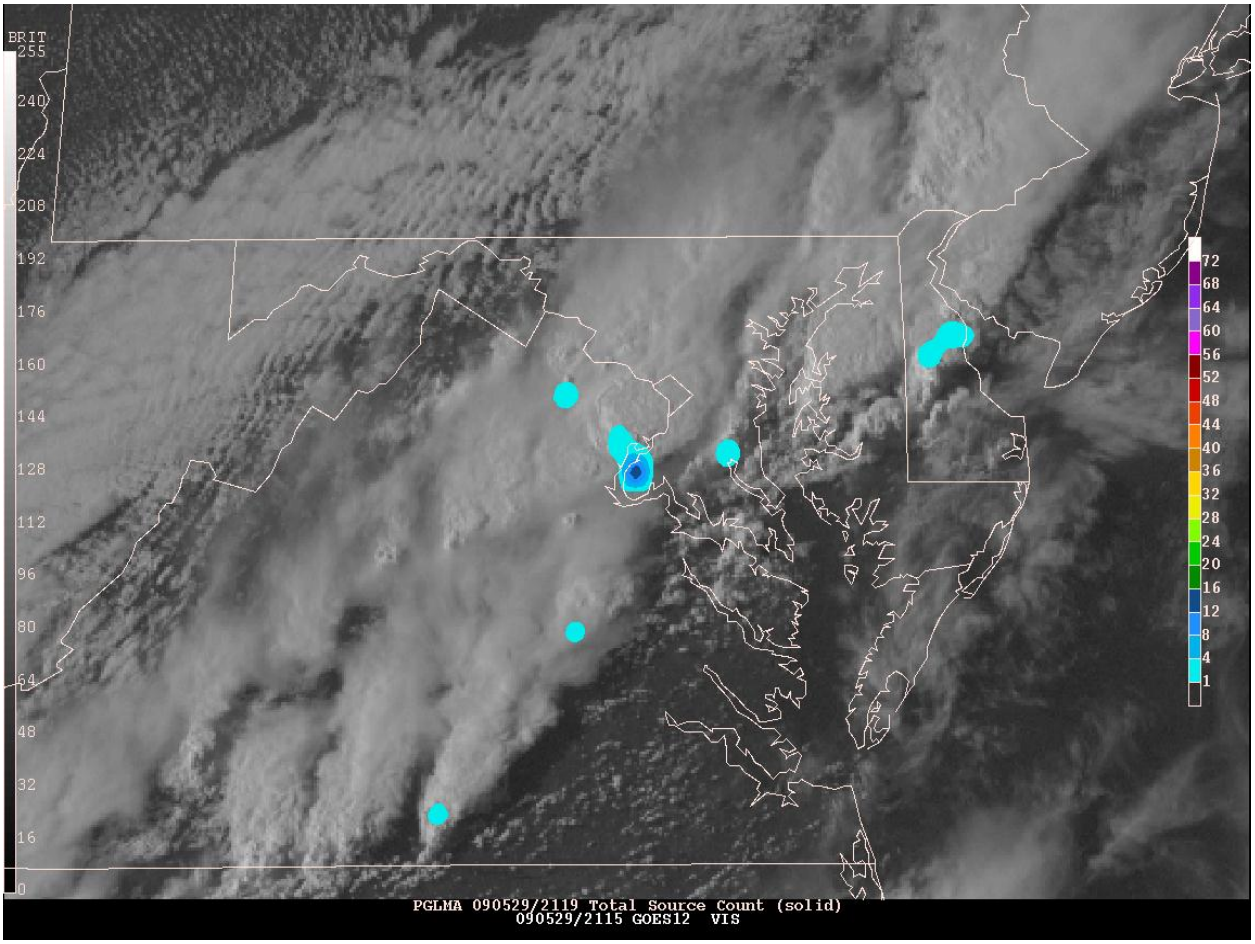

Figure 11 – Example of the GLM proxy 10-km NAWIPS grid total lightning source density product over the Washington DC LMA network on 29 May 2009 at 2119 UTC overlaid on visible satellite imagery from GOES-12 at 2115 UTC.

Common Themes

The foci of this year's experiment were product data flow and presentation and interactions among product developers and forecasters. To close, we highlight a few high-level themes that have application across a range of products.

With the new GOES-R Risk Reduction emphasis on blended products, it is worth noting that the constituent base-level fields in physical units remain of strong interest to scientifically minded forecasters. A concern is that this works against the goal of reducing the volume of data being presented to forecasters. Between overwhelming forecasters with too much data and providing a single tell-all product lies an important middle ground of flexible display tools for overlays from multiple sources. In 2009, forecaster requests to combine heritage imagery with new products required the creation of gridded, (not imagery) products within NAWIPS, which had their own usability shortcomings for products with rapid updates. Attention must be paid to developing new user interfaces that support real-time blending of products through adjustment of transparency, contouring, and color maps in an iterative and responsive manner. The success of such interfaces (http://tantek.com/log/2007/02.html#d19t1813) is tied to their elegance and depends on artistry and craftsmanship as much as measurable requirements.

Capturing forecaster feedback on the CI product and implementation of new or adjusted products in just a few weeks' time was a highlight of 2009. This is to be contrasted with the fitful adjustment of the lightning products, which will only be finally addressed after a full year's wait. The Proving Ground can serve as a demonstration within NOAA of how to do rapid product iteration by fostering an environment which champions product teams with a close connection between product scientists and the operational product code. It is one of the Proving Ground's greatest strengths to be able to refine products outside of the years-long bureaucratic formalisms that have characterized research-to-operations transitions in the past.

APPENDIX

Provided below is an example of a daily briefing constructed during the 2009 Spring Experiment for 26 May, 2009.

SPC HWT GOES-R Proving Ground – Spring Experiment Daily Report

Date of event: 26 May 2009

Written on: 27 May 2009

Author(s): Chris Siewert

General Discussion:

This first day of the week following Memorial Day has a small area of slight risk for severe thunderstorms in N.E. TX into S. OK (see Fig. A1). Ongoing convection from the morning hours over OK allowed us to test out the LMA products finally. We found that the 1-km LMA image did not work, but the 10-km GLM proxy image did (see Fig. A2). The problem with the 1-km image was remedied and the PGLMA 10-km grid also now works, so we are able to overlay the LMA sources on other images such as visible or IR satellite imagery. Upon comparing the 10-km LMA image to the NLDN (Fig. A2), it was noticed that some of the signals that should have been seen were not (ie single strikes). It was pointed out that the image colorbar threshold *may* be too low to pick up individual strikes during the 2-minute interval. I emphasize the word *may* because the LMA picks up lightning *sources*, not *flashes* like the GLM will, and an individual flash will have multiple sources, but it may be less that the threshold is set at now, which I believe is 16 sources to color a pixel.

The new stippled displays for the CTC and CI products are now available. This allows us to see through the signals to the image it is overlaid on, which helps us better determine whether or not the signal is associated with a cumulus cloud or if it is a false alarm (see Fig. A3). The contour values are now labeled as well, which actually adds an interesting aspect to the display. When zoomed out the locations of CTC or CI are now more evident (see Fig. A4). However, it should be noted that on this particular event (from last week Friday), most, if not all, of these signals turned out to be false. This is suspected to be due to the rapid return of moisture (finally) back into the eastern and central US, with small Cu firing everywhere. Basically, anywhere there was some thin cirrus, there was a good chance it was over a small Cu cloud and thus caused a lot of false alarms.

We spoke with a couple forecasters here at the SPC during our interactions with the EFP and EWP towards the end of last week regarding the CTC and CI products that they have available in the EFP. Following an EFP map briefing a forecaster talked with me about bringing the products out to SPC operations as they found it may be useful for them. I told them that this is in the works and discussed the possibility of having me sitting in on a few forecast shifts to work with them and they seemed excited about that. Also, the suggestion to let the CTC product keep calculating CTC even after a cloud reaches mature phase was brought up multiple times since the forecasters thought it may be useful to have that information not just only for a CI perspective but also for a continued development perspective. I told them that this may cause a lot of false alarms but we would look into it.

This week the EWP is not operating due to the Memorial Day holiday, so our main interactions will be with people in the EFP or in VORTEX-II if they have a chase day. Dan Lindsey is our new visitor this week from CIRA and we will begin to go more in depth on the severe hail probability product. He explained to us what the hail product is. The product provides a forecast of a probability of severe hail currently on the 0-1 hour timeframe only. Plans to expand this up to 6 hours are in the works. The product takes GOES-12 10.7 micron data and combines it with the SPC mesoanalysis fields (LI, shear variables, sfc dewpoint, etc…) to provide the probability of severe hail over a 0.5 x 0.5 degree lat/lon box during a 1-hour time period. Because it is such a limited time frame, the probabilities rarely exceed 10% over any given area due to the nature of the calculations. Plans to include other satellite fields, such as a cloud top cooling product, will hopefully improve the short term forecasts in the future.

The morning briefing tackled the severe weather that took place near Dallas in the late evening hours. First we examined the performance of the CTC/CI products prior to the first watch issued in the past 9 days, which happened to be a severe thunderstorm watch issued at 2220 UTC. The first signal in the CTC and CI was seen at 2145 UTC right on the southwest edge of where the watch box would be (see Fig. A5). Strong signals occurred inside the watch box area at 2202 UTC and at 2215 UTC there were more signals, but they were false alarms due to an expanding anvil edge. There were numerous severe hail and wind reports, including one 2" hail report in downtown Decatur, TX at 0500 UTC. We examined the hail product's performance during this time period and saw that it zeroed in on the areas where the hail reports were (shown by the blue letter a's) between 2200 to 0300 UTC (see Fig. A6).

We also examined a storm that initiated in S. TX around 1000 UTC overnight (see Fig. A7). The storm was relatively isolated and not impacted by cirrus. The cloud typing product also identified water cloud in the area much prior to that time period. However, the cloud began to grow around 0945 UTC and was not picked up by the CTC or the CI products, but showed signs of cooling of about 8 K over 15 minutes between 0945 and 1002 UTC. The CTC product, and thus the CI product finally picked up the growing convection at 1015 UTC, but at that time there was already a 35 dBZ echo associated with it (see Fig. A8). We are unsure why the CTC or CI products did not see what seemed to be a classic nighttime case of CI for this event.

Action Items:

CI/CTC:

- New stippled display to be evaluated
- Look into possibility of making the CTC product continue after CI occurs
- Look into CTC/CI detection differences
- Thin cirrus over small cu false alarms continue
- Diagnostic over east coast/warm sector continues

GLM:

- PGLMA now working

CIRA:

- Awaiting extended forecast time periods

GENERAL:

- EWP week off
- Awaiting VORTEX-II real-time events

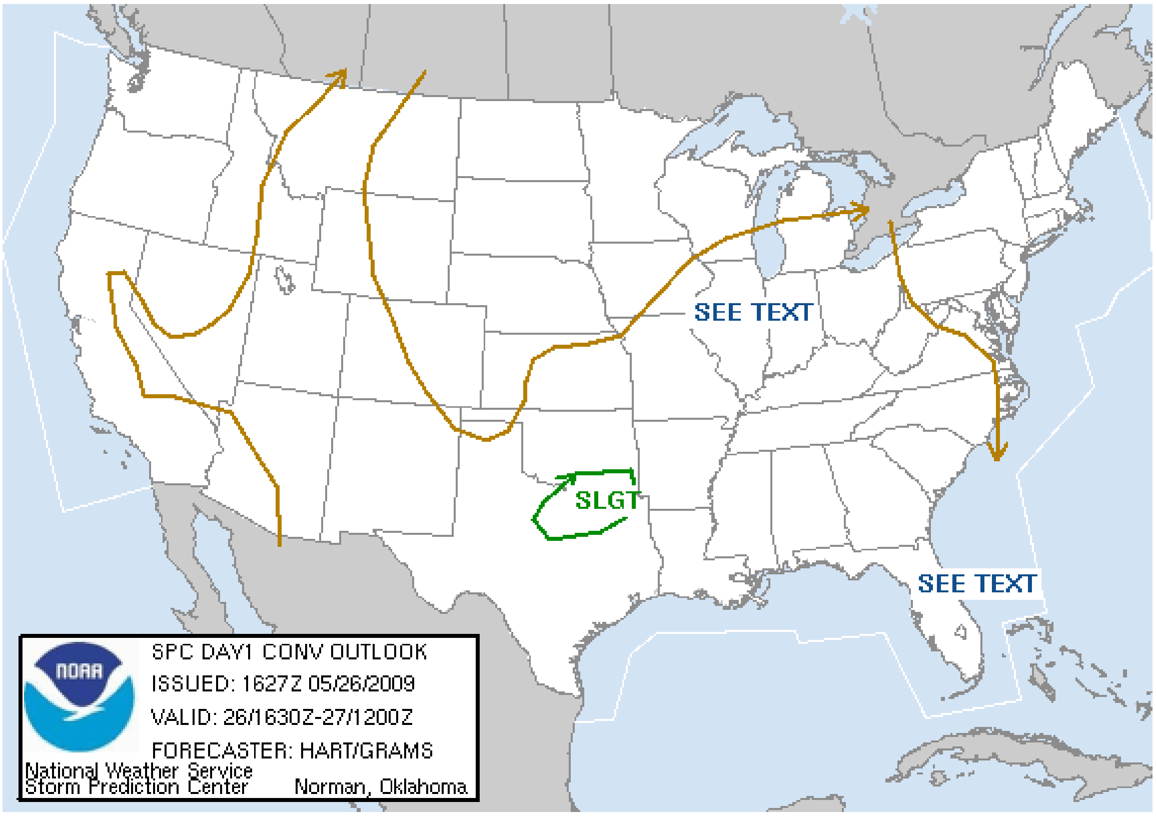

Figure A1: Convective outlook for 26 May 2009.

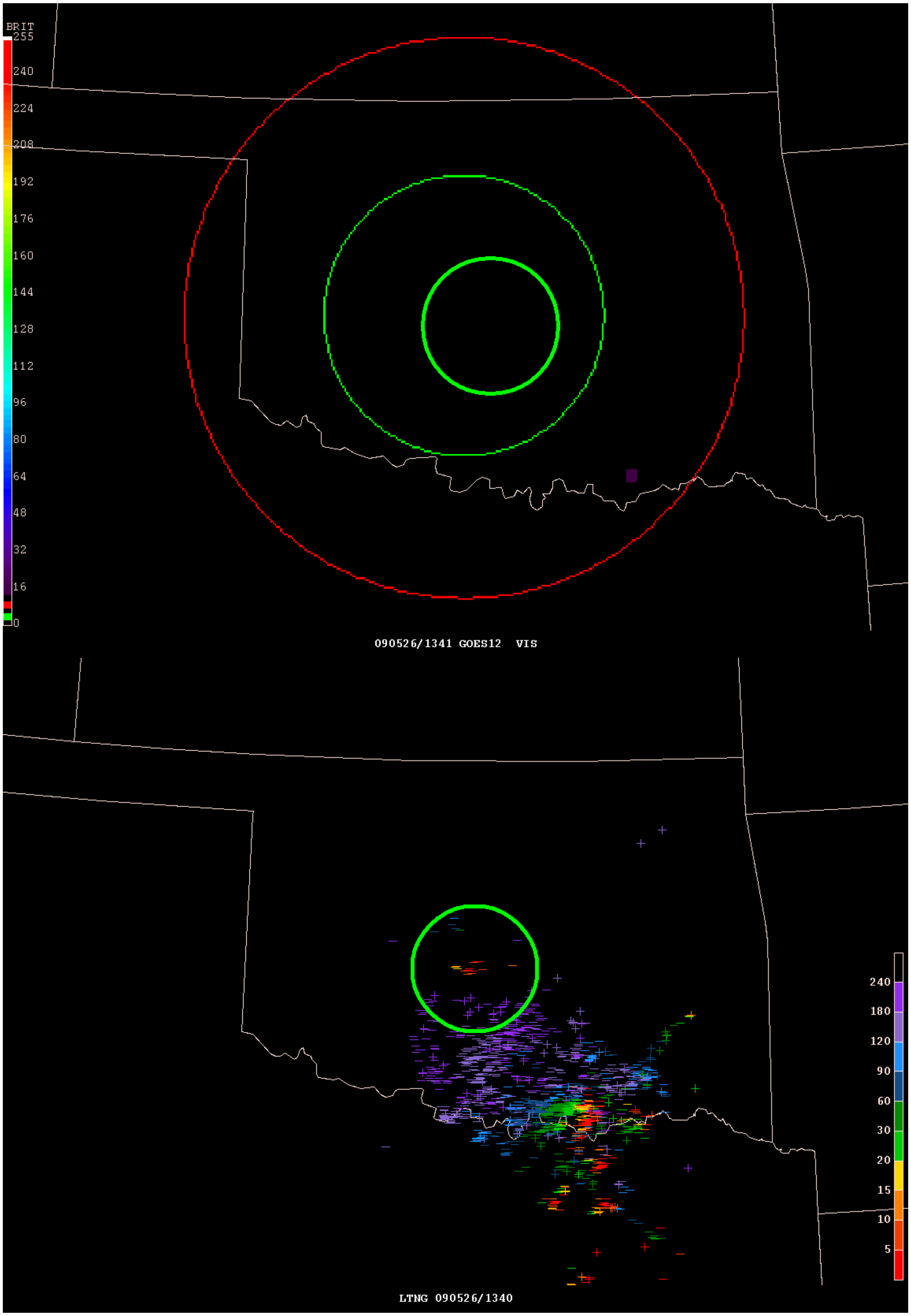

Figure A2: 10-km LMA image (top) and NLDN flashes (bottom) for 1340 UTC.

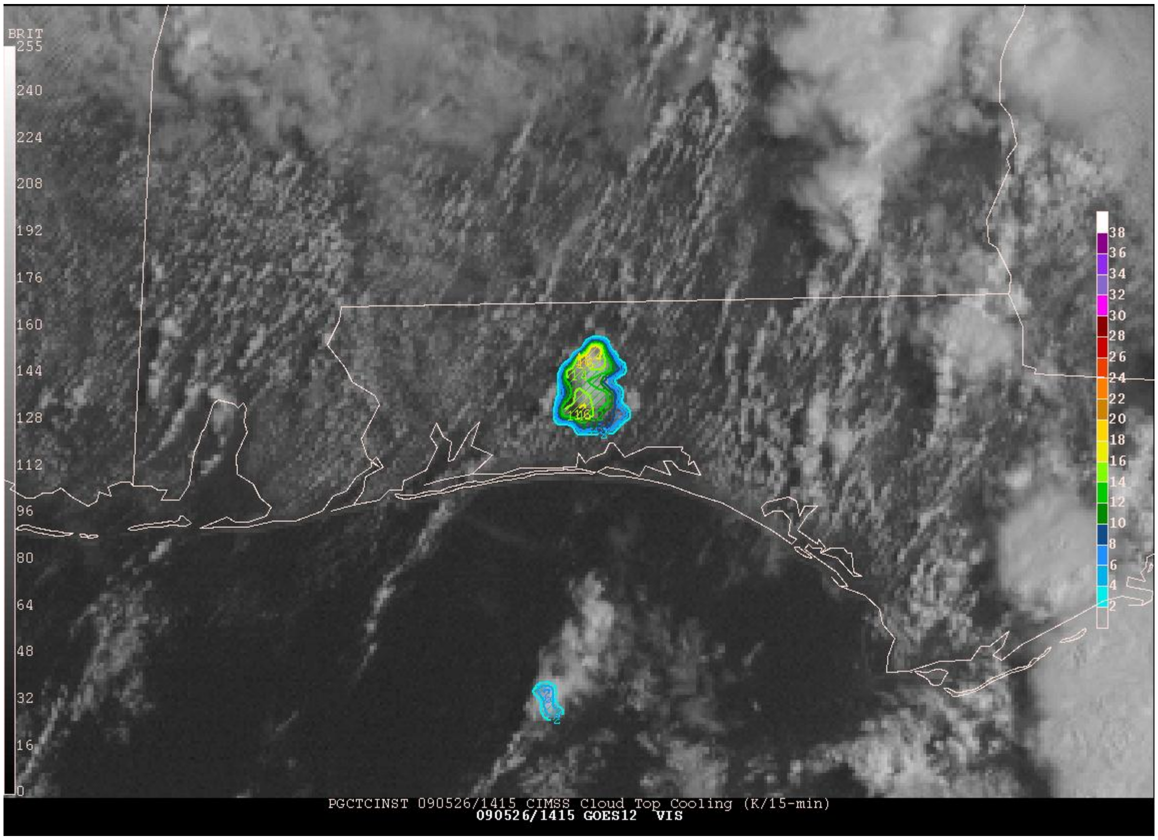

Figure A3: Instantaneous CTC overlayed on visible imagery for 1415 UTC on 26 May 2009. The new stippled display allows for partial viewing of the image underneath.

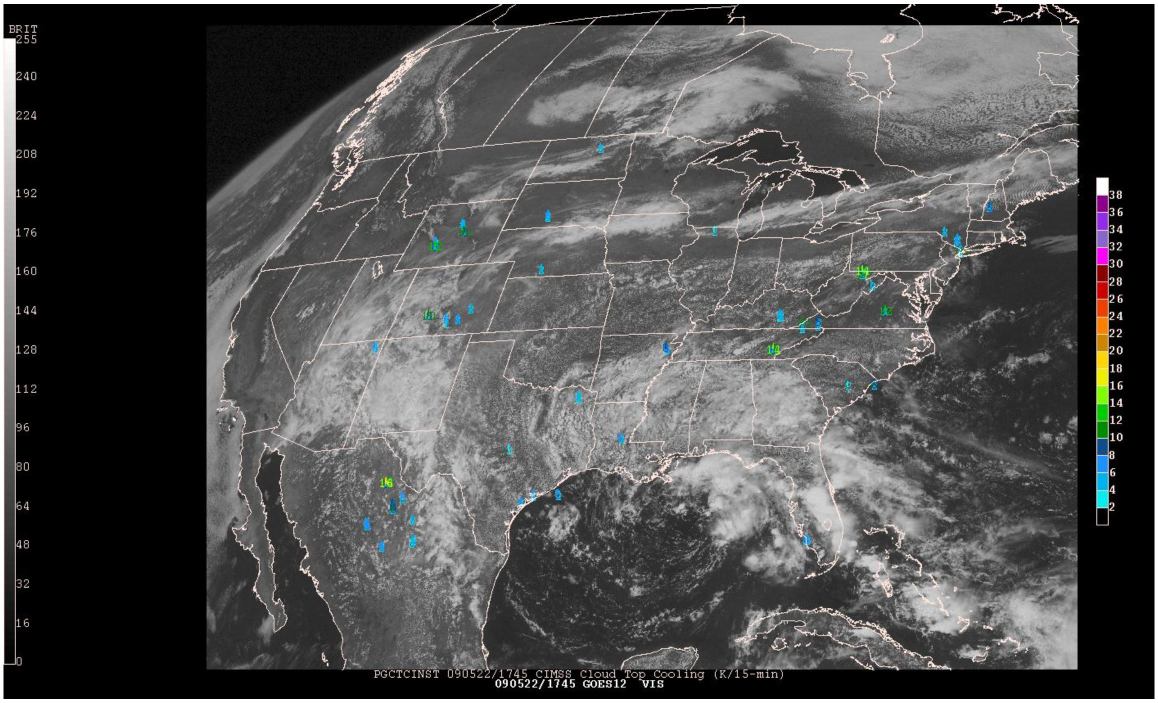

Figure A4: Instantaneous CTC overlayed on visible imagery for 1745 UTC on 22 May 2009. Areas of CTC are now more apparent when zoomed out. Note that most, if not all, signals seen during this time period were false alarms.

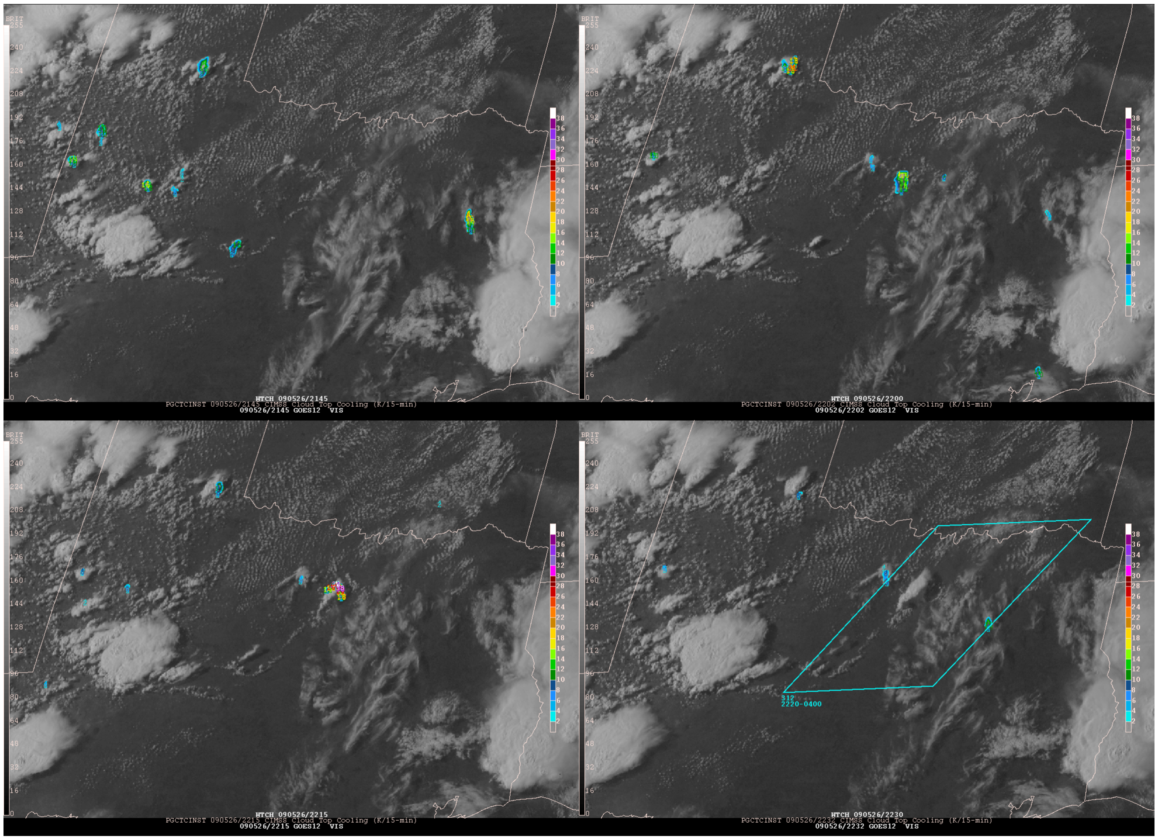

Figure A5: Instantaneous CTC overlayed on visible imagery and watches for 2145, 2202, 2215 and 2232 UTC on 26 May 2009.

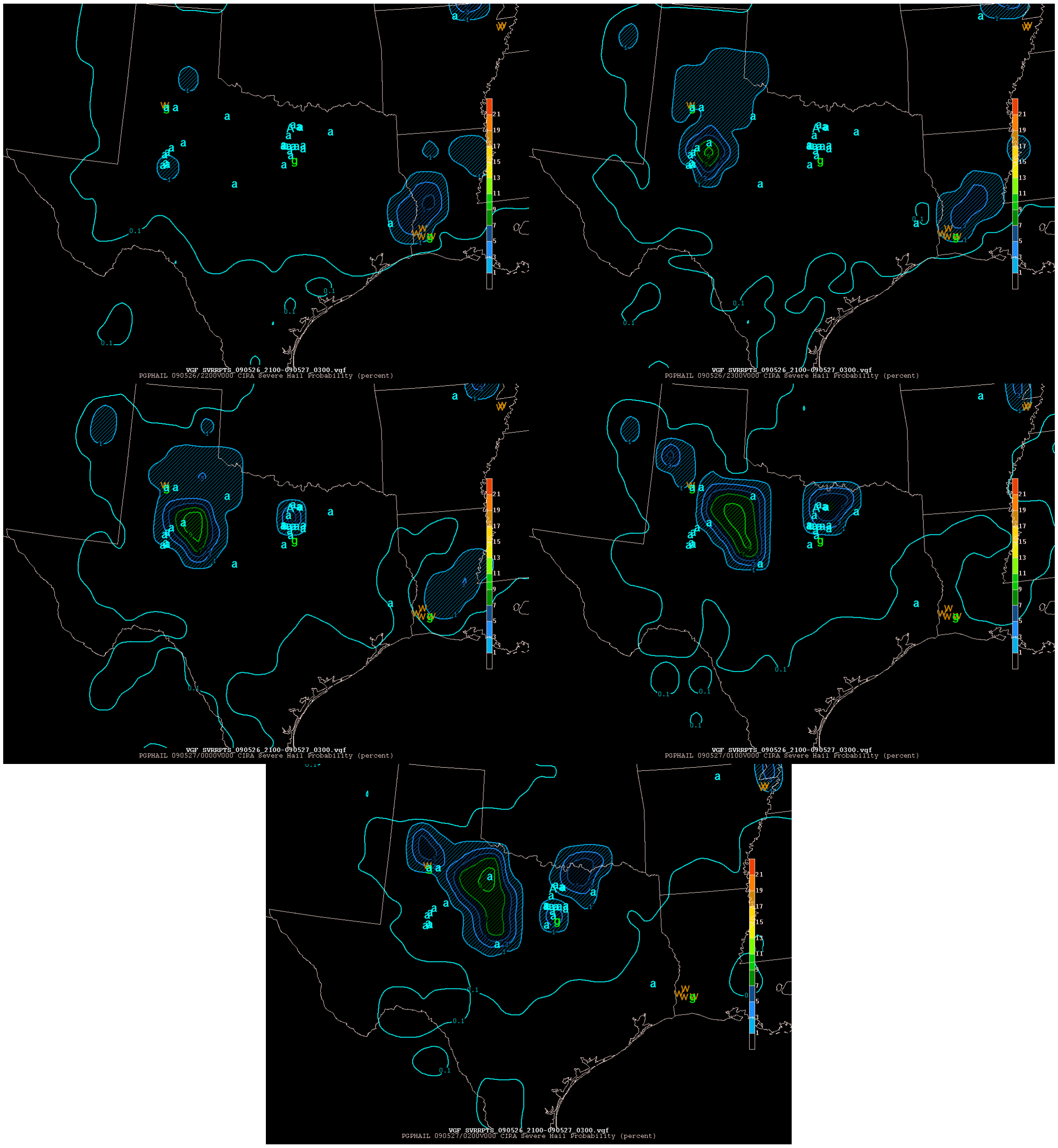

Figure A6: 0-1 hour probability of severe hail and severe storm reports for the time period of 2200 to 0300 UTC on 26-27 May 2009.

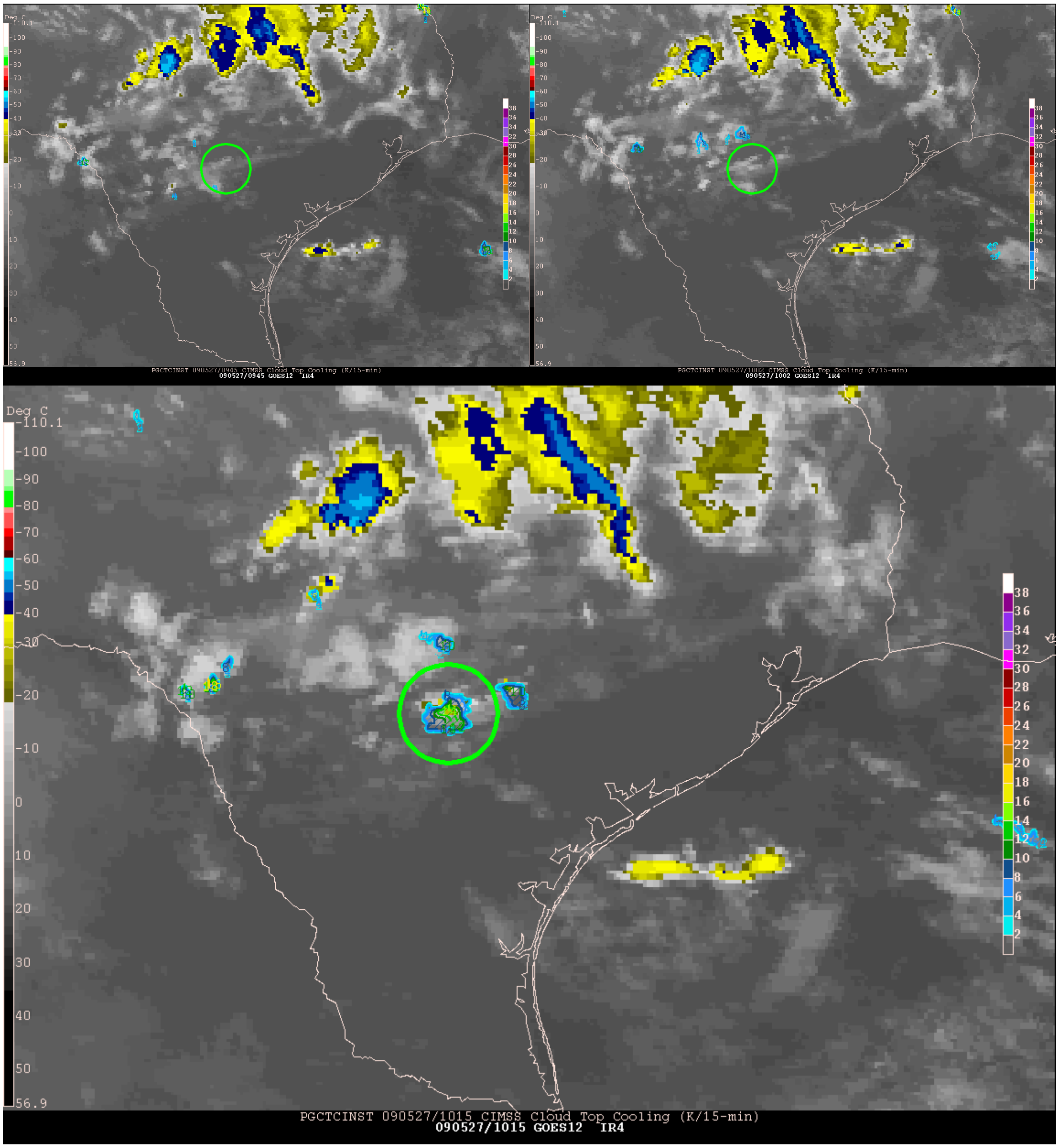

Figure A7: Instantaneous CTC overlayed on IR imagery for 0945, 1002 and 1045 UTC on 27 May 2009.

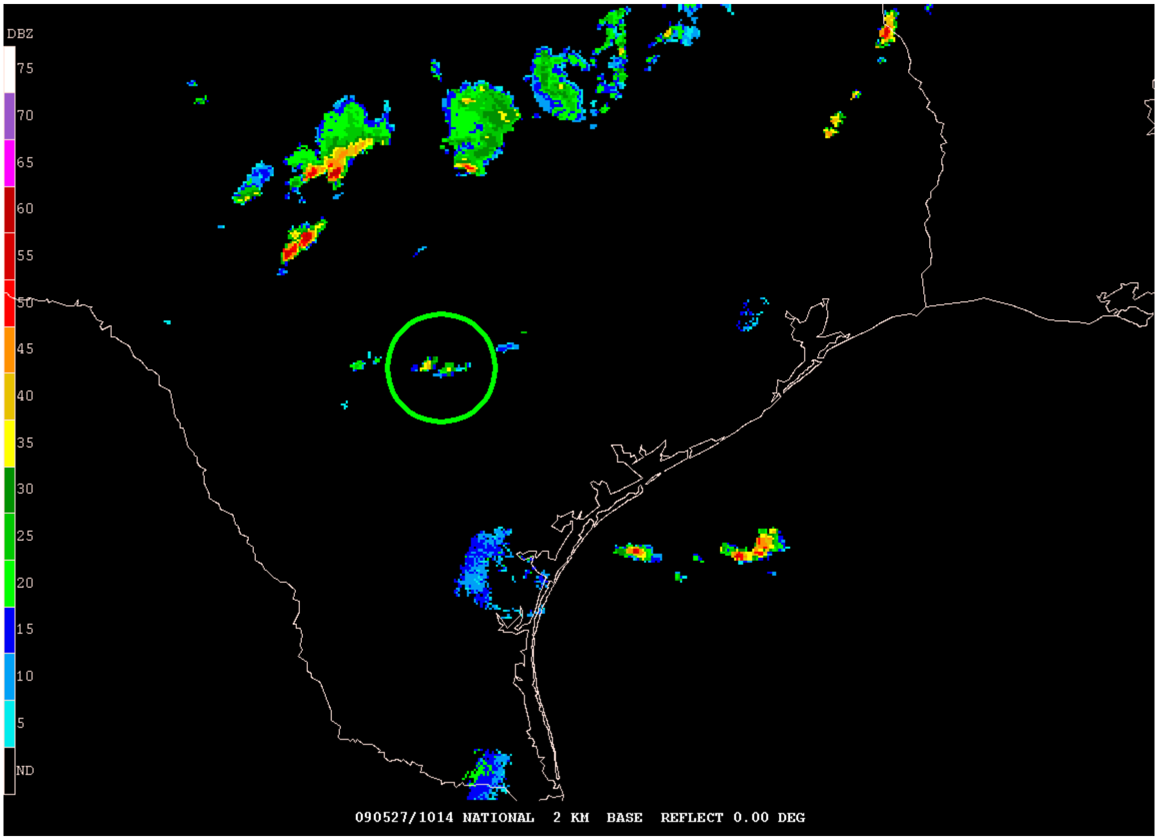

Figure A8: Radar reflectivity for 1014 UTC on 27 May 2009.