Aviation Weather Testbed – Final Evaluation

Project Title: 2016 GOES-R/JPSS Demonstration

Organization: NOAA's Aviation Weather Testbed (AWT)

Evaluator(s): Aviation Weather Center (AWC) forecasters, Central Weather Service Unit (CWSU) forecasters, and Air Traffic Control Systems Command Center (ATCSCC) National Aviation Meteorologists (NAMs)

Duration of Evaluation: 6 January 2016 – 30 September 2016

Prepared By: Amanda Terborg (UW/CIMSS and NOAA/AWC)

Final Submitted Date: 28 October 2016

Table of Contents

1. Summary

The 2016 demonstration at the Aviation Weather Center (AWC) in Kansas City, MO, took place from 6 January – 30 September 2016, it's purpose two-fold: (1) it provided a pre-operational environment in which to test and evaluate new GOES-R/JPSS proxy products, and (2) it also aided in familiarizing forecasters with the capabilities of our next generation GOES/JPSS satellite series. Following the structure of the last several years, the 2016 evaluation was again divided into two long-term evaluations. Additionally, two two-week long intensive experiments were also include; one Winter Experiment in February of 2016 and one Summer Experiment in August of 2016. Details of these periods and experiments can be found in Table 1 below.

Table 1. AWC 2016 demonstration schedule and descriptions

Evaluation Period	Description
6 January – 30 April Evaluation Period I	*Focus* - winter/early spring aviation hazards (icing, cloud and vis, etc.) and also early season convection *Training* – one-on-one training on the forecast floor
8 - 12 February 22 – 26 February Winter Experiment	*Focus* – cloud and visibility with GFE, with a secondary focus on icing and turbulence non-convective Collaborative Aviation Weather Statements (CAWS); graphic forecasts for global regions *Training* – real-time training and demonstration with internal (week 1) and external (week 2) participants
15 May – 1 September Evaluation Period II	*Focus* – summer aviation hazards, especially convection. *Training* – one-on-one training on the forecast floor and also at the Air Traffic Control Systems Command Center (ATCSCC) in Warrenton, VA, with the National Aviation Meteorologists (NAMs)
14 – 26 August Summer Experiment	*Focus* – cloud and visibility with GFE, with a secondary focus on convection; the Hazard Services tool for Convective SIGMET and the Collaborative Aviation Weather Statement (CAWS) *Training* – real-time training and demonstration with participants

Participation throughout the two long-term evaluations included only AWC forecasters, while the two experiment periods consisted of a wide variety of external participants from the Central Weather Service Units (CWSUs), Weather Forecast Offices (WFOs), the Alaska Aviation Weather Unit (AAWU), Hawaii Forecast Office, the Federal Aviation Administration (FAA) and other flight services companies including FedEx and the United Parcel Service (UPS), and research scientists from the Air Force Weather Agency (AFWA), the GOES-R program, and various National Oceanic and Atmospheric Administration (NOAA) laboratories. The following report details the activities and results of the entirety of the 2016 GOES-R/JPSS demonstration.

2. Introduction

Past experiments within the AWT have focused on the operation setup of the Aviation Weather Center. New concepts were explored for the current desks and issuance of products in the legacy N-AWIPS systems common to the National Centers for Environmental Prediction. The 2016 demonstration; however, took place amidst the beginnings of a paradigm shift. With the transition to AWIPS-2 on the horizon, or at least closer than in previous years, there has been much debate over the future of the system in AWC operations. As a National Center with complex and global forecast responsibilities, there are many challenges to consider in this transition. The goal of the AWT this year was to begin addressing these challenges and explore innovative solutions that will provide a viable route forward while also maintaining and improving the integrity of the AWC mission.

In 2016, the notable focus points were these: 1) the Digital Aviation Services effort utilizing the Global Forecast Editor (GFE) on the Advanced Weather Interactive Weather Processing System (AWIPS-2) for the creation of cloud visibility grids as a replacement for the current text Area Forecasts (FAs), 2) the exploration of Hazard Services as a production platform for Convective SIGMET issuance in AWIPS-2 D2D, 3) the continued evolution of the Collaborative Aviation Weather Statement (CAWS), and 4) the exploration of graphical based forecasts for the Tropical desk, also as a replacement for the current text FAs.

The Digital Aviation Services effort is perhaps the most significant push within the AWC. Midway through 2015, the FAA issued and official document stating the retirement of the text FAs and it is this that led to the exploration of alternatives for both the domestic and tropical FAs. The domestic FA desks already issue graphical based forecasts via the GAIRMETS. However, the retirement of the text piece has provided an opportunity to explore ways in which to improve the graphical forecasts, specifically in cloud and visibility forecasts and Terminal Aerodrome Forecast (TAF) writing. Both the Winter and Summer Experiments explored this digital aviation product concept in detail through the creation of aviation cloud and visibility grids using the GFE tools in the AWIPS-2 system (Fig. 1). These grids were then disseminated to WFO forecasters in the Operations Proving Ground (OPG) to be refined based on specific regional and local knowledge of climate and weather patterns, and also used as an automated tool in the generation of the TAFs, thereby producing a more consistent aviation forecast across the National Weather Service.

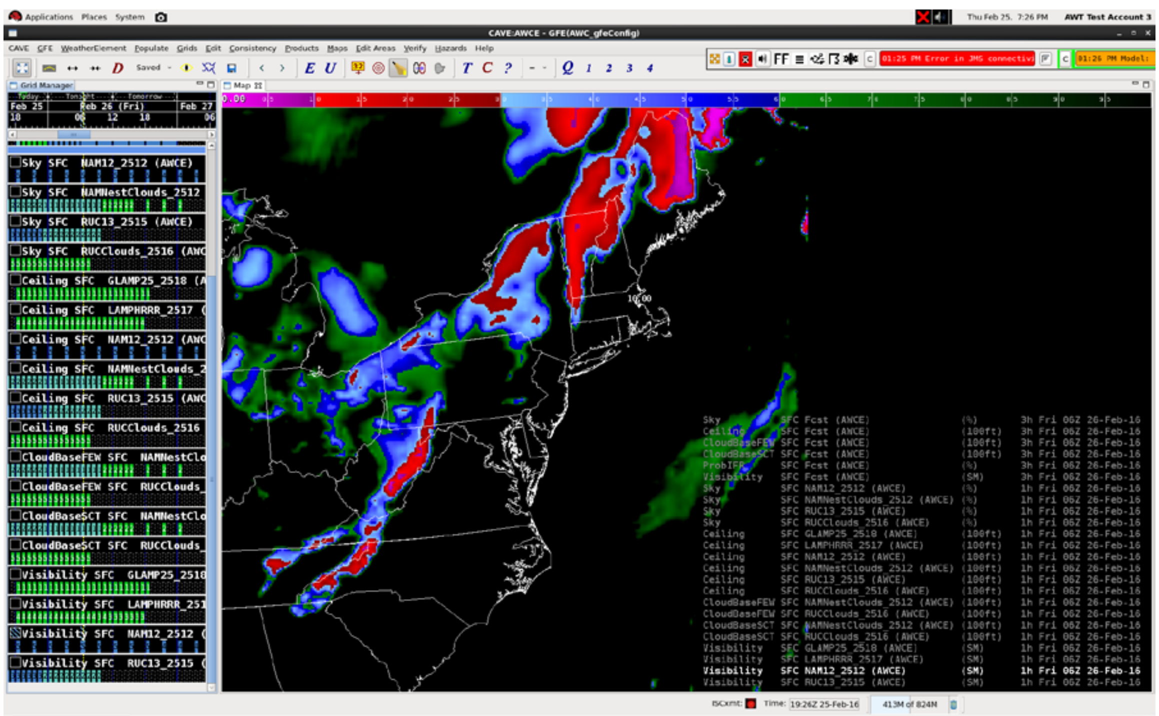

Figure 1. Sample C&V grid produced in AWIPS-2 GFE for the DAS effort in the AWT

While by in large these digital aviation grids stick to the realm of models and long-term forecasts, the potential for satellite data remains. Not only in using various satellite imagery and cloud based derived products, but also in the integration of this data into GFE. A generic satellite image in this product platform isn't of particular use. However, the potential of this functionality was well noted by many forecasters. Instead of simply flowing satellite imagery into the GFE system, forecasters suggested a smart tool concept, which would provide them a way to pull specific information out of the imagery that would aid them in the various C&V related grids. In a future where 16 channels of Advanced Baseline Imagery are available, along with a plethora of derived products, there is an enormous amount of potential here to be tapped.

Because of the different environment and needs, explorations into tropical desk alternatives for the text FA have taken a different route. Currently there are no graphical AIRMETs issued for the tropical regions. Additionally, the Tropical desk creates products based on international aviation standards. It therefore follows that a graphical-based alternative be explored, one similar in nature to the graphics produced for the other WAF desks. If adopted, this product would provide a 0, 6, 12, and 24-hour forecast of IFR, MVFR, surface winds, convection, turbulence, and convection (Fig. 2). For the 2016 demonstration, the concept of surface winds and wind shear was explored in more detail and some thought was put into the use of Derived Motion Winds for this effort.

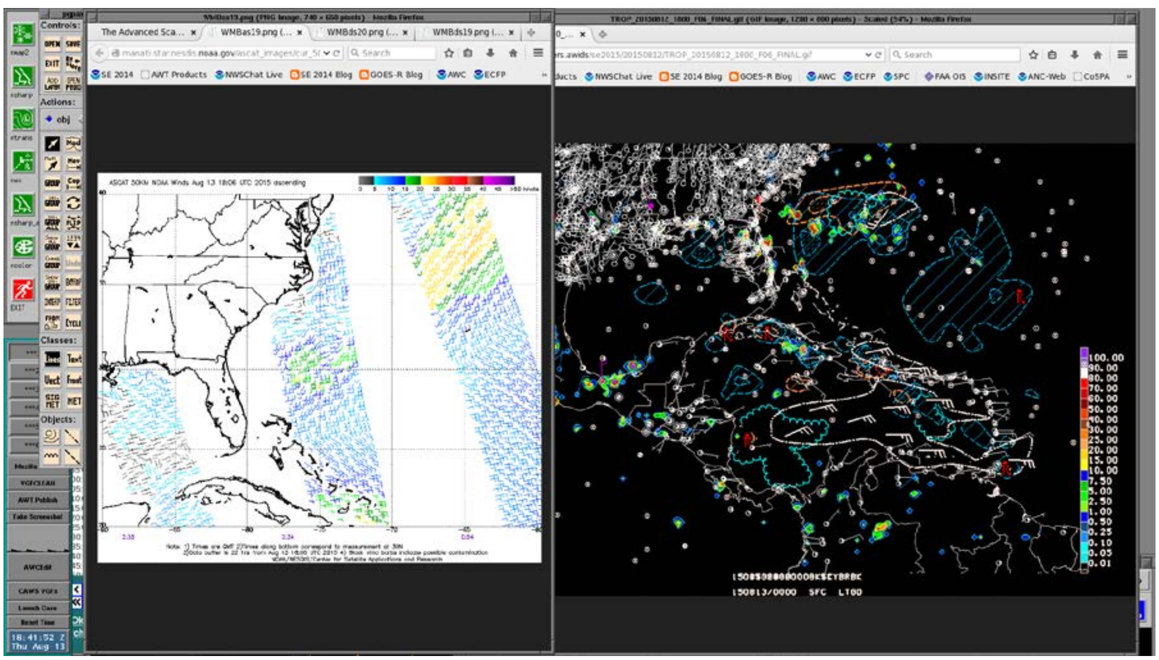

Figure 2. Example of the graphical alterative for surface winds in the tropical FA domain

Beyond the DAS focus, the AWT took advantage of some ‘low hanging fruit’ in the AWIPS transition and began exploring an alternate means for issuing Convective SIGMETs. As far as production platforms and the products themselves, CSIG is one of the least complicated. After much discussion, it was decided to utilize the Hazard Services platform for the construction and issuance of polygons (Fig. 3). This capability was introduced in the 2016 Summer Experiment. As this was the first foray into issuing products with AWIPS-2, it was a bit of a learning curve for forecasters and became an extended lesson in knobology. However, it also provided and opportunity to evaluate various legacy and next generation satellite products into AWIPS-2, collecting guidance for the future transition to AWIPS-2, specifically for a National Center’s perspective from D2D.

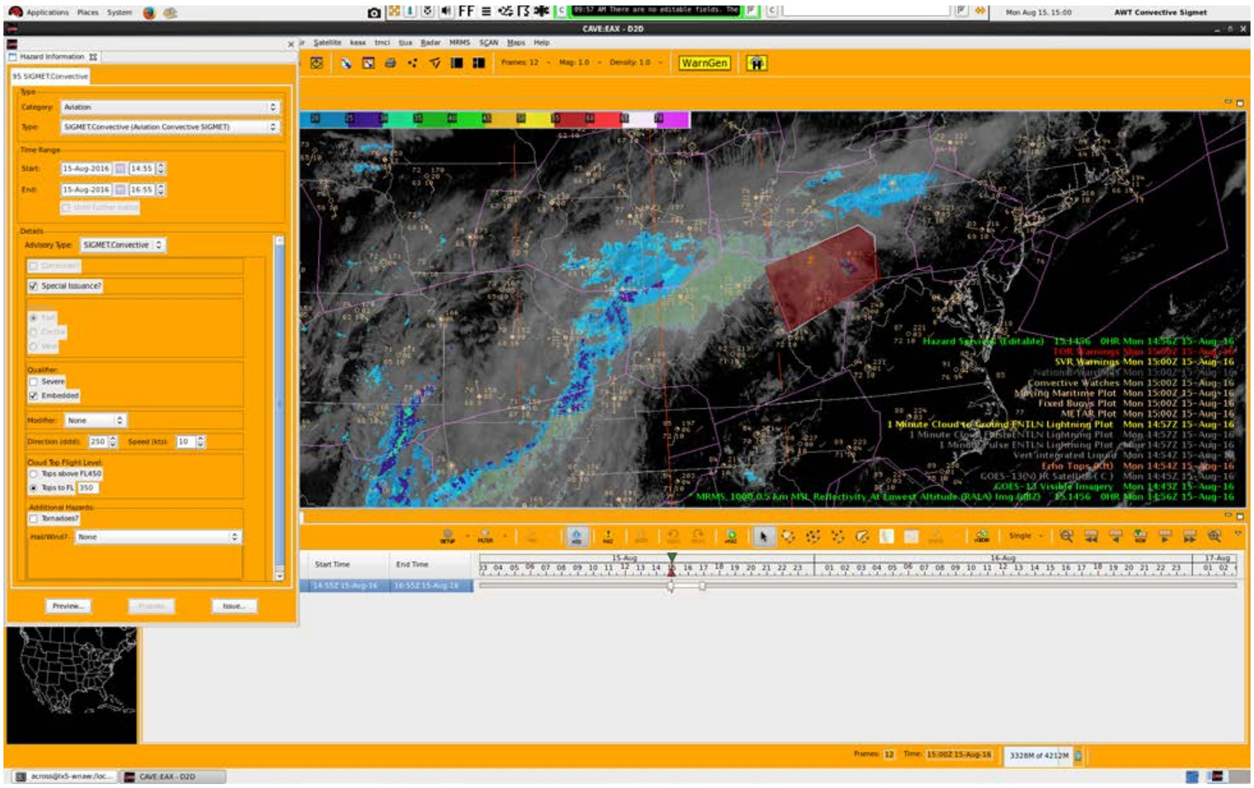

Figure 3. Sample Convective SIGMET issuance within the Hazard Services platform; overlaid with satellite and radar echo tops.

The final, and perhaps more minor concepts, was the continued evaluation of the CAWS desk. The CAWS concept is one that is continually evolving, subsequently making its requirements rather fluid. In the 2016 Winter Experiment the idea of a non-convective CAWS was explored; i.e. a CAWS for hazards like icing, turbulence, and winds. The Summer Experiment continued to focus on convection and continued efforts towards improvement. In particular, much comparison with the automated Collaborative Convective Forecast Product (CCFP) and the distinct differences between the two was examined. As the CAWS is still a relatively new product, a continued evaluation of the usefulness of various satellite products was completed.

Both evaluation periods and their subsequent two-week experiment periods contained much collaboration with outside entities. The DAS and C&V grid effort to place in full collaboration with both the Operations Proving Ground and also the Aviation Weather DEcision (AWDE) services testbed at the FAA's Tech Center in Atlantic City. All CAWS evaluations were also conducted parallel to AWDE. The OPG provided the WFO perspective, both in the end-to-end process of the C&V grid effort via DAS and also in their experience using the GFE editor in current operations. AWDE provided a user services perspective and their participants ranged from CWSU meteorologists to FAA Air Traffic Controllers (ATCs) and Air Traffic Mangers (Fig. 4). This collaboration provided a unique and very valuable opportunity for forecasters –WFO, CWSU, and AWC- to interact directly with their end users. Evaluation of Proving Ground projects was integrated into all of the AWT concepts and encompassed AWIPS-2 displays, and also some displays in the legacy N-AWIPS systems.

Figure 4. Summer Experiment participants in discussion at the CAWS desk in the AWT

3. GOES-R/JPSS Products Evaluated

A number of products were evaluated during the 2016 demonstration and are listed below in Table 2. These products were chosen based on AWC needs and applicability for the time of year. Providers were the University of Wisconsin's Cooperative Institute for Meteorological Satellite Studies (CIMSS), the Cooperative Institute for Research in the Atmosphere (CIRA), NASA Langley Research Center (NASA LaRC) and NASA's Short-term Prediction Research and Transition Center (SPoRT). Baseline products, those products that are implemented as part of the GOES-R initial continuity operational product set, and Future Capabilities products, those that offer new capabilities made possible by ABI, were utilized in the experiment.

Synthetic model-derived decision aids used to show the capabilities of baseline cloud and moisture imagery included the experimental HRRR/HRRR-x along with the simulated Advanced Baseline Imagery (ABI) from the GOES-R ground segment. Other baseline products included Satellite Derived Motion Winds, the Pseudo Geostationary Lightning Mapper (PGLM) and the ACHA Cloud Height Algorithms. Only one product, the Aircraft Flight Icing Threat, was evaluated as a Future Capability. Super Rapid Scan 1-minute imagery from GOES-14 was used to showcase the ABI 1-min rapid refresh mesoscale capability and available sector requests in the GOES-R era. Typically a 1-9 hour Nearcasting model is also included as the only Risk Reduction product; however, given the loss of the GOES-E sounder, the product was not evaluated this year.

One product from JPSS was also evaluated to a lesser extent. Ozone retrievals from AIRS, IASI, and NUCAPs were further explored when events arose.

Table 2. GOES-R/JPSS products evaluated within the 2015 Demonstration

GOES-R Demonstrated Product	Category
Aircraft Flight Icing Threat	Future Capability
ACHA Cloud Height Algorithms	Baseline
GOES-14 Super Rapid Scan imagery	Baseline
GLM Lightning Detection	Baseline
Satellite Derived Motion Winds (AMVs)	Baseline
Synthetic Cloud and Moisture imagery	Baseline
JPSS Demonstrated Products	**Category**
AIRS Ozone Retrievals	Baseline
Category Definitions: *Baseline Products* - GOES-R products providing the initial operational implementation *Future Capabilities Products* - New capability made possible by ABI *Risk Reduction* – Research initiatives to develop new or enhanced GOES-R applications and explore possibilities for improving current products	

3.1 Aircraft Flight Icing Threat – University of Wisconsin Cooperative Institute of Meteorological Satellite Studies (UW-CIMSS) and NASA's Langley Research Center (LaRC)

The Flight Icing Threat (FIT) integrates various cloud properties from the GOES-R baseline DCOMP algorithm to generate a probability and intensity of icing conditions. It is composed of three components including (1) an icing mask available day and night which discriminates regions of possible icing, (2) an icing probability, estimated during the daytime only, and (3) a two-category intensity index which is also derived during the daytime only. While it is difficult to validate a product such as this given the lack of icing PIREPs and other methods of ice measurement, it has been shown to have skill in identifying areas of more significant icing conditions.

Funding to continue work on this algorithm was received in late 2015. As such, it was evaluated during Evaluation Period I of the 2016 GOES-R/JPSS Demonstration, and underwent an in detail examination during the Winter Experiment. Prior to this, several improvements had already been made after the 2015 GOES-R/JPSS demonstration. These included the addition of a 'heavy' category to identify the more intense icing associated with supercooled large droplets and convection, as well as improved estimates of cloud vertical structure that enable the inference of icing conditions embedded beneath glaciated clouds. Additionally, this year's evaluation was expanded to include an AWIPS-2 version of the product, which was examined by forecasters in D2D.

In general, forecasters continue to note that the FIT has a lot of potential. It provides situational awareness not typically available for icing conditions, typically in areas that don't see a lot of in situ icing reports from aircraft. This is beneficial both to G-AIRMET and SIGMET issuances. The product was also found useful in the non-convective CAWS portion of the Winter Experiment. While a non-convective CAWS is not likely to be made an operationally issued product, the concept explored the need for a product that would fit in between a G-AIRMET and a SIGMET, similar to what is currently issued at the Alaskan Aviation Weather Unit. This 'in-between' product would identify icing areas not as broad as the forecasted moderate or greater conditions in a G-AIRMET, but less specific than the severe conditions within a SIGMET or 'warning' product (Figure 5).

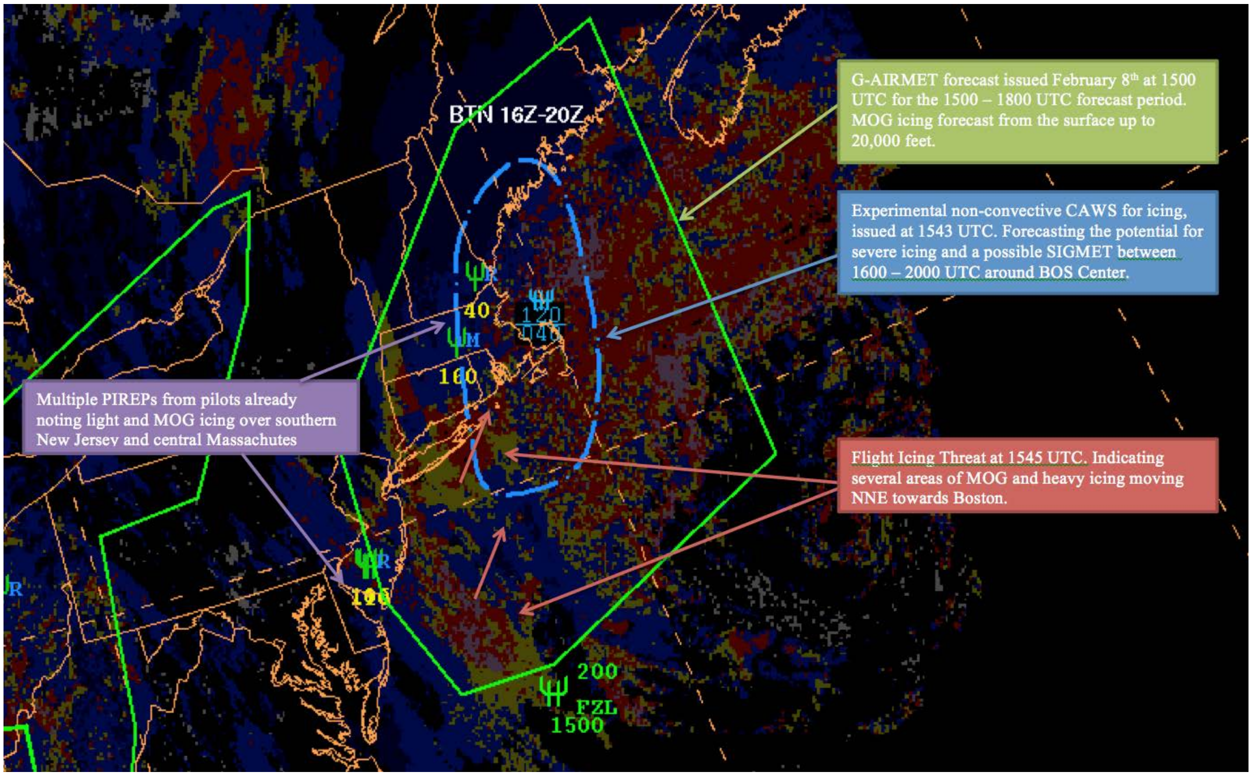

Figure 5. February 8th 1545 Flight Icing Threat intensities with the G-AIRMET and experimentally issued non-convective CAWS for icing at 1543 UTC. The CAWS is smaller than the G-AIRMET area, identifying potential areas that may require a SIGMET later in the day.

The FIT was found to be particularly useful in exploring this concept as seen in Figure 5. Its ability to discern icing intensities (during the day only) within the clouds helped to narrow down smaller areas in which a non-convective CAWS may need to be issued. In some cases of widespread clouds of multiple layers, the FIT product is more uncertain and it became somewhat difficult to determine which particular areas to really key in on. While this 'messiness' depicted the inherent nature of multi-layer clouds, forecasters mentioned that it might be helpful to apply some sort of smoothing technique in some cases as N-AWIPS does not current support this capability. AWIPS-2 D2D, however, does provide the ability to interpolate, and forecasters were able to utilize this if they chose.

While the algorithm did show continued improvement over the past few years, there were still a few caveats forecasters noted. Firstly, intensities were overestimated in the terminator region. Low sun angles and the shift from day to nighttime retrievals were the culprits behind this issue. Eclipse periods were also somewhat problematic. With the stray light during these periods, there was a significant erroneous increase in intensities. This occurred at relatively the same time each day and so was easy become accustomed to. Additionally, there were some cases in which undetected thin cirrus clouds overlapping liquid clouds were interpreted as SLD causing an overestimation of the icing threat. Lastly, thin cirrus over snow covered ground also caused overestimation at times. All of these caveats –terminator regions, eclipse periods, and cirrus cloud contamination- were significant, but with a good understanding of the cloud environment, not particularly difficult for forecasters to become accustomed to and subsequently keep in mind when issuing icing forecasts.

Beyond the non-convective CAWS, there were a number of CWSUs who noted the potential benefit of the product in their operations. CWSUs advise the traffic flow managers within their air space of various weather hazards that may impact air traffic. Icing is not typically one of the highest priority issues to forecast for in their daily duties, however it was suggested that the FIT would become useful in and around a major terminal, particularly the top and base of the icing layer. Icing is commonly seen in the ascent or descent phase of flight as a layer of clouds conducive to icing settles over a particular hub. Identifying the extent of the icing layer within these clouds as well as the estimated intensity of icing with the FIT would provide valuable situational awareness. There were several cases were the FIT showed high skill in identifying smaller scale areas of icing around terminals that would have provided this situational awareness, one of which is shown below in Figure 6.

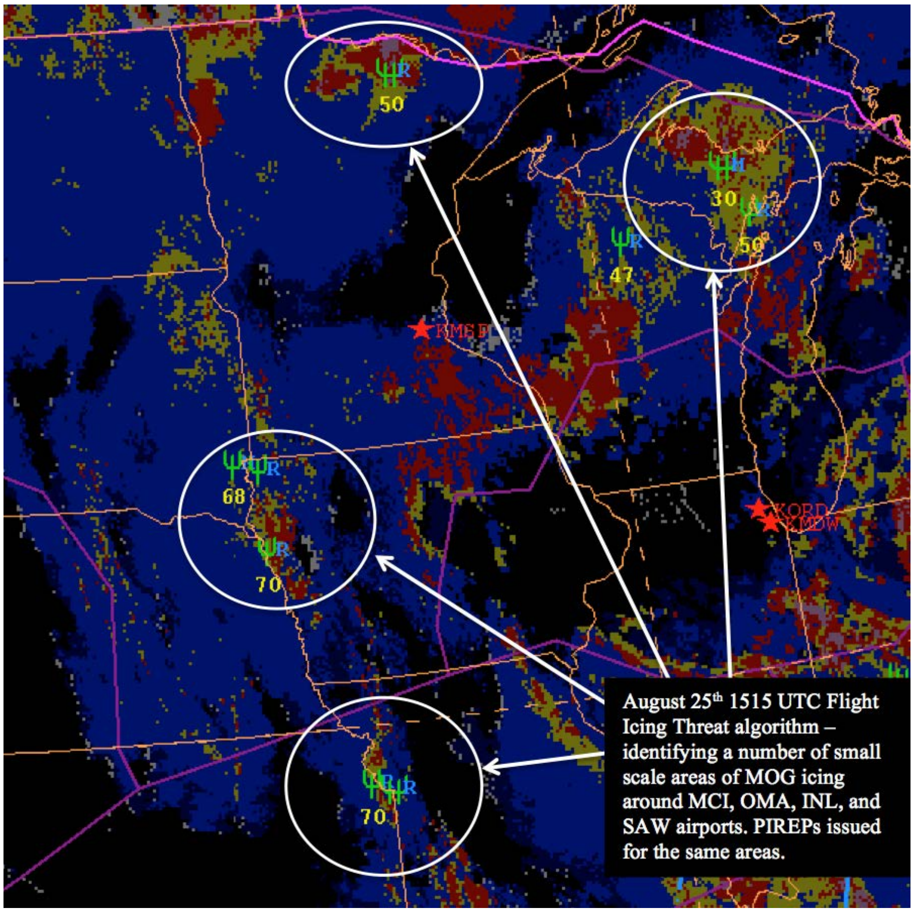

Figure 6. August 25th, 1515 UTC Flight Icing Threat and PIREP reports. CWSU forecasters commented on the usefulness of having icing forecasts around major terminals for situational awarness. The FIT showed high skill in identifying small MOG areas around several terminals in this case.

Lastly, a number of AWC international branch forecasters noted the potential of the FIT algorithm in the verification of global icing products included in the Significant Weather (SigWx) charts. As a proof of concept, LaRC provided global grids (made up of four geostationary satellites) of the FITs during the Winter Experiment, which were then compared to the icing forecast portion of the SigWx charts (Figure 7). There are, of course, caveats to consider in this effort, namely that the FIT may not be a completely accurate representation of icing conditions, particularly due to the specific conditions listed earlier. However, having any real time icing observations would be a vast improvement over current verification, which typically relies on quite heavily on PIREPs that can be sparsely spread over oceans and other flight sparse areas. Further evaluation of the global icing grids and their potential use for verification will continue in the future.

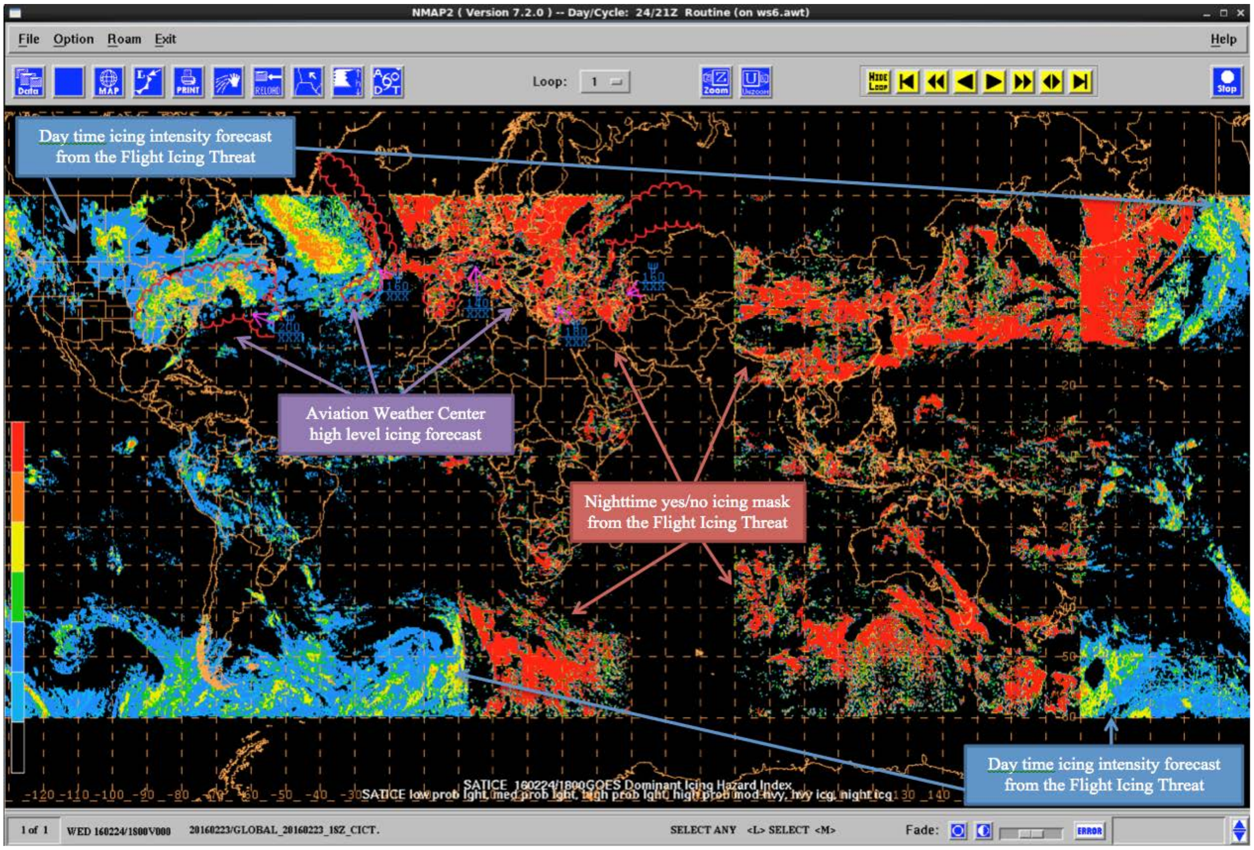

Figure 7. Significant Weather icing forecast valid on February 24th at 1800 UTC. Overlaid on the 1800 UTC global FIT grid.

3.2 ACHA Cloud Height Algorithms - University of Wisconsin Cooperative Institute of Meteorological Satellite Studies (UW-CIMSS)

The Algorithm Working Group's Cloud Height Algorithms (ACHA), including the Cloud Top Height, Cloud Top Temperature, and Cloud Emissivity products, were provided to the AWC in 2012. Cloud Top Heights saw the most use, and as a result of forecaster feedback over the past two years, a Cloud Top Altitude product was developed for the 2014 demonstration. This product provides cloud tops in feet instead of meters, as feet (or flight levels) are the common unit in aviation forecasting. Multiple concepts for this product were explored in the 2015 demonstration and continued evaluation was requested. Additionally, the need for more ceiling and visibility specific products was noted. From this came the Cloud Cover Layers and the Cloud Base Heights in the 2016 demonstration. The latter of these two was evaluated in both experiments, while the Cloud Cover Layers was evaluated in only the Summer Experiment. The domain of both of these was focused on the CONUS and both were available in N-AWIPS and AWIPS-2 D2D.

Estimating cloud bases is a challenging prospect given the lack of information in the satellite observations for some cloud types. How they are derived is therefore highly dependent upon the cloud type. The method is to first derive the cloud top height from ACHA and then to derive the geometrical thickness of the cloud layer. The cloud base height (CBH) is computed as the difference between the two. For cirrus and low-level water cloud, a direct estimation of the cloud geometrical thickness is possible from the satellite observations. For moderately thick clouds throughout the atmosphere, a set of regressions derived from CloudSat are used. Both the direct retrieval and CloudSat regressions use (1) the estimated cloud top, and (2) an estimated cloud layer thickness from cloud optical depth, cloud water path, etc., from GOES generated statistics. For the thickest clouds, the satellite observations provide little skill and the CCL Level from the NWP ancillary data is used to estimate the geometrical thickness. However, it is often the case that there are multiple layers of clouds which overlap. In these cases, the derived base is most indicative of that for the highest cloud layer. Treatment of these cases is being actively researched. The Cloud Base Heights were first evaluated in the 2016 Winter Experiment for the C&V effort. As mentioned in earlier sections, one of the major foci of the AWT experiments this year has been the Digital Aviation Services efforts and associated grid editing through GFE. The Winter Experiment was the first deep dive into this process and such was mainly an exercise in knobology. However, a cursory evaluation was done of the Cloud Base Height (hereafter referred to as CBH) product. The initial observation of this product by many forecasters was its high accuracy in single layer clouds. However, it did also have a marked struggled in areas multiple cloud layers (Figure 8). In those multiple layers, the bases were far too high, and it appeared the algorithm was estimating the base of the top most layer of clouds when compared to visible imagery.

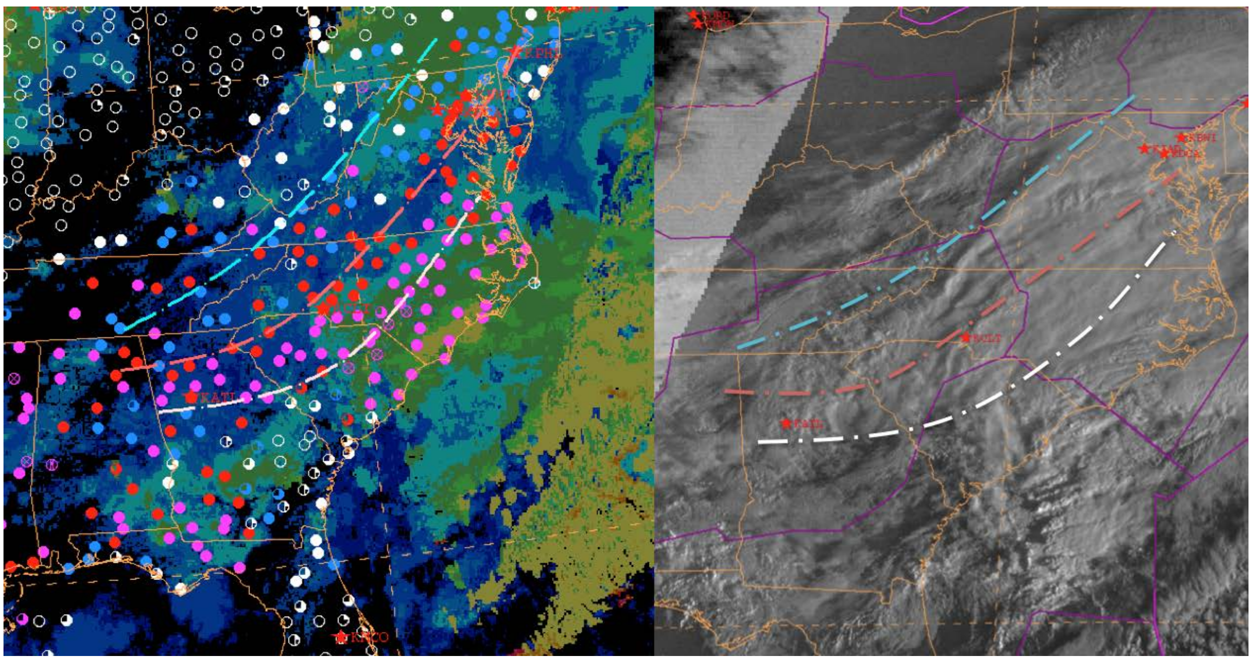

Figure 8. February 28th, 1255 UTC Cloud Base Heights (left) and visible imagery (right). Blue dashed lines indicates observed MVFR conditions, red IFR conditions and white LIFR conditions. Note that the varying cloud layers and the high cloud base heights, especially in the region of observed LIFR conditions. As noted, the CBH algorithm does struggle with areas of multiple and complex cloud layers.

Again, forecasters saw the potential of the ceiling heights in areas like San Francisco, which is frequently subject to stratiform cloud decks from the Pacific Ocean, but their use of the product tended to wane in more complex cloud situations. However, the 2016 Summer Experiment saw forecasters taking a second and much closer look. This was due in part to the transition of display systems. Due to the timing of product completion, the CBH product was only displayed in N-AWIPS for the Winter Experiment. The move to AWIPS-2 D2D and the increased capabilities of the system allowed much more flexible and expansive interrogation of the product in the C&V effort.

As in N-AWIPS, forecasters noted the struggle in areas of multiple layers of clouds. However, by overlaying the CBH on visible imagery, a more detailed examination of the cloud environment could be seen (Figure 9). Even with some continued inaccuracy of bases in multiple layers, the situational awareness in the initial stages of creating gridded forecasts was valuable. Several caveats, though, were noted with the product: 1) as the sun rose, the ceiling heights in areas of convection dropped significantly

(Figure 10), likely due to the transition from night to day cloud retrievals, and 2) fog and low stratus areas were not detected until several scans after the sun had risen (Also Figure 10). This was likely again due to the day/night retrieval transition and/or the low sun angles at that time of the morning.

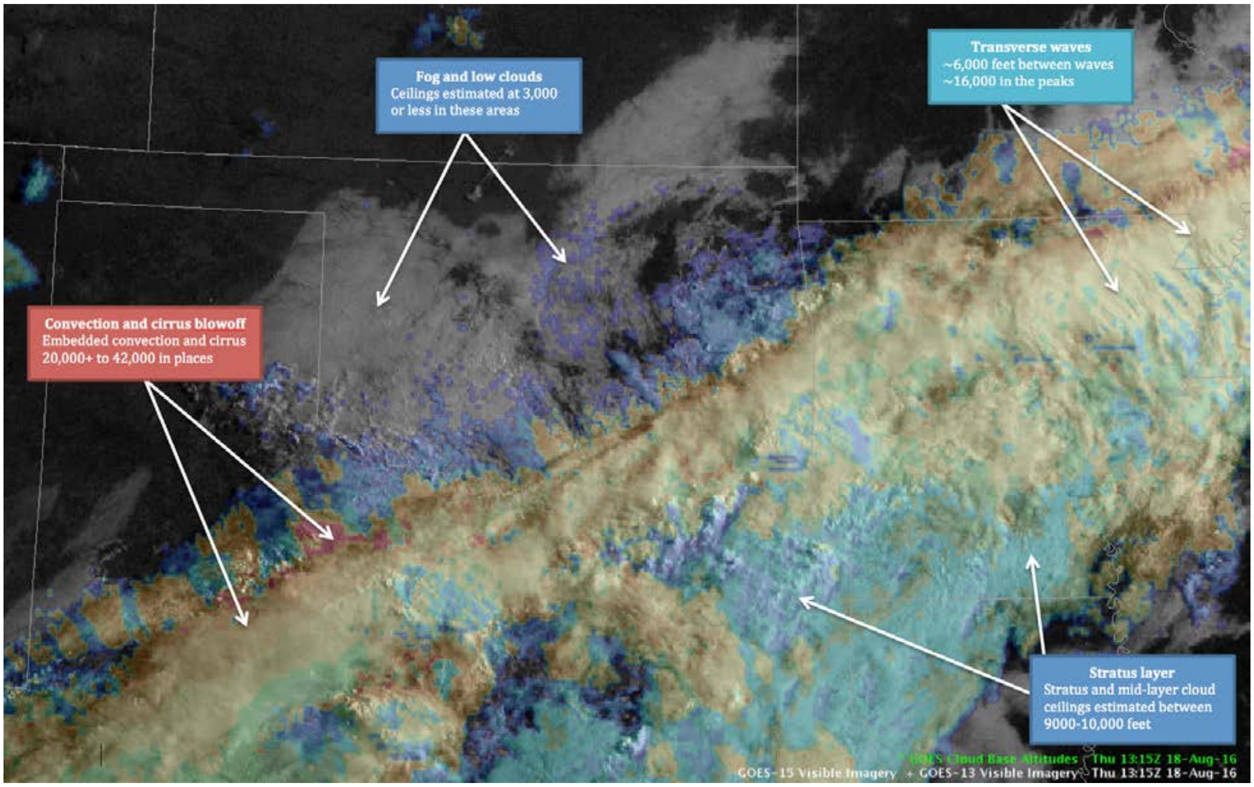

Figure 9. August 18th, 1315 UTC Cloud Base Heights overlaid on visible imagery. While the CBH still struggled with multiple cloud layers, particularly over Arkansas, the varying bases provided valuable situational awarenss of the complex cloud environment.

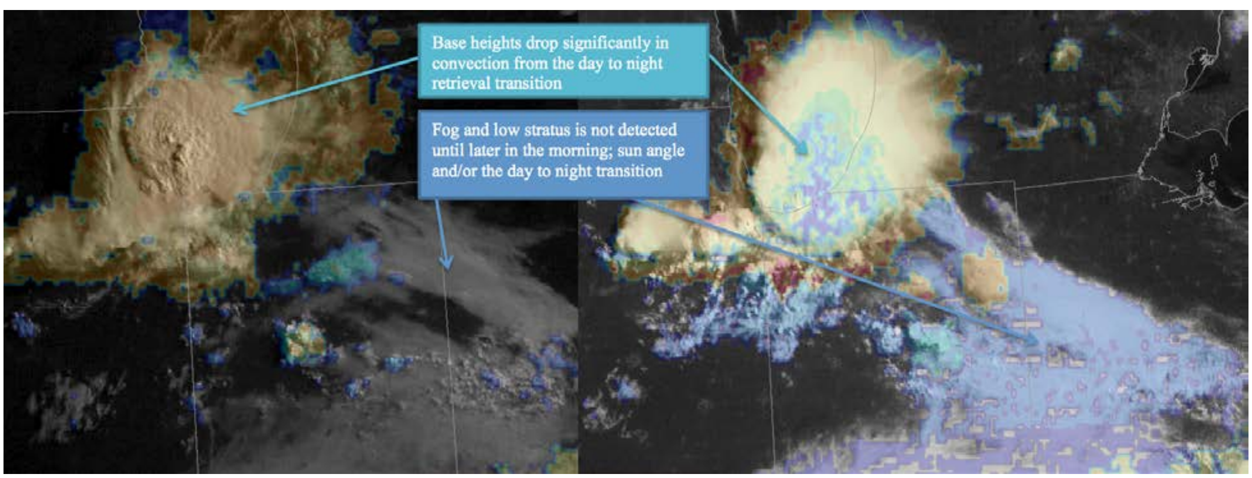

Figure 10. August 18th 1215 UTC (left) and 1400 UTC (right) Cloud Base Heights and visible imagery. Heights decreased significantly in the core of the convection, and fog and low stratus was not detected completely until later in the morning.

The Cloud Cover Layers product, an algorithm more simply defining cloud layers by pressure height (surface to 642 hPa, 643 to 350 hPa, and 350 hPa to the top of the atmosphere), was examined in much the same way, by overlaying on visible imagery for further situational awareness. Forecasters commented on multiple occasions that both of these products, as well as other generic satellite imagery, would be even more useful if accessible directly in GFE. The CBH, and visible and IR imagery, were integrated on a basic level (Figure 11).

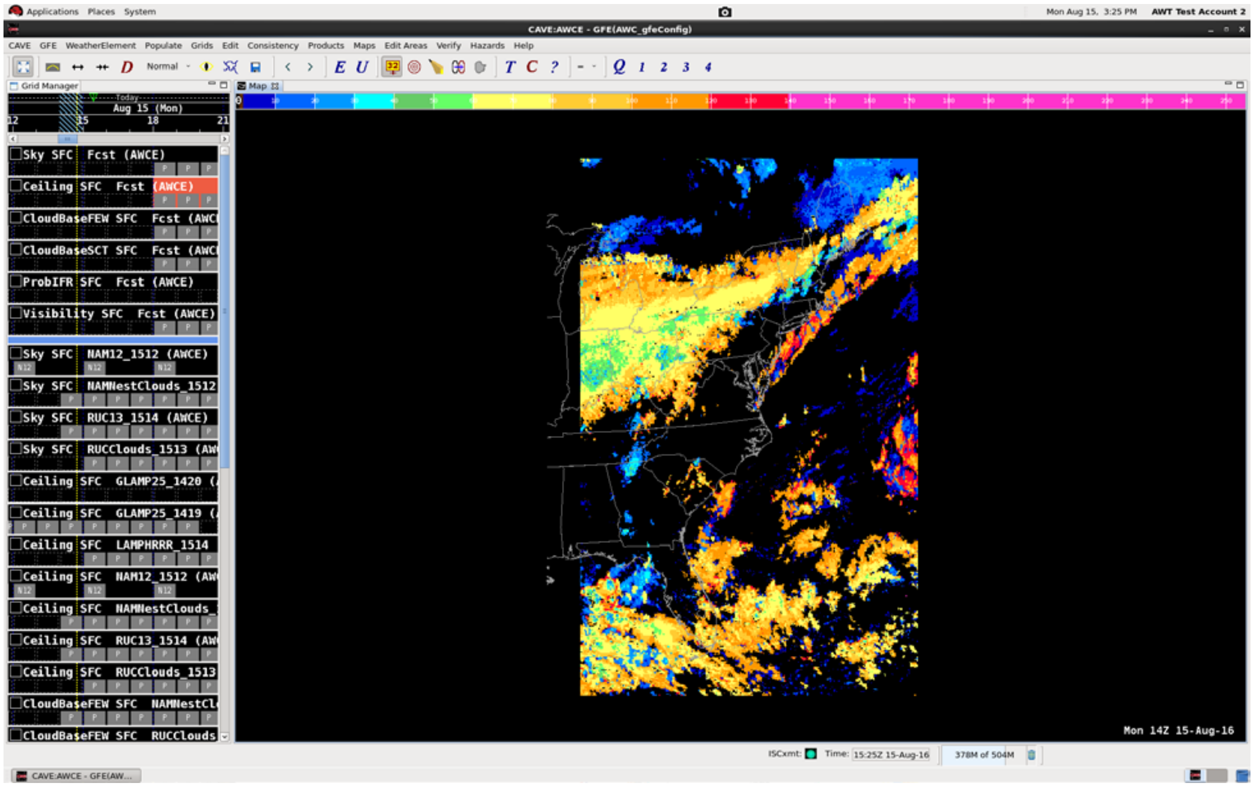

Figure 11. Cloud Base Heights displayed in GFE.

GFE is designed to house grids, display imagery in one-hour increments and pulling out specific parameters based on various preset configurations. The 2016 experiment featured only a simple display of satellite imagery by pulling it from D2D. Forecasters mentioned the importance of basing their grid editing process in reality, in conditions currently occurring. However, the simplistic display wasn't particularly useful to them. It would become valuable if configured to pull specific pieces of the satellite data and blend it with model data in the initial forecast hour. For example, a specific range of brightness temperatures from IR imagery, certain heights from the CBH, particular features in visible imagery, etc. This concept and further development of satellite data in GFE will occur in future long-term C&V evaluations.

3.3 GOES-R 14 Super Rapid Scan 1-minute Imagery - University of Wisconsin's Cooperative Institute for Meteorological Satellite Studies

Three periods of 1-minute Super Rapid Scan imagery (SRSOR) occurred during the 2016 demonstration, the first in February, the second in May, and the third in August. This data was made available in AWC operations via an LDM from CIRA and displayed in both N-AWIPS and AWIPS-2. The goal was to continue to explore the SRSOR and the usefulness of the higher temporal resolution in AWC operations. AWC forecasters made use of this data during all three periods, with more in detail evaluation completed during the first and third periods, as they ran concurrent to the Winter and Summer Experiments within the AWT.

During the Winter Experiment, 1-minute SRSOR imagery was found to be valuable in better highlighting areas of turbulence and more specifically identifying the cause. One such case of this occurred on

February 23rd. An approaching low from Canada set off a plethora of turbulence PIREPs throughout the Great Lakes region. Over northern Illinois and Indiana, and SW Michigan, the reports were identifying that turbulence as chop from clear air (CAT). This CAT quickly resulted in the issuance of a SIGMET for turbulence in the area (Figure 12).

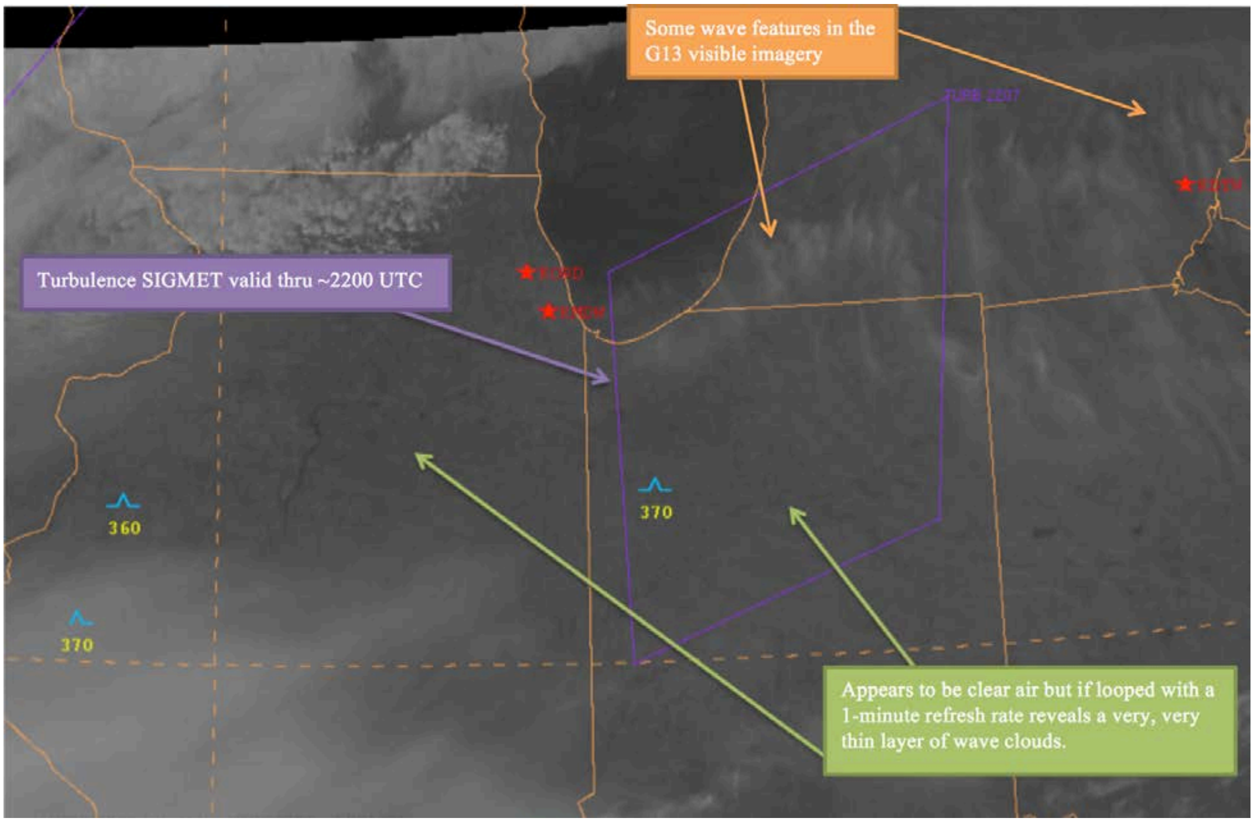

Figure 12. 1-minute imagery from the afternoon of August 23rd. When looped, the wave pattern over northern Indiana and Illinois becoms apparent, far more so than in current GOES-13 refresh rates.

GOES-13 visible imagery at the time appeared relatively clear and the ~7-minute rapid scan refresh showed some cloud features in SW Michigan but nothing over Illinois and Indiana that would suggest the cause of the reported turbulence. However, with the SRSOSR 1-minute rapid refresh rate, important cloud movements were revealed. What appeared to be clear air in the GOES-13 imagery was actually a series of waves visible in a very, very thin layer of clouds (Figure 12). Without the 1-minute refresh, these details were extremely difficult to discern.

1-minute imagery has also been continually useful in the issuance of CAWS forecasts. While a CAWS is typically issued as a roughly 4 hour forecast, the 1-minute imagery provides useful situational awareness on the progression of existing convection and initialization of developing convection. One example of this has been show over Chicago. For an existing area of convection a CAWS may be issued, not as a warning, but as a reaction. 1-minute SRSOR imagery can reveal important details of the convective environment such as how fast the convection is pushing east and subsequently when operators may be able to release grounded aircraft, and also whether or not the convection is beginning to dissipate and how long that will take (Figure 13).

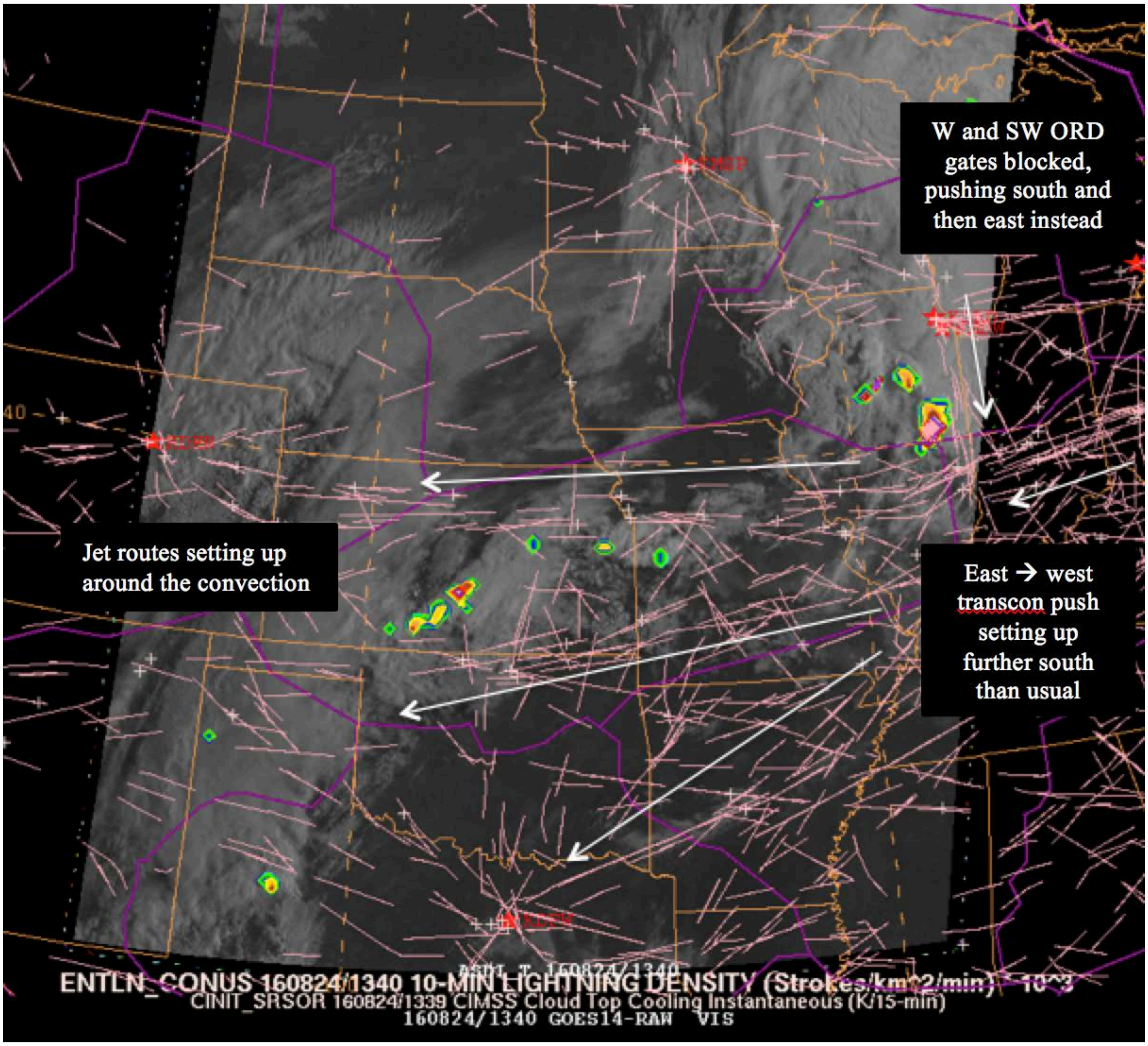

Figure 13. 20160823 1340 UTC SRSOR 1-minute imagery revealing features of existing convection in the Chicago and Kansas City ARTCC airspace and the reaction of air traffic flow.

AWC forecasters regularly utilize 1-minute imagery to issue CAWS statements on the operations floor, as well as Convective SIGMETs and other aviation forecasting products.

More information on SRSOR and can be found at http://cimss.ssec.wisc.edu/goes/srsor2015/GOES-14_SRSOR.html.

3.4 Lightning Detection

3.4.1 Pseudo Geostationary Lightning Mapper (PGLM) – NASA's Short Term Prediction Research and Transition Center

In an effort to create a proxy dataset to represent total lightning data from the Geostationary Lightning Mapper (GLM; Goodman et al. 2013), the Lightning Mapper Array (LMA) networks were utilized to create the pseudo-GLM (PGLM) product. The PGLM is generated from seven LMA networks: Northern Colorado, New Mexico Tech, West Texas, Oklahoma (central and southwest), Houston, TX, Northern

Alabama, and Washington DC. Before being translated into an AREA file and ingested into N-AWIPS, VHF data from these networks are sorted into flashes and the number of flashes are counted in each 8x8 km grid box. This creates the PGLM flash extent density and is given at a resolution to match the expected GOES-R GLM resolution. This is not an exact proxy for GLM data, but provides an excellent real-time product to investigate the use of total lightning and for training on total lightning and the GLM.

After feedback from the 2013 and 2014 experiments, a gridded version of the PGLM was provided to forecasters for evaluation in 2015 as an improvement over the McIDAS AREA file version. While the two versions are presenting the same flash density data, there are some subtle differences in the display (Fig. 14). The AREA file version of the PGLM is displayed as a series of 8x8 km grid boxes containing flash densities. However, the National Centers (NCEP) version of the Gempak software utilized at the AWC does not allow grids to be displayed in the raster format necessary to create the grid box feel. Instead it was necessary to adjust the gridded data to a filled contour. Additionally, the AREA file version utilized all 96 colors available with the N-AWIPS software. However, the conversion to grid only allowed the use of Gempak's ~36 colors. This resulted in a bottom heavy color scale, with more emphasis in the lower half of the flash densities.

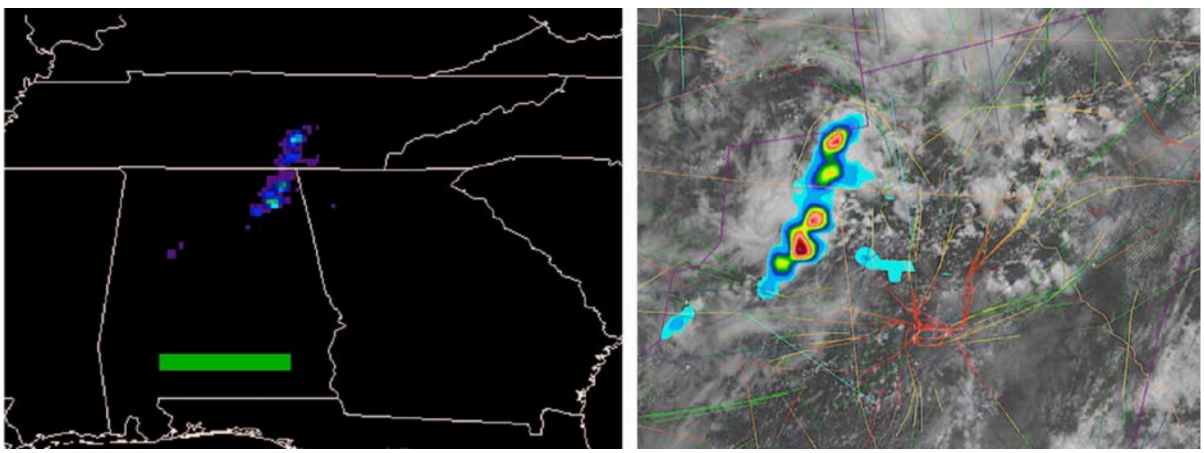

Figure 14. AREA file version (left) and gridded version (right) of the PGLM

After the 2015 Summer Experiment, the intention was to transition the new gridded version to the operations floor in place of the area version. However, with the future transition to AWIPS-2, it was decided that any new N-AWIPS product improvements should occur in parallel with the same product transition to AWIPS-2. As such, development began in the summer of 2016 to display the PGLM in D2D. As the PGLM is already a baselined product in later versions of AWIPS-2 D2D, this path was chosen for and evaluated in the 2016 Summer Experiment (Figure 15). While the AWC is not yet on AWIPS-2 on an operational basis, some do use the workstations out on the floor. Additionally, forecasters noted that the extra detail in D2D, such as the capability to sample flash counts, would be useful in issuing SIGMETs and also in monitoring CAWS areas.

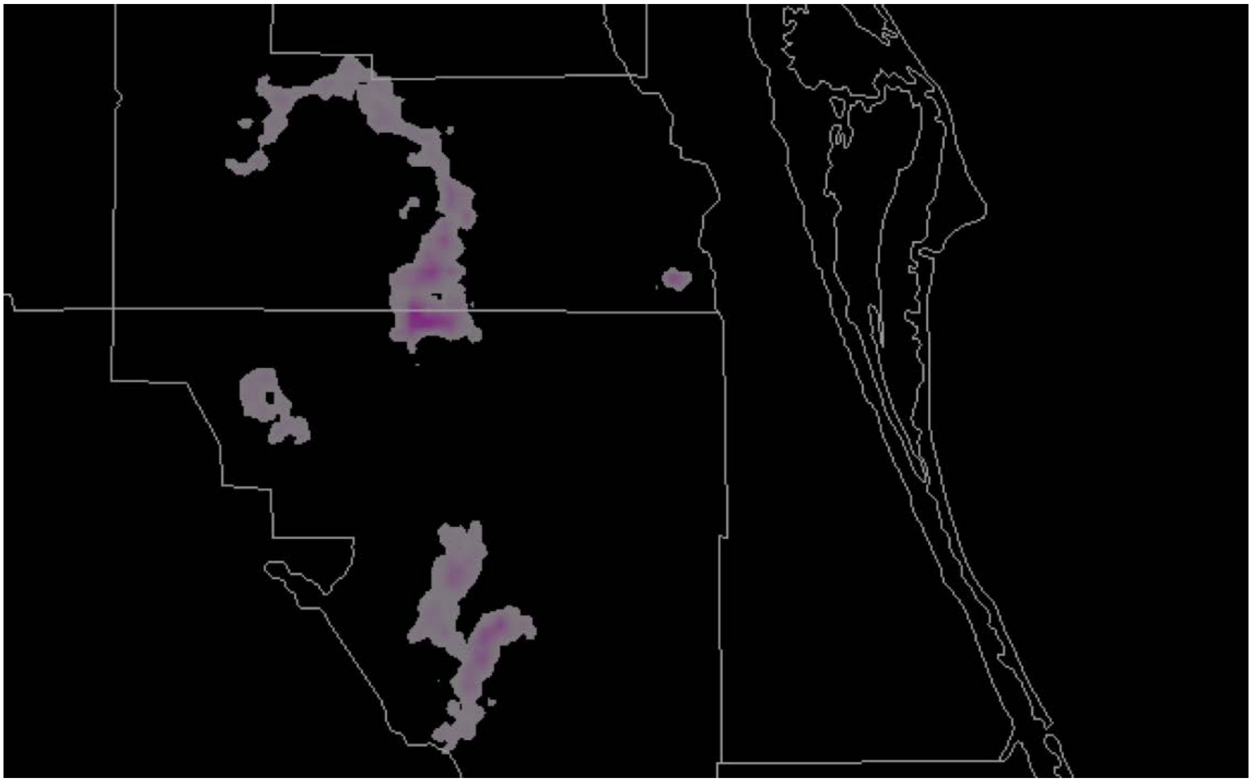

Figure 15. AWIPS-2 display of the PGLM data over the Central Florida LMA network

Evaluation, as in previous years, was limited to the LMA network domains. However, this year the addition of two new networks increased the coverage area. The first, in Toronto, will provide valuable detail in the high traffic corridor between the Northeast and Cleveland's ARTCC. This data has been quality tested and is available for display in AWIPS-2. The other new network of perhaps more value is Atlanta. This data is also available for display in D2D; however, because of the currently limited amount of sensors available to collect lightning information, caution was advised. For this reason, AWC forecasters have not yet evaluated this domain. In the future there is planned work for AWC CSIG forecasters to collaborate on a more formal evaluation of the Atlanta network along with the CWSU that is collocated with Atlanta Center.

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

Various forecast fields are collected from the 00 UTC run of both the NSSL-WRF and the NAM Nest, including pressure, temperature, water vapor, heights, canopy temperature, cloud water, cloud ice, snow, graupel, and rain, all of which are processed as inputs for a radiative transfer model. Synthetic radiances and brightness temperatures are generated through this model and displayed as simulated satellite imagery meant to represent the capabilities of the Advanced Baseline Imager (ABI) on GOES-R.

Newly available in the 2015 demonstration and continually evaluated in 2016 were the synthetic brightness temperatures from the experimental HRRR (hereafter referred to as HRRR-x). These were provided by CIMSS via the HRRR Validation website.This website provides a sectorized validation and guidance of HRRR-x simulated satellite imagery across the CONUS. Not only does it display a side-by-side comparison of the simulated and observed satellite images (water vapor and infrared), it also generates various validation statistics, including RMSE, Bias, and MAE. Additionally, it includes error matrix graphics that compare the statistics of all of the runs for a particular day. This is an easy way for forecasters to identify which run is performing best, as interestingly, it may not always be the current one.

Synthetic satellite imagery continues to be regularly used by forecasters as an additional model tool at the various desks in operations. In particular, the FA forecasters use it when issuing G-AIRMETs for turbulence. In a typical real-time satellite image, they will try and identify certain features specific to turbulence: breaking ridges, jets, mountain waves, and wind gradients, etc. With modeled satellite imagery, forecasters attempt to identify these features later in the forecast period, especially where they are located with certain other model parameters conducive to turbulence. This concept has been in use since the initial introduction of the simulated imagery to operations back in early 2013 and continues to prove valuable. In fact, one AWC forecaster will be presenting on this subject at the 2017 AMS conference in Seattle (Figure 16).

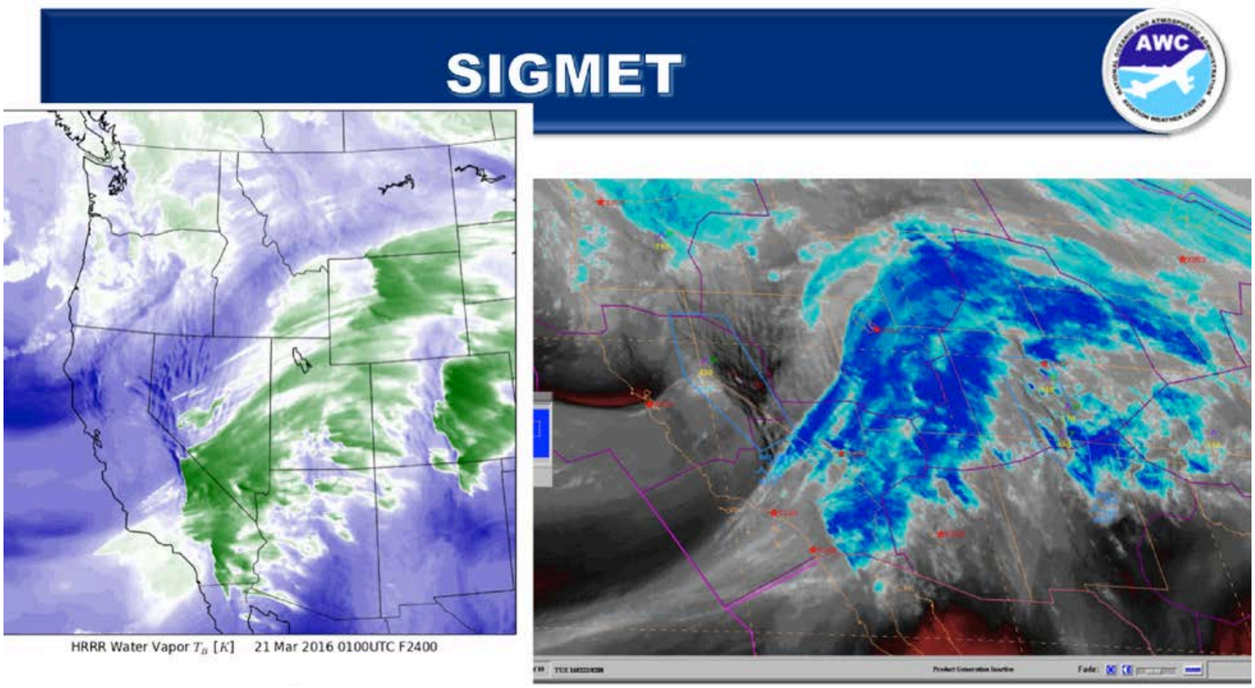

Figure 16. March 21 – 22nd, 2016. HRRR simulated WV indicated areas of mountain wave turbulence over the Rockies well ahead of the event triggering both a G-AIRMET as well as a string of SIGMETs over eastern Nevada and NE New Mexico. The HRRR-x WV image on the left is compared to GOES-W WV imagery and issued SIGMETs at 02Z on the 22nd.

Convection is another area in which the simulated satellite imagery is often used at the AWC. This year, the CAWS desk in particular has found it very useful. One of the goals of the CAWS is to add benefit to the automated CCFP forecast. If the confidence and coverage from the CCFP appears to differ from what various model and other data are indicating, CAWS are typically issued as a heads up for traffic flow managers. This is especially true if it surrounds a busy terminal such as Chicago. For example, CCFP may be showing high confidence of medium coverage over the airport, but simulated satellite and a few other model parameters are indicating earlier clearing (Figure 17). In this case, a CAWS would be issued to note the earlier clearing so that traffic flow managers can release ground stops earlier than planned.

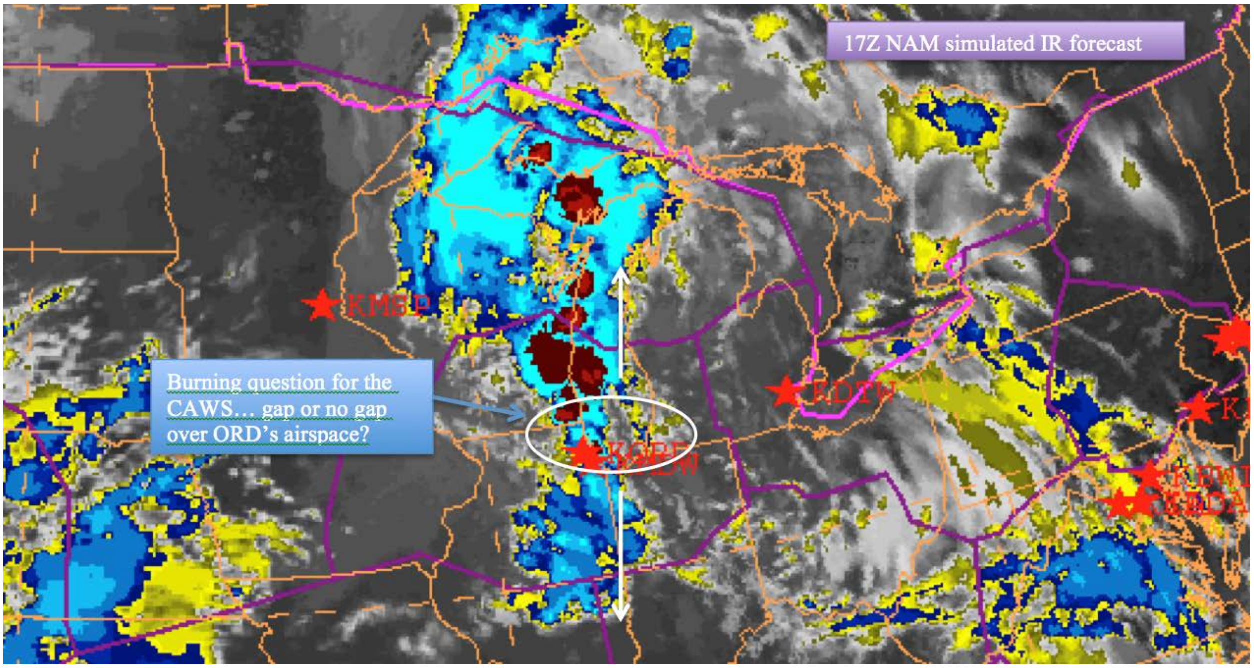

Figure 17. August 24th 1700 UTC synthetic IR forecast from the NAM Nest around Chicago. Forecasters were debating the necessity of a CAWS where skies seemed to be clearing early around the terminal.

On a final note, synthetic cloud and moisture imagery are currently being generated by the GOES-R Ground Segment via RAFTR, which utilizes Rapid Refresh and GFS data to simulate the sixteen channels and the high temporal refresh of the ABI. This data was made available through SBN in AWIPS-2 and through the NESDIS PDA system in N-AWIPS (Figure 18), and was meant to simulate the future data flow structure of GOES-R ABI imagery through the Ground Segment.

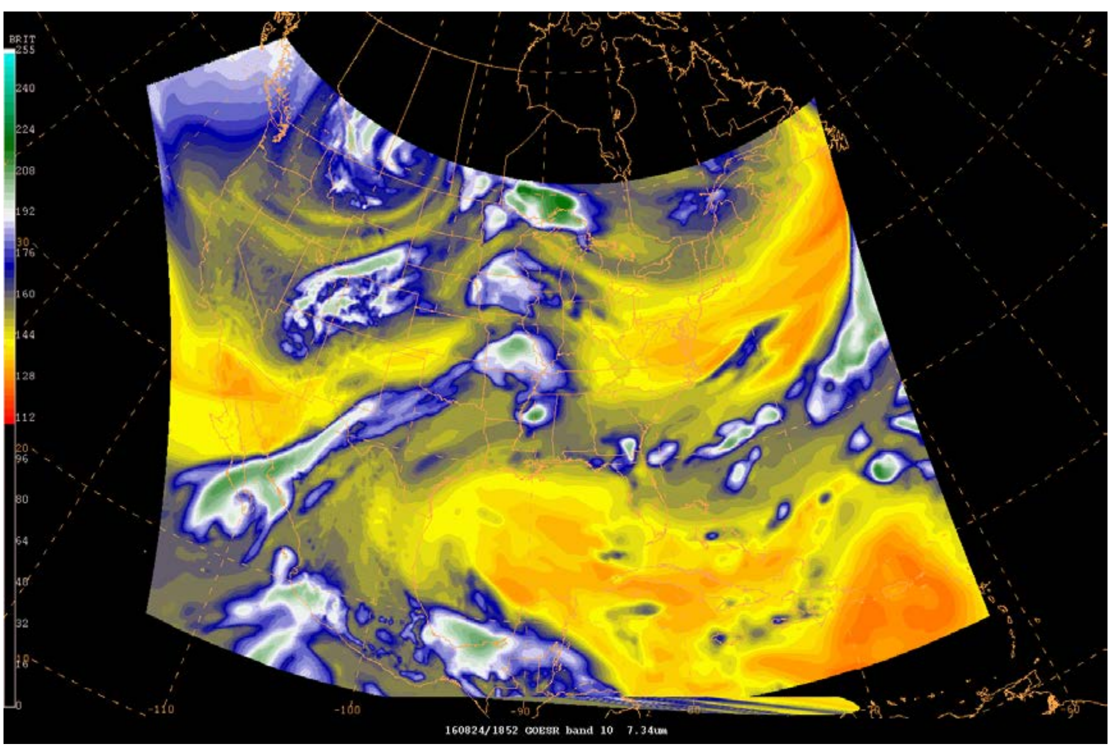

Figure 18. Simulated ABI imagery from RAFTR in N-AWIPS for AWC forecasters

While it was simulating a real-time feed of ABI as will be seen through the Ground Segment after GOES-R is launched, is still provided valuable insight into the 16 channels and temporal resolution, as well as the various sectors available in the GOES-R era. It was a first glance into the procedures necessary to call mesoscale scan sectors or perhaps more important for a National Center such as the AWC, a change to Mode 4 and continuous full disk scans.

Unfortunately the National Centers couldn't fully participate in DOE-4 due to certain necessary processing not being in place. However, an exercise similar to DOE-4, but geared towards National Centers is expected to take place later this fall. Further evaluation of this imagery and sectors will be completed at that time.

3.6 AIRS Ozone Retrievals - NASA's Short Term Prediction Research and Transition Center

The Atmospheric Infrared Sounder (AIRS) and the Infrared Atmospheric Sounding Interferometer (IASI) are instruments currently available on the polar-orbiting Aqua spacecraft and Metop spacecraft, respectively, and measure temperature and water vapor, as well as clouds, carbon monoxide, carbon dioxide, methane, sulfur dioxide, dust, and ozone. NASA SPoRT utilizes this data to generate AIRS and IASI Total Column Ozone and Ozone Anomaly products, which can aid in identifying regions of warm, dry, ozone-rich stratospheric air.

In 2015, AIRS data was explored in the area of turbulence forecasting. Some continued exploration as been done on that end. In addition, it was noted by the NAMs at the Command Center that the FAA actually does have a staff position dedicated to ozone forecasting. Ozone level thresholds are highly dependent on the type of aircraft and what sorts of filters are available; however, there are requirements for certain levels that force aircraft to reroute. To this end, the AIRS and IASI data were examined along with new Total Ozone and Ozone Anomaly data from NUCAPS for the 2016 demonstration period. Also NUCAPS provides vertical profiles of the atmosphere, and as such, ozone levels at 250 ppb of ozone, the FAA's general threshold, were generated as seen in Figure 19.

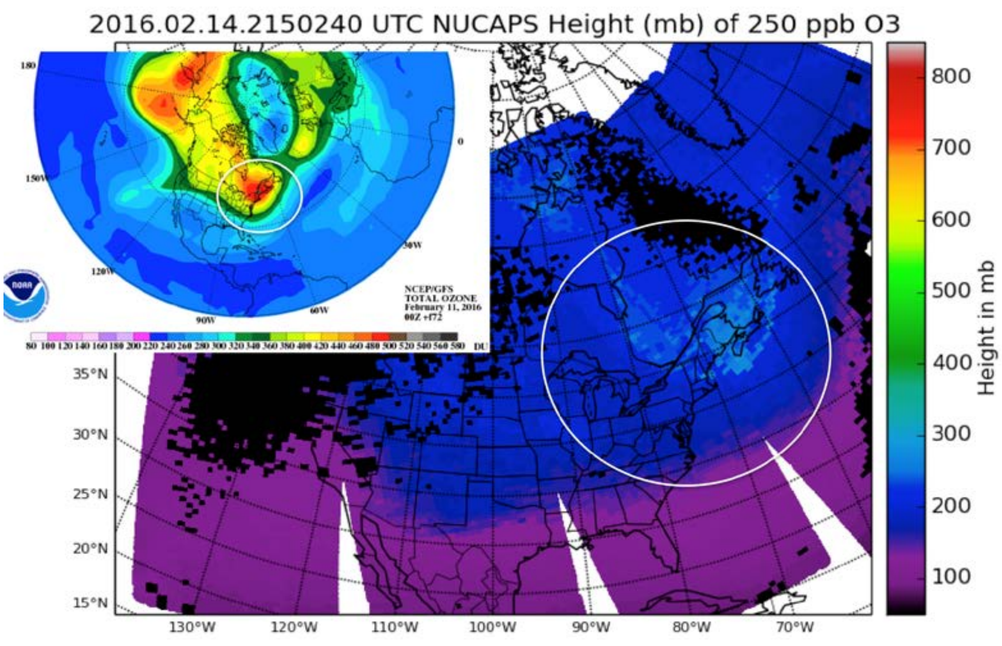

Figure 19. Height (mb) of the 250 ppb O3 level compared to the GFS forecasted ozone (smaller image in top left) on February 14th, 2016. Ozone affected airspace on in Northeast during this particular week.

There was a long snap of exceptionally cold weather in the Northeast from February 11-19th, 2016. This brought with it an extended period of higher ozone levels in the regions particularly up north of Boston Center. While no significant impacts to air traffic were observed, the NAMs kept an eye on the event all week long. It was revealed that the only data set they currently have to go on is the GFS forecast ozone. As such, in a post mortem overview of the event, the ozone anomaly data was made available as a comparison to the GFS forecast. NUCAPS revealed the 250 ppb level to have descended to roughly the 350-300mb height, which is low enough to impact traffic at cruising altitude.

After examining this case, the satellite derived ozone data was requested by the NAMs. It is now being displayed in their AWIPS-2 systems along with the forecasted ozone. Further examination of this proof of concept will continue to be evaluated in future demonstrations to determine 1) if there is any added value in having the observed ozone levels from NUCAPS and if additional levels would be useful, and 2) if the satellite derived imagery reveals that ozone events seem to occur at cruising altitudes at a higher frequency than currently realized given the difficulty in actually observing it.

3.7 Satellite Derived Motion Winds - University of Wisconsin Cooperative Institute of Meteorological Satellite Studies (UW-CIMSS), NESDIS STAR

Satellite Derived Motion Winds or Atmospheric Motion Vectors, are wind vectors generated by tracking cloud features in visible, IR, and water vapor satellite imagery. The generation process utilizes three satellite images, the first and third to track the cloud feature, and the second to target the features themselves. Heights of these wind vectors are assigned based on 1) measured radiances of the targets and 2) the spectral responses of the satellite and channel that is being sampled.

One of the main concepts for the AMVs taken from last year was the possibility of utilizing them to aid in the forecast or verification of compression issues around major terminals. Compression is caused when the winds at upper levels are much higher than winds near the surface. As arrivals near the terminal, these stronger upper level winds cause aircraft to quickly catch up with those at lower levels in lighter winds. It is the opposite on take off if there are strong surface winds and lighter winds aloft. Because of the minimum distance requirements between aircraft, traffic flow managers are required to spread traffic out further in these cases and often end up having to delay or hold other flights. O'Hare and the New York area terminals are those where compression is a common issue and causes the biggest problems.

In 2016 the AWC began producing forecasts of vertical winds using the SREF, the idea being to provide traffic flow managers a forecast vertical profile of winds. However, this would not be limited to just the terminal point. The arrival and departure points of each terminal contain an expansive chunk of airspace and wind conditions and differ from one end to the other. Therefore, plots from the various approach and departure gates around the main hubs are also created. The first airport this has been explored for is ORD (Figure 20).

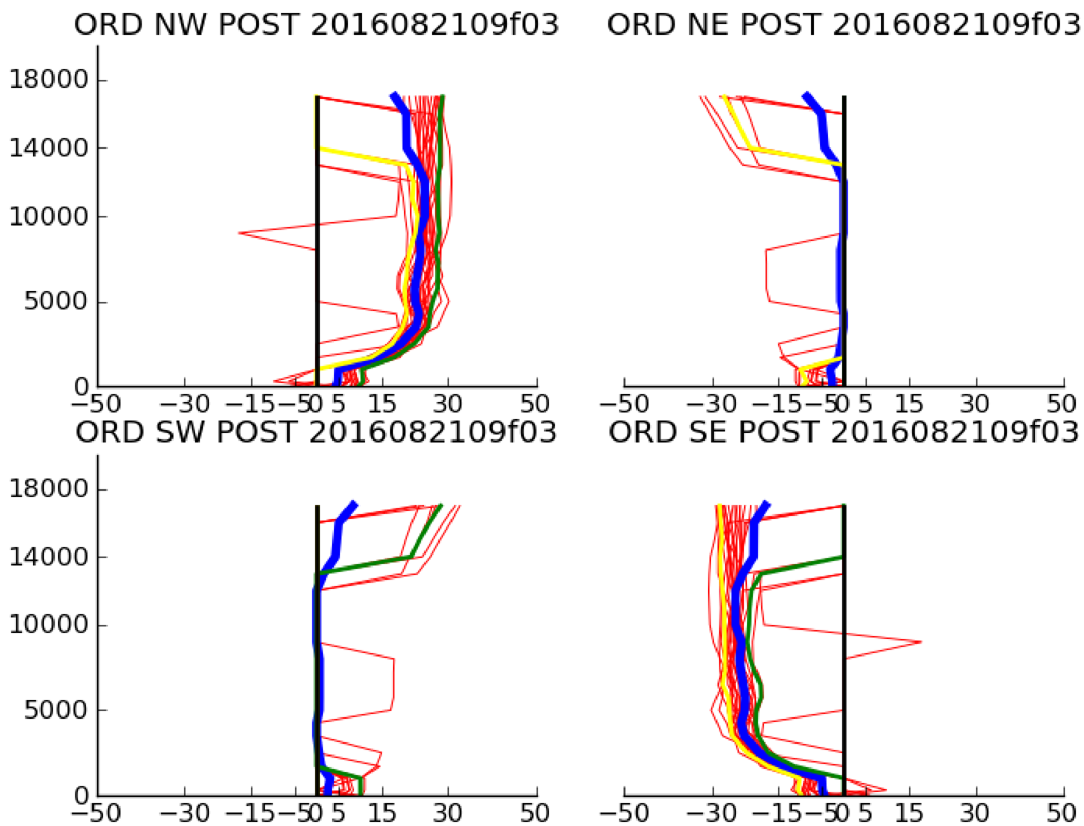

Figure 20. Post processed SREF wind forecasts at each departure point of ORD. Blue is the mean observed, green is 90% percentile, yellow is 10th, and red is the various SREF members. Currently be verified by aircraft soundings and RAOBs.

This is a very new concept and currently these plots are being verified using aircraft sounds and also RAOBs. The latter are typically only available at the center of the main hub and not at the various departure/arrival points. Additionally, aircraft soundings can be limited at times as they are only produced from certain types of aircraft.

It is here where AMVs could perhaps become useful. While AMVs are derived only for cloud objects in the top layer of clouds, the addition of many spectral channels from which winds can be derived will increase the density of winds in these layers. The layers themselves will not be consistent to a specific point, but by examining winds from various points within a region, forecasters may be able to get a better perspective on the vertical profile of winds. These could be compared to SREF wind forecast departure/arrival points as well as RAOBs and RAOB sounds to potentially 1) provide at least some wind forecast verification, 2) provide more insight on the accuracy and reliability of satellite derived winds, and 3) gauge whether satellite derived winds provide any information over and above current modeled winds.

This concept will be explored further in future demonstrations as the forecast wind concept continues to mature.

4. Summary and Conclusions

The Aviation Weather Center has a unique and challenging mission for a variety of customers, including general aviation, commercial airlines and the FAA, and also helicopter operations. The 2015 GOES-R/JPSS demonstration was designed around the needs of these customers and the products issued by AWC forecasters. In past years, future capabilities products were evaluated in more detail. This year the Aircraft Flight Icing Threat and the various ozone products from NPP were the only of those evaluated. Beyond that the focus shifted to baseline products including various ACHA Cloud Height algorithms, the PGLM for GLM lightning detection, Synthetic Cloud and Moisture imagery, Derived Motion Winds, and GOES-14 1-minute SRSOR imagery. The demonstration itself was separated into two long-term evaluations, Evaluation Period I and II, with two two-week, intensive experiments for each season embedded within.

The biggest change in the 2016 demonstration was the addition of the above-mentioned GOES-R/JPSS products to AWIPS-2. With the future in the latter system, AWC management has directed all development for N-AWIPS and AWIPS-2 to occur in parallel, with emphasis on AWIPS-2. The Winter Experiment marked the beginning of this effort, with various icing and C&V related products being displayed in D2D. The Summer Experiment further emphasized this as all convective related products along with additional C&V products moved. A push will be made to transition some of these products – identified via the 2016 evaluation period- to the floor. The ozone products from NPP are the first of this list to be successfully moved to the AWC's operation AWIPS-2 systems.

Some training will likely need to reoccur for these products at a later time. Currently everything in N-AWIPS operations has been trained on and reference materials such as quick guides and case studies provided. However, given the differences and particularly the improvements in AWIPS-2, some familiarization will need be needed. Some one-on-one training did occur during both experiments with those AWC forecasters who participated. Additionally, the NAMs were provided some brief training on the ozone products. Further training will occur in the 2017 demonstration period.

As a side note, Himawari training is expected to be completed by this winter. This will include mainly international branch forecasters at the AWC and will provide a first glance into advanced satellite technology, not only Himawari, but also the GOES-R ABI as it is very similar. Domestic operations forecasters at the AWC will not take this training. Because Himawari training is not officially required by the National Weather Service whereas GOES-R training next year will likely be, management elected to wait. This was done to avoid redundancy of foundational material and also provide training closer to the time when domestic forecasters will actually be able to utilize the data.

All of the feedback above was collected via in-depth discussions and blog posts. Some survey questions were provided via Survey Monkey during the experiments, but were kept as very broad 'which products did you use and how?' or 'any comments on the GOES-R products?' type questions. This was done due to the nature of the participants within the AWT. Unlike the Hazardous Weather Testbed, which is by-in-large geared towards NWS forecasters, the AWT contains airline operations personnel, FAA traffic flow managers, researchers in the aviation community, those in the general aviation community, and others, as well as forecasters. The mixed background of all of these participants makes posing very specific, scientific questions inefficient. By keeping them broad, it allows for a variety of feedback from perspectives all over the aviation community. Overall, for the long-term evaluation, in depth discussion continues to be the preferred method of feedback collection at the AWC.

From this feedback, products and concepts for various products continue to evolve. Some of the main comments are as follows:

- The Aircraft Flight Icing Threat algorithm has been much improved. There are caveats in certain conditions and there is still no way to provide probabilities and intensities of icing at night;

however, the product is very useful in the issuance of G-AIRMETs. Furthermore, it was of great use in the exploration of a non-convective CAWS or 'in-between' type product identifying small areas within the G-AIRMET that may require a SIGMET. This product will continue to be examined in the future at the AWC as well as at the Alaska Aviation Weather Unit.

- ACHA Cloud Height Algorithms, namely the Cloud Base Heights and to some extend the Cloud Cover Layers, were heavily used in both experiment periods for C&V. Some improvement is need in the estimation of cloud ceilings over the West Coast and also around the terminator. However, both products were valuable in the Digital Aviation Services effort as situational awareness and a starting point for grid editing. In the future these products will be further integrated into GFE for a more in depth evaluation.
- As ever, the GOES-14 SRSOR imagery was popular within the AWT. This year it was available for three periods: winter, spring, and late summer. The winter and summer periods coincided with the AWT Winter and Summer experiment periods. During the Winter Experiment forecasters found great use of the imagery for turbulence forecasting and also situational awareness on C&V. The Summer Experiment again saw 1-minute imagery use for C&V and also for Convective SIGMET, and particularly CAWS.
- New this year was the addition of the Toronto and North Georgia LMA networks to the PGLM product. Both of these networks are located around main hubs or busy airspace; Toronto covering the busy corridor of air traffic into the Northeast and North Georgia cover Atlanta Center. Data from these networks were made available via AWIPS-2 D2D. Toronto data was given a cursory evaluation; however, data quality issues with North Georgia prevented any evaluation there. In the future the AWC will collaboration with NASA SPoRT and the Atlanta CWSU for a more in detail evaluation.
- Synthetic satellite imagery has been a favorite of AWC forecasters since its transition to operations in 2013. Simulated data from the WRF and NAM Nest was made available in N-AWIPS and in 2015 the HRRR satellite data website was also made available to forecasters. It continues to be utilized for turbulence forecasting and G-AIRMETs at the FA desk, as well as for convection at the CAWS and Convective SIGMET desks. This year the GOES-R Ground Segment also provided simulated data from RAFTR using RUC and GFS data for the DOE-4 exercise. This data was meant to simulated real-time ABI and provided via SBN and the PDA system to mimic the 'true' GOES-R dataflow in the future. The AWC will participate in a National Centers version of DOE-4 later this fall and will continue to use other synthetic satellite imagery as situational awareness.
- Ozone data was originally explored for turbulence forecasting, and while this avenue has not been exhausted, the NAMs also noted the use of this data in forecasting ozone events and providing information to the FAA. Total Ozone and Ozone Anomaly product from AIRS, IASI, and NUCAPS are being generated along with derived heights of specific ozone levels. All of these products are now being displayed in the AWC operational AWIPS-2 system and will continue to be evaluated by the NAMs with the GFS forecast ozone for ozone events in the future.
- Derived Motion Winds have been discussed often at the AWC and yet satellite derived wind data has not been historically used. However, this year the FAA requested forecasts of vertical wind profiles be generated at arrival/departure points around major hubs in order to provide 1) better situational awareness of compression winds and 2) also provide forecasts of changing winds that may require changes in runway operations. Satellite derived winds may be useful in verification for this effort and will be explore more closely in the future.

More detailed feedback and case examples from the 2016 Demonstration can be found on the GOES-R Proving Ground AWT blog at:
http://goesrawt.blogspot.com/

General information about the 2016 Summer Experiment, all included datasets, the testbed blog, training material, etc., can be found at the AWT testbed home page: http://testbed.aviationweather.gov/page/public?name=2016_Summer_Experiment

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

5. References

Baum, B. A., P. Yang, A. Heymsfield, S. Platnick, M. King, Y-X. Hu, S. Bedka, 2005: Bulk Scattering Properties for the Remote Sensing of Ice Clouds. Part II: Narrowband Models. J. Appl. Meteor., **44**, 1896–1911.

Han, Q., R. Welch, J. Chou, W. Rossow, A. White, 1995: Validation of Satellite Retrievals of Cloud Microphysics and Liquid Water Path Using Observations from FIRE. J. Atmos. Sci., **52**, 4183–4195.

Heymsfield, A. J., S. Matrosov, B. Baum, 2003: Ice Water Path–Optical Depth Relationships for Cirrus and Deep Stratiform Ice Cloud Layers. J. Appl. Meteor., **42**, 1369–1390.

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.

Mecikalski, J. R., J. K. Williams, D. Ahijevych, A. LeRoy, J. R. Walker, and C. P. Jewett, 2013: Optimizing the use of geostationary satellite data for nowcasting convective initiation. *J. Appl. Meteorol. Climatol.*, In preparation.

Seemann, S. W., E. Borbas, R. Knuteson, G. Stephenson, H. Huang, 2008: Development of a Global Infrared Land Surface Emissivity Database for Application to Clear Sky Sounding Retrievals from Multispectral Satellite Radiance Measurements. J. Appl. Meteor. Climatol., **47**, 108–123.

Schmit, T. J., and co-authors, 2013: GOES-14 Super Rapid Operations to Prepare for GOES-R, Conditionally accepted *J. Applied Remote Sensing*.

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.

Sieglaff, J. M., L. M. Cronce, W. F. Feltz, 2014: Improving Satellite-Based Convective Cloud Growth Monitoring with Visible Optical Depth Retrievals. *J. Applied Meteor. Climatol.*, **53**, 506-520

Smith Jr., William L., et al., 2012: Determining the Flight Icing Threat to Aircraft with Single-Layer Cloud Parameters Derived from Operational Satellite Data. J Appl. Meteor. Climatol., Vol. not yet printed