Aviation Weather Testbed – Final Evaluation

Project Title: 2015 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: 1 February 2015 – 1 September 2015

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

Final Submitted Date: 1 September 2015

Table of Contents

1. Summary

The 2015 demonstration at the Aviation Weather Center (AWC) in Kansas City, MO, took place from 1 February – 1 September 2015, 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. While the AWC was once again fully staffed in 2015, forecaster training for the transition of the Collaborative Aviation Weather Statement (CAWS) to operations resulted in the cancellation of the 2015 Winter Experiment. To accommodate, the 2015 evaluation was again divided into two long-term evaluations with a two-week long intensive Summer Experiment also included. Details of these periods can be found in Table 1 below.

Table 1. AWC 2015 demonstration schedule and descriptions

Evaluation Period	Description
1 February – 15 May 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
Mid-Late March Winter Experiment	** Cancelled due to CAWS training and subsequent staffing issues**
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)
10 – 21 August Summer Experiment	*Focus* – cloud and visibility with GFE, with a secondary focus on convection and the Collaborative Aviation Weather Statement (CAWS); graphical Area Forecasts for tropical regions *Training* – real-time training and demonstration with external participants

Participation throughout the two long-term evaluations included only AWC forecasters, while the Summer Experiment 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 2015 GOES-R/JPSS demonstration.

2. Introduction

The structure of the 2015 demonstration remained based around the AWC's operational desks as in years past. These include World Area Forecast (WAF) and Tropical desks on the international operations branch (IOB), and the Convective SIGMET (CSIG), the Area Forecast (FA) desks, as well as the National Aviation Meteorologist (NAM) desk on the domestic operations branch (DOB). However, there were also several notable changes and transitions to AWC operations, including 1) the automation of the Collaborative Convective Forecast Product and the subsequent transition to the Collaborative Aviation Weather Statement (CAWS) desk), 2) the introduction of 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, and 3) the exploration of graphical based forecasts for the Tropical desk, also as a replacement for the current text Area Forecasts. A brief summary of AWC operations and these updates will be given herein.

The FA desks are responsible for issuing 0, 3, 6, 9, and 12-hour Graphical AIRMETs (GAIRMETs) and text forecasts every three hours as well as SIGMETs (if necessary) for hazards including cloud and visibility, turbulence, icing, freezing level, low-level wind shear, and low ceilings. Similarly, the WAF Tropical desk also issues FAs and SIGMETs for these threats, as well as for convection (Fig. 1). Domestic FAs and GAIRMETs area utilized mainly as flight planning guides by the general aviation community. On the other hand, the Tropical FAs are an important part of helicopter operations over the Gulf of Mexico and the Caribbean.

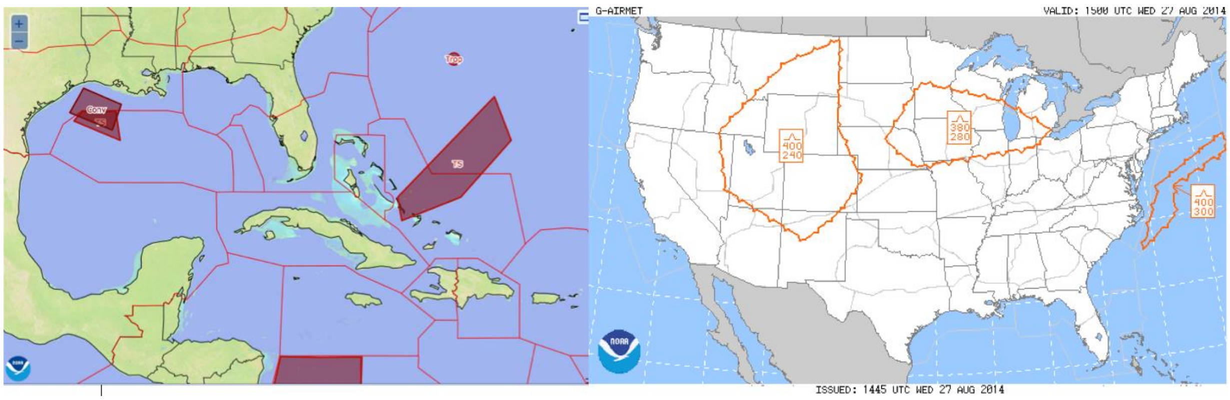

Figure 1. Tropcial domain with 1-hour international SIGMETs issued for convection (left), and a 3-hour G-AIRMET forecast for turbulence (right).

Midway through 2015, the FAA issued an official document stating the retirement of the text FAs. It is this that led to the exploration of alternatives for both the domestic FA and tropical desks. 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 Aerodome Forecast (TAF) writing. The 2015 Summer Experiment -outlined in more detail in later sections- explored this digital aviation product concept through the creation of aviation cloud and visibility grids using GFE tool in the D2D AWIPS-2 system (Fig. 2). These grids would be disseminated to the various CWSUs and WFOs, who would then refine the forecasts based on their specific region and local knowledge, and utilize them as an additional tool in the generation of the TAFs, thereby producing a more consistent aviation forecast across the National Weather Service.

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).

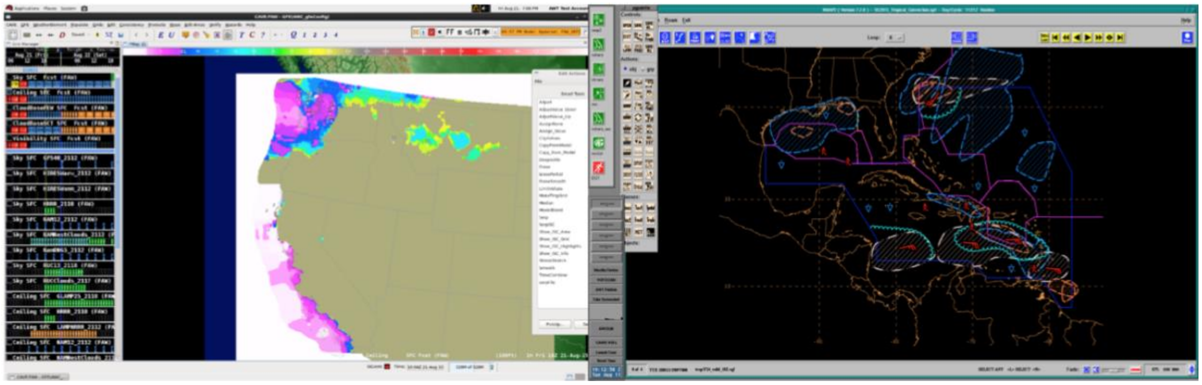

Figure 2. AWC generated grids via GFE (left) and graphical forecasts for Tropical (right). Tropical forecasts include IFR and MVFR in the red and scalloped blue circles, convection in orange circles and isolated red symbols, showers in blue circles and isolated blue symbols, turbulence in yellow circles, icing in green circles, and winds in red barbs.

The remainder of the WAF desks are responsible for every corner of the globe and output a 12 and 24-hour forecast of convection, icing, and turbulence, as well as jets and tropopause heights (Fig. 3). Flight planners, particularly those mapping flight routes over the oceans, use this information to find the safest and most cost efficient path for international flights.

Figure 3. Global Graphics 12-hr forecast. Red 'cotton balls' denote forecasted convection, and green arrows denote forecasted height and speed of upper level jets. White boxes indicate forecast tropopause heights.

On the other hand, CSIG and CAWS are domestic products, with CSIG outlooks and SIGMETs for convection (i.e. a 'thunderstorm warning' product for aviation) issued and/or updated every hour. In previous years these were sister products to the CCFP, an 8-hr forecast of convective probability issued every 2 hours (Figure 3). However, the CCFP is now run as an automated product, allowing for the evolution of aviation operations into the CAWS.

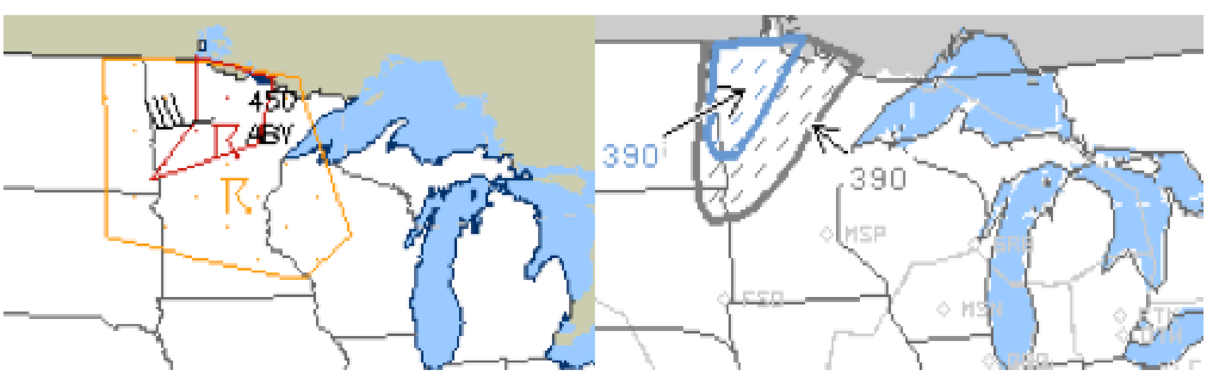

Figure 4. CSIG outlook and SIGMETs (bottom left), and CCFP 6-hr forecast (bottom right). Yellow outlined boxes contain the CSIG outlook, with red boxes indicating active SIGMETs. Boxes in the CCFP forecast give convective coverage and probability as well as flight levels at which it is likely to occur.

As suggested by the name –Collaborative Aviation Weather Statement- the CAWS is another piece of the mission to provide more consistent aviation products across the National Weather Service aviation entities. AWC forecasters are responsible for the physical creation of the product, but collaborate with the CWSUs, WFO aviation focal points, the NAMs, and the FAA (including airlines) to fine-tune its generation. It is a short-term, typically 4-hour, graphical and text-based forecast product that outlines significant impacts expected at terminals and/or busy enroute airspace. This product has been in the operational testing phase since March 2015.

Aside from aiding the issuance of the CAWS, the forecasters at the NAM desk, located in Warrenton, VA, within the FAA's Air Traffic Control Systems Command Center (ATCSCC), also provide real-time weather briefings and updates to traffic flow managers on weather hazards expected to impact aviation operations in the short term. Additionally, they issue long-term forecasts for days 1 through 7 as a broad scope of expected weather. This allows the FAA to make proper staffing decisions for upcoming shifts (Fig. 4). For all products, their focus typically remains on the busiest airspace and centers.

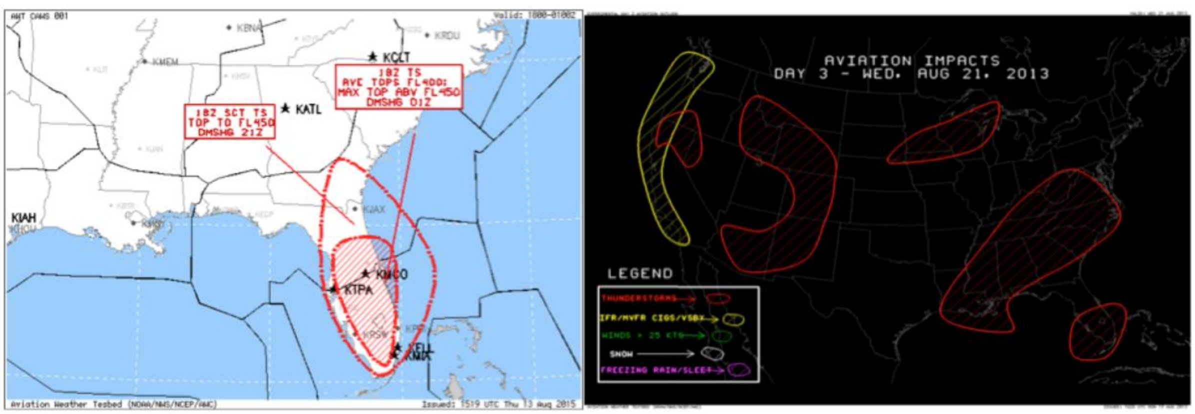

Figure 5. An example CAWS (left) and Day 3 outlook (right). The CAWS is the future version of the CCFP, in which AWC, CWSU and NAM forecasters work together to create an outlook of hazards expected, ideally at 4 hours, for traffic flow managers, while the long-term outlooks (Day 2-7) are generated by NAMs only for the FAA.

Like in 2014, Evaluation Period 1 explored winter and early spring aviation hazards, and as such was focused mainly on the FA desks and Tropical cloud and visibility concerns. On the other hand, the latter portion of Evaluation Period I and all of Evaluation Period II were convection-based, exploring both short and long term convective products. These evaluations took place at the CSIG, CAWS, Tropical and WAF desks in Kansas City, and with the NAMs at the ATCSCC. The broad-scale structure and one-on-one training in both long-term evaluation periods was designed to allow for flexibility around forecaster shifts and heavy workloads, while also providing ample time to hear the thoughts of as many as possible out on the operations floor.

The 2015 Summer Experiment took place in the Aviation Weather Testbed (AWT) during Evaluation Period II. This intense, two-week experiment period focused on three main concepts that stemmed from FAA operations and requirements: 1) the issuance and refinement of the CAWS for convection, 2) the exploration of national cloud and visibility (C&V) grids via GFE in AWIPS-2 as a replacement for the domestic text FA product, and 3) the creation of a graphical-based product for the Tropical desk as a replacement for the international text FA. The CAWS and C&V pieces took place in full collaboration with the Aviation Weather DEcision (AWDE) services testbed at the FAA's Tech Center in Atlantic City, NJ (Fig. 6). AWDE provided a user services perspective and their participants ranged from CWSU meteorologists to FAA Air Traffic Controllers (ATCs) and Air Traffic Mangers (ATMs). 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 these concepts and encompassed both N-AWIPS and AWIPS-2 displays.

Figure 6. The AWDE testbed (left) and AWT testbed (right) during the 2015 Summer Experiment at the AWC

3. GOES-R/JPSS Products Evaluated

A number of products were evaluated during the 2015 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 along with NSSL-WRF and NAM Nest Simulated Satellite forecasts. Other baseline products included Satellite Derived Motion Winds, the Pseudo Geostationary Lightning Mapper (PGLM) and the ACHA Cloud Height Algorithms. Future Capabilities products included the GeoColor imagery and also encompassed those products within the 'Convective Toolkit'; i.e. Cloud-top Cooling and Overshooting Top Detection, and the GOES-R Convective Initiation, as well as the HRRR Lightning Threat Forecast. Super Rapid Scan 1-minute imagery from GOES-14 was used to showcase the ABI 1-min rapid refresh mesoscale capability. Additionally, a 1-9 hour Nearcasting model was included as the only Risk Reduction product.

A number of MODIS/VIIRS products from JPSS were also evaluated to a lesser extent. The Day/Night Band was examined, and the Dust Enhancement products and AIRS Ozone Retrievals were explored when an event arose. The Cloud Layers and Snow Cover Discrimination product, while noted in the original plan, was not evaluated due to lack of funding.

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
Convective Initiation	Future Capability
Cloud Top Cooling/Overshooting Top Detection	Future Capability
GOES-14 Super Rapid Scan imagery	Baseline
GeoColor imagery	Future Capability
Nearcasting Model	Risk Reduction
Pseudo Geostationary Lightning Mapper	Baseline
Satellite Derived Motion Winds (AMVs)	Baseline
Simulated Cloud and Moisture imagery	Baseline
JPSS Demonstrated Products	**Category**
AIRS Ozone Retrievals	Baseline
VIIRS/MODIS Day/Night band imagery	Baseline
VIIRS/MODIS Dust products	Future Capability
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.

This product was introduced to AWC forecasters during the 2013 Winter Experiment and was further evaluated during Evaluation Period I of the 2015 GOES-R/JPSS Demonstration. Improvements in 2014 included a projection change and minor adjustments to the color curve, both of which made the product much more aesthetically pleasing and subsequently, easier to interpret. However, forecasters still had concerns about the product's ability to generate icing intensities in areas of high, deep clouds and at night. While there is still no solution for the latter, algorithm improvements have been made to address the high clouds as well as other accuracy issues.

Firstly, a proposal to combine LaRC's inputs with the GOES-R DCOMP version of the FIT algorithm was approved for funding in the summer of 2015. These inputs dramatically increase the icing intensity solutions in the presence of higher clouds. Secondly, additional algorithm advancements have been made, including a method in which to better identify light and moderate or greater (MOG) icing in most clouds, while also estimating some areas with the potential for severe icing. Additionally, LaRC's inputs are run for a merged GOES-E/GOES-W version of the product, which is preferable to the current GOES-E only version (Fig 7.)

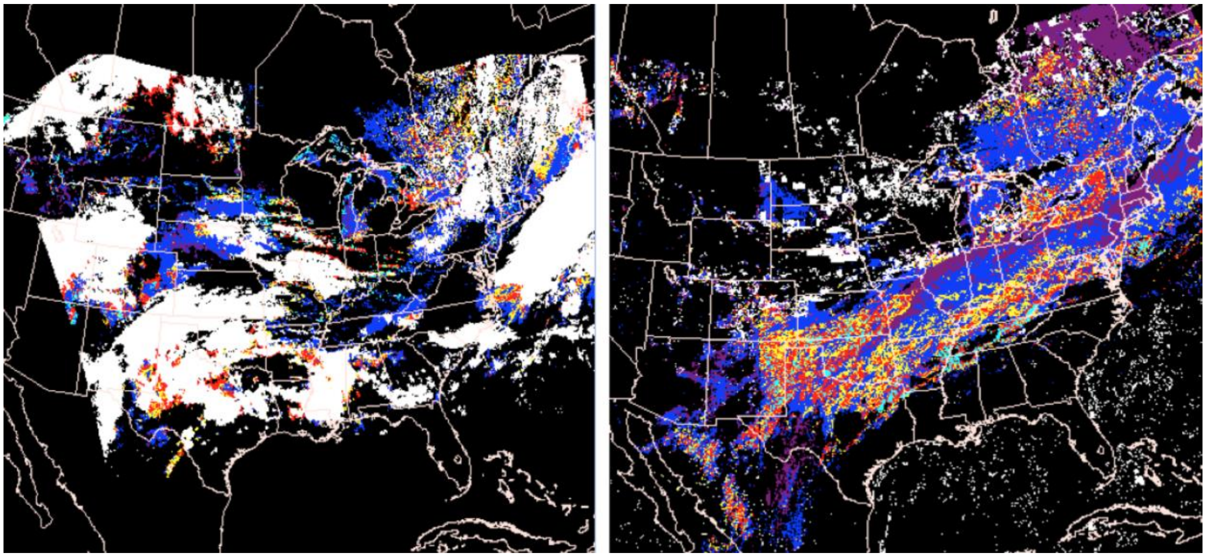

Figure 7. The current version of the Flight Icint Threat product utilizing GOES-R DCOMP inputs only (left) and the anticipated version with LaRC's inputs and improvements included (right).

While this did improve the usability of the product, it is still of little use during nighttime icing situations, when only a 'yes/no' mask is available. However, something that was found to provide valuable information was the icing layer altitude boundaries, found within the suite of products produced via the icing algorithm. This product provides an estimate of the icing top and base in feet and its accuracy was improved within the algorithm advances above. Icing GAIRMETs require a base and top estimation, providing pilots with information about how far they need to divert or ascend/descend to avoid the hazard or get out of it. As such, the satellite-derived icing bases and tops would be beneficial for situational awareness.

Given the funding approval date of mid-summer and the cancellation of the 2015 Winter Experiment, the product was looked at in N-AWIPS in an unofficial capacity during the 2015 demonstration by using the NASA LaRC version to examine the algorithm advancements in both the FIT and the icing layer altitudes. These products will be examined in more detail during the 2016 Winter Experiment at the AWT in February.

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. Additionally, the domain of this product not only included the CONUS, but also hemispheric and global. This extension was designed to supplement the IOB branch of AWC operations, where large data void areas across the globe result in forecasters becoming very reliant on satellite imagery to issue their products. The cloud altitudes were evaluated within the Summer Experiment on a CONUS and international (tropical) scale and were available in both N-AWIPS and AWIPS-2.

AWC, CWSU, and WFO aviation focal points continue to show interest in the Cloud Top Altitude products as cloud bases and heights are required for the issuance of the vast majority of aviation related forecast products. During the 2015 Summer Experiment the altitudes were of particular interest in the issuance of CAWS amendments and for situational awareness. In aviation operations it is imperative that traffic flow managers know where tops are and how high. Ideally, traffic is directed over thunderstorms as long as possible. Once aircraft began to shoot gaps and divert around thunderstorms, fuel costs and delays begin to increase significantly. With an accurate and real-time analysis of tops, these effects can be minimized.

Cloud altitudes were explored to that end in the 2014 Summer Experiment and further examined this year. While feedback was similar, the additional thoughts from AWDE and their end user perspective put an interesting twist on this concept. Typically when traffic flow managers ask about 'tops' they are referring to radar echo tops, as that has become the norm in aviation services. Cloud tops or altitudes aren't quite the same thing. The top of an echo can, but doesn't necessarily, equate to the top of the cloud. Often times cloud altitudes can be 2000+ feet higher. Therein is where AWDE's feedback came.

When a traffic flow manager sees a difference of 2000 or more feet, he or she sees a large chunk of usable airspace. In areas like New York or Cleveland Center, losing that amount of airspace would likely cause significant delays and diverts as well as financial loss. So, when looking at cloud altitudes versus echo tops, they are far more inclined to pay attention to the echo top and it has become a habit over many years. Should they be doing this? From a safety standpoint, perhaps not. After all, despite the fact that the echo may be much lower, there are still potential hazards such as severe turbulence or icing, lightning, and wind shear to consider. Even the experienced pilot who has been flying through and around storm clouds for years can be caught off guard.

An example of using cloud tops versus echo tops was shown one afternoon during the experiment and is shown below in Figures 8 and 9. Early in the morning a complex of thunderstorms was proceeding east through the central Plains. Radar indicated echo tops of >FL350 while cloud altitudes indicated tops of ~FL380, with the notable exception of a couple of areas where cloud altitudes were FL450+. The reason became obvious when looking at the Overshooting Top Detection product, where several detections were indicated. Note that at this particular time they were also fairly obvious in the visible imagery, but this will not always be the case. A rapidly growing storm, for example, may have a much higher cloud altitude as the updraft is just beginning to mature but has not yet lifted the precipitation core.

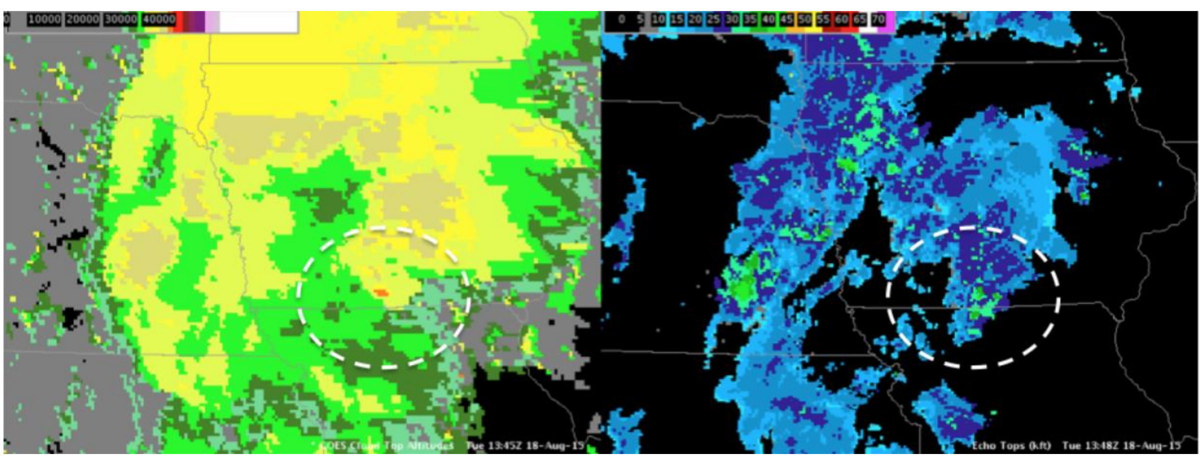

Figure 8. AWIPS-2 two-panel comparing satellite derived cloud heights (left) and radar echo tops (right). This was a case in which cloud tops were much higher the radar echo tops. This was due an overshooting top, noted in the white dashed circle

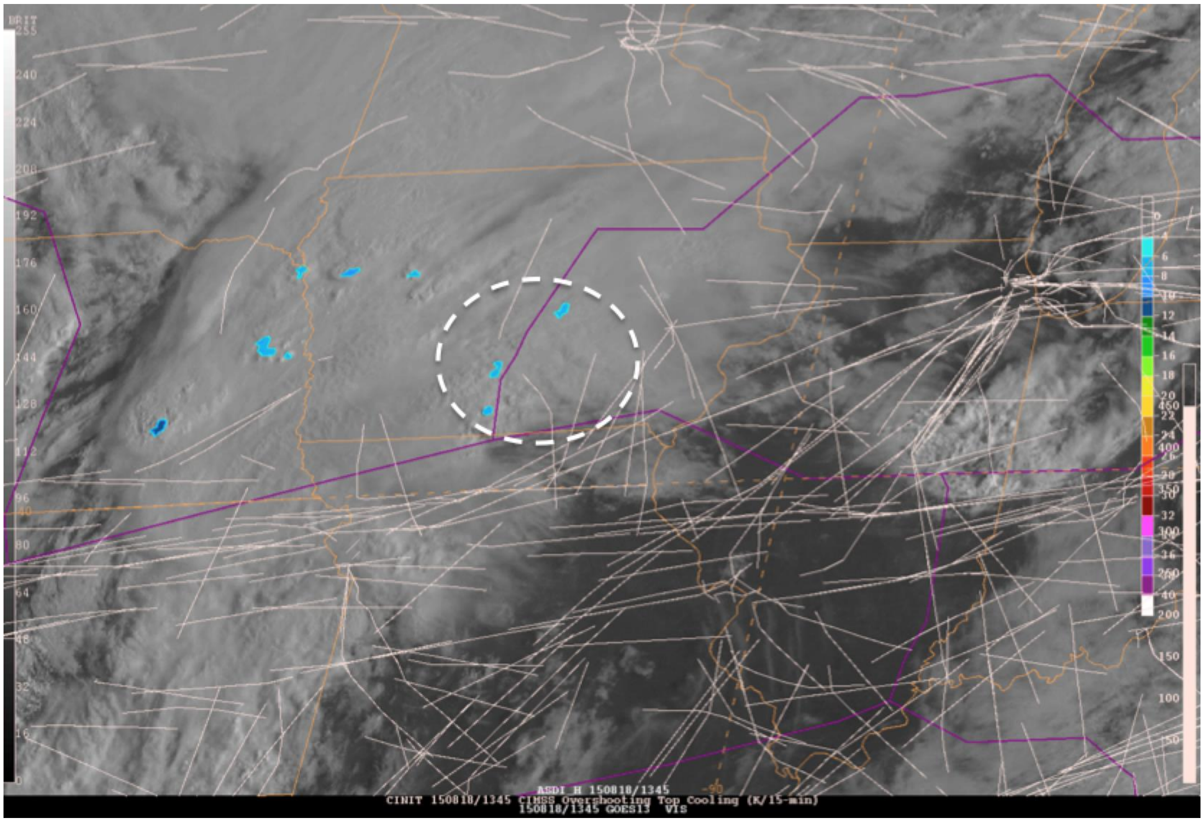

Figure 9. Visible imagery and Overshooting Top Detection showing the overshooting tops associated with the comparison in Figure 8

More exploration of this relationship between echo top and cloud altitudes would be valuable. To this end, it was noted that it would also be useful to identify and display only convective cloud tops, to further isolate the areas in which echo tops may need to be monitored more closely. After feedback from earlier in the year, the ACHA group has already proceeded with this work and is currently testing a new, convective version of the product, to be examined in later evaluations at the AWC.

Convection was not the only hazard for which the cloud altitudes were examined. It was also found to have potential use in cloud and visibility forecasts. While identifying a ceiling height from a cloud top altitude is difficult, if not impossible in some cases, it was still found to be useful, particularly at the Area Forecast desks. These desks issue G-AIRMETs for IFR conditions that are by in large geared towards general aviation pilots, some of who may not be instrument rated. Essentially, they may not land at an airport reporting IFR conditions or even fly into an area of clouds reported as IFR. FAA regulations also state a particular height (dependent on region but typically ~FL180) above which general aviation pilots must not fly. Thus, if a pilot who is not instrument rated finds it necessary to ascend and avoid IFR conditions in their path, it is important that they also know the height of the top of low cloud layer. Should that height exceed the FAA-stated limit it would be necessary for them to fly around, divert to another airport until the ceilings cleared, or return to their origin.

To this end, forecasters were able to utilize the cloud altitudes with the color scale highlighting altitudes of FL180 and below to better identify the tops of the low clouds. It was noted, however, that the scale in its current form was somewhat difficult to interpret in N-AWIPS. This issue will be addressed for WE16. Also to be addressed for WE16 and beyond is the issue of satellite-derived ceiling heights. The ACHA group has already proceeded with work to product a derived ceiling height product from the cloud altitudes and an estimated cloud thickness. It is anticipated that this product will be evaluated at the AWC in both N-AWIPS and AWIPS-2 during the 2016 demonstration period.

Lastly, cloud altitudes were examined for convection and shower activity in tropical areas. MIT/Lincoln Labs, in collaboration with the FAA, have created the Offshore Precipitation Capability (OPC) product. This is a sister product to the Corridor Integrated Weather System (CIWS), which utilizes radar, satellite, lightning and other observations, and model data to provide short-term (0-8 hour) convection forecast. The OPC utilizes many of the same datasets, but provides this forecast offshore. Additionally, in lieu of radar data in the offshore areas, it relies more heavily on satellite-based parameters. In the near future, cloud altitudes (provided by the ACHA group) will be integrated into the OPC in an effort to further improve the accuracy of the product.

3.3 Convective Toolkit

3.3.1 GOES-R Convective Initiation – University of Alabama in Huntsville and NASA's Short-term Prediction Research and Transition Center

The GOES-R Convection Initiation, introduced into AWC operations nearly two years ago, continues to be evaluated for use in aviation operations. In the 2015 demonstration it was examined in Evaluation Period II and during the Summer Experiment, and in both N-AWIPS and AWIPS-2. The focus of the evaluation was around the CAWS issuance and stemmed from feedback collected last year. Specifically, forecasters wanted to determine 1) if areas of consistent marginal signals (i.e. ~50%) by-in-large result in low-topped and weaker cores, and 2) how much extra confidence this would provide when used with other tools like the Nearcast.

As mentioned above, the CAWS product is a short-term forecast of aviation weather hazards expected to impact major terminals and jet routes. Ideally this is issued during the early morning hours as traffic flow managers are putting together the plan for the day, and gives them at least four hours lead-time to the impending hazard. For this reason, the 0-2 hour period of the CI isn't necessarily useful. However, a concept was explored during the Summer Experiment, wherein forecasters were issuing amendments to the CAWS, something not currently done in operations. In the experimental setting it was found that amendments were typically issued within that 0-2 hour period, thus making the CI useful for situational awareness.

One such occurrence took place on August 19th. The forecast was typical for a summer afternoon in the Northeast, calling for scattered and low-topped convection. Early in the morning a CAWS was issued (Fig. 10) in anticipation of this convection developing in Cleveland Center's airspace as well in the area surrounding Philadelphia (PHL). Additionally, it indicated that all convection would not impact the New York TRACON and D.C. area airports, and important fact given the inherent business of that airspace.

However, shortly after 1600 UTC the CI began to show consistent signals of around 50% just north of Baltimore (BWI). This, along with increases in radar reflectivity and lightning activity, resulted in forecasters issuing an amendment for this area, pulling the area of impact further south to include PHL and the north end of the D.C. TRACON (Fig. 10). While it didn't directly impact a terminal, the amount of flights in and out of that airspace and the resultant impact of convection necessitated this action. The CI was not only useful for situational awareness, but helped better identify the particular area into which the CAWS was extended. Should the amendment be made an operational norm, the CI will become a useful tool.

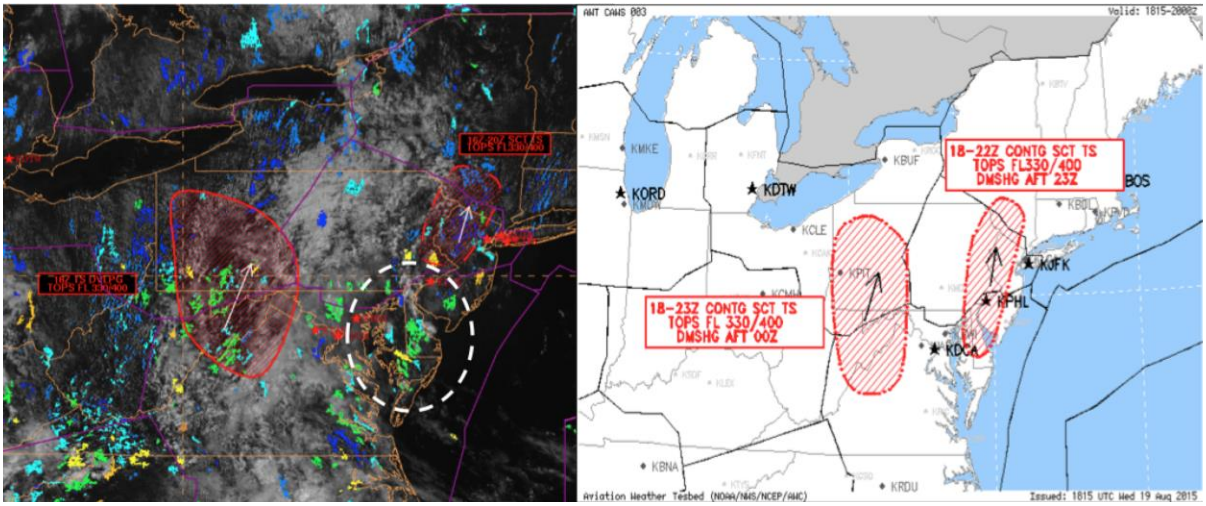

Figure 10. GOES-R CI and experimentally issued CAWS from August 19th (left) and experimentally issued CAWS amendment (right). The white dashed circle in the CI shows the 50%+ signals that aided in the decision to issue the experimental CAWS amendment

Similar to amendments, the CI was also noted to be useful in the issuance of short-fused CAWS. These are fairly rare, and typically reactionary. An example of this was shown on August 10th around O'Hare. Convection developed around the terminal and became stronger and more organized than originally expected. By the time the forecaster noted this, the terminal was already being impacted. A reactionary CAWS was issued to identify specific gates in and out of ORD that would continue to be affected as well as estimated the estimated time when the terminal would be clear. The CI was not being looked at for this particular case, but if it had, the forecaster may have seen the higher signals (which were upwards of 60-70%) in the area and been able to utilize them to provide traffic flow managers additional lead-time on expected impacts.

Aside from the CAWS, the GOES-R CI was also explored for use in CWSU operations. CWSUs are responsible for any flights within their airspace, which in areas like Cleveland, New York, and D.C. Centers can be a particularly daunting task. Any convection can cause a significant impact and is why an accurate forecast is vital. It is here where it was noted that the CI would be of use. Often times when convection is impacting the region, traffic flow managers will implement ground stops, or hold departures and arrivals for a specific terminal until the weather has passed. CWSU forecasters are responsible for providing situational awareness on the development and cessation of convection, its location and porosity, and the timing. The GOES-R CI can provide that extra information and lead-time on areas in which convection may be more likely given the strength and location of the signals. NAM forecasters at the Command Center also use the CI in this manner when providing real-time information to the traffic flow managers there.

Additionally, the GOES-R CI is another product being investigated for use in the FAA's Offshore Precipitation Capability product. It has already been integrated into their COsolidated Storm Predication for Aviation (COSPA) product. COSPA is a 0-8 hour forecast product that utilizes HRRR model data as well as a plethora of observations (radar, lightning, satellite, etc.) to generate not only a forecast of storms (winter or summer), but also their potential impact on aviation. The product currently integrates the GOES-R CI, using it as a way to increase the accuracy of the 0-2 hour forecast period for convection. The same concept will be explored for the OPC with the goal of improving the 0-2 hour period for offshore convection and precipitation forecasting.

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

The University of Wisconsin's Cloud-Top Cooling (CTC) Algorithm was designed to provide a satellite-based tool for diagnosing convective cloud growth. Using IR brightness temperatures and AWG cloud phase information, the algorithm (Sieglaff et al. 2011) identifies immature convective clouds that are growing vertically, and hence cooling (K/15 minutes). Additionally, the UW-CTC utilizes GOES visible optical depth retrievals (Sieglaff et al. 2014), which enables detection of growing convection beneath areas of thin cirrus clouds during daytime and allows for better detection of the strongest cooling rates with developing convection. It has been evaluated at the AWC for the past several years, and like the CI, the focused shifted to integration into operations. In the 2015 demonstration it was evaluated at the CAWS desk and also by some CWSU forecasters at the Summer Experiment.

As a real-time product, the CTC is another that does not provide an additional value in the issuance of a 4-hour CAWS. However, like the CI, it was noted that it would be of use in the case of a reactionary CAWS. The O'Hare case mentioned above was a good example of this and the benefit of using the CTC with the CI product. The CI was the first to note higher signals around the ORD terminal. Shortly thereafter, the CTC also noted some higher signals, further supporting the need for a reactionary CAWS.

Currently it is also often used a situational awareness tool for verification and would be very useful should CAWS amendments become operational. The CTC display over a visible satellite image allows forecasters to quickly key in on the signals in the fast-paced environment of their operations. If those signals are outside the expected domain, it allows them some lead-time to make the necessary adjustments.

Another interesting concept that arose from this year's evaluation related to the CTC on 1-minute imagery. With current GOES scan strategies the product updates every 15 minutes. However, it is important to consider that aircraft move much faster than satellite scans. In that 15 minutes, a larger commercial aircraft (i.e. a 767, 319, etc.) traveling at ~500mph (assuming no significant head or tail winds) could have covered around 125 miles. If weak CTC signals appear in a line of clouds, many aircraft will have already flown by or around them by the time the next scan has come in. Because of this, running the product on 1 or 5-minute satellite scans becomes much more practical. During the evaluation and the second experimental GOES-14 SRSOR 1-minute period, the CTC run on the SRSOR (a 15 minute difference every minute) was examined. Due to some N-AWIPS technical difficulty with displays, it was not a primary focus, but will likely be explored in more detail in future demonstrations.

3.3.3 Overshooting Top Detection – NASA's Langley Research Center

The Overshooting Top Detection (OTD) algorithm (Bedka et al. 2010) was designed as a means to identify anomalously cold groups of cloud pixels within an anvil cloud that are associated with overshooting tops, and subsequently, very strong updrafts. It contains not only a simple binary yes/no detection but also a magnitude of the overshooting tops. This year, the OTD magnitude product was evaluated for use mainly by the forecasters at the Tropical Desk, but also explored by CAWS and CWSU forecasters providing situational awareness to traffic flow managers.

It is well known that the AWC's Tropical Desk domain covers an area that is by in large data and radar void. For this reason forecasters rely heavily on satellite data. As mentioned above, this year there has been much exploration into a graphical product replacement for the soon to be retiring Area Forecast. Part of this graphical product includes a 0, 3, 6, 9, and 12-hour forecast for convection. While convection in this case equates to general thunderstorms, the OTD was still noted to be useful, particularly in the 0 and 3-hour forecasts. It aided in better identifying the location of convection, especially over radar sparse areas.

For the latter three periods it was more difficult to utilize the product for issuance of the forecast. However, it was noted to be useful for verification. Again, the forecast is typically identifying general thunderstorms, but any tool to help identify those areas where radar coverage is limited or non-existent becomes useful. Overshooting tops were also noted as something that may be a good input for offshore products such as the OPC.

Some exploration was also done surrounding situational awareness for traffic flow managers. As mentioned in earlier sections, traffic flow managers often utilize echo tops instead of cloud tops as a means to guide their decisions to reroute or divert flights. However, there are often cases were the region between the top of the cloud and the echo top is dangerous to fly through. One such case is with overshooting tops (Fig. 9 in the ACHA Cloud Tops section above). While overshooting tops can be easily picked out in visible imagery, this is not always the case, particularly in an area where convection is cluttered. For this reason, overshooting tops were noted to have potential use as a compliment product to radar echo tops.

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.

In 2013 it was noted that the AREA file version of the product made it impossible to overlay the flash densities on any other imagery, such as visible satellite or radar reflectivity. This becomes significant when working in the fast-paced environment at the AWC, particularly at the Convective SIGMET desk. For the reason forecasters requested a gridded version of the PGLM and after some delays last year, a GRIB2 version of the product was generated for use in time for the 2015 Summer Experiment.

While the two versions are presenting the same flash density data, there are some subtle differences in the display (Fig. 11). 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.

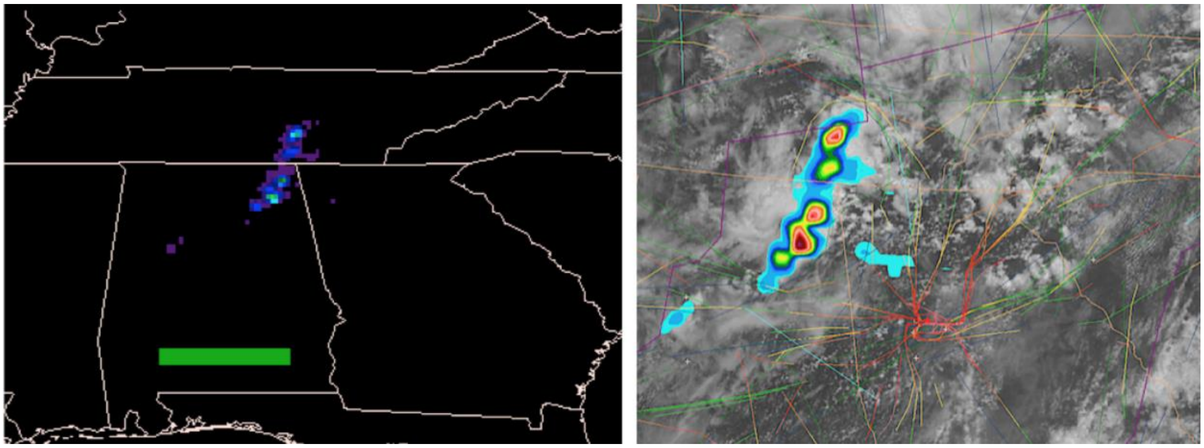

Figure 11. Area version of the PGLM (left) and the new gridded version (right)

Perhaps the most common use of the data during the Summer Experiment was in conjunction with the SRSOR 1-minute imagery. Being able to overlay the 2-minute PGLM data with visible imagery was found to be a useful situational awareness tool, particularly for CAWS forecasters as they monitored their issued products. As mentioned in previous reports, traffic flow managers attempt to prevent diverts until absolutely necessary. Typically, it is only when they start seeing lightning in the echoes that they will begin to consider changing traffic patterns en route. With the PGLM's ability to detect both intra-cloud (IC) and cloud-to-ground (CG), they will be able to identify lightning activity much more accurately, particularly in the vicinity of Gulf of Mexico and Atlantic flight routes where there may only be intra-cloud lightning. While traffic flow managers would not necessarily begin diverting traffic right away, if the CAWS forecaster pointed it out, it would potentially provide them with more lead-time to reroute traffic more efficiently later in the event. Overlaying it with 1-minute imagery would allow them also diagnose visible cloud structure at the same time and could potentially provide additional situational awareness of the convective areas. Below in Figure 12 was a day in which the PGLM and SRSOR imagery was overlaid and examined.

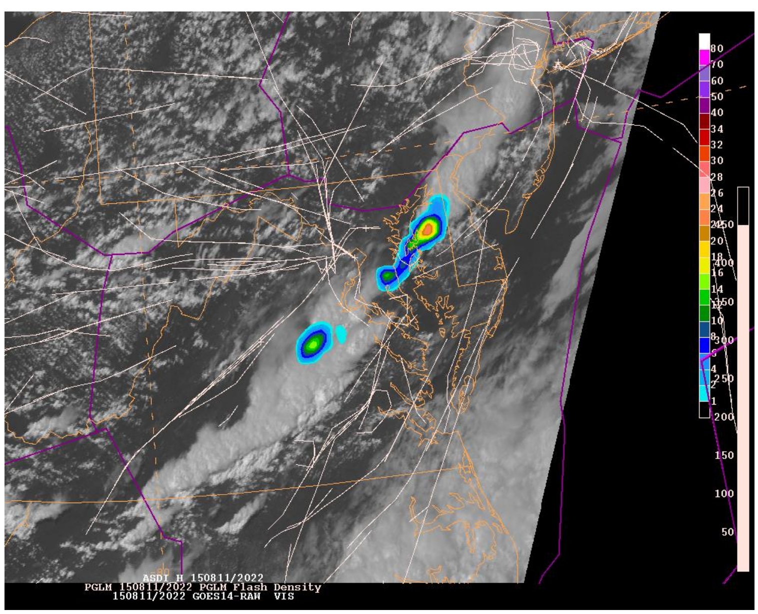

Figure 12. PGLM and 1-minute SRSOR imagery from August 11th used to monitor convective activity over the Northeast

Because the gridded PGLM product was not completed until mid-August (in time for the Summer Experiment) when the convective season was beginning to spin down, the product has not yet been evaluated in detail by Convective SIGMET forecasters. However, as its creation was a result of a direct request from those forecasters, it has much potential for their operations. It will allow them to overlay this imagery with visible satellite or other lightning datasets and further explore the benefits of having total lightning versus the current CG datasets (NLDN and the Global Lightning Detection). As mentioned above, exploring this concept in more tropical environments is of particular interest.

This concept and the potential use of this data in CAWS, NAM, and CWSU operations will be further explored in the 2016 demonstration period ahead of the expected launch of GOES-R and the GLM instrument.

3.4.2 WRF/HRRR Lightning Detection Algorithm – University of Alabama at Huntsville

The WRF and HRRR Lightning Threat Forecast is a model-based method for making quantitative forecast fields of lightning threat. The algorithm uses microphysical and dynamical output from high-resolution, explicit convection runs of the WRF and HRRR Models. Two separate proxy fields are used to assess lightning flash rate density and areal coverage, based on storms simulated by the models. One lighting threat field is based on the flux of large precipitating ice (graupel) in the mixed phase layer near -15C and has been found to be proportional to lightning flash peak rate densities while accurately representing the temporal variability of flash rates during updraft pulses. The second lightning threat field, based on vertically integrated ice hydrometeor content in the simulated storms, has been found to be proportional to peak flash rate densities while also providing information on the spatial coverage of the lightning threat, including lightning in storm anvils. Finally, a composite threat is created by blending the two aforementioned lightning threat fields after adjustments are made to account for the differing sensitivities of the two basic threats to the specific configuration of the WRF and HRRR models.

During the Evaluation Period II of 2014, it was noted that there was an issue with the model display lightning forecasts at orders of magnitude higher than was realistic. After some exploration, it was discovered that this was an N-AWIPS quirk, requiring a specific scaling value to be written into the restore file for this data. Because this occurred during the 2014 Summer Experiment, nothing but a cursory evaluation was done. NAM forecasters in particular noted that it could have potential use in further identifying the porosity of convection. This is especially useful in busy traffic areas in the Northeast and could have been potentially useful for CAWS issuance.

It was anticipated that the WRF/HRRR Lightning Detection algorithm would be evaluated during Evaluation Period II of 2015 as well as the Summer Experiment, in conjunction with the Pseudo Geostationary Lightning Mapper. However, as of early spring of 2015, the algorithm was removed not only from the operational HRRR data feed to the AWC, but also from the experimental feed. This prevented any further evaluation from being completed. If additional evaluation is requested in 2016, the AWC will pursue an alternate data feed.

3.5 Geocolor Imagery - The Cooperative Institute for Research in the Atmosphere

The GeoColor imagery was introduced to the AWC in early summer of 2015 and represents some of the potential for GEO/LEO image combination that will be available in the GOES-R era. Not only does it provide a seamless transition between day and night, but it also adds features like a natural color background and low clouds highlighted in pink and city lights at night. The product has been available for some time in AWIPS, but was generated in an N-AWIPS friendly format for the AWC and evaluated throughout the 2015 demonstration period.

During Evaluation Period I, AWC forecasters (along with forecasters from WPC and OPC) requested that the domain of the GeoColor be expanded further off shore and down into the tropical areas. This expanded region served both AWC and OPC/WPC/NHC forecasters and was implemented in early spring. A comparison of both domains is shown below in Figure 13.

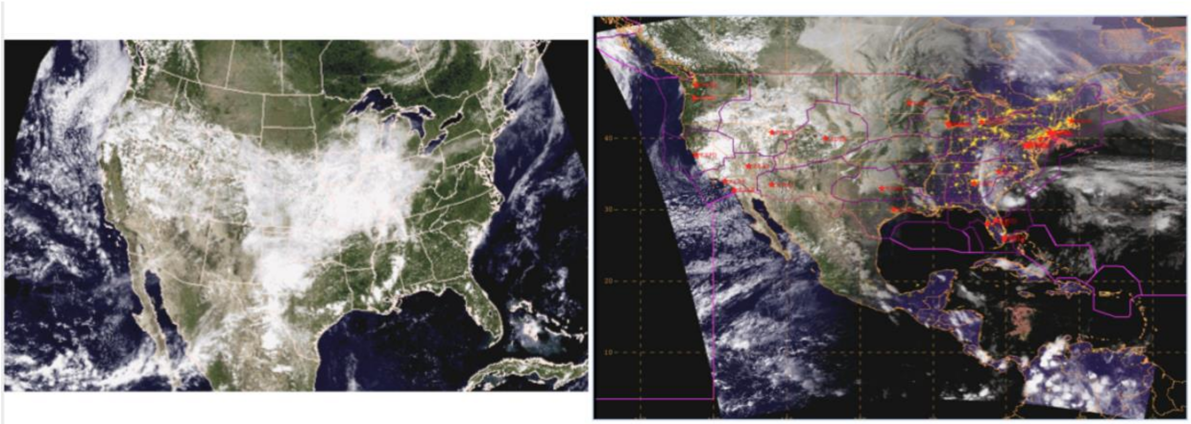

Figure 13. The old GeoColor domain (left) vs. the new, expanded GeoColor domain (right)

The GeoColor imagery continues to be useful as a way in which to confirm what other products, such as the GOES-R Fog and Low Stratus, are indicating. This was shown on August 10th during the Summer Experiment. Participants at the C&V desk were examining the current low stratus and fog conditions along the West Coast in preparation for creating their grids and noted a fairly significant decrease in probabilities along the northern California Coast. To determine if this was accurate, they also examined the GeoColor imagery (Figure 14).

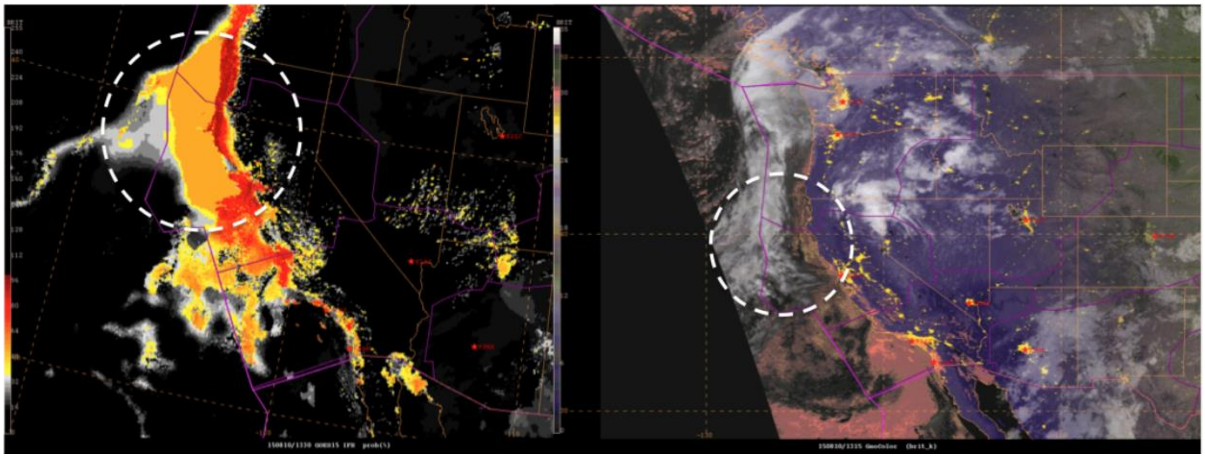

Figure 14. 20150812 Fog and Low Stratus (left) and GeoColor (right) imagery. The GeoColor was used to confirm the higher cloud level off the West Coast

Immediately notable was the presence of a higher cloud layer associated with the retrograding low pressure system. This cloud layer was proceeding slowly eastward and obscured the satellite's ability to provide information on the low clouds below. Thus, the Fog and Low Stratus algorithm was using only model data in that area and probabilities decreased.

Aside from providing context in fog and stratus situations, forecasters at the CSIG and CAWS also often utilize this data. The GeoColor provides an aesthetically pleasing full CONUS view, which is particularly helpful for the broad scale nature of many aviation hazards. It is also useful as a background image for many observations, i.e. surface stations, lightning, etc. Additionally, some of the derived satellite products have been overlaid on this imagery to provide further context, including the Cloud Top Cooling, Overshooting Tops, and most notably, the NearCast Model.

Lastly, the AWC's Tropical desk has also taken an interest in this imagery. With extension of the domain shown above in Figure 11, it now includes most of the Caribbean and Atlantic tropical areas for which Tropical forecasters are responsible. With the lack of observations in that area, this imagery becomes particular useful, not only for situational awareness, but also for verification of forecasts later on. During the Summer Experiment it was examined multiple times to provide further context to various features in the Gulf of Mexico and Caribbean islands, particularly at night. August 17th was an example of this. Participants at the Tropical desk within the Summer Experiment were attempting to distinguish between fog and clouds over the Yucatan peninsula early in the morning. Conditions were not ideal for low clouds, but with current visible imagery it was difficult to tell whether the existing area of clouds would be low enough to cause ceiling issues. However, the GeoColor showed none of the pink coloring assigned to low clouds or stratus over the same area, providing further confirmation that it was not fog after all.

3.6 The NearCast Model - University of Wisconsin's Cooperative Institute for Meteorological Satellite Studies

The NearCast Model, provided by UW-CIMSS, integrates the hourly full-resolution (10-12 km) information from the 18-channel GOES sounder. Using a Lagrangian approach in which multi-layer moisture information is transported forward in time using dynamically accelerating winds initialized with GFS modeled wind and height fields, this 'model' generates 1-9 hour 'NearCasts' of atmospheric stability and moisture indices. These nearcasts were designed to fill the 1-9 hour information gap that exists between longer-range (beyond 12 hours) numerical forecasts and observation-based nowcasts, and to enhance current NWP forecasts by successfully capturing characteristics (gradients, maxima, and minima) observed by GOES satellites that will define the development of convective instability (or stability). The Lagrangian approach allows for this information to be provided several hours in advance, even after subsequent IR satellite observations have become cloud contaminated.

Within the NearCast suite are a number of products, each based on a particular parameter typically used in forecasting atmospheric instability (or stability) and moisture availability. In previous years the layers and layer differences were evaluated but for the 2015 demonstration, only the theta-E difference was examined. Additionally, after feedback from the previous year's demonstration, the NearCast display was changed from a solid to hatched fill. This allowed for better diagnoses of clouds and patterns below when overlaid with visible or other imagery.

The NearCast model was originally designed to aid in the forecasting of severe convective events and has been shown to perform best in those situations. However, in the AWT it has also been shown to be useful in further identifying areas in which only scattered or weak convection is anticipated. Because it can be used to forecast a wide variety of convective modes, it has become a common product used at the CAWS desk in AWC operations and this was the focus of the evaluation during the 2015 demonstration. Not only can it help to further identify convective mode and porosity, but as a 0-9 hour forecast product, it also meets the 4-hour ideal lead-time for the issuance of a CAWS.

A case from August 19th showed this. A boundary progressing east was expected to set off some weak and scattered convection in the New England area in the late morning and early afternoon hours and, among other tools, forecasters also looked at the NearCast to try and better identify which terminals and airspace would be affected. The 1500 UTC image below in Figure 15 shows the area of unstable air (blues and purples) in the central New England area, with more stable air (greens, oranges, and yellows) over the coastal region. By 2300 UTC (Fig. 15) the NearCast still kept that unstable air onshore and inland, suggesting that the worst of the convection would stay just west of the New York airports. Other model forecasts were suggesting a similar setup.

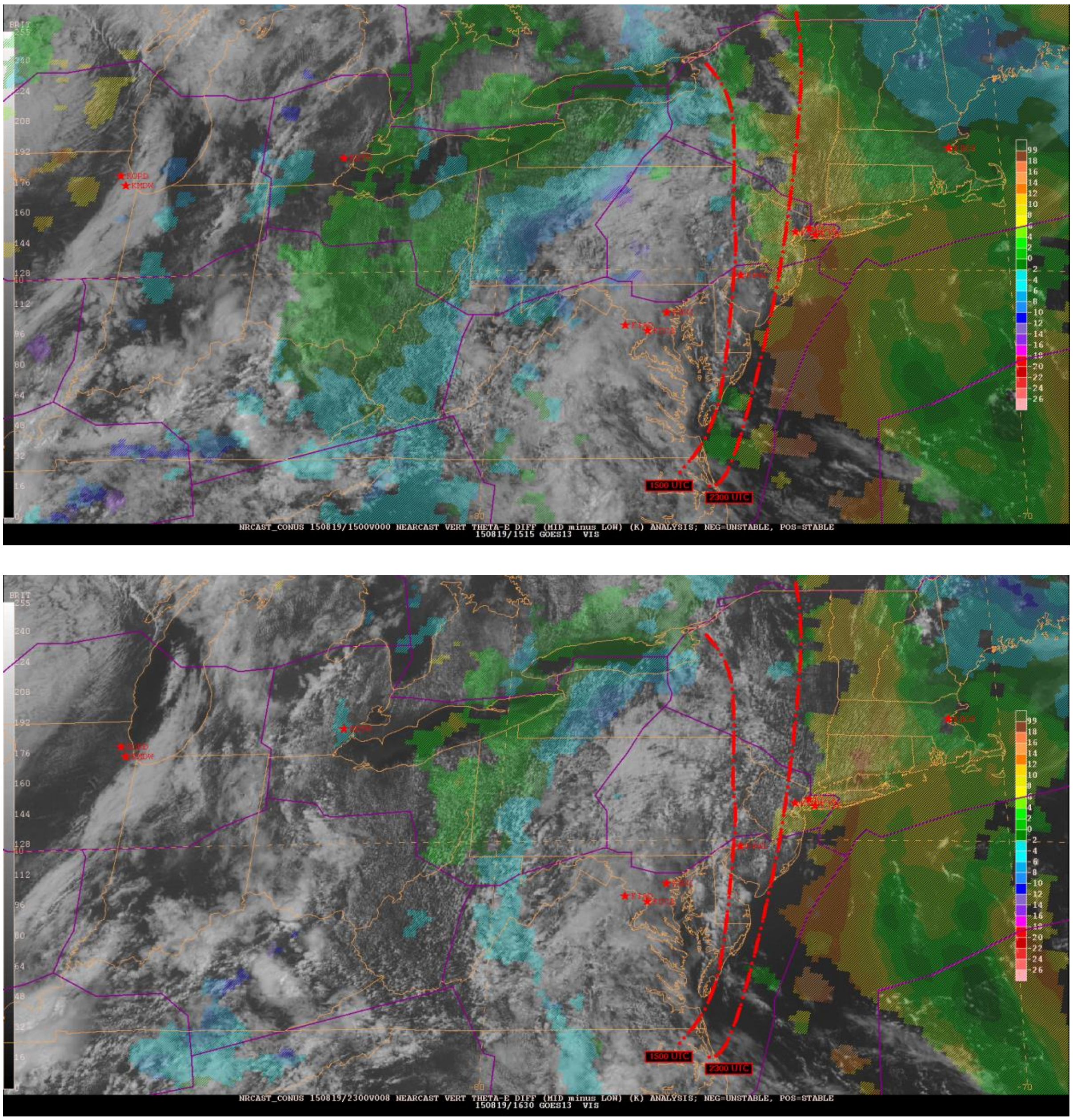

Figure 15. 20150819 1500 UTC NearCast (top) and 2300 UTC NearCast (bottom) with dashed lines indicating the boundary of moisture indicated in the Theta-E difference parameter

This is a big deal. The old adage in the aviation industry is 'New York first, New York second, New York third' and always rings true. Any disruption to the New York terminals is significant and being able to identify when the terminal may or may not be affected is important. In this case, a CAWS was issued (Fig. 16), but kept just to the west of the New York TRACON. Given this forecast, the participants at the AWDE testbed said that they would not have put any ground stops in the program for the day. Because there were still some potential impacts to the western gates of the New York airports, they also said they would not rule out the possibility of a ground delay, and in actuality there were several issued later in the day for a short period of time.

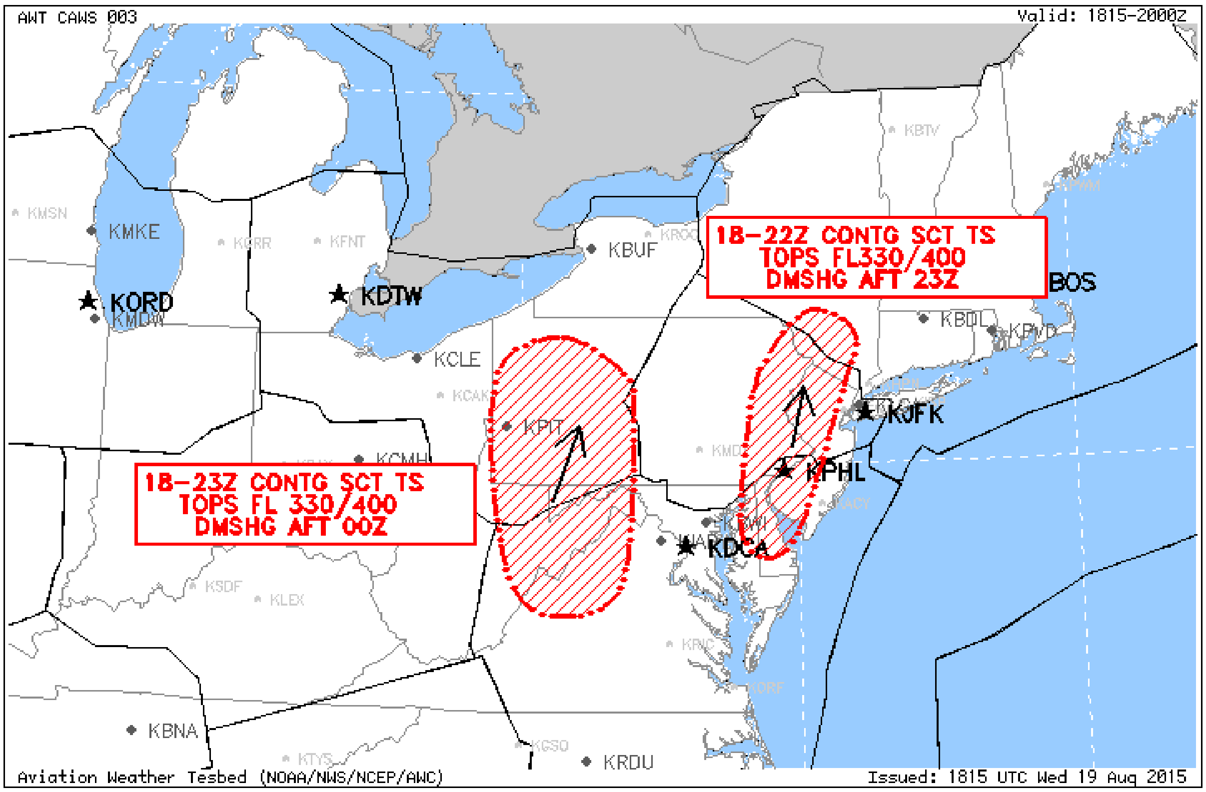

Figure 16. 20150819 1815 UTC experimentally issued CAWS forecast

Again, the NearCast is a commonly used tool out in AWC operations at the CAWS desk, as it has proved to be useful as an additional tool to identify the areas and porosity of convection later in the day whether severe or not. CWSUs and NAMs have also shown an interest in the tool for the same reason.

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

Two periods of 1-minute Super Rapid Scan imagery (SRSOR) occurred during the 2015 demonstration, the first in May and then second in August. This data was made available in AWC operations via an LDM feed from SSEC and a second feed from CIRA. The goal was to continue to explore the SRSOR and the usefulness of the higher temporal resolution in AWC operations. Do the benefits of 1-minute imagery outweigh a 5-minute refresh? Does it improve the ability to forecast for certain events or in certain areas? Similar questions and inquiries surrounding the scan types and usefulness of the SRSO were addressed by way of a survey (constructed by Bill Line, SPC Liaison, and adjusted by the AWC Liaison for aviation specific details) that was sent out during the May

SRSOR period. As a center in which both international and domestic aviation forecasts are produced, the results were varied but often biased towards one group or the other.

Domestic forecasters at the CSIG desk are perhaps the closest thing that the AWC has to warning-type forecasters, as CSIGs are essentially ‘thunderstorm warnings’ for aviation. These forecasters are examining real-time radar, satellite, lightning, etc. data to identify echoes hazardous to aircraft and have always noted benefits when the SRSOR imagery is available because it allows for better monitoring of convective initiation in sensitive areas (i.e. the Northeast and other busy traffic corridors of the Golden Triangle region).

G-AIRMET forecasters have also noted the potential use of the 1-minute imagery in issuing their SIGMETs for dust and turbulence. The latter in particular has been mentioned more often. There are particular satellite features that a forecaster examines when looking for turbulence (gravity waves, breaking rigdes, etc.) that, like convective features, could possibly be better identified with 1-minute imagery. However, the challenge again comes in the large domain. Given its large size along with the plethora of other products being issued at these desks, the consensus has remained that 5-minute imagery would likely suffice for these operations. In any case, the concept of utilizing 1-minute imagery for these SIGMETs will be further examined in the future.

Domestic terminal operations are another area in which the 1-minute imagery was examined during this period, specifically for NAM and CWSU operations with the FAA. As mentioned in previous sections, the FAA prefers at least a four hour lead time on large scale events, and associated forecast products like the CAWS. In these cases 1-minute would have little use. However, in the real time monitoring of these events, particularly around busy terminals and airspace, the 1-minute imagery is useful. For example, if an area of convection is moving over the New York TRACON (TRAffic CONtrol) area, the 1-minute data was examined to look for potential decay or back building that may allow ground stops or delays to be ended earlier or force them to last later than scheduled. In the same manner, it could be used to examine those same areas should they be located over busy airspace like that found in Cleveland Center (ZOB) and monitored by CWSUs. One example of utilizing the 1-minute imagery for monitoring traffic flow was noted during week two of the Summer Experiment on August 13th in the Southeast U.S. and is shown below in Figure 17.

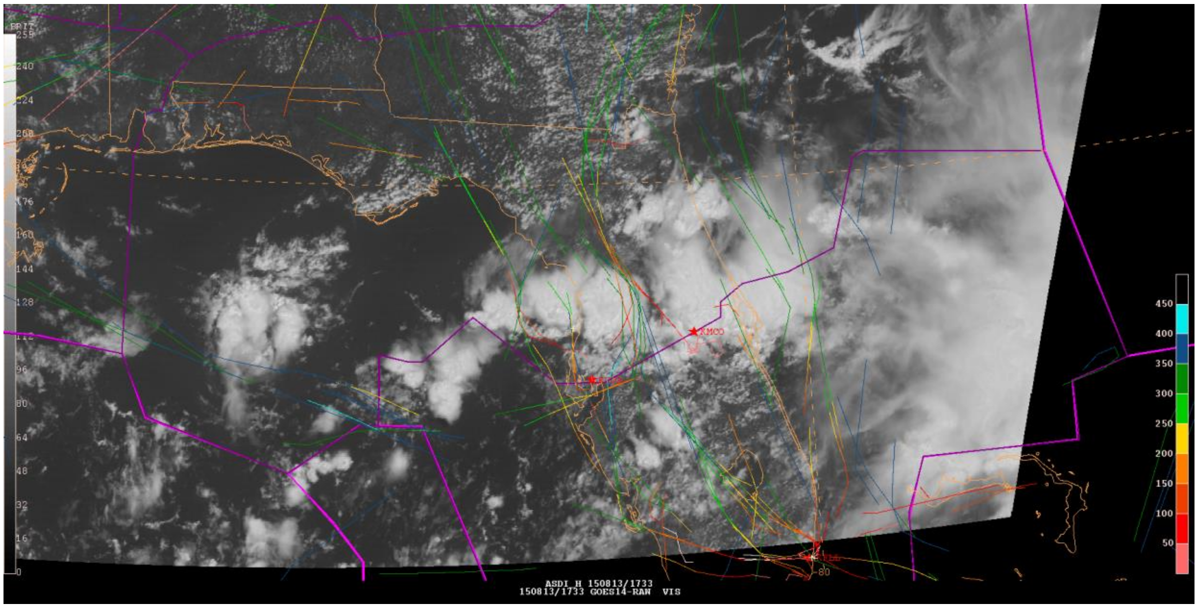

Figure 17. SRSOR 1-minute imagery and ASDI flight tracks over Florida. 1-minute imagery was used on occasion for monitoring ongoing convection in the major north-south routes into and out of the Florida terminals

Ceiling and visibility monitoring for FAA operations was another area in which the 1-minute was explored. One terminal in particular that was mentioned was San Francisco. Stratus is a common occurrence along the West Coast, particularly the San Francisco Bay area. The location of the terminal and the parallel orientation of its runways make operations extremely challenging during fog situations.

On a typical day SFO will have two parallel runways in operation. As arrivals approach the terminal, there is a point at which both will make a turn and be face to face before making the final turn towards the runways. When stratus is affecting the terminal or nearby arrival routes, FAA regulations require them to either increase the spacing between aircraft or shut down one of the runways. What makes SFO so difficult is the micro scale of the fog behavior. It can be hanging over the terminal at the top of an hour, and have moved out into the bay fifteen minutes later, and back over the terminal fifteen minutes after that. It can even be affecting one end of the terminal but be totally clear at the other. This makes it extremely challenging to forecast and is where the 1-minute SRSOR imagery would be potentially useful.

During the Summer Experiment forecasters studied the 1-minute imagery over SFO during a quiet convection day. It wasn't one of the most challenging days at the terminal, but fog was still an impact. The fog and stratus deck was not extensive due to the retrograding low offshore, but there was enough of a layer over the Bay area that visibilities dropped to a few miles. However, the terminal itself actually remained in the clear (Figure 18). There was some question about how far onshore the fog would proceed before daytime heating caused it to dissipate. In this instance, the 1-minute imagery was very useful in identifying the very small-scale, short-term movements of the fog in and around the Bay.

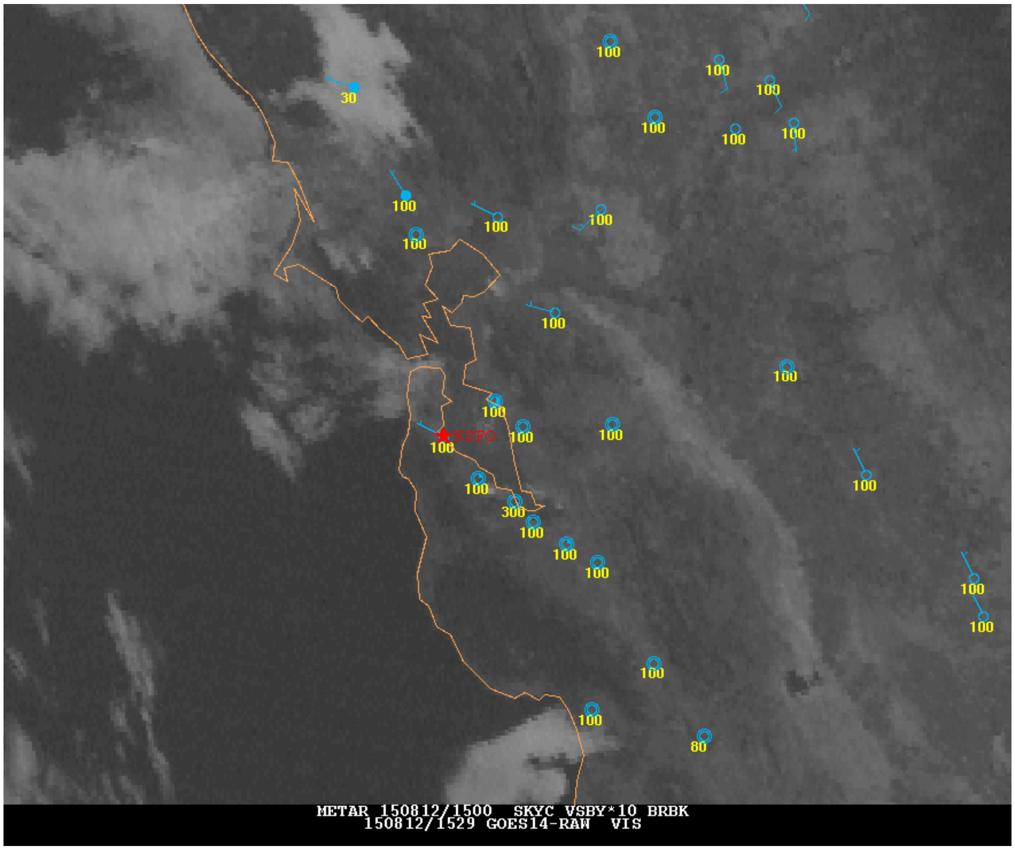

Figure 18. 20150812 1529 1-minute SRSOR and ceiling observations surround SFO

Another interesting domestic concept mentioned by CWSU forecasters at the Summer Experiment was in diversions. Typically all diversions are handled, depending the height and location of the aircraft, by traffic flow operators in whichever Center the aircraft happens to be in, or the closest tower or TRACON. Any weather related information would be relayed to them via the CWSUs forecasters, and they would then use it to determine which diverts to relay to the pilots. Essentially, instead of getting a message with a ‘rapidly growing echo ahead’, pilots would receive a ‘new heading of 040’. This essentially leaves it to the discretion of the pilots when it comes to shooting the gaps between storms.

For this reason, CWSU forecasters noted that it could be very useful to have SRSOR information in the cockpit. As noted in earlier sections, commercial aircraft can cover upwards of ~150 miles (again, highly dependent on aircraft type and size, as well as head/tail winds) during the 15 minute latency of current GOES satellites (30 minutes during Full Disk mode), making the data of little use for short term diversions. However, with only ~10 miles covered in a minute, 1-minute satellite imagery and potentially 30-second satellite imagery use in the cockpit would become much more viable. It would still be a challenge for pilots to examine this imagery from a satellite view when they are flying and looking at it from a vertical perspective, but it was noted that any additional information might prove useful.

International use of 1-minute imagery is different than that of domestic. Currently, the GOES satellites provide a full disk only every three hours. This leaves a 3-hour latency in some areas and limited coverage in the Southern Hemisphere. AWC international forecasters are required to forecast for every corner of the globe. With the potential of having even 15-minute or even 10-minute (with the proposed mode 6) imagery available, there would be a big improvement. Given the extensive domain, the international forecasters see no need for 1-minute imagery over the CONUS sector. They would prefer to drop the high latency in favor of the continuous full disk scans and a lower latency as proposed for mode 6.

Lastly, while most of the focus remained upon training forecasters on utilizing the baseline imagery at higher temporal resolution, there was also some exploration into integrating it into the various derived products, specifically the Cloud Top Cooling and Pseudo Geostationary Lightning Mapper products. It was noted to have potential use, but more in depth evaluation is necessary to determine precisely how. Higher temporal resolution imagery will also be tested with aforementioned FAA tools like the OPC in the future by utilizing Himawari rapid scan imagery.

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

3.8 Simulated 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. The focus of the 2015 demonstration was on the low through mid/high-level water vapor levels (bands 8 – 10; 6.19, 6.95, and 7.34 μm), the clean infrared channel (band 14; 10.35 μm).

Newly available in the 2015 demonstration and also evaluated 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 (figure 1 below). 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.

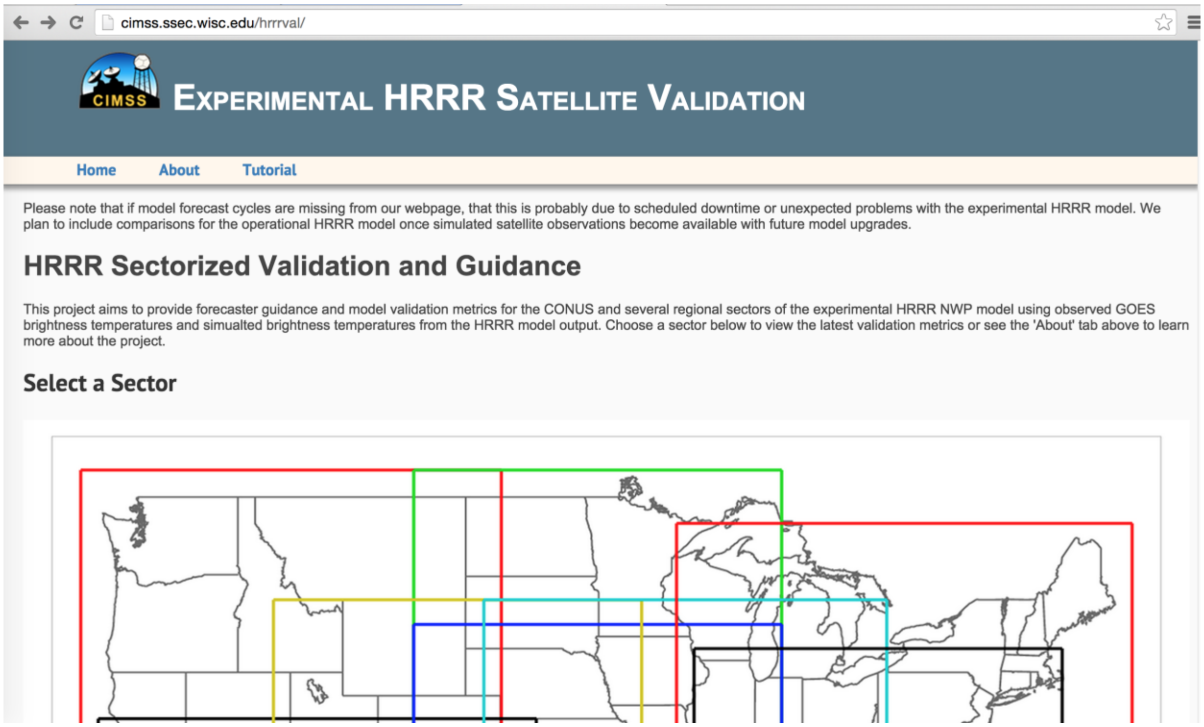

Figure 19. Univ. of Wisc./CIMSS HRRR simulated imagery validation webpage

During this year's demonstration, the evaluation of the simulated imagery was two-fold. Forecasters 1) examined the new simulated imagery from the HRRR-x and its performance and usefulness in forecasting convection, and 2) explored how the capabilities of the GOES-R ABI, specifically the three water vapor bands, could be utilized in AWC operations. The HRRR-x imagery was found to be of particular use for CAWS forecasters. Operational HRRR data is commonly utilized in AWC operations already, giving them some familiarity with its performance and biases. In examining the HRRR-x imagery, forecasters immediately noted that, while it did well in identifying the location of convection, it also appeared to be significantly overdoing the intensity (Fig. 20) in most runs.

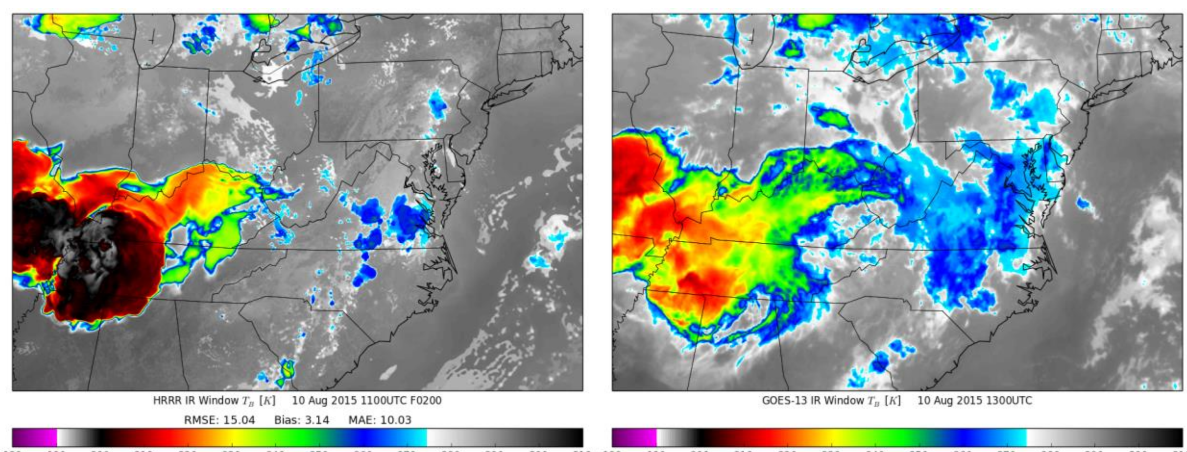

Figure 10. HRRR simulated satellite (left) and current GOES-13 IR imagery (right) comparison display from the HRRR validation website

It is here where the statistics provided on the HRRR validation site became very useful. CAWS forecasters strive to provide the most accurate forecast, both of the time of impact of convection over a terminal, and also the time at which that convection clears enough to lift ground stops or delays.

The statistics available on the site provided a quick way to identify how well the model run performed and if a previous run did better. Below in Figure 21 is an example that occurred during the Summer Experiment on August 10th. Forecasters were anticipating scattered convection in the Southeast later in the afternoon, but likely staying northwest of Atlanta's northern gates until after 20Z. The HRRR-x simulated imagery was utilized to better identify timing and location. As the convection was expected to fire west of Atlanta around 18Z, the 11 – 14Z runs were examined. While the 13Z run showed a more organized are of convection, the 14Z kept it more scattered. However, performance statistics for the 13Z were much better, encouraging forecasters to go with that run instead. By 18Z, visible satellite and PGLM data validated that forecast well.

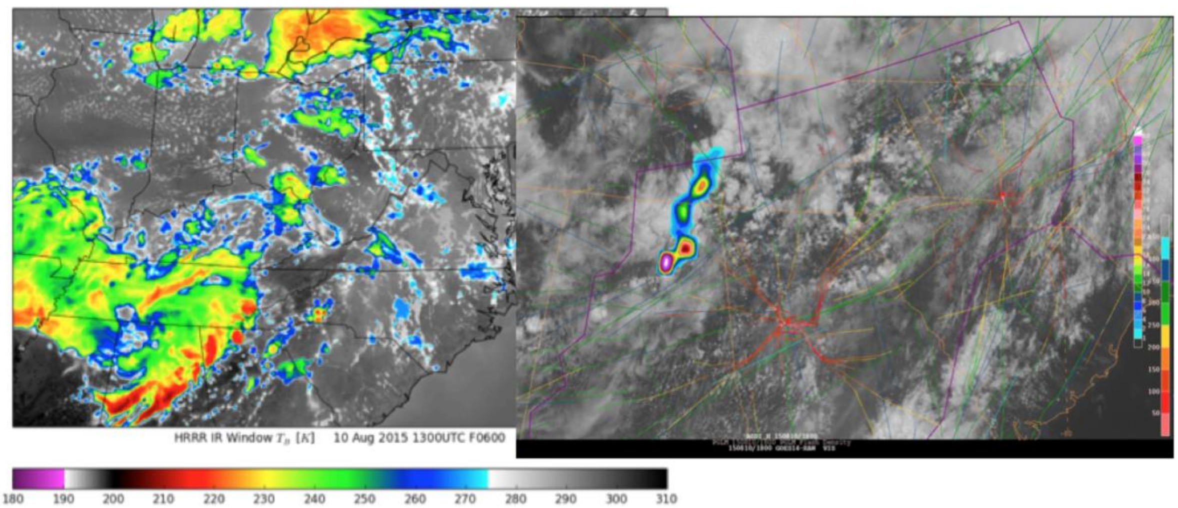

Figure 11. 6-hour forecast from the 1300 UTC simulated HRRR run (left) and visible and PGLM imagery at 1800 UTC (right)

This imagery was utilized often during the Summer Experiment alongside the WRF and NAM simulated imagery, and it was noted that it would be useful for the validation site to contain statistics for the latter two as well. Additionally, forecasters found the side-by-side view of the simulated imagery and real-time GOES images very valuable. With the single panel restriction of N-AWIPS, forecasters are unable to do this on the fly with the current simulated imagery. Having that capability available on the site for WRF and NAM simulated images would be very useful as well.

CWSU forecasters in particular found this imagery helpful. Their AWIPS systems are often tethered to whichever Weather Forecast Office they are nearest to, and subsequently are often plagued with bandwidth issues. For this reason, they often choose to view products in a web browser already, including simulated imagery. The HRRR validation website would be an additional tool for them to utilize and the link was passed on to many of them during their time at the Summer Experiment.

The second concept explored in the 2015 demonstration, as mentioned above, was the potential of the GOES-R ABI for AWC operations. After feedback from last year, forecasters were interested in looking specifically at the three water vapor levels to further identify turbulence features such as building ridges, jets, etc. and subsequently get a better idea of the vertical extent of the turbulence. One such case that was explored occurred on August 18th (Fig. 22)

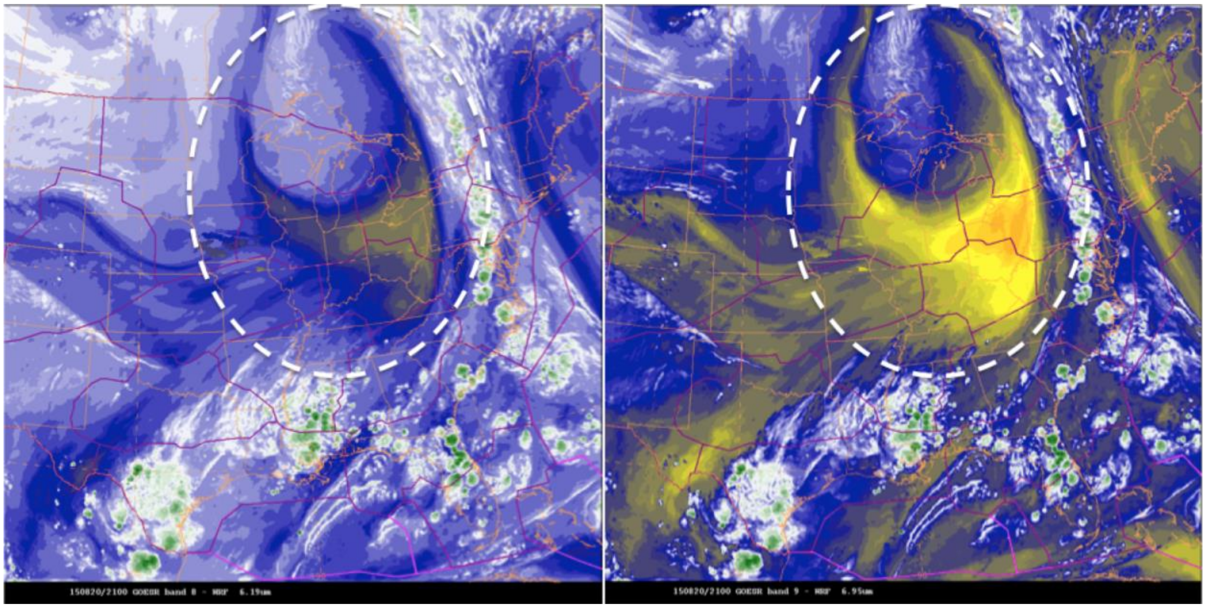

Figure 12. WRF simulated imagery from August 19th; channel 8 high-level water vapor (left) and channel 9 mid-level water vapor (right)

An upper level low was proceeding across the Great Lakes area and forecasters examined the jet features associated with it in the three levels of simulated water vapor. In this case, the western most portion of the jet over Minnesota was much more visible at lower levels, i.e., the drier air did not extend nearly as high, indicating that perhaps the jet would not extend as high in that area either. Therefore, the chance of any turbulence associated with the jet in that area would decrease with altitude. More exploration is needed into this concept, but it does have potential, particularly for areas over open oceans. Also, this evaluation was done with simulated satellite imagery. It was noted that it would be very useful to utilize actual satellite imagery, perhaps GOES sounder information or new Himawari AHI data.

Another challenge with this data comes in integrating it with current tools used to diagnose jet structure. There are GFS and other model fields in NSHARP that display the atmosphere vertically. Instead of examining a number of horizontal fields and attempting to glean a vertical perspective, forecasters have a display of vertical structure in front of them. It was noted that somehow translating the GOES-R ABI water vapor levels into a vertical display would be extremely useful. This concept and other potential ways in which the ABI can be used in AWC operations will be examined in the 2016 AWT demonstration and will utilize both the simulated ABI and Himawari AHI.

3.9 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. During the 2015 demonstration, these satellite-derived winds were evaluated only an in an exploratory sense. The concept was discussed with forecasters for potential use and some cursory evaluation was completed.

There were two main ideas that stemmed from this exploration. The first was the potential of using these winds within the AWC’s international operations. Currently, forecasts for surface winds are issued the Tropical desk and jets at various levels are forecast at both Global Graphics desks for the Significant Weather (SigWx) charts. The latter are required to identify any jets with winds of 50 mph or greater for routing purposes, particularly over major oceanic routes. The biggest challenge with these forecasts is that there is no good method to verify the locations of the jets. Derived satellite winds have the potential to greatly help in this matter, particularly with the expected ten levels of winds available with the GOES-R ABI.

They would be similarly useful for the Tropical desk. Currently an Area Forecast is issued with the forecast surface winds over the Caribbean and Gulf of Mexico. With the future transition of the FA to a more graphic product, surface winds would still be included. The Tropical desk also struggles with wind verification to some extent. During the Summer Experiment the concept of using satellite derived winds, as well as ocean surface winds like ASCAT was explored (Fig 23). There were pros and cons to both. Scatterometer winds like ASCAT are generated from polar satellites, and as such the temporal and spatial resolution limited the usefulness for verification purposes. Satellite-derived motion winds have a good temporal and spatial resolution, but identifying features close enough to the surface to be useful for the Tropical forecast is difficult. However, the concept is still of interest and both types of winds will be further explored in the 2016 demonstration.

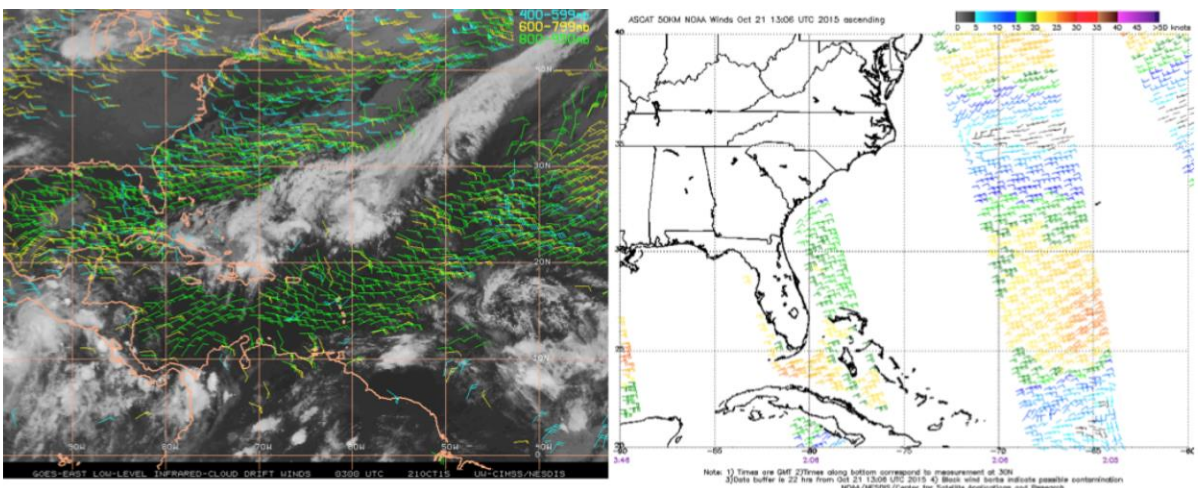

Figure 13. Satellite-derived motion winds and ASCAT winds utilized at the Tropical desk during the Summer Experiment

The second idea that stemmed from the cursory exploration of satellite derived motion winds was the possibility of utilizing them to better identify 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. The potential of utilizing satellite-derived winds to better identify where compression may be an issue is of great interest to forecasters, particularly the NAMs, and will be further explored during the 2016 demonstration.

3.10 VIIRS Imagery - University of Wisconsin Cooperative Institute of Meteorological Satellite Studies (UW-CIMSS), the Cooperative Institute for Research in the Atmosphere (CIRA), and NASA's Short Term Prediction Research and Transition Center

As one of two, world area forecast centers, the AWC is responsible for forecasting over the entire globe, and as such utilizes polar satellites as well as geostationary satellites. The 2014 demonstration looked into the Day/Night Band and several Dust RGBs. In an effort to continue to explore ways in which to utilize polar data in realtime operations while also looking at potential concepts that will be possible with the GOES-R ABI, this year's demonstration looked at Day/Night Band and CIRA's Dust Enhancement RGB. After much positive feedback from last year, the latter was made available in AWC operations (only being available as a web display in the past) and has been utilized on several occasions.

One such case occurred on April 8th. Most often the Dust Enhancement is used to better identify the location of blowing dust for SIGMET issuance. However, on this particular day it actually aided in the decision not to issue anything. As is usual in the spring, an upper level system had set up over the Southwest U.S. and the associated upper level jet had surface winds in the afternoon gusting to 30+ mph, particularly across New Mexico (Fig. 24). The forecaster working the FA desk was expecting these winds to result in blowing dust and by 1800 UTC radar reflectivity was picking up weak echoes. However, surface observations remained clear. At 1940 UTC the first useable MODIS pass and Dust Enhancement image arrived, shown below in Fig. 24. Like the radar, it showed some weak indications of dust in the Four Corners area, but the majority of New Mexico remained clear.

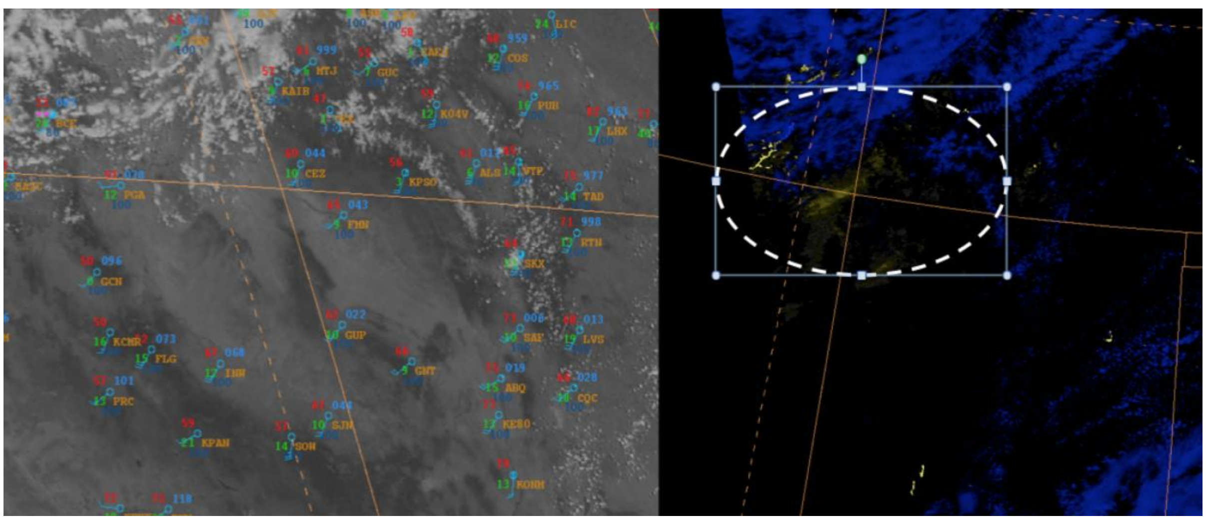

Figure 14. GOES-W visible imagery and observations (left) and MODIS Dust Enhancement imagery (right) over the Four Corners region from April 8th, 2015

Though there may have been some lofted dust, the few weak radar echoes and overall clear surface observations indicated that it was not widespread enough to warrant the need for a SIGMET. The FA forecaster was collaborating with ZAB (Albuquerque Center) during the afternoon and passed on the Dust Enhancement imagery. As the satellite-derived product seemed to be supporting their original assessment and lacked any strong signals, a final decision was made not to issue the SIGMET. Although this ended up as a null case it still showed the value of the satellite-derived imagery as a decision support tool at the AWC. Additionally, while a similar product will be available via the GOES-R ABI, this case also shows how current polar imagery can be used in an operation situation.

The Day/Night Band (DNB) is continuing to be explored at the AWC as well. This band will not be available with the GOES-R ABI, but has been found to be useful in aviation operations. During the 2015 demonstration the product was examined more closely for turbulence forecasting. Strong, deep convection can set off nightglow waves, or ripples caused by chemical reactions high in the atmosphere. These waves emit a faint glow of light that the DNB is sensitive to. One question that arose from visualizing these waves was whether or they could cause clear air turbulence if significant enough.

A case from late April of 2014 was examined (Figure 25 below). Thunderstorms along the Gulf Coast set off widespread nightglow waves. Turbulence Pilot REPorts (PIREPs) were collected for the same event for comparison. The convection occurred at ~0700 UTC, a time during which air traffic is at its lowest over the CONUS. For this reason, only a handful of reports were collected. Most were associated with the convection itself, however one report was of interest. In northwestern Mississippi a fairly large commercial aircraft reported clear air turbulence at FL400. Whether the nightglow waves would reach this low in the atmosphere and cause turbulence, or if the waves even cause turbulence at all is still in question and requires more research. However, this potential concept is of great interest to aviation and will be further explored in the 2016 demonstration along with other ways in which to use the DNB.

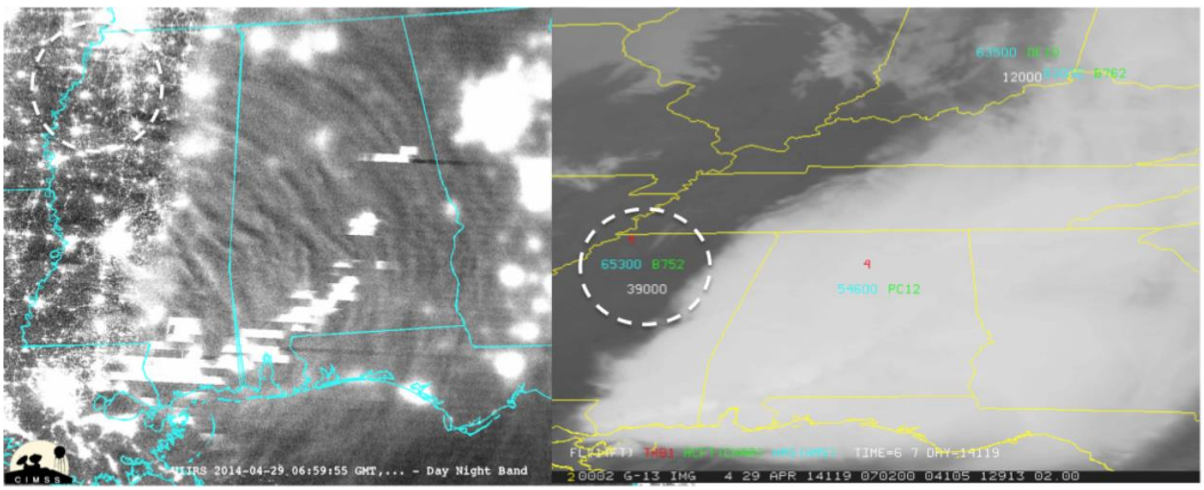

Figure 15. Nightglow waves seen by the Day/Night band on April 29th of 2014 (left) and associated PIREP reports for the same event (right). Red is the turbulence category (4 = moderate clear air), cyan is time, aircraft type is green, and height in feet is yellow

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

The Atmospheric Infrared Sounder (AIRS) is an instrument currently available on the polar-orbiting Aqua spacecraft and measures 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 Total Column Ozone and Ozone Anomaly products, which can aid in identifying regions of warm, dry, ozone-rich stratospheric air. These regions can indicate the possible presence of a stratospheric intrusion or tropopause fold. During the 2015 demonstration, an exploratory evaluation was done with the AIRS ozone products, particularly for turbulence forecasting.

In particular, the AIRS Total Column Ozone was examined with the RGB Airmass product. The Airmass imagery allows forecasters to qualitatively evaluate various airmass characteristics. Red coloring often indicates that a dynamic processes such as a jet streak has caused a stratospheric intrusion, but can also be caused by other thermodynamic conditions that result in dry air. Utilizing it with the Total Column Ozone can aid in quantifying this analysis. Only red/orange colored areas on the airmass imagery that are in close proximity to a mid-latitude cyclone and correlated with higher levels of ozone would be indicative of the presence of stratospheric air. An example of this is shown below in Figure 26.

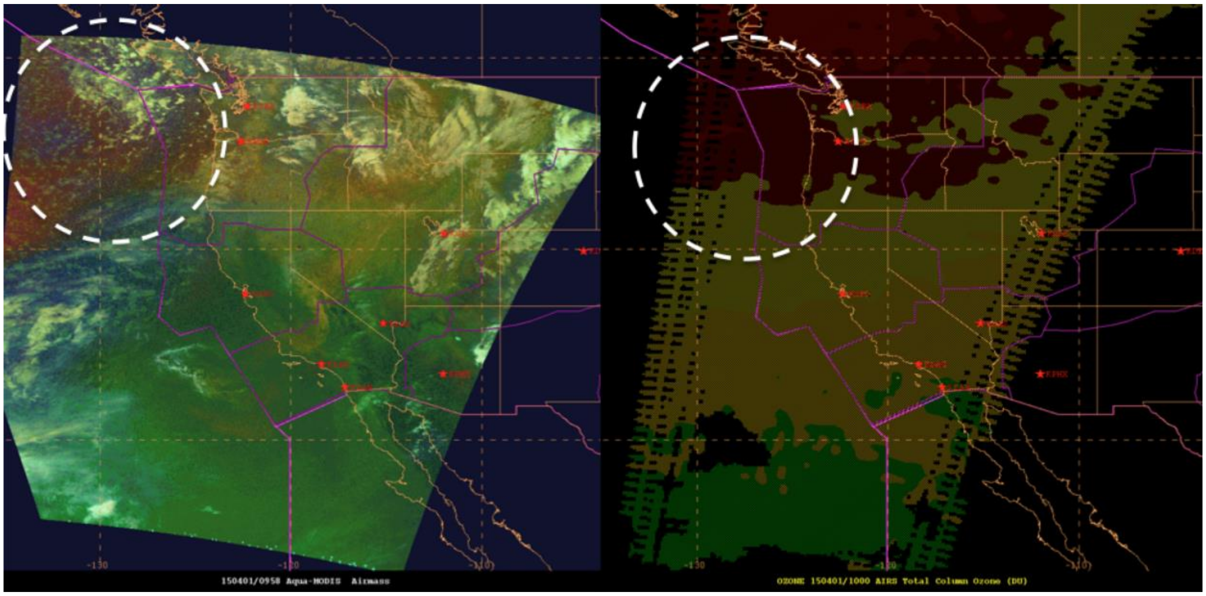

Figure 16. MODIS RGB Airmass (left) and AIRS Total Column Ozone (right). The dashed white cirle represent the area of reddish coloring (i.e. stratospheric intrusion) in the Airmass and higher ozone values in the AIRS imagery

This has a lot of potential use for identifying areas of turbulence, particularly clear air. The above example shows a case in which a system off of the West Coast did result in a stratospheric intrusion. Given the relatively quiet airspace in this region, the turbulence reports were fewer, but several were noted during this time.

Total Ozone and the Ozone Anomaly products by themselves also have the potential to be used to identify areas of high ozone that might impact major flight routes. Ozone can cause flight crew and passenger sickness as well as other issues, and the FAA employs an individual at the ATCSCC to forecast and monitor ozone levels. While it is very difficult to estimate an exact altitude at which the ozone is worst, these products could still be potentially used to narrow down which areas may impacted.

As with any polar imagery, the challenge comes in the spatial and temporal resolution. The Aqua satellite is only available over the CONUS and surrounding waters twice day. Additionally, the latency between the pass and data being received for processing is about 4 hours. This latency makes it very difficult to utilize the AIRS products as real-time situational awareness tools for turbulence forecasting.

The AIRS products will be further explored in the 2016 demonstration period to 1) further examine the potential use in identifying turbulence, and 2) look into ways in which the latency issue can be mitigated.

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. While some evaluation of those products continued this year, several of the baseline products, including Cloud Top Heights, the PGLM when it became available, and to some extent the Synthetic Cloud and Moisture imagery were examined most closely. The demonstration itself was separated into two long-term evaluations, Evaluation Period I and II, and concluded with a two-week, intensive experiment.

Following the successes of the one-on-one training and discussion with forecasters last year, that training method was adopted one again for the 2015 demonstration period. Additionally, several formal training sessions were conducted as a supplement to the on-shift training. After feedback from last year, this formal training was slightly redesigned, putting less focus on the guts of the algorithm and more on aviation based applications. Full details of algorithm generation were still available in a shared archive for those interested in reading through them. However, application based training continues to be the most useful way to introduce a product. Forecasters also continued to suggest providing audio to the '2-minute case studies' as an additional piece of that that application-based training. To that end, a small group was established towards the end of 2014 to kick start this efforts. Unfortunately various union/labor issues with its formation have severely limited the activities that are able to officially take place for the moment. Lastly, feedback regarding the one page quick guides continues to be positive, and they are often utilized in operations. In the next demonstration period it was suggested that these quick guides be updated to include any products that are made available in AWIPS-2 as well as N-AWIPS.

Like in 2014, feedback for the 2015 demonstration period was received via in-depth discussions and blog posts. Some survey questions were provided via Survey Monkey during the Summer Experiment, 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. The anticipated 2016 Winter Experiment may differ, given that the participants in previous winter experiments remained restricted to AWC and CWSU forecasters. If that is the case, some more detailed survey questions may be explored. However, overall for the long-term evaluation, in depth discussion continues to be the preferred method of feedback collection at the AWC.

One product that continues to evolve from this feedback is the Aircraft Flight Icing Threat. Last year a projection change and color bar adjustment were made to improve the aesthetics of the display and forecasters recommended that the NASA LaRC inputs be integrated into the version using only the GOES-R DCOMP inputs. In mid-2015 funding was approved to make this happen. This will add solutions for icing in higher clouds and also provide a merged CONUS view of the product. Sample imagery was available throughout the 2015 demonstrations period and the product, along with the icing layer bases and tops, will be evaluated in more detail at the 2016 Winter Experiment. Additionally, this suite of products will be made available to the Alaska Aviation Weather Unit for demonstration in 2016.

The Cloud Altitudes produced via the ACHA algorithms was perhaps the most heavily evaluated in 2015 and the potential uses for this data continue to expand. Firstly, it continues to be well received among AWC and CWSU forecasters who are involved in forecasting for traffic flow operations. AWDE participants, those will the social sciences perspective on decision making from aviation forecasts, also seemed interested and spawned some interesting discussion on the usefulness of echo tops versus cloud altitudes/tops. CSIG forecasters also have some interest in this concept and it was their feedback in early 2015 that resulted in the development of the Convective Cloud Tops, a new product to be evaluated in 2016. Beyond convection, the Cloud Altitudes were also examined for ceiling and visibility purposes; specifically they were evaluated by those issuing AIRMETs and text Area Forecasts for general aviation pilots. Some aesthetic improvements were suggested for future demonstration. Furthermore, a Cloud Ceiling Height product is being developed to supplement this as well as other ceiling and visibility applications and will be evaluated in 2016. Another concept discussed surrounding the cloud altitudes was its use in identifying Ice Crystal Icing, icing that occurs in the anvil of a thunderstorm. LaRC will be using a form of cloud heights in the development of a satellite-derived ICI algorithm. Lastly, the Cloud Altitudes were given a cursory examination at the AWC's international desks this year and will continued to be examined next year. In the tropical regions of the international forecasting responsibilities, the cloud altitudes have also been provided to the developers of the Offshore Precipitation Capability to further enhance the accuracy of offshore precipitation forecasting.

The Convective Toolkit products have been a part of the AWT demonstrations for quite a few years. As such, forecasters are fairly familiar with them by now and the 2015 evaluation was more focused on their continual use and integration, particularly for the issuance of a CAWS. The majority of these products, the CTC, OT, and CI, were noted not to be of particular use for a CAWS issuance given its 4-hour ideal period. However, if amendments should become the operational norm, these products would become great decision support tools, particularly the CI. Additionally, these products were all examined for their potential as inputs to aviation-based forecast tools like OPC, CIWS, and COSPA. In fact, the CI is currently being utilized in the current operational version of the latter.

Interest in the NearCast Model (which can be used with the Convective Toolkit for further situational awareness) continues to grow, particularly amongst CAWS forecasters. With its 0-9 hour forecast period, this product fits nicely within the 4-hour forecast of a CAWS. When used with other tools, it also can provide valuable information on convective mode and persistence. This is particularly useful in identify the timing, location, and porosity of convection around busy terminals and airspace. Some AWC forecasters are now using the NearCast operationally for CAWS issuance and it is anticipated this will continue in the future.

Lightning detection via the Pseudo Geostationary Lightning Mapper was improved this year through the transition from the area version of the product to one in grid format, allowing this data to be overlaid on satellite and other lightning datasets. It was made available towards the end of the 2015 demonstration period and the convective season, but forecasters have already noted its increased usefulness as a gridded product. Evaluation of this product will continue in 2016.

GOES-14 was once again taken out of storage on two separate occasions in 2015; May 18th – June 12th and August 10th – 21st, the latter corresponding directly with the 2015 Summer Experiment at the AWT. Again, the goal of this imagery is to continue to familiarize forecasters with the temporal resolution of next generation satellite technology. Forecasters evaluated and utilized this imagery throughout both periods, though in more detail during the experiment. The broad scale and fast paced nature of AWC operations continues to make 1-minute a challenge to absorb and use efficiently. However, for some concepts, such as fog/stratus behavior around SFO, real time monitoring of convection around terminals, and perhaps for turbulence forecasting, it still has much potential use. Similarly GeoColor imagery, a new capability from 2014, was another tool developed not only to highlight the capabilities of the next generation imagers like ABI and AHI, but also the potential benefits of GEO/LEO merged imagery. In 2016 both the 1-minute, as well as GEO/LEO capabilities will be further examined.

Simulated satellite imagery continues to be a popular tool amongst forecasters and this year synthetic radiances from the experimental HRRR model were available via the HRRR validation website. Much positive feedback came from the website and the side-by-side HRRR-X/GOES comparison capability. Additionally, forecasters found the available statistics helpful as a way in which to determine which run of the simulated imagery was the most accurate, and more broadly, how the HRRR-x model performed as a whole. Forecasters also examined the three water vapor levels for turbulence forecasts and found that more study is needed, perhaps through use of the Himawari imagery.

A baseline application studied in an exploratory manner was Satellite Derived Motion Winds or AMVs. Many levels of these winds will be available GOES-R and there were several interesting concepts that will be examined in 2016, including the use of these winds for verification of international forecasts and whether these winds can be used to better identify compression issues. Another baseline application that was given a cursory evaluation was AIRS ozone retrievals from MODIS. While this is not GOES-R, it still provided insight on the future potential of ozone-based products possible from the ABI imagery. Not only could the ozone retrievals be used in conjunction with the RGB Airmass to identify turbulence, it also has the potential to help identify areas of high ozone within major flight routes, which can cause flight crew sickness and other issues.

Lastly, several more polar concepts were explored via the VIIRS imagery, including the Dust Enhancement and the Day/Night band. The Dust Enhancement was transitioned to AWC operations early in 2015 with formal training provided to forecasters, and it is now being used in operations in blowing dust events. The Day/Night band has been used on occasion for better identification of fog/stratus over SFO during the night, and it also being explored for the used in clear air turbulence forecasting surrounding nightglow waves. These and other concepts will be pursued in 2016.

More detailed feedback and case examples from the 2015 Demonstration can be found on the GOES-R Proving Ground AWT blog at:
http://goesrawt.blogspot.com/

General information about the 2015 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=2015_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.

Bedka, K., J. Brunner, R. Dworak, W. Feltz, J. Otkin, T. Greenwald, 2010: Objective Satellite-Based Detection of Overshooting Tops Using Infrared Window Channel Brightness Temperature Gradients. J. Appl. Meteor. Climatol., **49**, 181–202.

Bedka, K., R. Dworak, J. Brunner ,and W. Feltz, 2012: Validation of Satellite-Based Objective, Overshooting Cloud Top Detection Methods Using Cloudsat Cloud Profiling Radar Observations. J. Appl. Meteor. and Climatol., In Press.

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.

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

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.

Monette, S. A. and Velden, C. S. 2012: Examining Trends in Satellite-Detected Tropical Overshooting Tops as a Potential Predictor of Tropical Cyclone Rapid Intensification. *J. Appl. Meteor. Climatol.*, **51**, 1917-1930

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

Walker, J.R., W.M. MacKenzie, Jr., J.R. Mecikalski, and C.P. Jewett, 2012:An Enhanced Geostationary Satellite-based Convective Initiation Algorithm for 0-2 Hour Nowcasting with Object Tracking. *J.Appl.Meteor.Climatol*. **51**. 1931-1949