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Use of GOES-16 Imagery and Products in the NOAA/National Weather Service Storm Prediction Center (SPC) and Hazardous Weather Testbed (HWT)

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Abstract

With the launch of the first satellite in the Geostationary Operational Environmental Satellite - R (GOES-R) series in November of 2016, the next generation of satellite data began flowing to forecasters across the United States. The increases in temporal and spatial resolution, along with vast improvements in spectral coverage have made GOES-R, now GOES-16, very important in monitoring severe convection across the contiguous United States. The Storm Prediction Center (SPC), responsible for the forecasting of severe weather across the US, is one of the many primary users of this data.

Another user and evaluator of the GOES-16 imagery and products is the Hazardous Weather Testbed, or HWT, located adjacent to the SPC in Norman, Oklahoma. Each year for most of the last decade the GOES-R Proving Ground (Goodman et al. 2012) has held experiments in the HWT, called the Experimental Warning Program (EWP) Spring Experiment, to test out new products and familiarize forecasters with the vast amount of new products available in the GOES-R era. During the Spring Experiment, the GOES-R Proving Ground conducts a demonstration of recently developed experimental products and capabilities alongside a forecaster's standard operational datasets and products. These experimental products are associated with next generation geostationary (GOES-R) and polar orbiting (JPSS) satellites. This experiment was initially designed to increase forecaster familiarity with the future GOES-R capabilities that would be available across the National Weather Service. In this way, EWP forecasters were readied for receipt and use of the GOES-R data prior to the launch of the first satellite in the series (GOES-R) which occurred on November 19, 2016. Now that the satellite is operational, the focus of the experiment has shifted to evaluating the products and capabilities of the satellite in a real time simulated operational environment and providing feedback to the product developers and to the National Weather Service. Additionally, feedback received from participants each year is utilized in the continued development of GOES-R/JPSS algorithms to improve the products for future operational use by forecasters in the local forecast offices as part of their daily routine. Use of this data in both the SPC and HWT Spring Experiment by National Weather Service (NWS) forecasters is presented.

Introduction

The HWT provides a place where product developers can observe their products being used in an operational environment by a NWS forecaster. They can interact directly with the users of the product during a real time convective weather event across the United States. Feedback received from the forecasters leads to continued modifications and development of the products to be used within operation in the future as part of the Research to Operation/Operations to Research (R2O2R) process. The training and education received by the forecasters also helps to ensure readiness for the GOES-R series and JPSS series data in their operational workflow.

The mission of the EWP is to improve the prediction of severe convective weather at the warning scale (0-2 hours). This happens by simulating a real operational environment for the forecaster and demonstrate new and experimental products for the forecasters to use in their warning environment. Norman is unique in that a large community of researchers, operational meteorologists, students, and private industry are all located within the same building, or block of buildings. The aim is to serve all of the NWS WFOs and CWSUs nationwide, Most of all, this testbed is a vital component in the R2O2R process where new products can be demonstrated in a real time system by real time forecasters which provide feedback to those developers on ways to improve the product for use by all eventually in NWS operations.

Figure 1: Forecasters participating in the Spring Experiment in the HWT.

The 2018 HWT EWP Spring Experiment

In 2018, the GOES-R/JPSS Proving Ground activities were conducted during the weeks of April 30, May 7, May 14, and May 21 with five NWS forecasters participating for the first week and three NWS forecasters and one broadcast meteorologist participating each week for the following three weeks. In an effort to extend the satellite knowledge and participation to the broader meteorological community, and to recognize the critical role played by the private sector in communicating warnings to the public, broadcast meteorologists sponsored by the GOES-R Program participated in the Spring Experiment for the fifth year in a row, working alongside NWS forecasters. Training modules for each demonstrated product were sent to and completed by participants prior to their arrival in Norman. Each week, participants arrived in Norman on Sunday, worked eight hour experimental warning shifts Monday-Thursday and a half-day on Friday before traveling home Friday afternoon.

Shifts typically began a couple of hours before convective initiation was expected to occur as many of the products demonstrated this year have their greatest utility in the pre-convective environment. At the start of each Monday-Thursday experimental warning shift, the weekly coordinator interrogated the large scale weather pattern across the CONUS and determined where to operate for the day. Forecasters, working in pairs, provided experimental short-term forecasts for their assigned County Warning Area (CWA) via a blog (www.goesrhwt.blogspot.com). Early in the shift, these were primarily mesoscale forecasts discussing the environment, where convection was expected to occur, and what the applicable demonstration products were showing. Once convection began to mature, one forecaster in the pair would switch to issuing experimental warnings for their CWA while the other forecaster would continue to monitor the mesoscale environment and compose blog posts. Blog posts regarding the use of demonstration products in the warning decision-making process were written during this period along with continued updates on the mesoscale environment.

The products demonstrated in the 2018 experiment are listed below:

- GOES-16 Advanced Baseline Imager (ABI) Imagery, Baseline Derived Products, Channel Differences, and RGBs.
- ProbSevere All Hazards Model
- NUCAPS Temperature and Moisture Profiles (JPSS)
- GOES-16 Geostationary Lightning Mapper (GLM)
- All-Sky LAP TPW, Layered PW, and Stability Indices
- GOES-16 Convective Initiation Probability

A few cases will be highlighted featuring the GOES-16 imagery and products as well as cases from the Geostationary Lightning Mapper (GLM).

The GOES-16 products played an important role in forecasting for a convective event in the Des Moines, Iowa, area on 3 May 2018. The forecaster noted a closed upper low moving across southern Nebraska early in the afternoon from upper-level water vapor imagery (Fig. 2a). Visible imagery showed low clouds across much of the County Warning Area (CWA), with some more vigorous cumulus clouds beginning to develop across the far southern portions of the CWA in the clear warm sector. GOES-16 derived-motion winds revealed a 110+ knot southwest-to-northeast-oriented jet core at 300 mb across Iowa with another jet core advancing into southern Iowa throughout the afternoon from northern Missouri, which agreed with the GFS forecast for the area. Winds in the 750mb to 850mb layer were generally 20 knots on average across the area with slightly stronger winds advancing into the southern portions of the CWA implying increased low-level warm air advection (Fig. 2b). These observations helped increase confidence for convective initiations across the southern portion of the CWA later in the afternoon with increasing lift arriving into the region. The forecaster also noted looking at the derived stability indices for the event, but due to large cloud cover there was not much to be determined, however the All-sky version did show some increasing values of CAPE also moving into the region from the south, though the values were underdone.

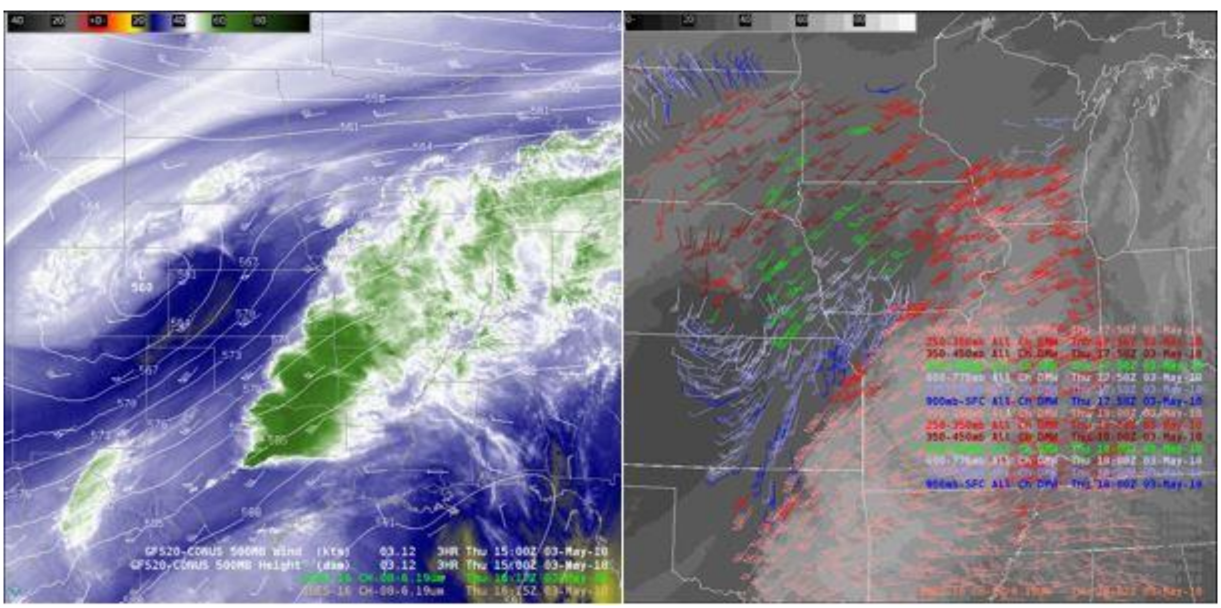

Figure 2: (a. left)1617 UTC 03 May 2018 GOES-16 6.19um “upper-level water vapor” imagery with GFS 500mb heights (white contour) and winds (white wind barbs) and (b. right) 1800 UTC 03 May 2018 GOES-16 Derived Motion Winds (colored by height, blue – low-level, green – mid-level, and red – upper-level) with GOES-16 6.19um “upper-level water vapor” imagery (gray scale)

The imagery and products were also used heavily by forecasters for monitoring convective trends in storms once initiation had occurred. Some of these trends include watching for convective initiation in the one minute visible satellite data along with monitoring storm top properties and features such as overshooting tops (OTs) and above anvil cirrus plumes (Fig. 3). The imagery also played an important role for the forecasters assessing relative storm strength and severity and for monitoring for further convective growth or decay.

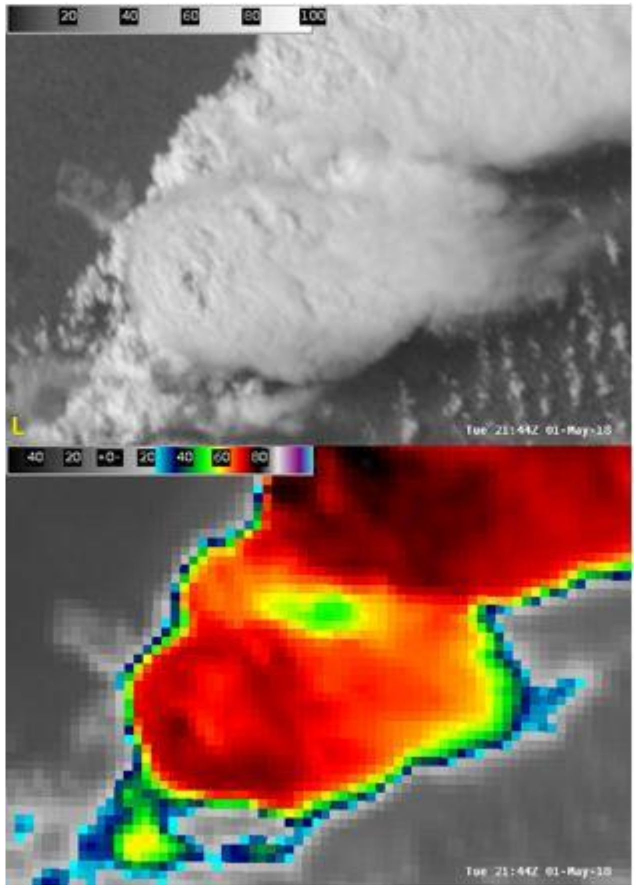

Figure 3: 2144 UTC 01 May 2018 GOES-16 0.64um "Red" Visible Imagery with 10.35um "Clean" IR Window Imagery over Southwestern Kansas.

Another important suite of products that forecasters evaluated during the experiment were the GLM Total Lightning Products. A group of separate products were presented to the forecasters for their use and feedback. The products used most by forecasters and seen as most useful within operations were the Flash Extent Density at intervals of both five minute accumulation with one minute updates and two minute accumulation with one minute update. The total energy and average flash area products were also seen as extremely valuable to NWS operations and warnings.

Many forecasters chose to utilize the Flash Extent Density either at 2-min or 5-min summations to maintain awareness of storm activity across the area of interest. This was particularly useful in areas where other data sources are sparse or not available such as over the ocean or other areas where there is no radar coverage (Fig 4). It is important for aviation and shipping purposes to be able to identify regions of thunderstorms in these regions for safety of the public. Forecasters found that Flash Extent Density, particularly when summed across multiple minutes, could provide easily understood guidance on the strongest cells or call attention to quickly intensifying storms cells at a glance. Some forecasters also utilized the flash energy product for this purpose.

Forecasters continuously stressed the importance of seeing the GLM data across multiple products (specifically Flash Extent Density, Total Energy, and Flash Area) and in context of other data for a better understanding of both the lightning data itself and using it to better estimate convective strength. Group discussions with forecasters commonly mentioned how a single product such as Flash Extent Density could provide some information about a flash and potentially about storm behavior. However, pairing Flash Extent Density with Flash Area allowed forecasters to more easily diagnose convective specifics, for example, identifying long flashes through the stratiform region (Fig. 5). This is again important, especially to emergency management and other public safety services. The GLM is able to show the full extent of lightning flashes within the cloud, which can come to the ground at any point, providing valuable information to help keep people safe at events or in airplanes across the country.

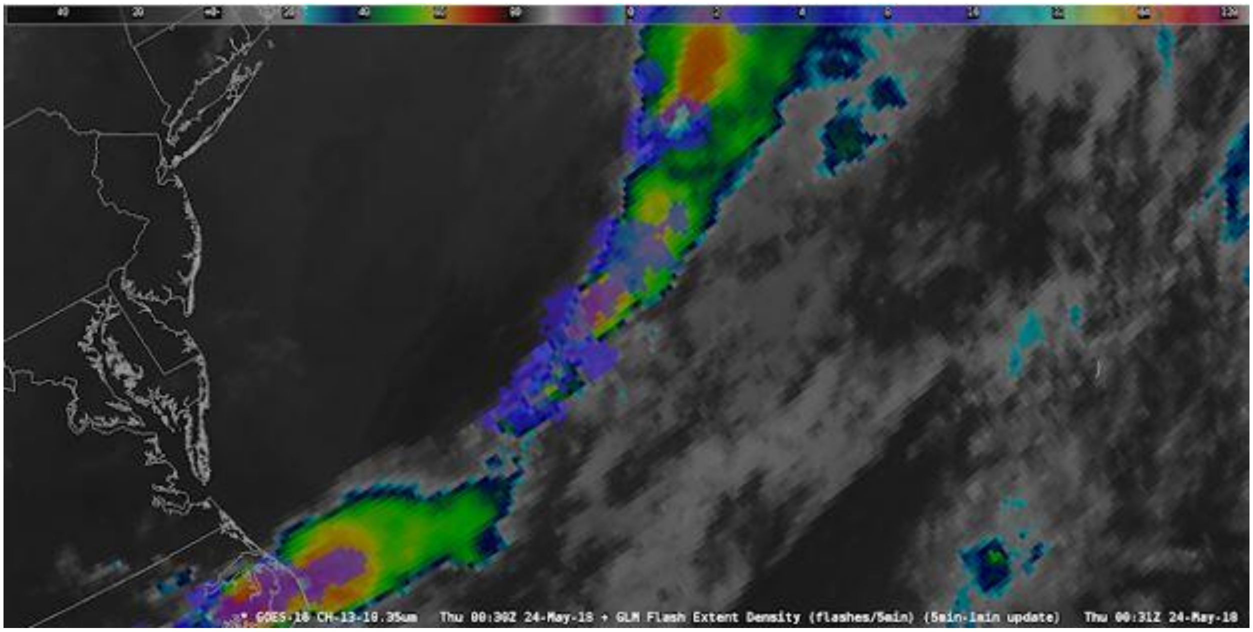

Figure 4: GLM 5 minute Flash Extent Density overlaid on GOES-16 10.35um IR imagery over the Atlantic Ocean off the East Coast of the United States

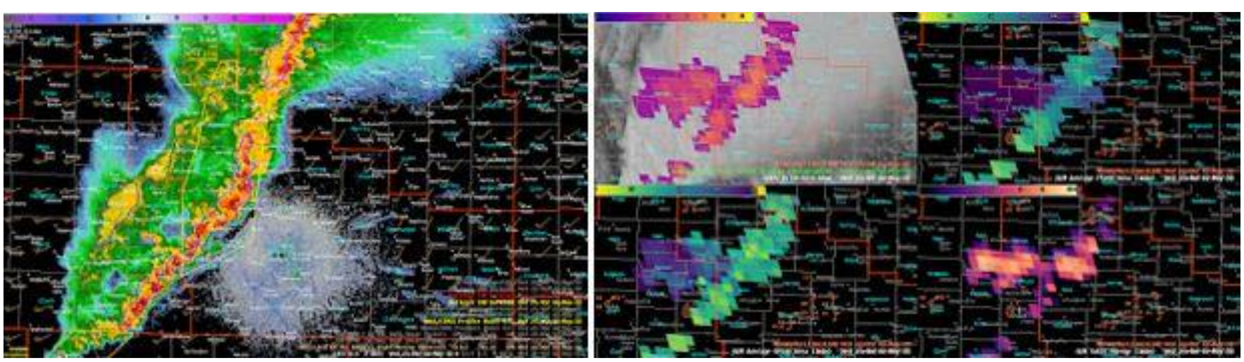

Figure 5: (left), Radar reflectivity of a squall line with a large trailing stratiform region and (right), 4 panel layout of GLM 1 minute flash extent density (upper left), average flash area (upper right), average group area (lower left), and total energy (lower right) showing the extent of lightning well back into the stratiform region of the line away from the convective cores.

Additionally, higher flash rates associated with the smaller flash sizes helped forecasters identify new or intensifying updraft regions within a longer convective lines. This along with the identification of the so called “lightning jump” (Schultz et al. 2009) aided in signaling a strengthening updraft and was often a precursor to rapid storm intensification from both satellite and radar data. This combination of new data provided forecasters additional understanding of how storms were evolving throughout a convective event.

Use of GOES-16 in the SPC

Since the launch of GOES-R in late 2016 the Storm Prediction Center, responsible for all of the convective forecasting for the contiguous United States (CONUS), has been receiving data since early in 2017. The substantial improvements over previous series of geostationary satellites has led to satellite data being used more heavily in the SPC than before. Forecasters have commented that the increase in spatial resolution of the visible and IR channels as well as the increase in temporal resolution to five minutes over the CONUS with one minute mesoscale sectors has been a big improvement for convective forecasting and analysis over the last two years. The imagery is used heavily for forecasting of convective in hours to days in advance. The addition of three water vapor channels (Fig. 6) has allowed forecasters to discern atmospheric features more easily which otherwise would not be able to be observed from previous satellites. In the example shown in Figure 6, the forecaster noticed the two upper level water vapor channels showed a anticyclonic wave moving across the Midwest US, but when looking at the low level water vapor, he noticed that there was a cyclonic MCV from overnight convection embedded within the upper level anticyclonic flow. This gave the forecaster confidence that downstream convection could initiate later in the day as this vortex advanced across the region into a more unstable air mass.

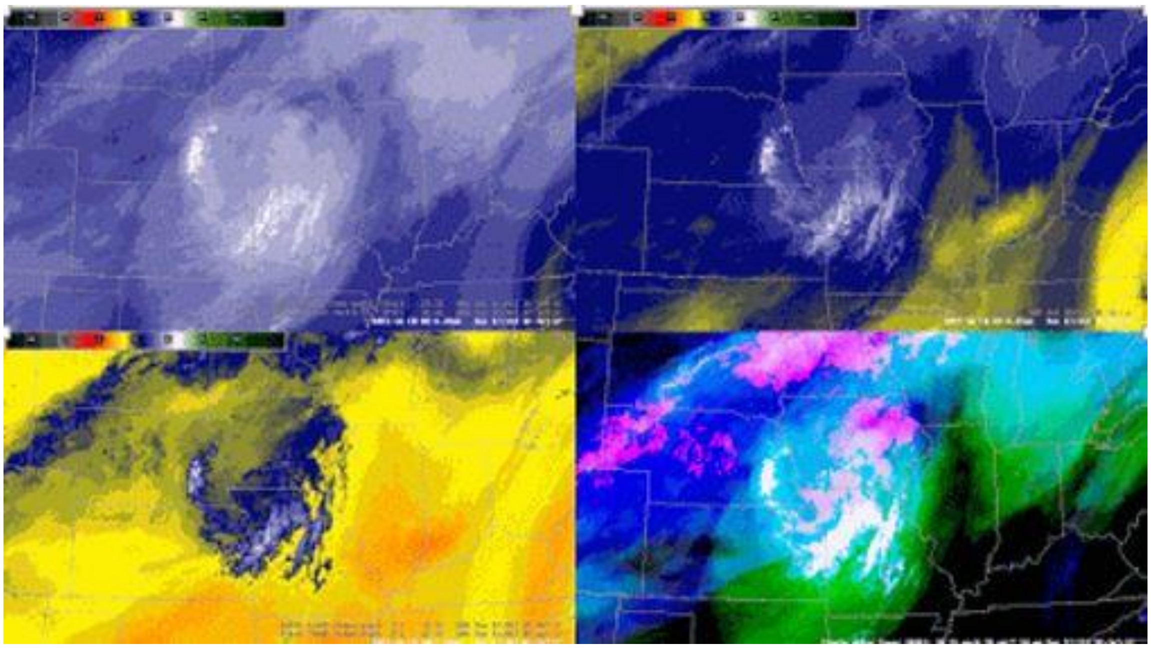

Figure 6: 4 panel layout with 6.2um “upper level WV” (upper left), 6.9um “mid-level WV” (upper right), 7.3um “low-level WV” (lower left), and the Simple Water Vapor RGB (lower right)

The forecasters also use the satellite data heavily when issuing their short term mesoscale discussions and when issuing severe thunderstorm and tornado watches. Prior to convective initiation, satellite data is the main source of information when monitoring for convective development. An example of a mesoscale discussion issued by an SPC forecaster is shown in Figure 7, which highlights the use of this data in a real time environment. Forecasters have found using the IR data at night has provided a drastic improvement as well. Being able to better monitor ongoing convection in the absence of visible imagery is very important for keeping track of severe thunderstorms. Also, being able to monitor for convective initiation at night using Infrared imagery has drastically improved with the temporal and spatial improvements seen with GOES-16. Some forecasters have said that it is so good, it’s like having visible data at night. The imagery has also proved useful for seeing and tracking low-level boundaries which may be important for convective development as well as monitoring cloud top properties related to convective growth or decay. With GOES-16, forecasters are also able to see updrafts through thin cirrus which is something not seen before with the previous GOES. Overall, this imagery has led to very positive feedback and improvement of convective monitoring from forecasters in the SPC.

DISCUSSION...One-minute visible imagery exhibits several fields of maturing/towering cumulus across the region this afternoon. The primary corridor for more rapid development exists from the Black Hills southeastward along a weak surface trough, where satellite and radar already have shown a few initial attempts at deep convective initiation. An 18Z UNR sounding sampled warm 700mb temperatures associated with the base of an EML, currently limiting convective growth away from higher terrain. Therefore, initial development should remain rooted to the Black Hills. However, gradual moistening/cooling aloft will overspread the region from the west and increase convective potential at lower elevations through the afternoon.

Figure 7: SPC Mesoscale Discussion showing 1 minute satellite data use in monitoring for convective initiation

Another of the new products used pretty extensively at SPC is a suite of RGB products. The two RGBs used most at this point in operations is the Nighttime Microphysics RGB for monitoring fog and low clouds at night prior to visible imagery being available and the Fire Temperature RGB. The Nighttime Microphysics RGB aids forecaster is analyzing areas of fog or thick low clouds which could be slow to dissipate during the day and thus inhibit destabilization of the boundary layer which could hinder convective development. SPC also has fire weather forecasting responsibilities across the CONUS and the Fire Temperature RGB has come in useful for monitoring wildland fires and showing where there are ongoing fires across the region (Fig. 8).

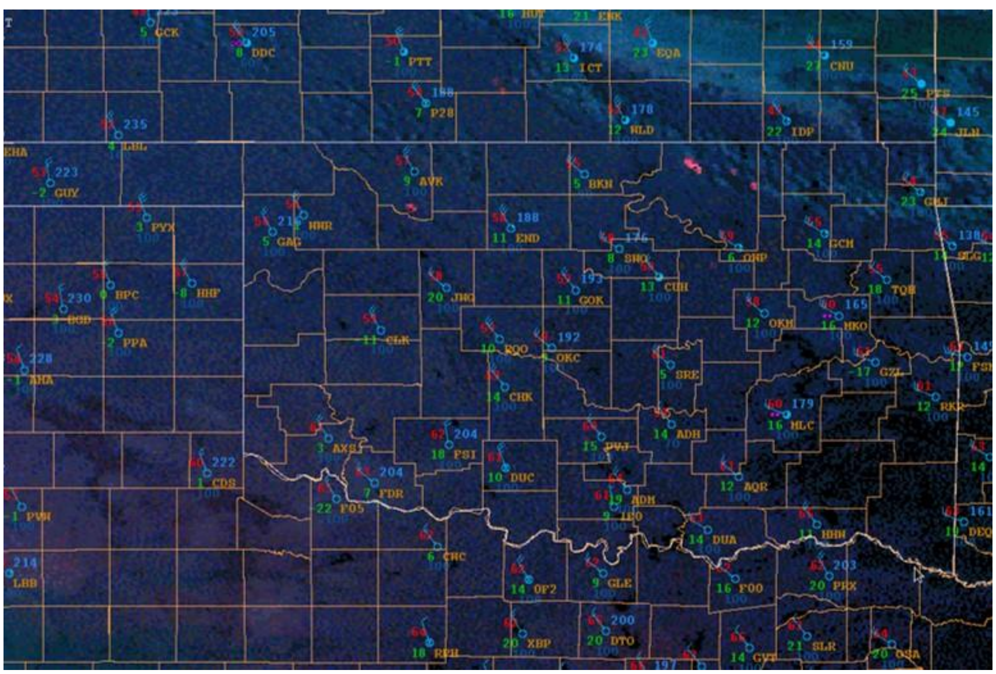

Figure 8: Fire Temperature RGB from GOES-16 showing a few wildfires ongoing across northern Oklahoma, shown in the red pixels. This is one of the tools used by SPC forecasters to monitor wildfires across the United States.

Summary

In 2018, the GOES-R/JPSS Proving Ground activities were conducted during the weeks of April 30, May 7, May 14, and May 21 with five NWS forecasters participating for the first week and three NWS forecasters and one broadcast meteorologist participating each week for the following three weeks. The forecasters utilized the new capabilities of the GOES-16 satellite extensively during this testbed experiment and showed many of the uses of this data during warning operations. The data aided forecasters in the forecasting and monitoring of severe convection across the United States. The new spatial and temporal resolution of the imagery proved to be most beneficial, especially the use of 1-minute mesoscale sectors for convective initiation monitoring, as well as for watching storm tops for further convective growth or decay of updrafts. The GLM data also proved to be very beneficial and was used to monitor for convection in data sparse areas and offshore over the oceans. This was important for aviation forecasting and safety for the general public during outdoor events. One of the best qualities of the GLM instrument is to be able to see the spatial extent of lightning within the cloud, with flashes often extending well out into the anvil and stratiform regions of convective storms and complexes. Being able to see the extent of lightning will be huge for public safety as often times people are most struck by lightning by bolts from these anvil or stratiform regions, or areas of lighter precipitation when people are most likely to not seek shelter.

The new satellite data has also been used heavily in the Storm Prediction Center since early 2017 and has shown many benefits to forecasters using the data for convective forecasting. Again, the increases in spatial and temporal resolution, especially for the IR channels has proved to be the most appreciated benefit for monitoring for convective initiation and growth. The SPC has also used some of the RGB products, especially to aid in the fire weather forecasting responsibilities. Overall, the addition of the GOES-R series data has improved forecaster use of satellite data in operations and increased forecaster confidence during convective and fire weather situations.

References

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