

VIIRS and MODIS Multi-Spectral Imagery Assessment for Aviation Weather and Cloud Analysis – 2013-14, Fall / Winter

Introduction

This report describes the 2013/14 assessment of multi-spectral imagery produced by the NASA Short-term Prediction, Research, and Transition (SPoRT) Program from the MODIS and VIIRS polar-orbiting instruments for application by its Weather Forecast Office (WFO) collaborators within the NWS Southern and Eastern Regions. The report is intended for NOAA and NASA program managers, operational forecasters, product developers, other institutions participating in JPSS and GOES-R Proving Ground and research-to-operations activities, and the general satellite remote sensing community.

Products evaluated include the Day-Night Band (DNB) Red, Green, Blue (RGB) composite imagery, the Nighttime Microphysics (NTmicro) RGB, and the SPoRT Hybrid GEO/LEO 11-3.9 μ product. The DNB RGB imagery is only available from Suomi National Polar-orbiting Partnership (NPP) VIIRS instrument. The product combines the DNB channel itself with the 11 μ infrared (IR) channel similar to a daytime RGB product developed by NESDIS that uses the GOES visible and infrared channels to differentiate high and low cloud features while providing high-resolution detail of the cloud structure. The NTmicro RGB is created using a combination of short and longwave IR channels and channel differences based on the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT) “RGB Best Practices” (2012) recipes derived from operational use of the Spinning Enhanced Visible InfraRed Imager (SEVIRI) launched in 2002. The NTmicro RGB imagery from MODIS and VIIRS provide a near real-time product similar to the future Advanced Baseline Imager (ABI) instrument on GOES-R. The SPoRT GEO/LEO Hybrid 11-3.9 μ difference imagery uses 4km GOES imagery and then replaces portions of this base image with the same spectral difference from 1km MODIS and VIIRS imagery. Several of SPoRT’s WFO collaborators have used the Hybrid 11-3.9 μ previously, but it was included in this assessment for comparison to the NTmicro RGB which uses this same channel difference as the “green” component of the RGB composite. The DNB and NTmicro RGBs provide enhanced capabilities to the analysis of clouds at night through their ability to depict the structure, thickness, and thermal characteristics of cloud features within a single image.

Low clouds and fog can present significant ceiling and visibility hazards to aircraft operations. NWS WFOs responsible for short-term forecasts at specific airports (i.e. Terminal Aerodrome Forecast (TAF)) within their warning area rely on accurate information concerning both the spatial extent and timing of hazards that may affect aviation operations at these locations. GOES 11-3.9 μ difference imagery has traditionally been used to analyze and track low clouds and fog at night to support the preparation and amendment of TAFs. The DNB and NTmicro RGB products provide additional information within a single image to increase the forecaster’s awareness of cloud characteristics that apply to aviation hazards. In particular, the NTmicro RGB contains additional channels in order to help differentiate low clouds from fog which is not readily apparent using the traditional 11-3.9 μ imagery. Although MODIS and VIIRS products are only available a few times per night for a given location, the assessment aimed to determine the value added to the short-term forecast of ceiling and visibility, particularly as they apply

to the TAF at both inland and coastal WFOs. In addition, the assessment served to expose forecasters to the application of complex, multi-spectral imagery (i.e. RGB composite), and hence, the future paradigm of satellite imagery that will be seen in the JPSS and GOES-R era. The assessment also provides benefit to GOES-R product developers via pre-launch feedback from users of current instruments that can produce RGB imagery and how to best deliver products that help meet aviation forecast needs.

The assessment was conducted in two periods. For coastal WFOs in the NWS Southern Region, users evaluated the above products from 1 December 2013 through 31 January 2014, coinciding with the regional climatology of high frequency IFR and LIFR events. Similarly, inland WFOs within the NWS Southern and Eastern Regions evaluated the products from 15 September to 31 October 2013. The participating WFOs and the number of user feedback submissions via an online “2-minute survey” of 10 questions (mostly multiple choice) is shown in Figure 1.

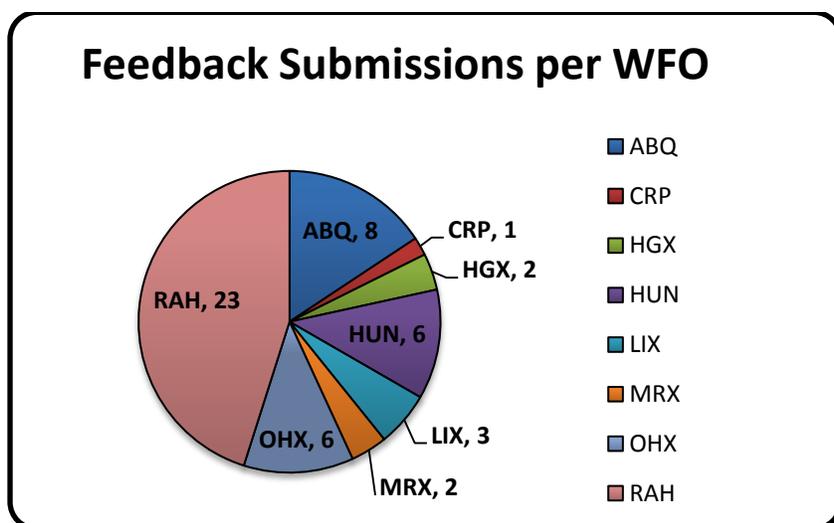


Figure 1. A total of 51 submissions via online user feedback form were provided during the assessment by forecasters to SPoRT. Participating WFOs are listed on the right via 3-letter abbreviation and the number of submissions per office is shown next to the WFO within the pie chart. Abbreviations include ABQ: Albuquerque, CRP: Corpus Christi, HGX: Houston/Galveston, HUN: Huntsville, LIX: Slidell, MRX: Morristown/Knoxville, OHX: Nashville, RAH: Raleigh.

NWS forecasters provided feedback via the online survey or blog posts after viewing data within their native display system for a relevant event where products were used to support aviation hazards and cloud analysis. The report will include a product description, the methodology used for this assessment work, a discussion of results from user feedback, and a summary with recommendations. Although the report is written by SPoRT personnel, feedback and input from each of the WFOs was encouraged.

Product Description

All of the products used during this assessment period are derived from the Moderate Resolution Imaging Spectroradiometer (MODIS) aboard the NASA Terra and Aqua satellites, and the Visible Infrared Imaging Radiometer Suite (VIIRS) aboard the Suomi National Polar-orbiting Partnership (S-NPP) satellite. MODIS observes the Earth using 36 spectral bands. Each polar-orbiter provides a daytime and a nighttime set of passes across the CONUS domain in a 24 hour period. (For more information, please visit <http://modis.gsfc.nasa.gov/> or <http://weather.msfc.nasa.gov/sport/modis/>). VIIRS observes the

Earth and its atmosphere at 22 visible and infrared wavelengths and follows a similar schedule to NASA Aqua (For more information, please visit <http://www.raytheon.com/capabilities/products/viirs/> or <http://weather.msfc.nasa.gov/sport/jpsspg/viirs.html>). A short description of products used during the assessment is as follows:

SPoRT Hybrid GEO/LEO 11-3.9 μ :

The spectral difference product, also known as the thermal difference or fog product, is produced by differencing the brightness temperatures in the 11 μ and 3.9 μ channels. This technique highlights differences in the thermal emissivity between water clouds (3.9 μ) and the surface temperature (11 μ) (Elrod 1995), where the surface is the cloud top temperature or the land surface if clear. Using a predefined temperature difference threshold (2.5K), the resultant imagery produces shades of blue for smaller differences representing high, ice-crystal clouds and shades of yellow for larger differences corresponding to fog and low clouds. Users are familiar with this product (although color enhancements vary) from the current GOES imager with 4km resolution (i.e. GEO imagery), however, polar-orbiting MODIS and VIIRS instruments (LEO imagery) are able to better discern mesoscale cloud features due to their 1km or better resolution. While forecasters recognize the value of the improved resolution, the infrequent passes of LEO instruments make it difficult to view a time series (i.e. loop) of the imagery. In order to have continuity both in space and time, NASA SPoRT has developed a technique to embed LEO-based imagery from the VIIRS and MODIS instruments within standard GEO imagery, referred to as the SPoRT Hybrid GEO/LEO 11-3.9 μ imagery (see Figs. 2 and 3). This allows infrequent, LEO imagery to be viewed in a loop while providing context via standard GEO imagery both at the time of the LEO pass (in areas not covered by the MODIS and VIIRS instruments) as well as in between LEO passes (when no MODIS or VIIRS data exists).

Insertion of LEO imagery within a corresponding GEO image provides context of cloud features with which forecasters have familiarity, helping with the application process and easing the burden of identifying features in single frame imagery. Further, by fusing LEO data it into the GEO imagery, there is no requirement for the forecaster to remember when a particular LEO pass will be available. There are two items to keep in mind when using this product. First, this product is only valid at night for fog detection. Secondly, regions of multi-layered stratus clouds could be indicated as fog, when fog may not actually be present.

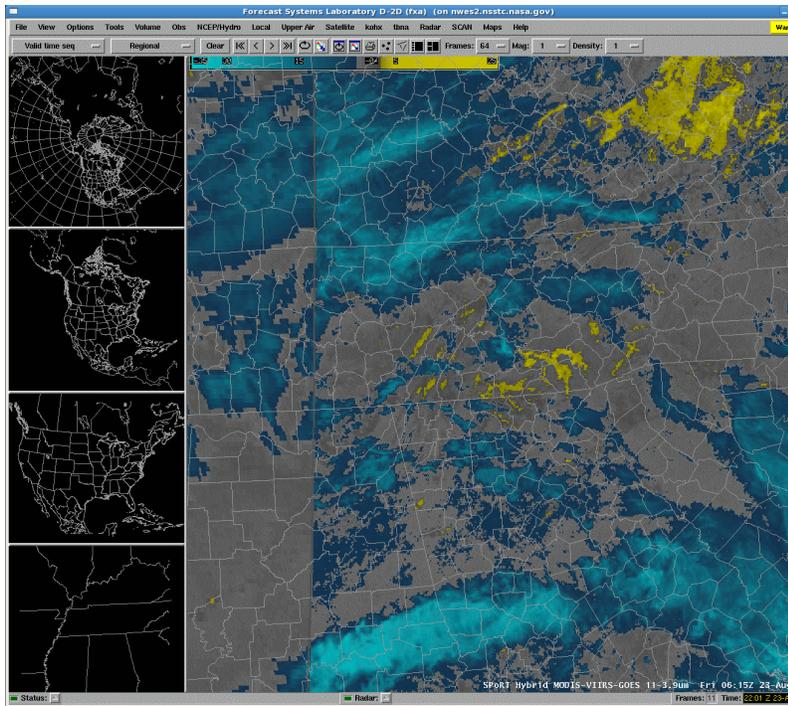


Figure 2. SPoRT Hybrid GEO/LEO 11-3.9 μ imagery within AWIPS/D-2d for 0615 UTC on 23 August 2013. VIIRS data is on the right side of the image while GOES fills in the rest of the scene on the left. Details in high and low cloud features are more readily apparent within the VIIRS swath area compared to GOES data near this same time (see Figure 3)

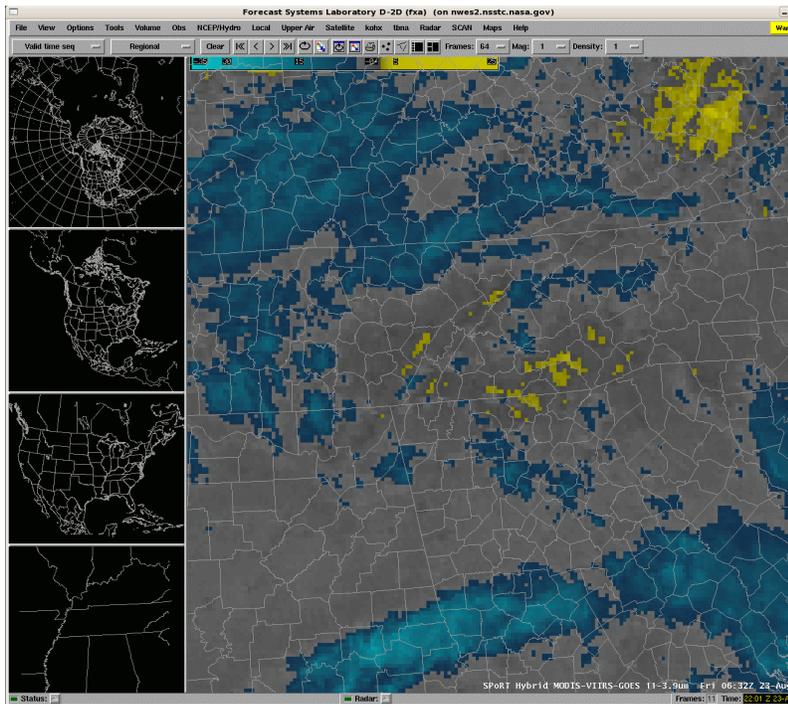


Figure 3. SPoRT Hybrid GEO/LEO 11-3.9 μ imagery within AWIPS/D-2d for 0632 UTC on 23 August 2013. Only GOES data is available at this time, however this continues to show the progression of low and high cloud features seen in the previous image where high-resolution data was available (see Figure 2.)

VIIRS Day-Night Band Radiance and Reflectance RGBs:

The VIIRS low-light channel (a.k.a. day-night band or DNB) provides a night-time image of reflected and emitted light, but with the resolution of day-time visible imagery. Analogous to how visible imagery senses reflected sunlight, the DNB senses reflected moonlight and can be used to detect small-scale features at night that are not as readily seen in standard IR channels. The DNB radiance is the raw image from the sensor of emitted and reflected light. Because the cities lights are far brighter than reflected moonlight, the clouds can appear very faint while ground sources appear very bright. The DNB radiance is normalized by the available amount of moonlight (phase and angle) in order to focus on the reflected portion of the imagery and hence create the “DNB Reflectance” product (Figure 4).

Normalizing provides a more consistent brightness in the resulting image throughout the moon cycle. The RGB products that incorporate the DNB radiance and reflectance were developed by the Naval Research Lab (NRL) and used by Navy meteorologist via the NRL NexSat data portal online. The DNB radiance and reflectance RGB products assign the DNB channel (0.7μ) to the red and green colors of the composite while the IR M15 channel (11μ) is assigned to the blue component of the RGB. The resultant image shows warm, reflective clouds and city lights in yellow shades (i.e. equal amounts of red and green, but lack of blue), while cold, reflective clouds will appear blue (i.e. equal amounts of red and green, but large amount of blue).

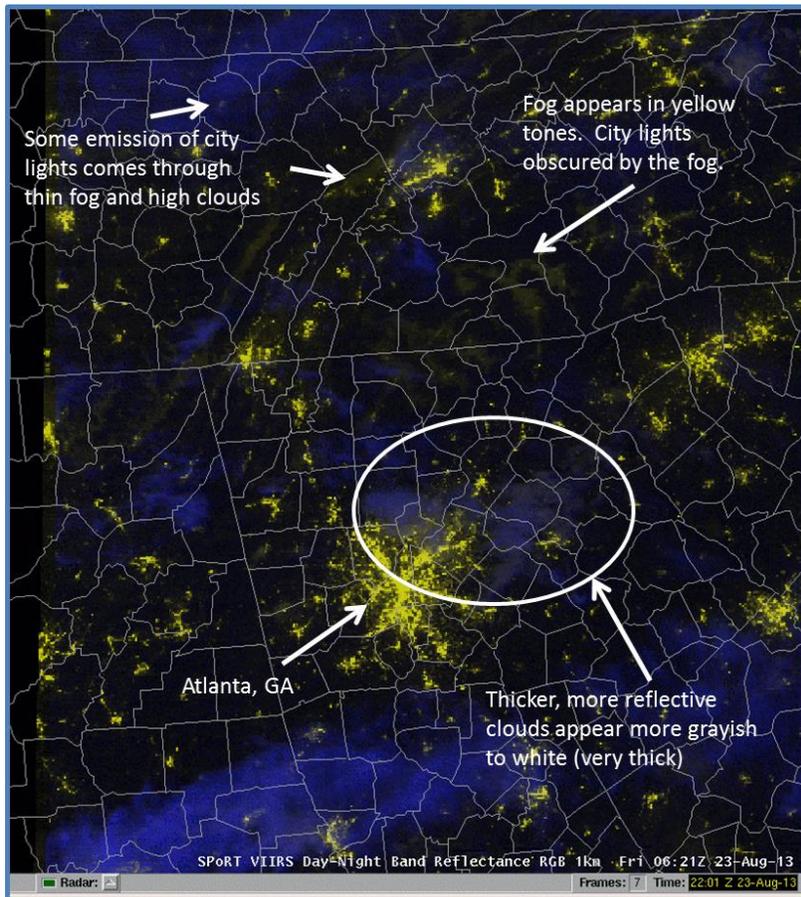


Figure 4. VIIRS DNB Reflectance RGB imagery for 0621 UTC on 23 August 2013 centered on north Georgia displayed within the AWIPS/D-2d software. City light emissions saturate pixels with bright yellow and the metro city area of Atlanta is noted in the lower center of the image. Blue cloud features are thick enough to be reflective and they are cold. Fog can be seen in faint yellow in the upper center portion of the image where faint yellow cloud objects are in the upper valleys of the Appalachian Mountains in north Georgia and south central Tennessee.

Features with high reflectance in the DNB and very cold temperatures in the M15 IR channel retrievals will appear white. The combination of the DNB and IR channels in an RGB is useful in the determination of cloud height and thickness. A particular strength of the DNB RGB over using just the infrared or DNB images separately is the ability to discern areas of low cloud and fog, especially around cities and low lying areas. As surface emissions by city lights tends to “bloom” when scattered by thin clouds, the RGB product can lend context as to whether the thin clouds are high level cirrus which would appear blue, or low clouds and fog which would have a yellow cast. Additionally, since this product contains a visible component, optically thin cirrus clouds will allow reflectance and emission by lower sources to be seen by the sensor and hence detection of low to mid cloud features beneath the cirrus. This is especially significant since cirrus clouds saturate IR thermal channel signals and are thus masked from lower cloud emissions in all other nighttime satellite imagery.

RGB Night-Time Microphysics:

False color (RGB) composite products allow for multi-channel information to be shown simultaneously and in such a way as to help highlight a particular weather or atmospheric phenomenon. Several RGB composite products have been developed by EUMETSAT that can be applied to current MODIS and VIIRS instruments to demonstrate new applications of multispectral data and to prepare forecasters for the GOES-R era (http://oiswww.eumetsat.int/~idds/html/product_description.html). The Night-Time Microphysics RGB composite combines three channels to build a composite image that helps to better delineate cloud types. The 12-10.8 μ channel difference is applied to the red component of the RGB. This channel difference is physically related to optical depth and is typically used as a proxy to cloud thickness. The green component of the RGB is the difference between the 10.8 μ and 3.9 μ channels and is the same difference used by MODIS and VIIRS in the Hybrid GEO/LEO 11-3.9 μ product previously described. This physically relates to the particle size and phase of the cloud and is used to diagnose if clouds are water- or ice-based. The blue component is assigned to the 10.8 μ infrared channel which gives the temperature of an emitting surface, and often it is used to diagnose cloud top temperature. However, in the absence of clouds the 10.8 μ infrared channel relates more to the earth surface temperature. This composite was originally designed to help delineate all variety of cloud features by utilizing a physical, microphysical, and thermal component within a single image. As an IR-based product the highest cloud features will be the ones depicted in the image, and any clouds below this initial ceiling will be obstructed from view. Also, one might consider that an IR-based product could be used at all times of the day, but the 3.9 μ channel has a solar, or reflective, component (in addition to the radiance component) and during the daytime this solar influence changes the relationship of the 10.8 μ and 3.9 μ difference used in the green component of the RGB.

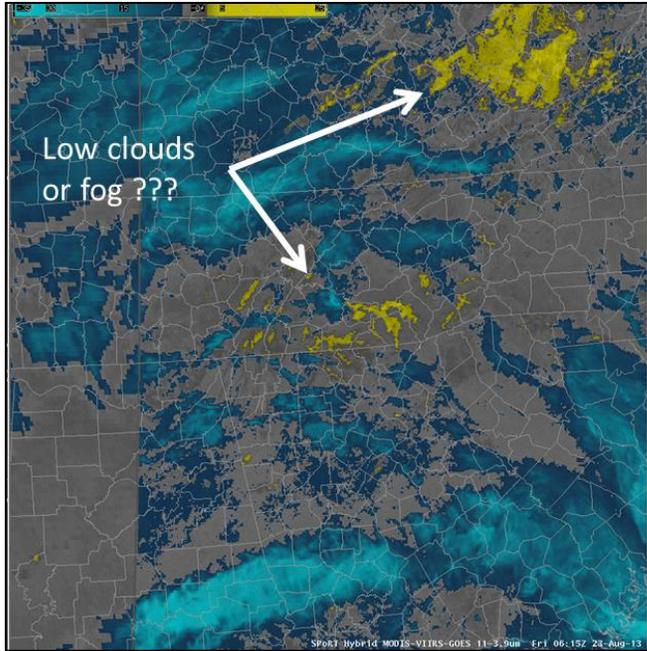


Figure 5. SPoRT Hybrid GEO/LEO 11-3.9 μ product (GOES on far left side, and VIIRS on right 3/4th of image). Same as Figure 2 but annotations to image point out similar yellow cloud objects representing low clouds or fog. In the absence of surface observations, a user may not be able to distinguish whether the yellow shades represent low clouds or if they indicate fog.

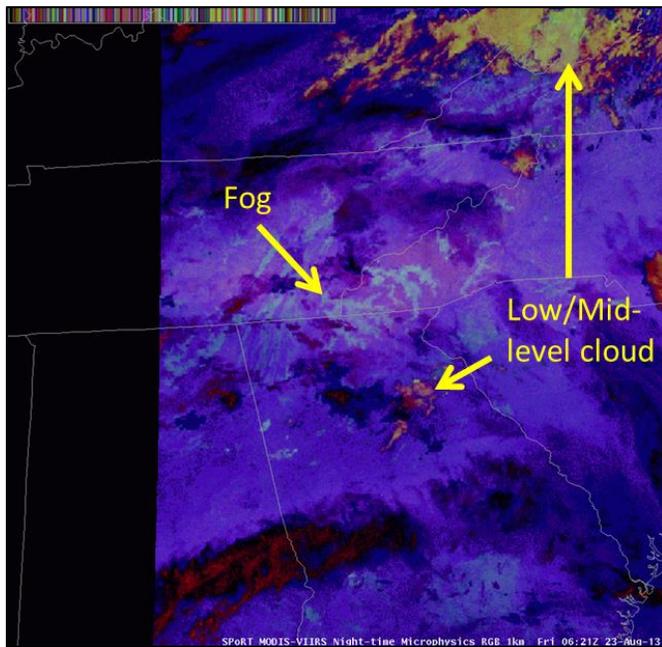


Figure 6. VIIRS NTmicro RGB centered on north Georgia from 2013 August 23 at 0621 UTC. Color differences in RGB for the “low cloud and fog” objects from Figure 5 allow the differentiation of fog from low clouds as annotated on image.

As described in the Hybrid product section, a positive difference at night indicates low water-based clouds or fog, but it does not provide information on specifically which of these features exist at that time (Figure 5). An advantage of the NTmicro RGB is its ability to assist users with differentiating between low clouds and fog in the overnight period, through the added use of the red component to see thick vs thin cloud features, as well as the blue component to provide the relative temperature of the cloud objects with positive 10.8-3.9 μ differences. Fog is often comprised of smaller water droplets and is relatively warm compared to low-level stratus clouds. Also, in the case of thin fog, some of the surface emissions can be mixed with emissions from the small water droplets that make up the relatively thin fog. These factors change the resulting value of the channels and channel differences, and hence, the amount of color contributed from the various R-G-B components for fog verses low clouds (Figure 6). Fog tends to be a dull aqua to nearly gray shades while thick, warm low level stratus with slightly bigger water droplets tends to be a bright aqua color in the southern U.S., and trends toward more yellow and green shades at higher latitudes.

Methodology

SPoRT had steadily transitioned a new RGB imagery suite of products to its WFO partners as part of efforts to demonstrate and test future GOES-R capabilities and new Suomi NPP products. SPoRT has conducted previous assessments regarding GOES and MODIS products that were applied to low cloud and fog analysis, and this assessment of new RGB imagery was the next phase in the evolution of products to address the short-term forecast challenges of aviation hazards during the nighttime period. However, this assessment was also an opportunity for users to become familiar with future imagery capabilities using current, real-time data (i.e. MODIS & VIIRS), and it allowed product developers to better understand the strengths and limitations of how RGB imagery products are able to be applied for the given forecast issue. The NTmicro and DNB RGBs were provided to address analysis of cloud features for possible hazards to aviation and to determine how their application impacts the TAF product, particularly regarding low clouds and fog. The SPoRT Hybrid 11-3.9 μ product was included for comparison to the RGB imagery as this is the current product used by SPoRT collaborators to address low cloud and fog issues.

Prior to the start of the assessment period, each office was contacted to determine their interest in participation, product familiarity and training needs. Training was provided by SPoRT in several ways. Although a basic level of training was recommended via COMET modules (e.g. “Multispectral Satellite Applications: RGB Products Explained”) through the NWS Learning Management System (LMS), SPoRT also developed training specific to the southern U.S. region where products were to be evaluated for use in operational aviation forecasts. A teletraining session was held shortly before the start of each assessment period in order to deliver these training materials and provide an opportunity for a direct question and answer session between users and product developers. The focus of the training session was to provide users with an understanding of how the RGB products are created, their strengths and weaknesses, and a case example of their application to aviation forecasts. The product information and case example were used to create a “micro lesson” of 8 minutes in audio length. This micro lesson is a self-paced, web-based training module that can be used by those unable to attend the teletraining. Additional examples detailing how each of the products could be used in the operations were provided by the WFO Huntsville (HUN) Applications Integration Meteorologist (AIM). Additionally, “Quick Guides” (single-sheet, double sided) were created that briefly describe and illustrate what the products are, what to look for in the imagery, and the caveats one should keep in mind. Essentially, the Quick Guides provide a reminder of the important points covered in the more robust teletraining and micro lesson. These Quick Guides are laminated and sent to each WFO for easy reference, directly within the operations area. Both the micro lesson and the PDF version of the Quick Guide were made available from the Transition tab on the SPoRT website (<http://weather.msfc.nasa.gov/sport/training/>) for the WFOs to review and make available to forecasters via their local intranet.

For a SPoRT assessment to be successful, it is crucial that our partners provide feedback on their experiences with the products. To strike a proper balance between the needs of the assessment and the often busy operational forecast environment, SPoRT has developed the 2-minute feedback form,

which can be accessed at any time on the SPoRT website. Forecaster respondents answered questions using easily clickable radio buttons corresponding to their choice of 3-6 predetermined answers (Appendix I). Comment boxes were also provided if a question and predefined answer did not adequately capture the information they were trying to convey, but also allowed for a more detailed feedback in paragraph form. For this assessment, questions were designed to rate the products impact on assessing fog and low clouds for aviation forecasts (i.e. TAF) in the overnight periods. Initially, users were asked if they used or referenced any of the training materials (i.e. micro lesson, Quick Guide), sought help from a fellow forecaster, relied on their previous experience, or had not seen any training at all. An additional choice allowed users to indicate that they had seen the training materials, but that they still were not able to interpret the RGB imagery and would need additional help. Users were also asked which of the three products they preferred for the given event. These responses help to frame user feedback regarding impact rankings of these products on aviation. For example, someone who has not yet seen the training or consulted a peer with more experience may tend to answer differently from users who have benefited from those resources. Several questions ask users to rank the impact on aviation forecasts, in general, and one questions specifically addresses the issue of whether or not the NTmicro RGB helped differentiate areas of fog from areas of low clouds. The survey goes a bit further and asks users to provide the product that gives them more confidence when analyzing low clouds and fog if it is not the NTmicro RGB. At the end of each survey, a comment box is provided for any additional information the forecaster feels is necessary or has the time to provide. At the end of the assessment all of the responses were analyzed by SPoRT to gain a better understanding of how the products may or may not have met the aviation forecast needs of users, and any problems that might need to be addressed moving forward. Results are presented in the next section.

In addition to the evaluation form, SPoRT also hosts The Wide World of SPoRT, a blog on the Wordpress website and provides access to its WFO partners to write content and share images describing their experiences. Forecasters are encouraged to highlight examples of specific product applications in order to educate others in the community by providing examples and lessons learned. During the assessment, the HUN AIM created three blog posts which addressed a range of potential operational uses of the various VIIRS and MODIS products being evaluated, a sample of which can be seen in Figure 7. In this particular example, an area of low clouds extended across portions of southern Texas, from just west of Houston to the Austin/San Antonio metro and further west into the Texas Hill Country. In the Hybrid imagery the cold, cirrus cloud emissions (aqua blue) saturate the imagery, allowing for viewing of these types of high clouds, even when they are relatively thin. However, clouds or other features below the cirrus cannot be seen by the infrared channels used in the Hybrid. VIIRS Day Night Band Radiance RGB has a visible wavelength component (0.7 μm) for the red and green portions of the RGB and the 10.8 μm channel for the blue. Low, thick clouds have large reflectance and result in yellow shades in the DNB and these low clouds can be seen through the thin cirrus layer (grayish blue) as it is more translucent to visible wavelengths compared to infrared. The VIIRS Day Night Band RGBs can thus offer a better depiction of the low level cloud features at night when thin cirrus exists.

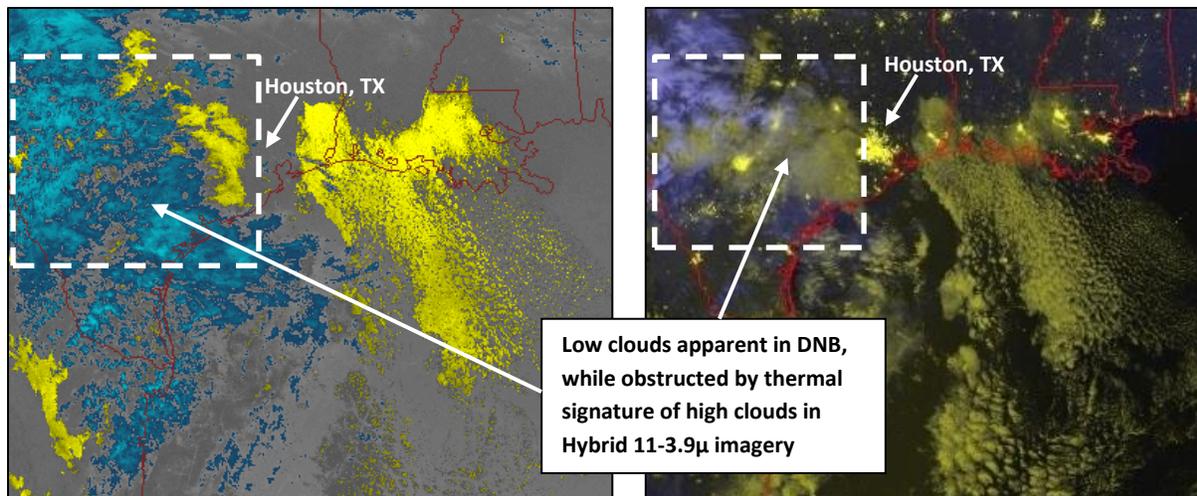


Figure 7. The SPoRT Hybrid GEO/LEO 11-3.9 μ with VIIRS inserted (left) and the VIIRS Day-Night Band Radiance RGB Imagery (right) for 0749 UTC on 19 December 2013.

The SPoRT NWS chat room (address nasa_sport) was also provided to all forecasters at each participating NWSFO as a forum for feedback during the evaluation. The chat room was created to enable efficient communication between SPoRT and collaborators in an open forum setting. In addition, the chat room has proven to be valuable for communicating information about specific products and any related technical issues. Communication was also conducted via email with users to acknowledge their submitted feedback and respond to their comments or ask for clarification. These conversations lead to improved understanding of the product's impact and uses that can then be shared with other forecasters during and after the assessment is completed.

Results

User Feedback to Assessment Questions

Online submission of feedback from operational forecasters came from 8 different WFOs stretching from Albuquerque, NM to Raleigh, NC (Figure 1). In all, 51 surveys were submitted during the two assessment periods described in the Methodology section above. In addition, a variety of blog posts and e-mail correspondence occurred as part of the feedback being considered here from users. Overall, the majority of responses indicated that the NTmicro RGB was the preferred product and 2/3rd of the users said it had some to large impact on general aviation forecast issues (Figure 8).

Impact of NTmicro RGB to Aviation Forecast Issues (in general)

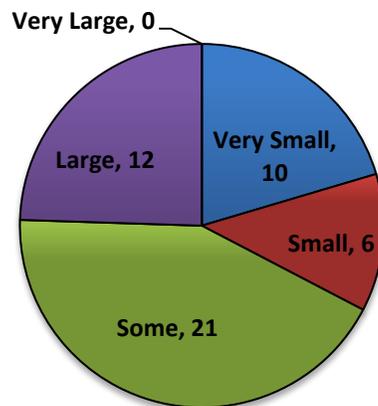


Figure 8. Distribution of WFO feedback when asked to rank the impact of the NTmicro RGB imagery for general support of aviation forecast issues.

As a whole, the products were consistently available to users, however, a few periods of short data outages or individual WFO data flow interruptions did occur and influenced a small percentage of the responses. The assessment of the products, in particular the RGB imagery, was influenced by the infrequent availability of MODIS and VIIRS data (i.e. 1-4 passes per night) when compared to traditional GOES imagery (~48 images per night). This availability issue and the forecaster's low amount of prior experience (in general) with RGB imagery were notable limitations with this assessment.

Users indicated that training resources used in operations consisted mostly of referencing the Quick Guides provided by SPoRT. Some also cited the micro-lesson module and consulting with other peer forecasters as training used during events. More than one training resource could be selected if applicable, and there were 19 user feedback submissions where 2 or more forms of training resources were selected. However, the large majority (80%) of users indicated that they used prior experience to interpret the various products and nearly half of the feedback submissions answered that experience alone was enough. Although users had the option to choose that they were unable to interpret the imagery and would need additional help, no users made this choice. A comment from the LIX WFO indicated:

“Still getting used to the RGB Day/Night microphysics and Reflectance/Radiance products. There is a considerable amount of detail present with respect to cloud thickness, cloud top temperature. Still having some trouble seeing the difference between stratus and fog. [...]”

While the feedback showed that 65% of users preferred the NTmicro RGB product, the Hybrid GEO/LEO 11-3.9 μ was preferred 15% of the time, and just as many users indicated no preference. Only 2 users indicated events where the DNB RGB was the preferred product, and these involved analysis of low

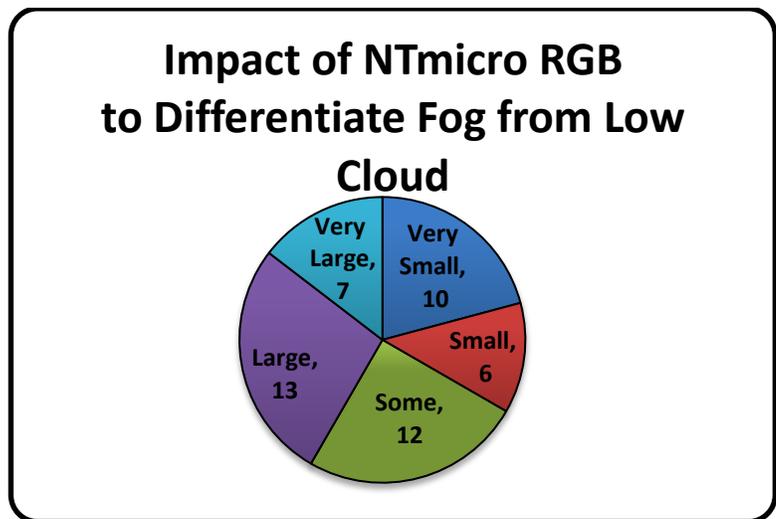
stratus clouds. The infrequent availability of the DNB was sited as the primary limitation to regular, wide operational application.

The impact of the NTmicro RGB to aviation forecast challenges, in general, was rated to be “Some” to “Large” by 33 of the 49 responses, and no one indicated a “Very Large” impact (Figure 8). On the other hand, 16 responses indicated only a small or very small impact, and 2/3rd of these were in the “very small” category. Note that nearly as many users that indicated very small impact of the NTmicro RGB as those who indicated a large impact. There was likely a wide range of user experience with the NTmicro RGB as this was the first season where many forecasters were learning to interpret the imagery. This might explain some of the variability in the impact. Also, there were different types of weather patterns across the domain of users with variable impacts to ceiling and visibility conditions depending on the situation.

In addition, the specific NTmicro RGB impact for differentiating fog from low clouds had responses ranging from some to very large (Figure 9). While the general impact to Aviation did not reach the “Very Large” category, 7 submissions of feedback indicated this category to describe the NTmicro RGB impact to help forecasters differentiate areas of fog from areas of low cloud. The MRX WFO commented on this utility via the online feedback form on 20 September 2013, stating:

“I looked at the Nighttime Microphysics product in hindsight to see how fog around TRI was depicted this morning. The product did an outstanding job of clearly showing areas of fog vs. clouds, even though there were some thin midlevel clouds over the fog areas. It was far superior to the 11-3.9 um product in this regard.[...]”

Figure 9. Distribution of WFO feedback when asked to rank the impact of the NTmicro RGB imagery to help differentiate fog objects from other low cloud features in the imagery.



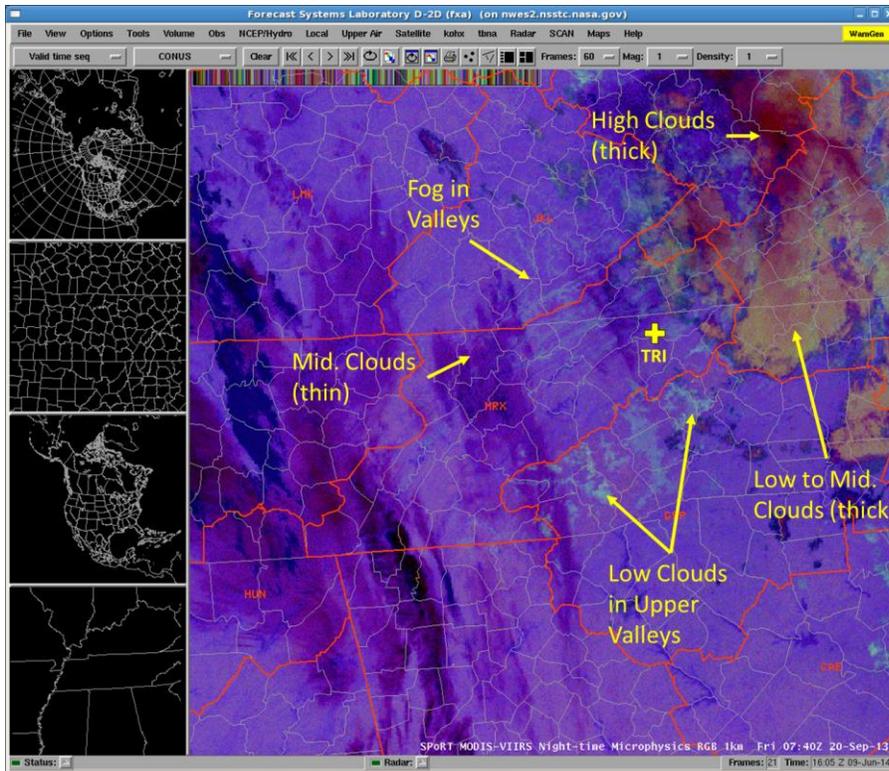


Figure 10. Nighttime Microphysics RGB from VIIRS, centered over the MRX WFO county warning area in eastern Tennessee on 20 September 2013 at 0740 UTC. Image is being displayed within the user's native software, AWIPS/D-2d. All types of clouds are present (see annotations) and the MRX WFO was able to differentiate fog from other cloud types based on the RGB coloring of cloud objects. In particular the fog near the TRI METAR site (see yellow cross) is seen between areas of thin mid. level clouds. See Figure 11 for comparison to GOES 11-3.9 μ difference imagery.

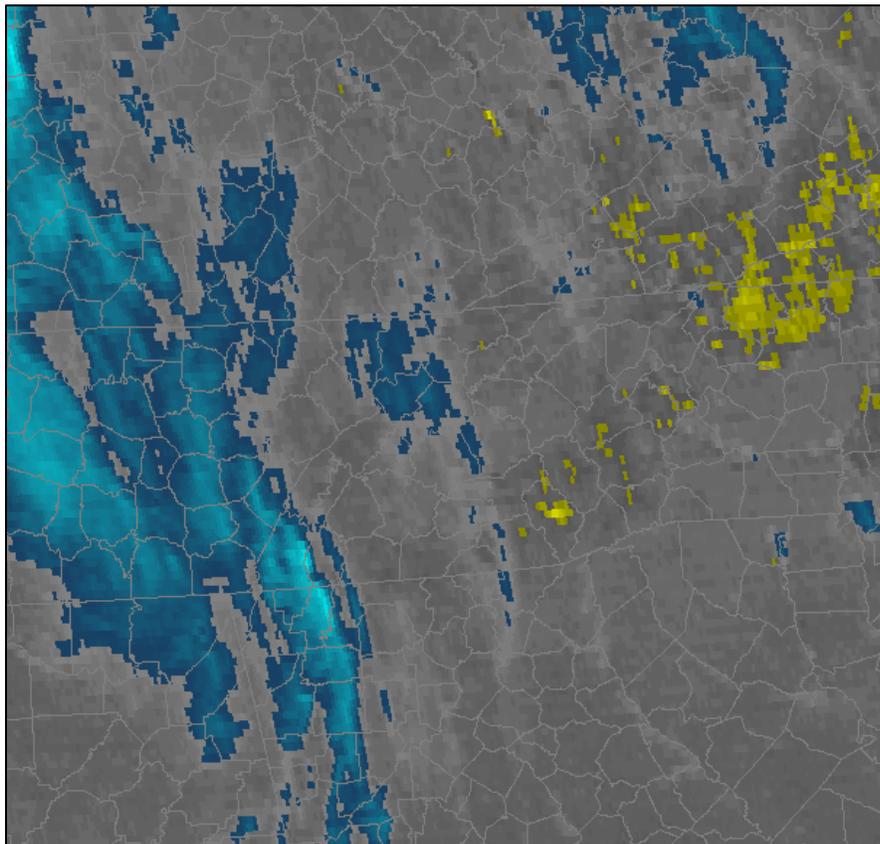


Figure 11. SPoRT Hybrid GEO/LEO 11-3.9 μ imagery for 0745 UTC on 20 September 2013 centered over the MRX WFO county warning area in eastern Tennessee. Only GOES data is available at this time

In a post-frontal situation on 22 September 2013 in the OHX, MRX, and HUN county warning areas (Figure 12), relatively clear skies at night resulted in wide spread fog in low-lying areas with a few low clouds intermixed. An OHX forecaster applied the NTmicro RGB and provided the following comments:

“In this case, generally shallow fog showed up very well on the Nighttime RGB images- much easier to see than the stock 11 - 3.9. The images clearly depicted river valleys being impacted by dense fog, especially near the Cumberland Plateau. [...]”

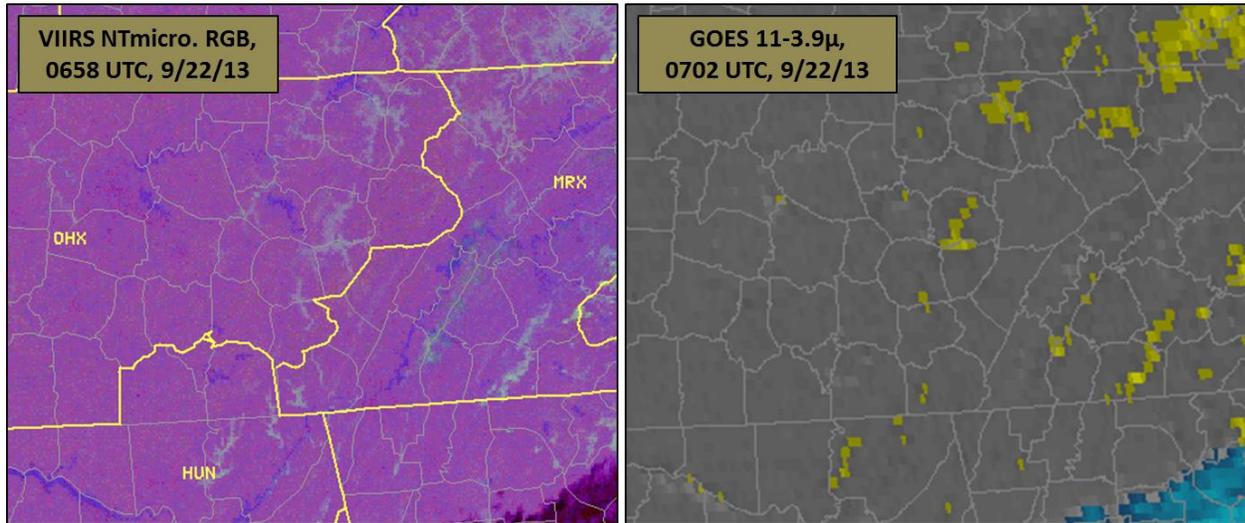


Figure 12. The VIIRS Nighttime Microphysics RGB (left) from 0658 UTC on 22 September 2013 is compared to the GOES 11-3.9 μ difference imagery centered in the region of middle to eastern Tennessee, covering the Nashville (OHX), Morristown/Knoxville (MRX), and Huntsville (HUN) county warning areas (yellow outline). The GOES 11-3.9 μ difference imagery has a color enhancement with shades of yellow for positive differences (low clouds and fog) and blues for large negative differences (high clouds).

Aside the resolution difference, the NTmicro RGB imagery (Figure 12) identifies water bodies (purple), thick vs. thin areas of fog (dull aqua vs. gray) in the eastern OHX area, and fog vs. low clouds (dull aqua vs. bright aqua) when comparing the northern vs. southern MRX areas. A short-time later on 4 October 2013, the MRX WFO continued to reinforce the value of the NTmicro RGB imagery to differentiate low clouds from fog (Figure 13). Forecaster feedback for this event not only indicated “Very Large” impact of the imagery to distinguish fog from low clouds, but also included these comments:

“The 0633Z (VIIRS) and 0645Z (MODIS) Nighttime microphysics product really made it obvious where the clouds were and where the fog was. I wish this product was able to be updated more frequently so we can see the evolution of the fog development. The 11-3.9 product could not distinguish between them at all. [...]”

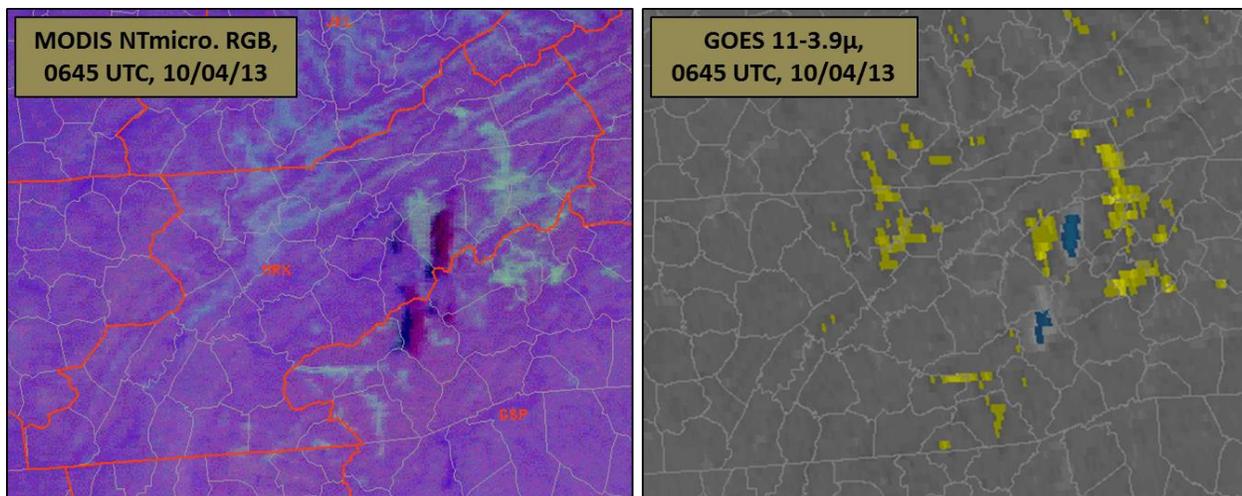


Figure 13. The MODIS Nighttime Microphysics RGB (left) from 0645 UTC on 04 October 2013 is compared to the GOES 11-3.9 μ difference imagery centered in the region of eastern Tennessee, covering the Morristown/Knoxville (OHX), county warning area (red outline). The GOES 11-3.9 μ difference imagery has a color enhancement with shades of yellow for positive differences (low clouds and fog) and blues for large negative differences (high clouds).

The right portion of the NTmicro RGB in Figure 13 is characterized by bright aqua clouds indicating low clouds as well as purple to dark blue cloud objects that represent mid. to high, thin clouds. The center to upper portions of the NTmicro RGB show dull aqua coloring which corresponds to fog in low-lying valleys or rivers. The NTmicro RGB more easily distinguishes the fog from the surface background and the low cloud features when compared to the GOES 11-3.9 μ difference imagery which tends to show fog and low clouds as similar features and is limited in its ability to communicate height and thickness of cloud objects.

However, 20 users choose a different product as providing them more confidence for examining low clouds and fog. When asked to specify the product giving them more confidence, nearly all 20 users responded that they preferred the 11-3.9 μ difference imagery for the given event. However, 11 of these 20 responses indicating more confidence in the 11-3.9 μ product over the NTmicro RGB, also answered that the NTmicro RGB had some to large impact on general aviation forecast issues .

Regarding the DNB RGB value to Aviation issues, half of the feedback indicated very small impact, however 14 responses indicated some to large impact for several events. The ABQ WFO examined the DNB Reflectance RGB on 17 October 2013 stating:

“The VIIRS DNB was similar to the NT microphysics and under full moonlight the RGBs were stunning”

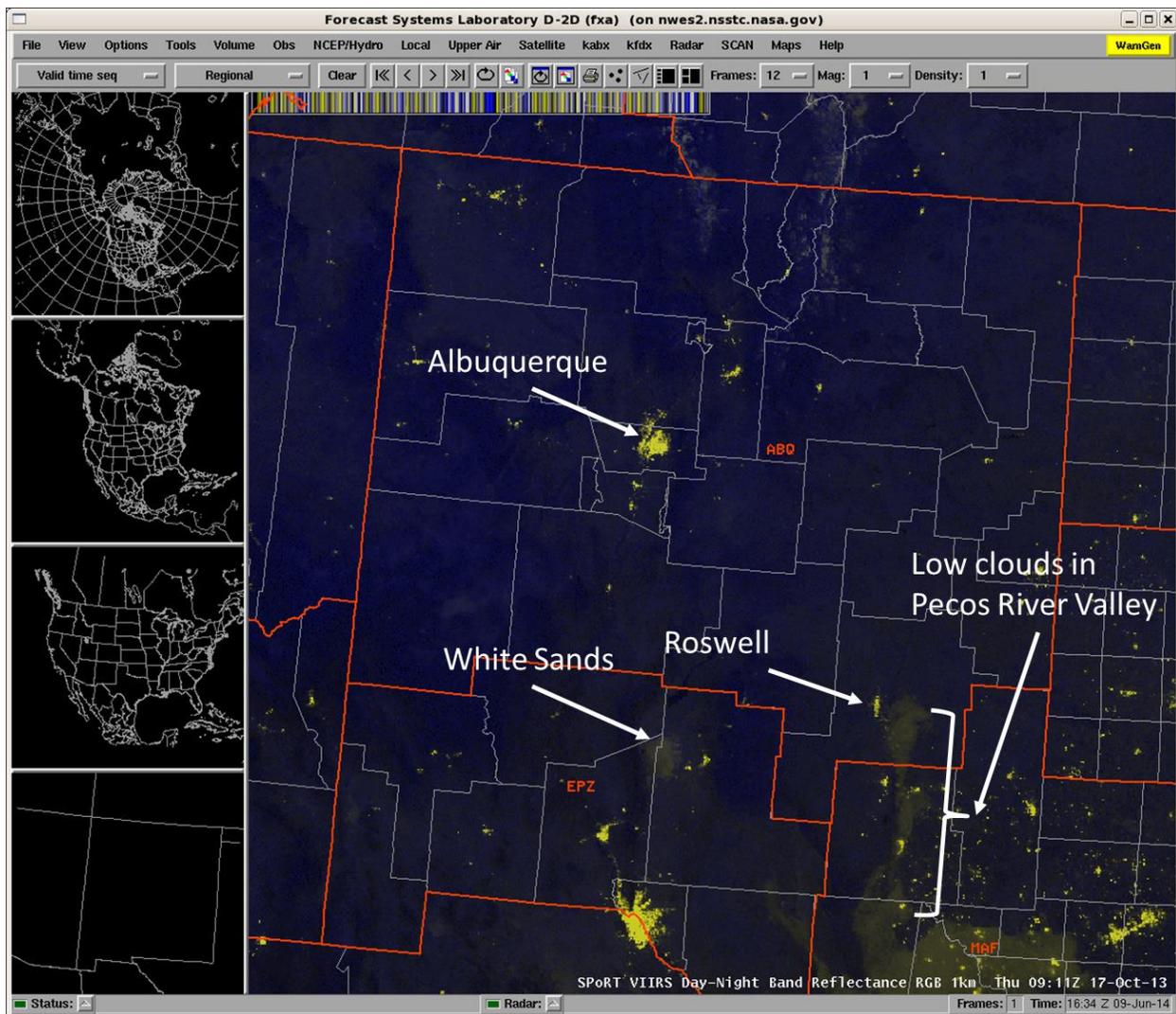


Figure 14. VIIRS Day-Night Band Reflectance RGB Imagery for 0911 UTC on 17 October 2013 centered over New Mexico and the Albuquerque county warning area. Bright yellow represents surface emissions of light that saturate the sensor. Most of the bright yellow pixels are due to city lights such as those indicated for Albuquerque and Roswell. Lighter shades of yellow represent relatively warm, reflective clouds. Low clouds moving northward in the Pecos River Valley are indicated and were noted by ABQ forecaster comments in the assessment of the product. Other reflective surfaces such as White Sands National Park, noted in the image, are also visible.

While most users indicated that the DNB RGB was used to examine fog and low clouds, feedback also indicated other applications were apparent. These applications, although infrequent, included analysis of precipitating cloud structures, changes in city light patterns, lightning awareness in active thunderstorms, and snow cover analysis.

Response to the SPoRT Hybrid GEO/LEO 11-3.9 μ product was mixed, but 18 of 46 responses indicated “very small” impact. However, nearly half these responses indicated that they did not view the product in a loop. Hence, there may have been misunderstanding of the question or the application of the product by some users as the primary purpose of the hybrid imagery is to insert high resolution imagery from polar-orbiting instruments (i.e. MODIS and VIIRS) into the loop of more frequent GOES imagery in

order to provide context to the less frequent polar-orbiting instrument imagery. In some cases, the Hybrid made users aware that a MODIS or VIIRS pass was available and they then examined the various RGB imagery products. A comment by a forecaster at the ABQ WFO said this:

“Again as was the case for the 17th, the hybrid 11-3.9micron product provided a heads up of the availability of higher resolution MODIS/VIIRS data. The hybrid product also helped increase confidence on the location/timing of low clouds approaching Roswell (KROW).[...].”

When asked what existing products at the WFO were complemented by the Hybrid or RGB products being evaluated, 29 of 51 user feedback submissions were left blank for this question. The remaining responses had similar products listed as being complemented. The most frequently mentioned product complemented included the GOES 11-3.9 μ difference imagery; however, other products were occasionally mentioned such as GOES Low Cloud Base and Fog Depth derived products, surface observations of ceiling and visibility, and radar reflectivity.

User Additional Comments

At the end of the online questions, users were provided a “comment” box where they could make additional notes about the event and/or provide additional details about the application (or lack thereof) of products being evaluated. There were at least 8 instances where users specifically noted that the NTmicro RGB showed details of cloud structures and/or fog that was more easily seen than with traditional 11-3.9 μ m imagery. Two separate comments from the RAH WFO were:

“Compared to the 11-3.9 product, the different clouds layers jump out more easily and tell a much more complete story than just the 11-3.9 product.” (From 9/19/13 event)

“...the RGB product provided a much easier way to identify the location of the stratus vs. the traditional 11-3.9 product and based up on the shading it was apparent the clouds were high based. Very handy!” (From 10/16/13 event)

A mixture of comments indicated both difficulty and ease to differentiate fog and low cloud characteristics via interpretation of the RGB colors when forecasters were applying the NTmicro RGB. Those users experiencing difficulty with the color interpretation typically indicated less impact to operations, but they commented how they were “still working to sort out the details” of the product. However, whether the impact was small or large, user comments noted that the NTmicro RGB provided an awareness of the non-uniform nature of the cloud features. One feedback submission from RAH (see below) suggested that they would like a 4-panel display to individually see the contributions from each of the red, green, and blue components along with the resulting RGB composite in order to understand the contribution of each color to the imagery. And, like several other comments, it suggested that a geostationary platform for the NTmicro RGB was very desirable.

“... it was hard to see the difference between the fog and low stratus. One thing I think might be helpful here is to have the ability to separate the R B and G bands and load them up in a 4-panel with the original image so one can see exactly how much red, blue and green are going into the product. If I had this product with the same frequency as a GOES image it would easily be the best product for evaluating LIFR, IFR, MVFR and VFR flight categories.”

Although most of the comments on the NTmicro RGB were positive, there was some mention of the temporal resolution restricting the use of the suite of products. Email conversations with one SOO indicated that although training was provided and well attended, he was struggling to motivate his forecast staff to use the products with any regularity due to this limitation. In addition, several user comments indicated that the infrequent polar-orbiting satellite pass at night were not enough to find value in operations (in particular for the DNB RGB which has only have 1 pass per night in most cases) and they would prefer the use of the GOES or SPoRT Hybrid 11-3.9 μ imagery due to its 15-minute frequency. However, more experienced users from WFO ABQ described an event where progression of low clouds in subsequent NTmicro RGB products assisted with the timing of this feature and its eventual impact to the Roswell (KROW) TAF site (Figure 15). A loop of the SPoRT Hybrid 11-3.9 μ imagery alerted ABQ forecasters that high-resolution MODIS/VIIRS imagery was available in the early morning of 10 October 2013. Comments from submitted feedback indicated that the NTmicro RGB was useful when analyzing the structure of the low clouds since it was such a small area; however, it was unclear to them if there was fog or low cloud. Similarly, they commented that the DNB RGB imagery showed the low clouds and the full moon provided detailed imagery (Figure 14). The TAF for KROW was amended at 1044 UTC to add a scattered cloud layer at 800 ft. and a temporary condition of a broken cloud layer at 800 ft. for 4 hours. ABQ forecasters continued to use the SPoRT Hybrid 11-3.9 μ imagery to see the progression of the cloud feature and eventually issued their site forecast for KROW to include the broken cloud layer at 800 ft. in the prevailing conditions through 1700 UTC.

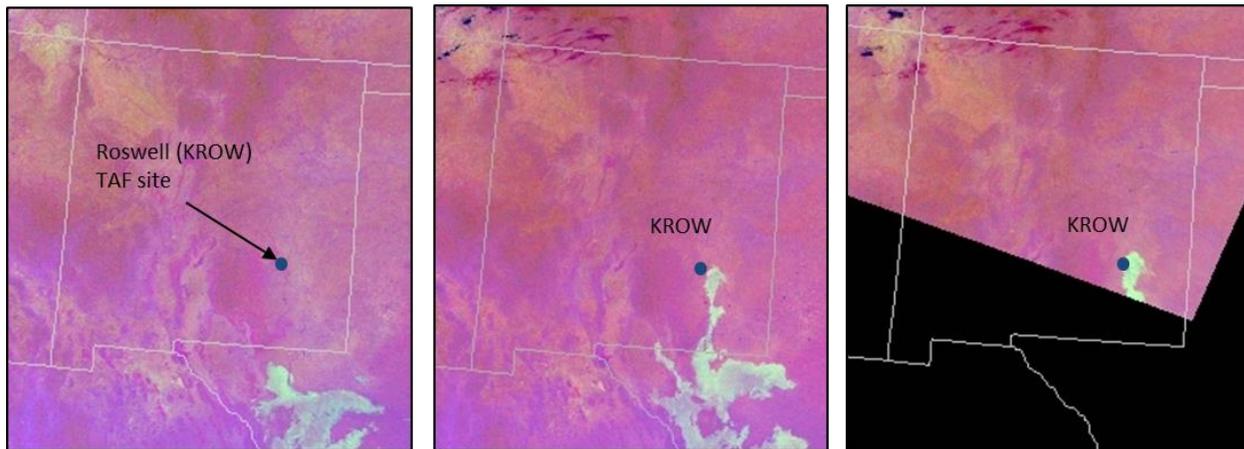


Figure 15. Nighttime Microphysics RGB Imagery from Terra MODIS (left), S-NPP VIIRS (middle), and Aqua MODIS (right) on 17 October 2013 at 0520, 0911, and 0930 UTC respectively, centered over New Mexico. The airport at Roswell (KROW), represented by the blue dot, is a TAF site for the ABQ WFO. These images were used to analyze the progression of low clouds moving northward in the Pecos River valley toward KROW. The bright aqua represents thicker, low cloud while the gray to dull aqua indicates fog. Most of the other colors are a result of variations in topography due surface emission differences, except in the upper left of the 0911 and 0930 UTC images where mid to high clouds are indicated in the purple and dark blue.

ABQ forecasters used the NTmicro RGB imagery again on the following day, 18 October 2013, in a similar manner. However, they noted a better delineation of the colors of the cloud objects and suggested that this ability to distinguish fog from low clouds would have a significant impact:

“Colors were significantly more purplish/blue rather than aqua/light blue and obs supported ceilings less than 500 feet. This has a potentially large impact on aviation since those levels are typically VLIFR, “very low IFR,” and will close an airport down. The hybrid product and NT microphysics provided an opportunity to improve the forecast coverage of mostly cloudy skies in the morning, however no update was made for following shift.”

In fact, the ABQ and HGX WFOs provided feedback and noted four other specific instances where the NTmicro RGB assisted with forecasts and amendments to TAFs. Comments from a forecaster at Houston said this:

“I was able to use the VIIRS Nighttime microphysics 12/25 0736 UTC image to see the low strato cu cloud cover that was developing on the edge and under mid/high level clouds. It gave me confidence on the 9Z taf update to increase the 4kft cloud cover in the HOU and IAH tafs.”

The HUN WFO also indicated that a NTmicro RGB image provided confidence to leave a fog advisory in place for the morning period and in a separate event, how the extent and thickness of fog depicted in the NTmicro RGB helped estimate the timing of fog dissipation.

A few comments noted that the timing of the MODIS/VIIRS passes is limiting with respect to the forecast issue of radiation fog, as the satellite passes are typically several hours prior to sunrise. In addition, clouds over the user’s forecast region often blocked the view of potential fog and stratus features, and this issue is accentuated by the limited number of overpasses of MODIS/VIIRS and hence less opportunities to view breaks in the clouds or pre- and post-cloud scenes. However, even with the low opportunities to view MODIS and VIIRS imagery per night, users from RAH, MRX, and HGX specifically commented on their utility of the NTmicro RGB to identify corresponding colors of fog and low stratus within the gaps or along the edges of the mid to high level clouds. Furthermore, when cloud cover limited the impact of the NTmicro RGB to aviation issues, several comments included mention of regions outside the user’s area of responsibility where they could see fog and/or low stratus features likely impacting aviation operations.

Lastly, the Wide World of SPoRT Blog provides an opportunity for users to provide examples of images and products used in operations and a more detailed description of their application for a specific forecast issue. One blog from the Corpus Christi (CRP) WFO presented an example using a combination of the NTmicro RGB with the Hybrid 11-3.9 μ difference imagery (WFO CRP, 2014). The forecaster provides the NTmicro RGB imagery overlaid with surface visibility and ceiling observations. The forecaster used an external software package to analyze the individual contributions of red, green, and blue coloring in order to better understand the differences in the resulting color composite and hence cloud objects in the region. A subsequent post by CRP on January 20, 2014 outlined the detailed information from the NTmicro RGB compared to the 11-3.9 μ difference imagery regarding the various cloud types in a complex scene as well as the identification of the leading edge of and expanding fog area. Additional posts by the MFL, ABQ, and HUN WFOs expressed similar value in the efficiency of the NTmicro RGB imagery to analyze cloud and fog objects as well as the use of the VIIRS DNB RGB to reveal low level clouds under high, thin cirrus regions.

Summary and Recommendations

Ceiling and visibility restrictions due to fog and clouds are a hazard to aviation users who rely on forecasts by NWS WFOs. The analysis and short-term forecast of these hazards has typically been derived from in situ observations, geostationary satellite imagery, and short-term predictions by NWP models (not covered here). Specific to this assessment, the traditional 11-3.9 μ channel difference imagery from GOES satellites used to detect low clouds and fog was evaluated compared to multispectral (i.e. RGB) composite imagery products from high-resolution polar-orbiting satellites (Aqua, Terra, S-NPP). Operational forecasters from NWS WFOs participated in the assessment of the Nighttime Microphysics and Day-Night Band RGB imagery products to the traditional 11-3.9 μ channel difference to improve the analysis of clouds and aviation hazards, and more specifically, to evaluate the utility of the products to differentiate low clouds from fog. By seeing where areas of fog are occurring, forecasters can analyze where significant restrictions to visibility and ceilings are occurring versus where only ceiling restrictions to aviation exist. This also allows a user to anticipate the low IFR areas likely to dissipate due to solar heating versus areas with thicker cloud layers which may take longer to be modified. The Nighttime Microphysics RGB imagery (MODIS and VIIRS) uses this traditional 11-3.9 μ channel difference as one of its 3 components and adds information related to cloud thickness and temperature while the Day-Night Band (VIIRS only) combines the longwave IR channel to better delineate warm (low) vs cold (high) cloud features detected in reflected moonlight.

Of the 3 products involved in the assessment, the NTmicro RGB was the preferred product by 65% of users and 33 of 49 responses indicated some to large impact on aviation forecasts with 67% of users indicating additional value of the NTmicro RGB to have some to very large impact to differentiate fog from low clouds. In fact, 22% of those responses indicated “Very Large” impact alone when using the RGB imagery to differentiate fog vs. low clouds when compared to the traditional 11-3.9 μ channel difference imagery. Conversely, 33% of users indicated small to very small impact to aviation by the NT micro RGB with 2/3rd of these in the “Very Small” category. Forecasters often cited the infrequent availability of the product due to lack of satellite passes as a significant limitation to operational usage. This was especially true for the DNB RGB where half of the responses indicated “Very Small” impact to aviation issues. However, the DNB RGB had a wider set of applications by users (analysis of city light changes, snow cover, convective cloud structure, and lightning) than the NTmicro RGB and there is likely a familiarization period that will need to continue before users are versed in its applications.

For this assessment, the experience level with applying this type of RGB imagery product spanned a wide spectrum. Although pre-assessment training and Quick Guide reference were provided, there were several instances where users commented how they were still trying to come up on the learning curve of how to interpret the RGB imagery, but they also noted that more detail was available compared to traditional imagery. Interestingly, most users cited their prior experience as the main resource for applying the imagery for a given event while about 1/3 of users indicated using the Quick Guide or consulting with a peer forecaster. And, it should be noted, that when given the option to check “need additional help” regarding product training, none of the respondents chose this option even though some user feedback comments suggested otherwise.

Specific recommendations to the product developers:

- While product specific training was provided to forecasters, it may help for product developers to suggest to the prospective user audience that they take/review some of the fundamental training on RGB imagery concepts/products that exist from other groups (COMET, VISIT, WTDB, EUMETSAT) as a foundation for the more product specific information.
- Additional training in the form of a case library or repository of regional examples is suggested to allow users to more rapidly increase their experience level and readiness with the product.
- Due to the limited number of U.S.-based instruments that are available to create multispectral imagery, it is suggested that other international satellites with similar capabilities be used to increase the number of products per event and hence increase the application potential in the operational environment
- Users expressed the desire to be able to interrogate the RGB imagery to better understand the individual components that contributed to the final pixel value displayed and hence the science behind the color classification of objects in the image. Product developers should explore the possibility of adding functionality into the user's display system toward this end.
- For the operational forecaster in portions of the southern CONUS, a geostationary platform for these products is the most desired resource. The ABI on GOES-R will have this capability to create the NTmicro RGB imagery product (similar to existing SEVIRI on MSG). Implementation of that instrument as soon as possible is highly desired by users and strongly recommended.

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