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SPoRT TRANSITION OF JPSS VIIRS IMAGERY FOR NIGHT-TIME APPLICATIONS

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The NASA/Short-term Prediction, Research, and Transition (SPoRT) Program and NOAA/Cooperative Institute for Research in the Atmosphere (CIRA) work within the NOAA/Joint Polar Satellite System (JPSS) Proving Ground to demonstrate the unique capabilities of the VIIRS instrument. Very similar to MODIS, the VIIRS instrument provides many high-resolution visible and infrared channels in a broad spectrum. In addition, VIIRS is equipped with a low-light sensor that is able to detect light emissions from the land and atmosphere as well as reflected sunlight by the lunar surface. This band is referred to as the Day-Night Band due to the sunlight being used at night to see cloud and topographic features just as one would typically see in day-time visible imagery. NWS forecast offices that collaborate with SPoRT and CIRA have utilized MODIS imagery in operations, but have longed for more frequent passes of polar-orbiting data. The VIIRS instrument enhances SPoRT collaborations with WFOs by providing another day and night-time pass, and at times two additional passes due to its large swath width. This means that multi-spectral, RGB imagery composites are more readily available to prepare users for their use in GOES-R era and high-resolution imagery for use in high-latitudes is more frequently able to supplement standard GOES imagery within the SPoRT Hybrid GEO-LEO product. The transition of VIIRS also introduces the new Day-Night Band capability to forecast operations.

An Intensive Evaluation Period (IEP) was conducted in Summer 2013 with a group of “Front Range” NWS offices related to VIIRS night-time imagery. VIIRS single-channel imagery is able to better analyze the specific location of fire hotspots and other land features, as well as provide a more true measurement of various cloud and aerosol properties than geostationary measurements, especially at night. Viewed within the SPoRT Hybrid imagery, the VIIRS data allows forecasters to better interpret the more frequent, but coarse GOES Imagery. Night-time Microphysics and Dust RGB Imagery provides cloud analysis of cloud height, thickness, and composition in order for operational applications such as separating fog from low clouds, dust plume detection, and determining precipitating clouds in radar-void/blocked regions. The Day-Night Band has a particular benefit to seeing light from cities, fires, or other emissions as well as the reflection of moonlight off of clouds and smoke plumes, given the right lunar phase and angle. Examples from the VIIRS transition and IEP will be presented.

1. THE FRONT RANGE COLLABORATION

This evaluation was a collaboration between NASA’s Short-term Prediction Research and Transition (SPoRT) Center (Darden et al. 2002; Goodman et al. 2004) (http://weather.msfc.nasa.gov/sport/) and four Weather Forecast Offices: Albuquerque, New Mexico, Boulder, Colorado, Cheyenne, Wyoming, and Great Falls, Montana. Collectively, these offices are known as the Front Range collaborators for their geographic location. The Front Range collaboration began in 2013 as a joint project between SPoRT, these four WFOs, and the Colorado Institute for Research in the Atmosphere (CIRA). Both SPoRT and CIRA were working to evaluate a red-green-blue composite imagery to better diagnose snow cover. Considering the similar goals and geographic concerns a collaborative effort was started. The process also works well as a “buddy” system. Instead of one office evaluating a product in isolation, several partners contribute on a similar project. This helps promote collaborations as partners can share results and discussions.

Since that initial evaluation, SPoRT has continued to coordinate with these Front Range partners. In addition to combined efforts between SPoRT and CIRA, the Front Range collaborators share another unique distinction. The four WFOs represent three different NOAA National Weather Service regions. As a result, these efforts bridge institutional divides.

The next collaborative evaluation, and the topic of this write up, is part of the JPSS proving ground (http://www.jpss.noaa.gov/community_proving-ground.html). Here, the Front Range partners would conduct an Intensive Evaluation Period (IEP) using VIIRS imagery. Specifically, the project was focused on assessing the utility of the nighttime products from VIIRS. These include the use of the day-night band (DNB) and various red-green-blue (RGB) composite images. The Front Range collaborators evaluated these products during July and August 2013 and provided

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feedback on the utility of the various observations in operations.

The following sections will cover the details of the evaluation. These include the methodology for the assessment, the products evaluated, and future work.

2. METHODOLOGY

Assessments are one component to SPoRT's collaborations with our WFO partners. Figure 1 illustrates SPoRT's paradigm for collaborations. To start, SPoRT works with our partners to determine a specific forecast need or concern. From there SPoRT researchers work with our partners to determine if a specific product or tool is available that will address the particular concern. If so, two things occur.

First, SPoRT ensures that the product in question is transitioned to our partners in their local decision support system. For the National Weather Service, this has been AWIPS. However, the National Weather Service has been moving to a new version, AWIPS II. This is a critical part of any transition. While a web page can be used, and in some cases necessary due to AWIPS II evaluation restrictions, live data in AWIPS/AWIPS II is the most desirable. In this way, end users can evaluate the data in their own operational system and integrate, or fuse, these data with other commonly available meteorological observations (e.g., satellite, radar, models, etc.).

Concurrently with the transition of the product, training is developed. Some of SPoRT's training examples may be found on the NASA SPoRT web page (http://weather.msfc.nasa.gov/sport/training/). Training is vitally important so that forecasters understand what they are using, how it works, and general applications. This takes several forms as there are multiple ways that individual end users may most benefit from training. The most involved is a formal training module. This is usually no more than 15-20 min in length and is a full audio presentation available on the web or through NOAA's learning management system. This training provides the most background information on a product, how it is produced, and operational examples. Further training includes coordination calls for science sharing and to allow forecasters to ask questions of the developers.

The next two training items are interrelated and are geared more towards "just in time" training. One version is a short 5-8 min micro module to quickly highlight important aspects of the product and general operational uses. Complementary to this is a hard copy quick guide on one sheet (front and back) that can be made available on the operations floor.

The next step, once the products have been transitioned and training has been conducted is the formal assessment. SPoRT conducts both formal and informal assessments of products. Informal assessments are conducted through blog posts on the Wide World of SPoRT blog (http://nasasport.wordpress.com/) and through various e-mail and phone conversations on specific events. Formal assessments are conducted over specific intensive evaluation periods, often 1-3 months in length. SPoRT and our collaborating partners agree to more constant communications during the IEP and our collaborators agree to fill out a short survey after events. The goal is to quickly and concisely gauge the utility of the product, the scenario in which it was used, and the end user's thoughts, both for and against. These surveys are available through Google documents and are intended to take 2-3 min to complete in order to minimize the intrusion into our end users' other activities and responsibilities.

After a formal evaluation SPoRT and our partners will review the assessments. This will allow SPoRT to determine the effectiveness of the products during the assessment. Also, this will point out cases where the product was or was not useful and list recommended changes to the training or product itself. Lastly, in the case of a product that has been assessed highly, the determination may be made to completely transition a product fully to NOAA for full operational use. If not, SPoRT and its partners will make the recommended changes and prepare for another evaluation.

3. ASSESSED PRODUCTS

Eight satellite products were included in the evaluation, of which four were single channel products. All of these were available to WFOs Albuquerque, Cheyenne, and Great Falls in AWIPS I. WFO Boulder used a web page with high resolution graphics over their county warning area as the VIIRS imagery was not available in AWIPS II at the time.

Two single channel products included the 3.9 and 11 µm infrared imagery (Figs. 2 and 3, respectively). The 3.9 and 11 µm infrared imagery commonly used for fog and cloud detection at night were used as "control" products given their availability on the current GOES Imager (although at reduced spatial resolution). The improved spatial resolution from the VIIRS served as a good proxy for the imagery from the GOES-R Advanced Baseline Imager (ABI) instrument. VIIRS single-channel imagery is able to better analyze the specific location of fire hotspots and other land features, as well as provide a more true measurement of various cloud and aerosol properties than geostationary measurements, especially at night. Viewed within the SPoRT Hybrid imagery (Fuell et al. 2011; Smith et al. 2014), the VIIRS data allows forecasters to better interpret the more frequent, but coarse GOES Imagery.

The evaluation placed much of the emphasis on the VIIRS low-light channel (a.k.a. day-night band or DNB) (Miller et al. 2012). The DNB provided nighttime imagery of reflected moonlight from clouds and other features, and captured emitted light sources at the resolution of day-time visible imagery. SPoRT provided two basic, single channel DNB products to the Front Range collaborators; radiance and reflectance (Figs. 4 and 5, respectively). The radiance product is a calibrated and scaled image of emitted and reflected energy at visible wavelengths. The brightness of the clouds depends on the amount of moonlight incident on them (which varies daily with location and pass). The radiance product is normalized by the amount of available moonlight (based on phase and elevation angle) for every pixel in the image to obtain a scaled reflectance product. The normalization provided a more consistent brightness in the resulting image from one day to the next throughout the moon cycle.

A red-green-blue (RGB) composite radiance and reflectance product was produced and provided to end users for evaluation. The DNB imagery was used for the red and green components with the VIIRS 11 micron thermal channel as the blue component. This RGB composite used the high sensitivity of the DNB sensor and the ability of the infrared channel to detect cloud top height. The RGB products used the thermal infrared channel to infer the cloud height via temperature, while retaining the high-resolution texture and cloud type of the DNB. The composite resulted in the detection and better delineation of many cloud features throughout the atmosphere as well as surface features than single channel imagery alone.

The resulting DNB RGB composites showed city lights, ice and snow, and lightning as yellow. Low level clouds are yellow shades with thicker clouds a brighter yellow. Mid- to high, thick clouds are blue shades to white in appearance. Lastly mid- to high, thin clouds are blue shades. Just like the basic DNB reflectance, the DNB reflectance RGB may saturate in stray light regions due to the normalization process. These issues were addressed in the available training. A sample DNB radiance RGB is shown in Fig. 6.

The Day-Night Band has a particular benefit to seeing light from cities, fires, or other emissions as well as the reflection of moonlight off of clouds and smoke plumes, given the right lunar phase and angle.

Two additional RGB composite products were assessed and were derived for VIIRS using the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT) best practices guidelines (EUMETSAT 2012a,b). One is the dust RGB to, as the name suggests, detect dust plumes (Fig. 7). The RGB composite was used as dust can be hard to detect in conventional visible and IR imagery. This is due to dust usually being optically thin and appearing similar to other cloud types, such as cirrus clouds. The dust RGB contrasts airborne dust from clouds using channel differencing and the IR thermal channel. The combination results in a pink or magenta color for dust. To create the dust RGB, the red component was derived from the difference in the 12 minus 10.8 micron channels, for optical thickness. There is little contribution in thin clouds, while a large contribution occurs in thick clouds or dust. The green channel is the difference between the 10.8 minus the 8.7 micron channel and is related to the particle phase (i.e., ice versus water) or composition. Ice particles or quantities of particles with similar characteristics result in little contribution while a large contribution occurs with high clouds over desert regions. Lastly, the blue contribution directly uses the 10.8 micron channel and represents the temperature of the surface. A cold surface results in little contribution, while the opposite occurs with a warm surface.

The last RGB composite was the nighttime microphysics product (Fig. 8). The nighttime microphysics goes beyond the basic spectral difference product (10.8 minus 3.9 micron channel) that was used to distinguish between low clouds and fog. The nighttime microphysics RGB added another channel difference to indicate cloud thickness as well as repeats the use of the 10.8 micron thermal channel to enhance areas of warm clouds where fog was more likely. The advantage is a potentially superior method to observe fog as well as providing additional information about cloud type and composition. For the nighttime microphysics RGB, the red contribution comes from the 12 minus 10.8 micron channel difference. Physically, this relates to optical depth, which has a low contribution for thin clouds and a high contribution for thick clouds. The green contribution is the traditional spectral difference composite of the 10.8 minus 3.9 micron channels, which relates to the particle phase and size. In situations with ice particles or a cloud-free environment there will be little contribution. The high contribution occurs with water clouds that have small particles. Lastly, the blue contribution comes from the 10.8 micron thermal channel to observe the temperature of the surface. Like the dust RGB, cold surfaces contribute little to the blue component, while warm surfaces have a large blue contribution.

During the assessment, four products were supplemented by observations from the Moderate Resolution Imaging Spectroradiometer (MODIS). While not an exact match for the VIIRS channels, MODIS has similar channels to help provide additional polar observations. The MODIS data were used to add additional observations of long and shortwave IR imagery, as well as the dust and nighttime microphysics RGBs.

Both the nighttime microphysics and dust RGB imagery provides cloud analysis of cloud height, thickness, and composition in order for operational applications such as separating fog from low clouds, dust plume detection, and determining precipitating clouds in radar-void/blocked regions.

4. RESULTS

This section will show two visual examples during the IEP and will then provide a summary of the survey questions. The first example is from WFO Albuquerque while the second comes from the vicinity of both the Boulder and Cheyenne WFOs.

One item to note about the assessment is that it occurred during a time of continued staff shortage with our WFO partners, which limited the amount of time available to participate. Additionally, the focus of the evaluation shifted from a nighttime evaluation of these products for fires and associated features to a broader nighttime evaluation of the VIIRS products overall as the fire season was, minor. Lastly, no dust cases were observed during the assessment period.

4.1 WFO Albuquerque, 17 July 2013

This particular case was submitted by WFO Albuquerque on 17 July 2013. This case was of particular interest as it demonstrated a case of using RGB imagery in a poor radar coverage region. Figure 9 shows the Albuquerque radar reflectivity and indicates the region of interest with the red circle (Farmington, New Mexico east-southeast of the Four Corners region). Here the lowest radar level is 15,000 feet above ground level. In Fig. 9, the Farmington surface observation is reporting light rain, but the radar has no reflectivity observations.

A conveniently timed overpass of VIIRS provides a snapshot of the nighttime microphysics RGB image at 0753 UTC (Fig. 10). Here the 1 km resolution RGB composite shows a well-defined region of mid-level cloud cover over Farmington. This capability is not available in the current GOES infrared imagery alone.

With this image, the operational forecasters indicated that the nighttime microphysics RGB imagery could be used to infer where showers were likely in the region where radar observations are poor or show no precipitation at all. The forecasters also added that the cloud cover and visibility was not enough to affect aviation interests.

4.2 WFO Boulder / Cheyenne Vicinity, 21 July 2013

This case was highlighted by the SPoRT team to the Front Range collaborators as most of the activity was outside the domain of the respective county warning areas. The case occurred on 21 July 2013 at 0821 UTC. This served as a good example case as it demonstrated four of the available products in one event.

The general synopsis for this event showed mostly clear skies over both the Boulder and Cheyenne county warning areas. The main features were a storm complex in southwestern South Dakota into north-central Nebraska and another region of cloud cover in southeastern Colorado. The analysis started with the DNB reflectance product in Fig. 11.

The moon phase and elevation were extremely favorable for the DNB single channel reflectance imagery. This provided an image nearly of the same quality as a standard visible image. In the first part of the analysis of Fig. 11, several features stand out. First, the two main regions of storms / clouds in South Dakota (Feature 1) and southeast Colorado (Feature 2) are very clear. Secondly, given that the DNB is a low light sensor, numerous cities are visible (Feature 3). Also, a small band of clouds extends from north of Cheyenne, Wyoming into western Nebraska (Feature 4). The level is indeterminate, but the shadows cast by the clouds are clearly evident. Lastly, a very interesting curved and rippled feature is visible from northwest Kansas into eastern Colorado (Feature 5). The DNB single channel reflectance offers an excellent way to observe these features at a higher resolution than the current GOES 11 µm infrared channel. However, combined with the other products, several other determinations can be made about these features.

For instance Fig. 12 observes the same scene at the same time, but with the VIIRS 11 µm IR channel at 1 km resolution. This provides a powerful example of what the future Advanced Baseline Imager, with its 2 km resolution will look like in operations. Using the VIIRS IR channel, we note several additional details about the features. First, as this is an IR image and not a low light observation like the DNB, the city lights (Feature 3) are no longer present. The IR channel also highlights the coldest cloud tops (Features 1 and 2) and specifically highlights extremely cold cloud tops in Feature 1 in north-central Nebraska. Given the resolution, Feature 1 may be more convective while Feature 2 may be cirrus over another cloud deck. The clouds in Wyoming to Nebraska (Feature 4) are observed indicating some height, but are not as cold as the cloud tops observed in Features 1 and 2. Lastly, the interesting rippled cloud structure (Feature 5) is not visible, suggesting the clouds are at low levels.

The DNB radiance RGB composite, Fig. 13, combines the basic DNB radiance (similar to the reflectance in Fig. 11) and the 11 µm IR imagery and essentially provides a single image with all of the information observed in the previous two images (Figs. 11 and 12). Surface features and the lowest clouds will appear yellow while the coldest clouds will appear blue. Thinner or mid-level clouds will be whiter in color. We observe that the conclusions from the two previous figures do hold here. Features 1 and 2 are blue suggesting high, cold clouds. Feature 1 also has several streaks in it due to lightning flashes. These flashes confirm the convective nature of these storms suggested by the IR image alone. The city lights (Feature 3) are again visible and will appear yellow along with the curved and rippled cloud structure in Feature 5. This supports the IR only image that this cloud structure is composed of low level clouds or possibly fog. The clouds in Wyoming (Feature 4) have a white-blue color suggesting mid-level or potentially thinner clouds.

At this stage, these products provide a decent generalization of the situation. However, a couple questions remain. These include whether or not Feature 2 is cirrus or thicker cumulus clouds, the composition of Feature 4, and whether or not Feature 5 is a low cloud or fog. These can be addressed with the nighttime microphysics RGB composite.

The nighttime microphysics RGB composite is shown in Fig. 14. Using the channel combinations described in section 3, the nighttime microphysics can provide greater detail on the level of the clouds, their thickness, and general composition. To start Features 1 and 2 stand out as very red. This confirms again the thick, convective nature of Feature 1. Further, it indicates that Feature 2 is composed of optically thick clouds and not a thin cirrus shield alone. Again, as this is not the DNB, the city lights (Feature 3) are not observed. The band of clouds in Wyoming to Nebraska (Feature 4) have a stronger blue component indicating they are a lower than Features 1 and 2. These are likely mid-level clouds. Finally, the undular bore structure (Feature 5) is primarily a whitish blue. This indicates the clouds are relatively thin and warmer than the surrounding clouds. Furthermore these are low level clouds and not fog, which would be whiter as it would be influenced more by observations bleeding through from the surface. Additionally, Feature 1 shows a narrow band of clouds on the southwest sharing the same observational combination as Feature 5. This is likely a developing outflow from the active convection.

4.3 Survey Results

This is a brief summary of the survey results for the nighttime Front Range evaluation. The evaluation had two major setbacks. The first were the staff shortages with our collaborating partners. These shortages made it harder for our partners to regularly participate. Secondly, the assessment was primarily intended to focus on the nighttime evaluation of these products during fire weather, but this was a relatively quiet season for our partners. As such the assessment shifted to a more general nighttime assessment of the products discussed in section 3. Combined these two caveats limited the amount of feedback. The results that were received were extremely valuable, but further evaluations are needed to create a more viable dataset to draw stronger, statistical results.

The traditional pros and cons of polar orbiting imagery were described in the end user responses. Specifically, the resolution was greatly appreciated, especially when compared with traditional GOES imagery. In several cases, it was noted that the resolution of the VIIRS 3.9 µm and DNB imagery provided more accurate locations for fire hot spots than GOES imagery alone. This would be useful for incident support during the fire and for generating a more accurate burn scar location to deal with future flash flooding threats. However, the limited number of overpasses and the times of the overpasses were detrimental. For example, the time of the VIIRS overpass was usually too early in the night to use the nighttime microphysics to monitor fog during the morning commute hours. However, the very wide swath width of VIIRS was found to help offset some of the issues associated with limited overpasses.

One series of questions asked end users about the utility of the VIIRS DNB to understand cloud features as they obscured city lights. Only four responses were received here. However, one response indicated that the transparency of the cloud cover could be important. Having a qualitative assessment of cloud transparency could be used to modify temperature forecasts by inferring the amount of outgoing longwave radiation that could be trapped. Overall, in this role, the utility of the VIIRS DNB was rated low.

The surveys consistently indicated that two products were the most useful in operations. The first was the VIIRS DNB radiance and corresponding RGB composite products. The responses showed that the end users greatly appreciated the product's resolution. This made the radiance DNB products most useful in hot spot detections and supplementing the traditional 3.9 µm imagery from GOES. As state above, this superior resolution more accurately indicated the burn scar locations and would be valuable for future flash flood forecasts.

Another interesting response for the VIIRS DNB radiance products was to assess, qualitatively, the growth of a fire. The responses indicated that the brightness of the fire hot spot and the overall size could roughly provide feedback on how the fire was evolving. One recommendation was to color code the fire hot spots so that they appear different from city lights. This was considered more useful that detecting fire smoke plumes, which were not seen for a number of cases.

Lastly, the VIIRS DNB single channel radiance and its associate RGB composite were preferred over the related VIIRS DNB reflectance products. This was primarily due to the radiance product not normalizing the amount of light being observed as in the reflectance product. In cases of poor lunar elevation angle or phase, other light sources could saturate the reflectance image. The radiance, which was more of a raw observation did not appear to have as serious of a drawback with this.

Beyond the VIIRS DNB radiance products, the nighttime microphysics RGB composite was, by far, the most popular product. This was especially true to assessing cloud type and cloud features in the region. The resolution at which VIIRS provided the nighttime microphysics RGB was another strong capability in this product's favor. Many of the surveys expressed a continued interest in receiving these observations as part of both the GOES-R and JPSS proving grounds. The only limitation provided by our end users in the surveys stated that additional training is necessary to fully understand how to interpret the nighttime microphysics RGB composite product. In spite of this limitation, the majority of surveys indicated that the end users do wish to continue integrating this product into operations.

5. SUMMARY AND FUTURE WORK

The collaborative Front Range project, incorporating NASA SPoRT, CIRA, and the Albuquerque, Boulder, Cheyenne, and Great Falls, Montana Weather Forecast Offices was initiated to bring together partner WFOs with similar forecast needs and concerns. Each WFO has similar issues with radar poor regions and a strong reliance on satellite-based observations. Additionally, the Front Range collaboration was cooperative between research groups (SPoRT and CIRA) and spanned three separate NOAA National Weather Service Regions (Southern, Central, and Western).

When the opportunity came to establish and evaluation as part of the JPSS proving ground for the VIIRS nighttime imagery, the Front Range collaboration was an easy choice. The intensive evaluation period (IEP) took place over July to August 2013. Eight separate products were evaluated. These included the single channel VIIRS 3.9 and 11 µm imagery. The

VIIRS DNB provided four products. These were the single channel radiance (raw low light observations) and reflectance (normalized low light observations) as well as a radiance and reflectance RGB composite that combined the DNB channel with the 11 µm channel. Lastly, a RGB composite for dust and nighttime microphysics was evaluated.

The feedback from the surveys showed that two products were considered the most beneficial to operations. These were the VIIRS DNB radiance product (both the single channel and RGB composite versions) as well as the nighttime microphysics RGB. The main reasons given by the end users were the superior resolution of these products, which is particularly beneficial for fire hot spot locations and the ability to identify cloud type and features with the nighttime microphysics RGB.

The survey responses also indicated a great deal of interest to continue to incorporate these specific products into operations. The fact that the VIIRS nighttime microphysics served as a “sneak peek” at future GOES-R capabilities with the Advanced Baseline Imager, generated further interest in this product. Other recommendations included expanded training for the nighttime microphysics RGB product and to color code fire hot spots and city lights differently in the VIIRS DNB radiance product.

Following the NASA SPoRT paradigm of matching products to a forecast issue, producing training, and then conducting an assessment, SPoRT will take this feedback to develop plans for the follow-on assessment to these products. The request for additional training examples will be a major emphasis. Additionally, there are plans for a 2014 evaluation to generate a more robust survey data set as outside factors limited some participation. Also, there were no cases to observe the dust RGB during this Front Range assessment. The 2014 evaluation will provide SPoRT the opportunity to re-evaluate these products with a user base that is more familiar with them and has had additional training. This will allow all of the collaborators to determine how to continue to incorporate these specific products into operations.

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7. FIGURES

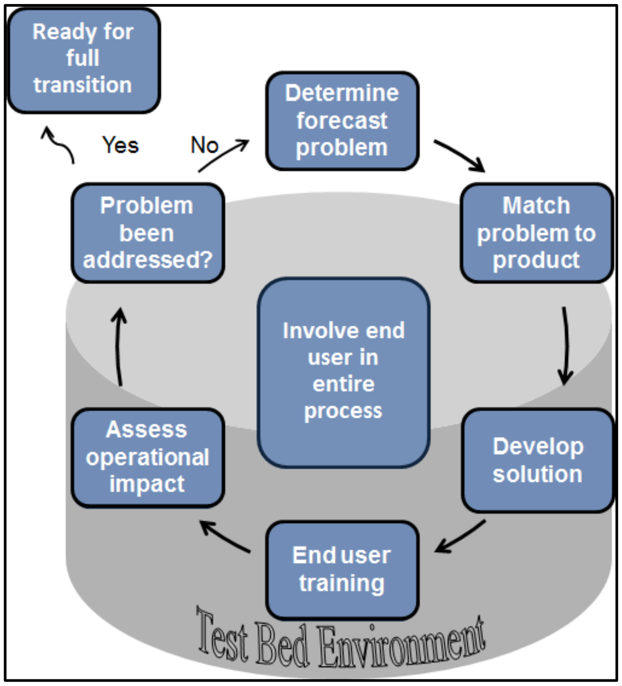

Figure 1. An illustration of NASA SPoRT's paradigm for collaborations with our partners. The collaborations begin with determining what the end user's forecast issue is and matching that with a particular NASA SPoRT capability. From there SPoRT and our collaborators work to transition a solution into the decision support system of our partners and develop training. From there the product/tool is assessed and the determination is made as to whether or not the problem has been appropriate addressed. This will determine if additional work is needed or a wider transition is called for. At every step, the end user is involved in the process.

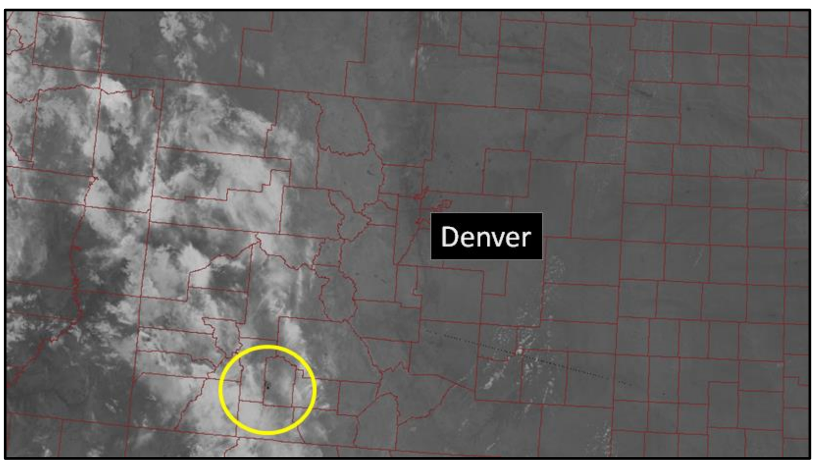

Figure 2. An example of the VIIRS 3.9 µm imagery in AWIPS covering most of Colorado at 0840 UTC on 4 July 2013. Denver is highlighted as a reference point. The main feature is the hot spot that can be observed from the Papoose fire in southwest Colorado in the yellow circle. The higher resolution of the VIIRS imagery makes it easier to observe these hot spots through cloud cover.

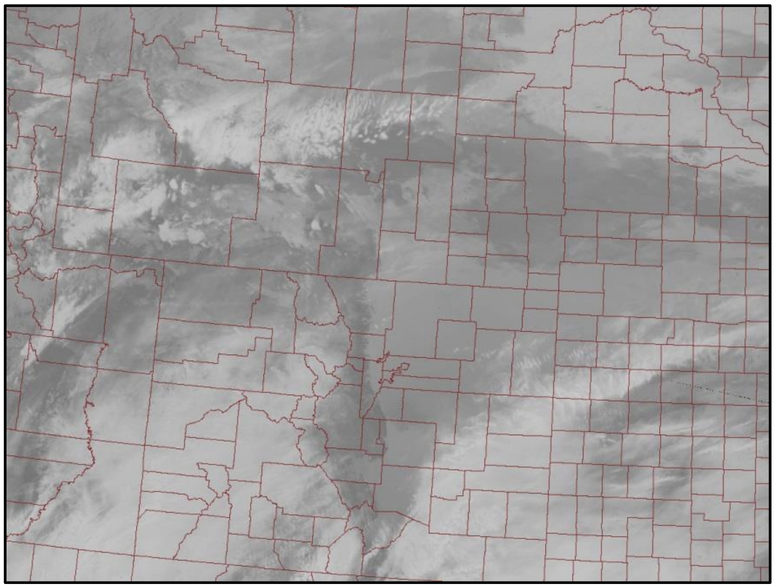

Figure 3. An unenhanced VIIRS 1 km 11 µm longwave image in AWIPS over most of Colorado and southern Wyoming.

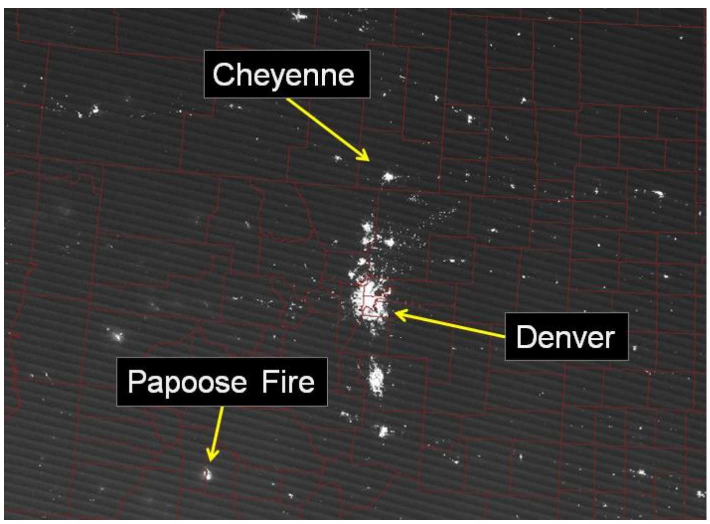

Figure 4. This is at the same time as Fig. 2 but now observes the same scene with the VIIRS 750 m resolution day-night band radiance product. Here the Papoose Fire stands out very well in addition to the city lights throughout the region.

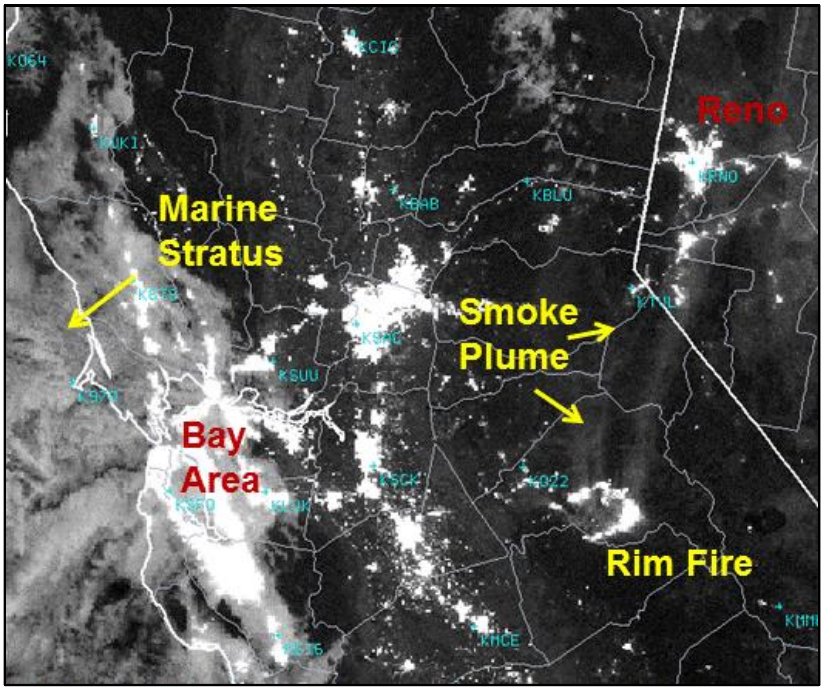

Figure 5. This image is an example of the VIIRS 750 m day-night band reflectance imagery for the Rim Fire in California at 3:52 AM (Pacific) on 26 August 2013. Although outside the region of the assessment, forecasters were interested in observing what the day-night band would show. The San Francisco Bay area lights are quite prominent along with the Rim Fire itself and the smoke plume drifting north from the fire. (Image courtesy of WFO Albuquerque.)

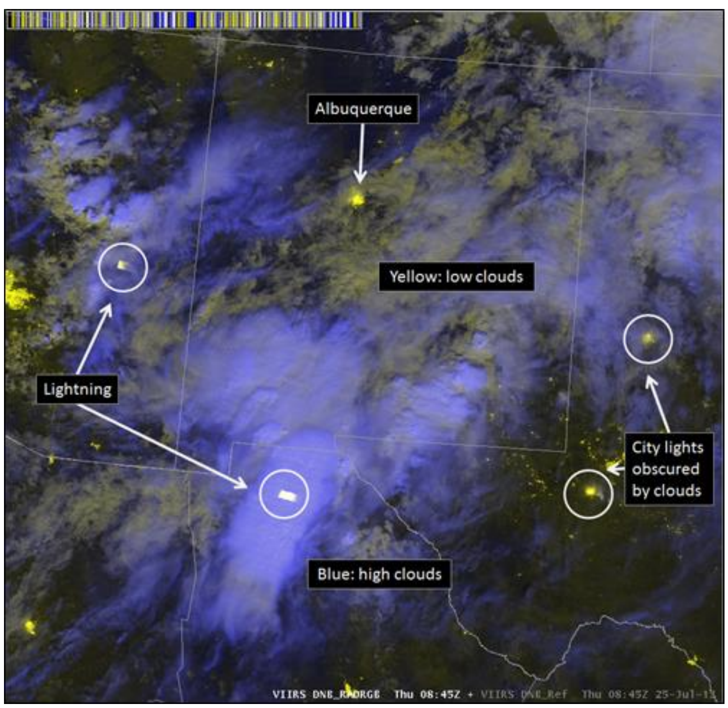

Figure 6. This example image in AWIPS highlights the VIIRS day-night band radiance red-green-blue composite produced by NASA SPoRT at 0845 UTC on 25 July 2013. Low clouds and surface features, such as cities, appear yellow, while higher clouds appear blue. Two white streaks in the image are highlighted and are flashes of lightning that occurred during this scan.

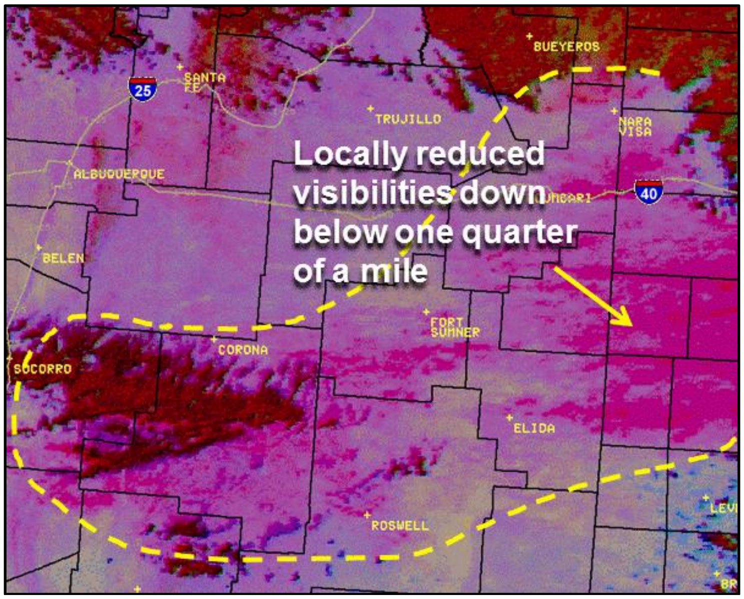

Figure 7. The assessment period did not have any dust events for evaluation. However, a large dust event occurred at 2:40 PM local time on 23 March 2013 in eastern New Mexico and into the Texas panhandle. The magenta colors are the detection of significant blowing dust by the VIIRS dust red-green-blue composite. A surface report near Portales, New Mexico reported dust reducing visibility to 91 m (~100 yards). (Image courtesy of WFO Albuquerque.)

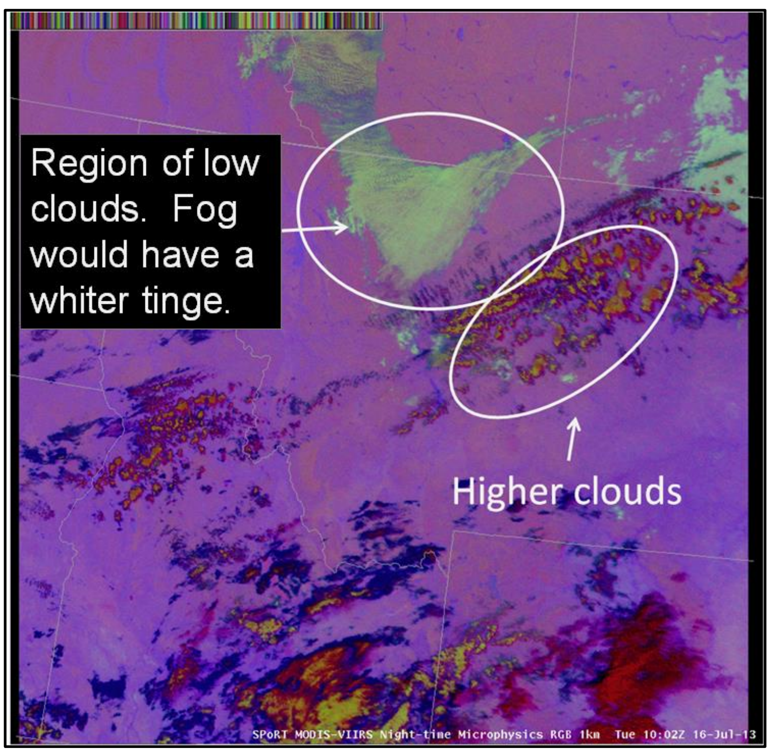

Figure 8. This is a sample AWIPS image of the VIIRS nighttime microphysics red-green-blue composite at 1002 UTC on 16 July 2013 covering the Great Falls, Montana county warning area and surrounding region. Closest to the Great Falls region are two highlighted features. To the southeast is a cluster of small, but relatively thick higher clouds. To the northwest is a low cloud feature. If it were fog the image would have had a whiter tinge.

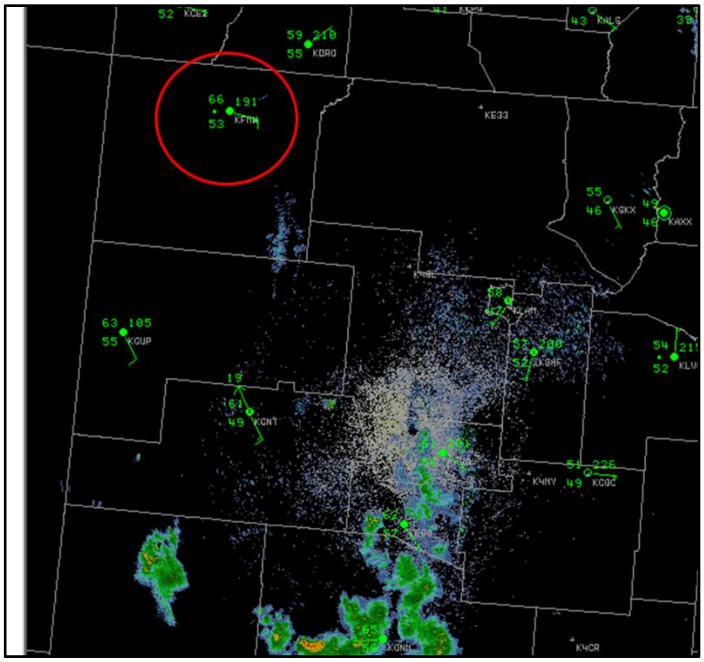

Figure 9. The radar reflectivity image from the Albuquerque, New Mexico Doppler radar at 0800 UTC on 17 July 2013. Farmington, New Mexico is circled in red in the northwest corner of the state. Of interest is the lack of radar reflectivity observations, due to the range of the radar from Farmington, and the fact that the Farmington surface observation is reporting light rain. (Image courtesy of WFO Albuquerque.)

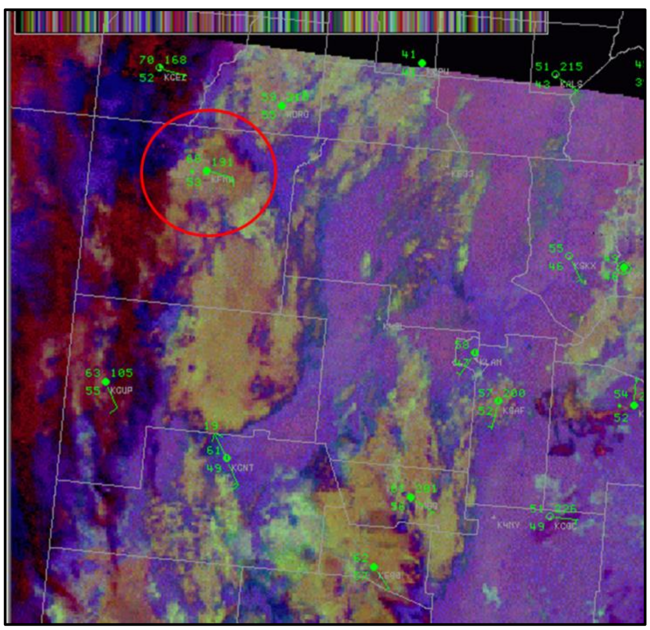

Figure 10. This VIIRS nighttime microphysics red-green-blue composite in AWIPS corresponds to Fig. 9 and occurred at 0753 UTC on 17 July 2013. Where there were now radar observations over Farmington, New Mexico in Fig. 9, the nighttime microphysics product shows a well-defined area of mid-level clouds and associated showers responsible for the Farmington light rain report. This example shows how this product can be used to infer showers in the region where there are no radar observations available. (Image courtesy of WFO Albuquerque.)

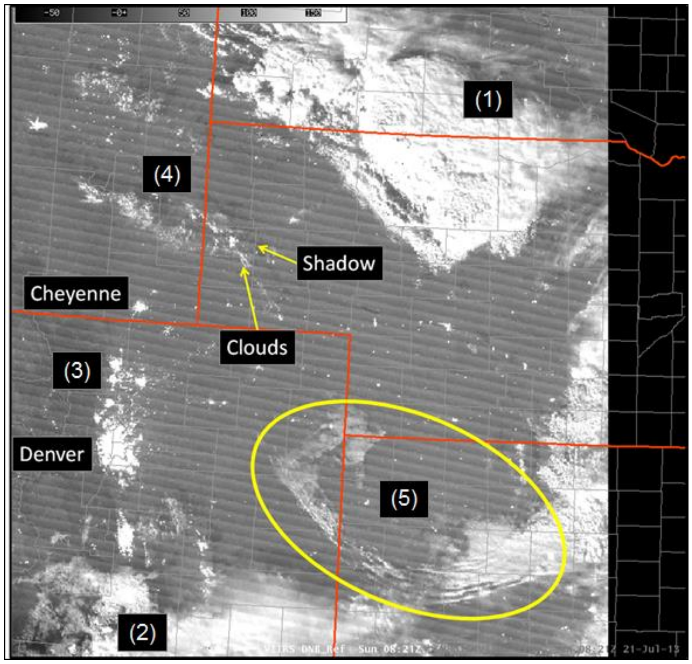

Figure 11. An example of the VIIRS day-night band reflectance product in AWIPS at 0821 UTC on 21 July 2013. The region contains most of the Boulder, Colorado and Cheyenne, Wyoming county warning areas as well as western Kansas and Nebraska. Four specific cloud features (1, 2, 4, and 5) are observed while city lights from Denver and Cheyenne are visible (Feature 3). Feature 5 is highlighted for the undular bore structure observed.

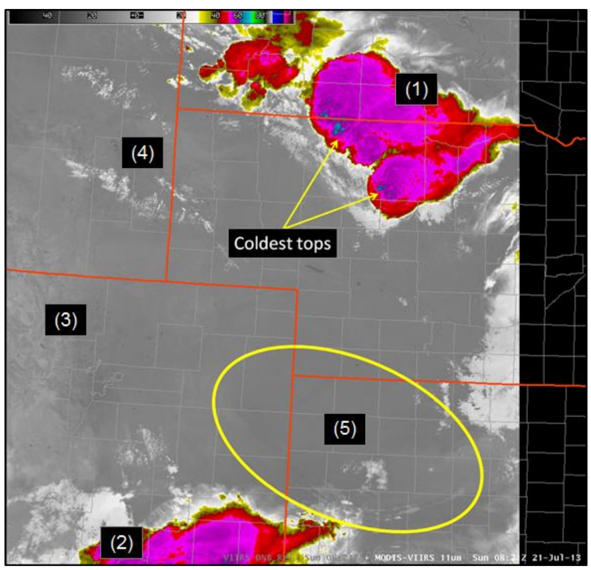

Figure 12. This image is at the same time as Fig. 13 but observes an enhanced version of the VIIRS 11 µm infrared imagery in AWIPS. Features 3 and 5 are not observed indicating they are low clouds, or in the case of Feature 3, city lights that this particular channel does not observe. Features 1 and 2 indicate very cold cloud tops while Feature 1 has the coldest. Due to the structure these are likely from strong convective updrafts. Feature 4 does not have much enhancement and indicates that these clouds are roughly mid-level clouds.

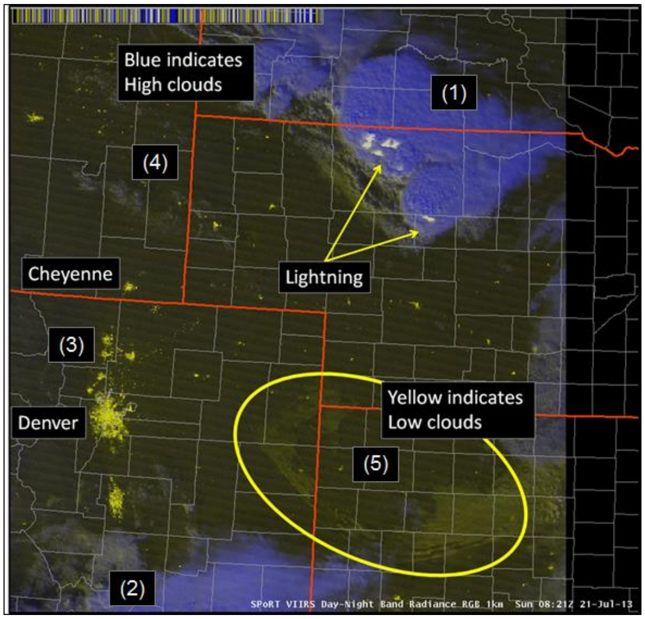

Figure 13. This image again comes at the same time as Fig. 11, but now shows the VIIRS day-night band radiance red-green-blue composite in AWIPS. The city lights (Feature 3) are observable again, while Feature 5 is yellow indicating that it is a low cloud. Features 1 and 2 are blue, representing colder, higher clouds. Additionally, lightning is observed in Feature 1, confirming it is an active convective region. Feature 4 is a faint blue-white indicating mid-level clouds.

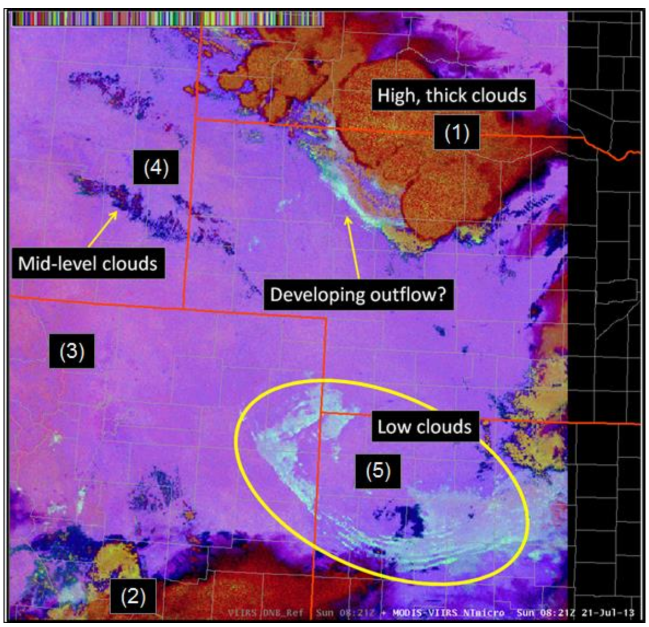

Figure 14. The last image in the sequence started in Fig. 11 shows the VIIRS day-night band nighttime microphysics red-green-blue composite in AWIPS. This particular composite does not observe city lights and therefore Feature 3 is not visible. Features 1 and 2 have a strong red component indicating optically thick clouds, while Feature 4 is less optically thick, but is darker blue, indicating mid-level clouds. The undular bore in Feature 5 is confirmed as a low cloud and not fog with the light blue observation. Also, to the southwest of Feature 1, a thin, light blue band is observed of low clouds, likely representing a developing outflow from the parent convection.