The 2015 NOAA Satellite Proving Ground at the National Hurricane Center – Final Evaluation

Project Title: The 2015 NOAA Satellite Proving Ground at the National Hurricane Center

Organization: NOAA/NWS National Hurricane Center (NHC)

Evaluator(s): NHC Hurricane Specialist Unit (HSU) and Tropical Analysis and Forecast Branch (TAFB) forecasters

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1. Executive Summary

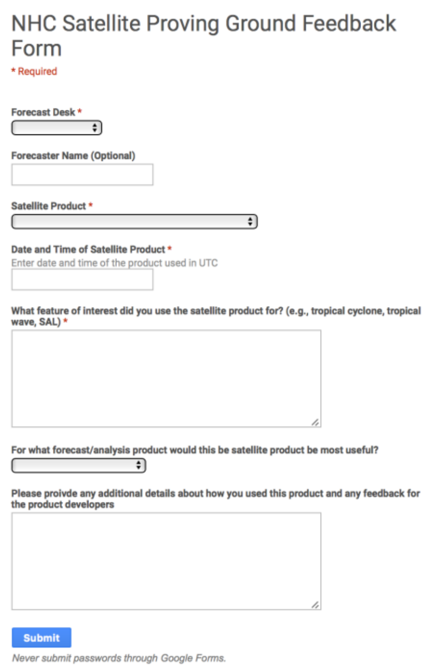
This report summarizes the activities and results from the 2015 NOAA Satellite Proving Ground (PG) at the National Hurricane Center (NHC), which took place from August 1st to November 30th. During this time 14 prototype GOES-R Proving Ground products and 1 JPSS product were demonstrated and valuable forecaster experience and feedback were obtained. One product was new to the NOAA Satellite PG at the NHC in 2015, the GOES-R Derived Motion Winds. The 2015 Atlantic hurricane season was relatively inactive, especially in the eastern portion of the basin where Meteosat data is available. The eastern North Pacific hurricane season, however, was extremely active and provided several opportunities for evaluations of Proving Ground products, especially those available in both basins.

The primary findings from the 2015 Proving Ground include the following: 1) Although forecasters have found a great deal of value in GOES-R Advanced Baseline Imager (ABI) Super Rapid Scan Operations (SRSO), there is still concern over accommodating the large data associated with loading and displaying high resolution imagery. This will need to be addressed in the coming months; 2) The lightning-based rapid intensification index could potentially be improved by distinguishing lightning that occurs within the radius of maximum wind from lightning outside the radius of maximum wind *if* the RMW could be accurately estimated in real-time; 3) Efforts should continue to obtain the low-latency VIIRS imagery, especially the Day-Night Band, becoming available from direct readout stations being deployed in Miami and Puerto Rico; 4) Several demonstration products have been utilized for several years and will probably be part of the initial GOES-R product set for NHC (Hurricane Intensity Estimate, Air Mass and Dust RGB products, some version of a natural color product, and the Saharan Air Layer image combination product).

2. Introduction

The purpose of the NOAA Satellite Proving Ground (PG) at the National Hurricane Center (NHC) is to provide NHC forecasters with an advance look at tropical cyclone-related satellite products for evaluation and feedback during the most active period of the Hurricane season (August 1 – November 30). A total of 16 products were demonstrated during the 2015 NHC PG, including 15 GOES-R baseline products, future capabilities, risk reduction products, and decision aids as well as 1 JPSS baseline product. Demonstration products and algorithms were provided by NESDIS/STAR, CIRA, CIMSS, CIMAS, SPoR,T and OAR. The ABI products are produced using proxy data from Meteosat, GOES, and MODIS. The GLM product is produced from proxy ground-based World Wide Lightning Location Network (WWLLN) data. NHC also has access to the Vaisala GLD360 ground-based lightning data in real time on their NWS National center Advanced Weather Interactive Processing System (N-AWIPS) systems as another proxy for the GLM.

Feedback on the utility of the NHC PG products was gathered through a web based form set up by Michael Brennan from NHC, informal email exchanges between the NHC participants and product providers, and a project review held at NHC on 27 Jan. 2016. The feedback form has proved to be easy to use and has increased the input from the NHC forecasters. Figure 1 shows an example of the form. The web page automatically sends an e-mail to all of the PG participants. Feedback on PG products was also provided by product developers via blogs, which are available from NASA SPoRT (http://nasasport.wordpress.com), CIRA (http://rammb.cira.colostate.edu/research/goes-r/proving_ground/blog) and CIMSS (http://cimss.ssec.wisc.edu/goes/blog/).


NHC Satellite Proving Ground Feedback Form
* Required

Forecast Desk *

Forecaster Name (Optional)

Satellite Product *

Date and Time of Satellite Product *
Enter date and time of the product used in UTC

What feature of interest did you use the satellite product for? (e.g., tropical cyclone, tropical wave, SAL) *

For what forecast/analysis product would this be satellite product be most useful?

Please proivde any additional details about how you used this product and any feedback for the product developers

Submit

Never submit passwords through Google Forms.

Figure 1. The feedback form used during the 2015 NHC Proving Ground.

2.1 Evaluation Strategies

As there are a large number of products in the NHC demonstration, the emphasis was product-dependent, with a higher priority for forecaster feedback placed on a subset of products. The 2015 demonstration was divided into five categories, each with its own evaluation goals (Table 1). Even with a new product added to the 2015 NHC PG demonstration, this approach allowed Liaisons to focus current training and evaluation efforts on a smaller subset of products with specific goals in mind.

Table 1. The 2015 NHC PG Evaluation Categories.

Category	Description	Evaluation Goal(s)
Mature	Products that have been included in NHC PG for several years, have received positive feedback, and proven useful for tropical applications. Less training needed.	Continue to make these products available so additional forecaster feedback can be obtained, time permitting.
Quantitative	Products that provide objective, quantitative guidance.	Perform a quantitative verification in the post-season and provide feedback to product developers, and to help gain forecaster confidence for eventual operational transition.
Introductory	Products introduced in late 2013, forecasters have received little exposure and limited feedback received.	Emphasize these products and obtain feedback on possible tropical applications.
Comparison	Products similar to other NHC PG products. As the GOES-R launch approaches, decisions will need to be made regarding the product sets to be routinely included on NHC AWIPS systems.	Encourage forecasters to display the comparison products along with the originals to provide feedback on the strengths and weaknesses of each.
Underutilized	Products included in the NHC PG for several years yet HSU applications still not clear	Work with HSU to determine if these products should continue to be included in their current form, be modified, or given less emphasis in NHC's eventual operational AWIPS configuration.

2.2 The 2015 Atlantic Hurricane and N.E. Season

Figure 2a shows the tropical cyclone activity in the Atlantic during the 2015 season. The Atlantic hurricane season was slightly below the 30-year average with 11 named storms. This included four hurricanes, two of which became major hurricanes. The U.S. experienced landfall from two systems this year. Tropical Storm Ana made landfall in the Carolinas, while Tropical Storm Bill made landfall in Texas. It is notable that the lack of storms in the eastern Atlantic continues to be a limiting factor for the use of Meteosat proxy data in the NHC PG.

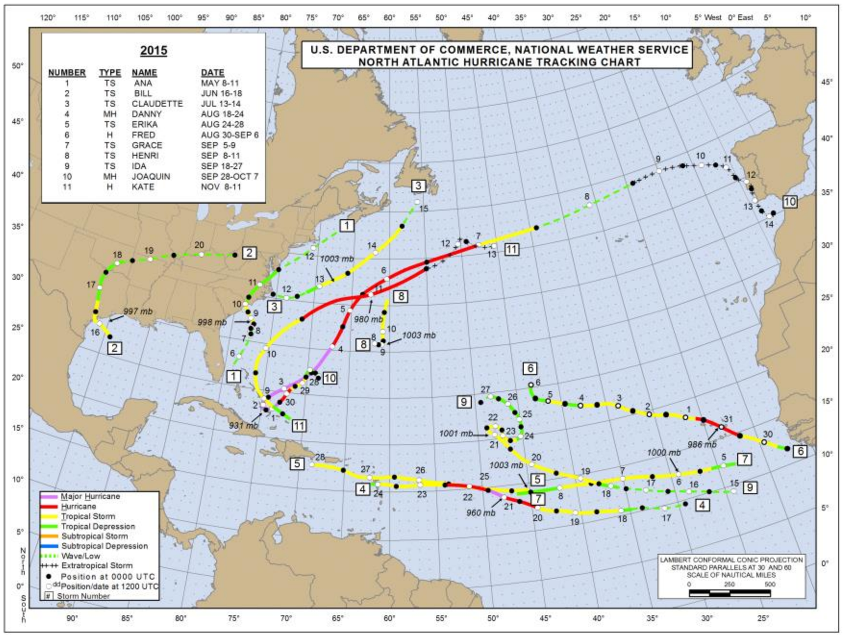
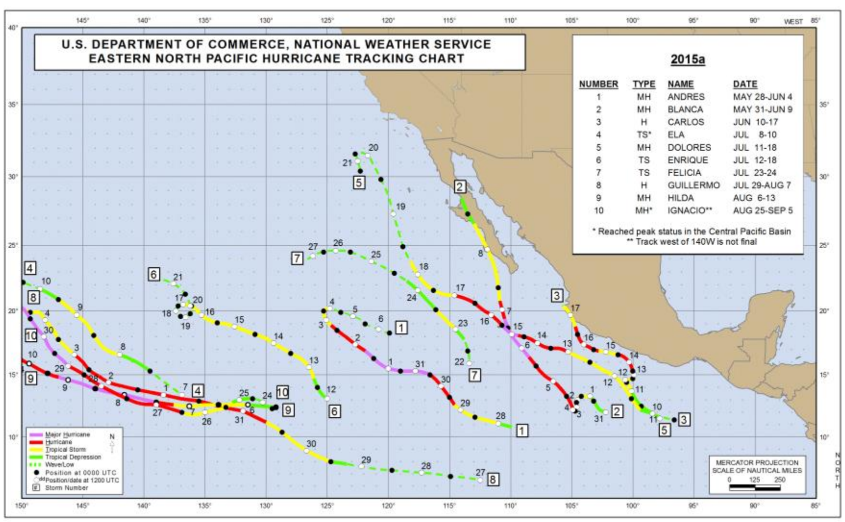


Figure 2a. 2015 Atlantic tropical cyclones (http://www.nhc.noaa.gov/data/tracks/tracks-at-2015.png

Figures 2b shows the tropical cyclone activity in the N.E. Pacific during the 2015 season. In contrast to the Atlantic, the eastern Pacific had an active hurricane season with 18 named storms. Of those, 13 were hurricanes, 10 of which became major hurricanes. This is well above the 30-year average. Furthermore, Hurricane Patricia became the strongest hurricane on record in the eastern North Pacific and North Atlantic, with a maximum wind speed at 185 kt and minimum pressure of 872 mb.



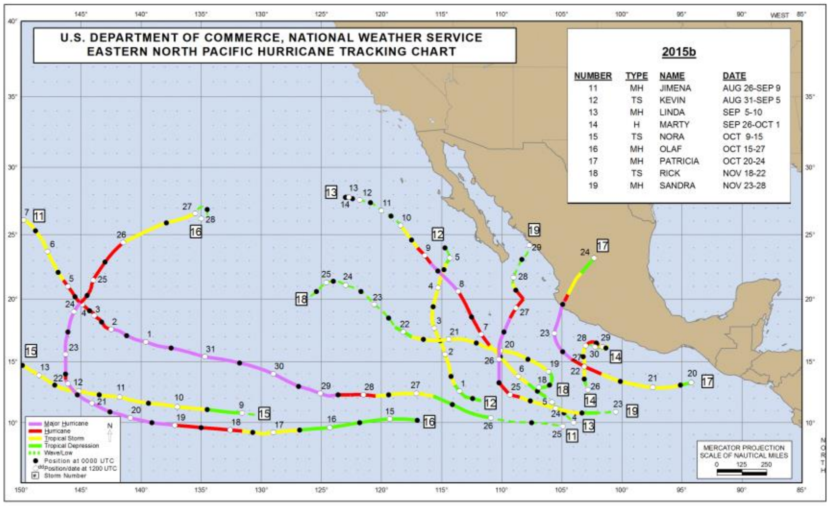


Figure 2b. 2015 Northeast Pacific tropical cyclones (http://www.nhc.noaa.gov/data/tracks/tracks-ep-2015a.png and http://www.nhc.noaa.gov/data/tracks/tracks-ep-2015b.png).

3. Products Evaluated

Table 2 summarizes the 16 products demonstrated in the 2015 NOAA Satellite Proving Ground at the National Hurricane Center (hereafter NHC PG). The products were primarily designed for the Hurricane Specialist Unit (HSU), which produces the tropical cyclone forecast product suite, but some were also applicable to the Tropical Analysis and Forecast Branch (TAFB), which provides marine forecast products over a large region of the tropics and subtropics. Product feedback was obtained from both the HSU and TAFB.

Table 2. The GOES-R and JPSS Proxy Products demonstrated in the 2014 NHC Proving Ground.

Product Name	Proxy Data	Product Type	Delivery Mechanism	Category	Evaluation Strategy
GOES-R Proving Ground Products Evaluated					
Natural Color	MODIS	Imagery	Web	Future Capability	Mature
RGB Air Mass	SEVIRI, GOES-E/W Sounder, MODIS	Imagery	N-AWIPS	Future Capability	Mature
RGB Dust	SEVIRI	Imagery	N-AWIPS	Future Capability	Mature
Saharan Air Layer	SEVIRI	Imagery	N-AWIPS	Future Capability	Mature
Pseudo Natural Color	SEVIRI	Imagery	N-AWIPS	Future Capability	Mature

Super Rapid Scan Imagery	GOES-E/W/14	Imagery	Web	Baseline	Mature
Hurricane Intensity Estimate	SEVIRI, GOES-E Imager	Text	Web	Baseline	Quantitative
Rapid Intensification Index	GOES-E/W Imagers, WWLLN	Text	Web	Risk Reduction	Quantitative
RGB Daytime Microphysics	SEVIRI	Imagery	N-AWIPS	Future Capability	Introductory
RGB Nighttime Microphysics	SEVIRI	Imagery	N-AWIPS	Future Capability	Introductory
RGB Convective Storms	SEVIRI	Imagery	N-AWIPS	Future Capability	Introductory
Derived Motion Winds	GOES-E/W Imagers	Point values	N-AWIPS	Baseline	Introductory
RGB Enhanced Dust (DEBRA-Dust)	SEVIRI	Imagery	Web	Future Capability	Comparison
Lightning Density	GLD-360	Point values	N-AWIPS	Baseline	Comparison
Tropical Overshooting Tops	SEVIRI, GOES-E/W Imagers	Point values	N-AWIPS/Web	Future Capability	Underutilized
JPSS Products Evaluated					
VIIRS Day/Night Band	S-NPP VIIRS	Imagery	N-AWIPS/Web	Baseline	Introductory

Category Definitions:
Baseline Products - GOES-R/JPSS products providing the initial operational implementation
Future Capabilities Products - New capability made possible by ABI
Risk Reduction – Research initiatives to develop new or enhanced GOES-R/JPSS applications and explore possibilities for improving current products

3.1 GOES-R Natural Color Imagery

The ABI will have blue and red bands, but no green band. Thus, it will not be possible to provide a true color image. As part of the GOES-R Algorithm Working Group (AWG) imagery team, a method to accurately estimate the green band from neighboring bands using look up tables (LUT) has been developed. A look-up table approach is used, where the green band is estimated from the blue, red, and near-IR (0.86 µm) bands, similar to those that will be available on the GOES-R ABI. The green band estimated from the LUT is then combined with the red and blue bands to produce a natural color image. This algorithm was tested using MODIS data to create storm-centered natural color images to demonstrate GOES-R Future Capabilities. MODIS contains the green band so actual true color images were also produced for comparison. These products were distributed as part of the RAMMB/CIRA tropical cyclone real time web page, which is also used to display a number of other experimental tropical cyclone forecast products. Further details on the color algorithm are described by Hillger et al. (2011). Because the natural color product uses MODIS, it cannot demonstrate the high temporal resolution of the ABI. A more qualitative color product that uses SEVIRI will also be demonstrated as described in section 3.5.

3.2 GOES-R Red Green Blue (RGB) Air Mass Product

The GOES-R RGB Air Mass Product is an RGB composite based upon data from infrared and water vapor channels from Meteosat Second Generation (MSG). Originally designed and tuned to monitor the evolution of extratropical cyclones, in particular rapid cyclogenesis, jet streaks and PV (potential vorticity) anomalies by scientists at European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT), it is also useful for tropical/subtropical applications as the GOES-R Future Capabilities product highlights differences between dry, tropical and cold air masses. This is accomplished by differencing the two water vapor channels (i.e., ch. 5 at 6.2 µm and ch. 6 at 7.3 µm) as depicted in the red colors, where red is associated with dryer air mass conditions locally; by ozone differences by differencing ch. 8 at 9.7 µm and ch. 9 at 10.8 µm, where green indicates low ozone & typically thus tropical air masses; and by using ch. 5 at 6.2 µm to indicate gross air mass temperature differences. The air mass product helps discriminate tropical air masses (i.e., moist and lower ozone) that are predominantly green, from subtropical air masses (i.e., drier) that are depicted as greenish red, and mid-latitude air masses, which typically have more blue colors. For tropical applications the RGB product should be helpful in determining and tracking the origin of air parcels as they interact with tropical systems, and improve identification of shallow upper-level features (cold lows and jet streaks). For more information on the interpretation of this product see Kerkmann (cited 2010). The use of this product in the GOES-R proving ground will provide important feedback concerning how similar products may be tuned for improved use in tropical applications. Because the product is provided in N-AWIPS format, the forecasters can overlay this on model fields to better understand the relationships with synoptic features in the storm environment. A version of the product was also developed from the GOES sounder.

This product was generated from SEVIRI data at SPoRT and GOES sounder data at CIRA and converted to N-AWIPS format. The N-AWIPS files were provided to NHC via the LDM feed from SPoRT.

3.3 GOES-R RGB Dust Product (EUMETSAT Version)

The GOES-R RGB Dust Product is an RGB composite based upon infrared channel data from the Meteosat Second Generation satellite. It is designed to monitor the evolution of dust storms during both day and night. The Dust RGB product makes use of channel differences that are close to IR windows near 8.7 µm and 10.8 µm. The resulting GOES-R Future Capabilities product depicts dust in magenta and purple colors over land during day and night, respectively. A dusty atmosphere can also be tracked over the water as magenta coloring. The product can also show low-level moist/dry boundaries. For more information on interpretation see Kerkmann et al. (cited 2010). The dust product will allow for the monitoring of dust storms over the African continent and tracking of dust plumes into the tropical Atlantic waters where easterly waves move and sometimes develop into tropical cyclones. The dust serves as a tracer for dry low- to mid-level air that originates over the Sahara Desert and has radiative influences on the atmosphere and affects the microphysics of cloud development. Dust plumes in the tropical Atlantic have been hypothesized to slow tropical cyclone development (Dunion and Velden 2004) and directly affect sea surface temperatures (SSTs) where tropical cyclones form (Evan et al. 2008). This product was generated from SEVIRI data at SPoRT and converted to N-AWIPS format. The N-AWIPS files were provided to NHC via the LDM feed from SPoRT.

3.4 GOES-R Saharan Air Layer (SAL) Product

The Saharan Air Layer (SAL) product is another example of a GOES-R Future Capabilities enhanced image product potentially related to tropical cyclone evolution. The SAL product uses a split window (10.8 and 12.0 μm) algorithm to identify and track dry, dusty air (e.g., Saharan dust outbreaks) in the lower to middle levels of the atmosphere. These dust outbreaks traverse the Atlantic Ocean from east to west and can reach as far west as the western Caribbean, Florida, and Gulf of Mexico during the summer. There is evidence that they can negatively impact tropical cyclone activity in the North Atlantic (Braun 2010). This product can also be used to track low- to mid-level dry air (usually dust-free) that originates from the mid-latitudes. Dry (and possibly dusty) air is indicated by yellow to red shading in the SAL product. Similar to the air mass product, the SAL product is not directly related to the Baseline products, but provides experience with image visualization techniques. The SAL product was provided to NHC in N-AWIPS format via the LDM feed from SPoRT.

3.5 GOES-R Pseudo Natural Color Imagery

Although the natural color product described above is very close to what will be available from GOES-R, the use of MODIS data provides limited time resolution. To provide additional experience with color products with improved time resolution, a pseudo natural color GOES-R Future Capabilities product developed from SEVIRI data was produced. Although not a quantitative algorithm like the MODIS-based natural color products, four SEVIRI bands (2 visible: 0.6 and 0.8 μm and 1 IR: 1.6 μm) are combined and special enhancement tables are applied to highlight ocean, land, aerosol, and cloud features in colors that are qualitatively similar to those in true color imagery. The 3.9 μm channel was used to supplement the visible and near-IR channels by providing continuous coverage through the nighttime hours. This product was provided to SPoRT through coordination with CIMSS and CIMAS and sent to NHC in N-AWIPS format via the LDM feed from SPoRT.

3.6 GOES-R Super Rapid Scan Operations (SRSO) Imagery

NHC indicated an interest in super rapid scan operations (SRSO) data during hurricane landfalls to gain experience with the utility of the high time resolution observations from GOES-R. Because rapid scan operations (RSO) are automatically triggered during a U.S. hurricane landfall, which precludes the possible use of SRSO, alternate approaches were planned for 2015. If there was a hurricane landfall outside the U.S., SRSO would be called if possible. Also, the auto-trigger of RSO is for the satellite closest to the landfall point (usually GOES-East). When possible, SRSO would be called on the other operational GOES satellite if the cyclone is within its field of view. Based on experience from the 2012 NHC PG, the SRSO data is most useful near sunrise for center fixing and aircraft go/no-go decisions. The plan included short periods of SRSO will be called centered around sunrise when possible. The current satellite systems at NHC are not set up to ingest 1-minute imagery, so SRSO imagery was ingested at CIMSS and CIRA and made available via web pages.

GOES-14 was brought out of storage during part of 2015, so there was a potential to collect much longer periods of SRSO data (SRSO for GOES-R, SRSOR). The SRSOR data provides 1 min imager data for 26 min during a 30 min period.

3.7 GOES-R Hurricane Intensity Estimate (HIE)

The Hurricane Intensity Estimate (HIE) is the only hurricane-specific product that is part of the official GOES-R Baseline set. The HIE is a GOES-R algorithm designed to estimate hurricane intensity [mean sea level pressure (MSLP) and max surface wind] from ABI IR-window channel imagery. The code was derived from the current Advanced Dvorak Technique (ADT), which is an objective and fully-automated algorithm that is operational now at the National Environmental Satellite, Data, and Information Service (NESDIS). The Cooperative Institute for Meteorological Satellite Studies (CIMSS) has adapted the current ADT code to operate on 15-minute Meteosat and GOES-East CONUS imagery, as a proxy to an ABI product demonstration. The HIE was run using 15-minute GOES-East CONUS (MSG) imagery for those systems west (east) of 60^{o}W. The HIE was provided to NHC via a web page (http://tropic.ssec.wisc.edu/real-time/adt/goesrPG/adt-PG.html), which is the same method used to provide the ADT.

3.8 GOES-R Lightning-Based Rapid Intensification Index (RII)

A prototype rapid intensification index (RII) was run in real time to demonstrate a decision aid using proxy GLM data from the ground-based World-Wide Lightning Location Network (WWLLN), proxy ABI data from current GOES, in combination with global model forecast fields, and sea surface temperature and oceanic heat content analyses. The various data sources were combined in a discriminant analysis algorithm that provides optimal weights of the independent variables to provide a classification of whether or not a tropical cyclone will rapidly intensify (defined as an increase in intensity of $\geq$ 30 kt) in the next 24 hours (DeMaria et al. 2012). For comparison a version of the experimental RII without the lightning predictors was also run. The RII is a text product that was provided via a web page at CIRA that was also being used by NHC to obtain experimental products as part of the NOAA Joint Hurricane Testbed.

The lightning predictors in the RII are the lightning density in the inner core (0-200 km from the center) and rain band region (200-400 km from the center) calculated over 6-hour time periods. Based on statistical analysis from the past few seasons, the inner core region was expanded from 0-100 km and the rainband region was expanded from 200-300 km. The text product also includes a time series of the storm-relative lightning density values for the life of the storm so the forecasters can see the evolution. In addition, forecasters have the ability to plot the flash locations from the GLD-360 ground based network over shorter time periods, which complemented the RII. Although there are quantitative differences between the GLD-360 and WWLLN data, they are qualitatively similar, and both give an idea of the distribution of the flashes around the storm.

3.9 GOES-R RGB Daytime Microphysics

The RGB Daytime Microphysics product is a GOES-R Future Capabilities RGB product based on visible (0.8-µm) and infrared (3.9-µm and 10.8-µm) SEVIRI channels from Meteosat Second Generation (MSG). The visible reflectance (0.8-µm VIS) in red approximates the cloud optical depth and amount of cloud water and ice. The 3.9-µm shortwave infrared solar reflectance in green gives a qualitative measure of cloud particle size and phase. The 10.8-µm infrared brightness temperature produces blue shading as a function of surface and cloud top temperatures. The warmer the surface, the greater the blue contribution, so warmer land and ocean surfaces appear blueish. Low clouds appear yellow to greenish (small droplets) to magenta (large droplets). High ice clouds appear deep red (large ice particles) to bright orange (small ice particles).

The RGB Daytime Microphysics product has several potential tropical applications. It can help identify severe convective clouds with strong updrafts, which is useful in forecast tropical cyclone intensity and intensity change. This product can clearly distinguish between ice phase clouds at high elevations and water phase clouds at lower elevations. It can also identify subtle microphysical variations within clouds that are not apparent on other images or RGB products and help discriminate between precipitating and non-precipitating water clouds. These characteristics are can be used for convective monitoring in the maritime environment.

More information on the RGB Daytime Microphysics product can be found at http://www.goes-r.gov/users/comet/npoess/multispectral_topics/rgb/navmenu.php_tab_1_page_6.12.0.htm. The RGB Daytime Microphysics product is provided to NHC in N-AWIPS format via the LDM feed from SPoRT.

3.10 GOES-R RGB Nighttime Microphysics

The RGB Nighttime Microphysics product is a GOES-R Future Capabilities RGB product based on infrared (3.9-µm, 10.8-µm, and 12.0-µm) SEVIRI channels from Meteosat Second Generation (MSG). The infrared difference in red (12.0-µm - 10.8-µm IR) in red approximates the cloud optical depth. The infrared difference in green (10.8-µm - 3.9-µm IR) gives a qualitative measure of cloud particle size and phase. The 10.8-µm infrared brightness temperature produces blue shading as a function of surface and cloud top temperatures. The warmer the surface, the greater the blue contribution, so warmer land and ocean surfaces appear bluish. Low clouds appear in shades of tan and light green. Mid-level clouds lean toward green (thin, less red) to light brown (thick, more red). High ice clouds appear deep red (large ice particles) to bright orange (small ice particles).

Tropical applications of the RGB Nighttime Microphysics product are the same as for the daytime version described in the previous section.

More information on the RGB Nighttime Microphysics product can be found at http://weather.msfc.nasa.gov/sport/training/rgb_ntmicro/RGB%20Nighttime%20Microphysics%20Reference%20Guide.pdf. The RGB Nighttime Microphysics product is provided to NHC in N-AWIPS format via the LDM feed from SPoRT.

3.11 GOES-R RGB Daytime Convective Storms

The RGB Daytime Convective Storms product is a GOES-R Future Capabilities RGB product based on visible (0.6-µm), near-infrared (1.6-µm), water vapor (6.2-µm and 7.3-µm), and infrared (10.8-µm) SEVIRI channels from Meteosat Second Generation (MSG). The product is generated by differencing various SEVIRI MSG channels. Red is produced by differencing the two water vapor (6.2-µm and 7.3-µm) channels, green is produced by differencing the two infrared (3.9-µm and 10.8-

μm) channels, and blue is produced by differencing the near-infrared and visible (1.6-μm and 0.6-μm) channels.

This product shows the background as blue/magenta. High-level, thick ice clouds, including convective cumulonimbus clouds, are red. Yellow is usually indicative of small particles within convective cloud tops. Compared to many satellite images, this RGB shows the most intense cells, which can help distinguish new convection from dissipating convective activity. This lends to tropical applications such as cloud discrimination (e.g., convective vs. stratiform), genesis, and intensity forecasting.

More information about the RGB Daytime Convective Storms product can be found at http://www.goes-r.gov/users/comet/npoess/multispectral_topics/rgb/navmenu.php_tab_1_page_6.9.0.htm. The RGB Daytime Convective Storms product is provided to NHC in N-AWIPS format via the LDM feed from SPoRT.

3.12 GOES-R Derived Motion Winds

The GOES-R Derived Motion Winds product allows forecasters to overlay satellite derived winds on satellite imagery to better diagnose and analyze atmospheric features such as jet streaks, shortwave troughs, etc. The algorithm uses ABI visible and infrared observations to extract atmospheric motion. The choice of spectral band will determine the intended target (cloud or moisture gradient) to be traced, its height in the atmosphere, as well as the scale of its motion. The mid- to upper-tropospheric levels (100-600 hPa) use the mid-wave (6.7μm – 7.3μm) water vapor channels and longwave (10.7μm) infrared channel for deriving vectors. The lower levels (600-950 hPa) are provided by combining the visible and infrared channels, depending on the time of day. During daylight imaging periods, the visible channel usually provides superior low-level tracer detection than the longwave infrared channel due to its finer spatial resolution and decreased susceptibility to attenuation by low-level moisture. During the nighttime imaging period, the shortwave (3.9um) infrared channel compliments the longwave infrared channel to derive the motion vectors.

More information about Derived Motion Winds can be found at http://www.star.nesdis.noaa.gov/goesr/product_winds_dmw.php. The product is currently available for GOES-East and GOES-West at 15-minute increments, displayed as wind barbs that can be overlaid on satellite imagery. Data is created in ASCII format and is converted to a GEMPAK readable upper-air observation file. These files will be used by N-AWIPS and AWIPS II NCP.

3.13 S-NPP VIIRS Day/Night Band

The VIIRS Day-Night Band (DNB) is a new low-light sensing capability on the current Suomi National Polar-orbiting Partnership (S-NPP) satellite, the first of 3 next-generation polar-orbiting satellites in the JPSS series. The DNB has numerous NWS applications, including nighttime tropical cyclone center fixing, and cloud, fog and smoke detection. The DNB can also be used in conjunction with the ABI to give high resolution snapshot to complement the high time resolution from the ABI. The DNB senses reflected moonlight at night. It can be used in similar ways to the visible channel during the day. It measures reflected moonlight and emitted light from surface sources such as city lights and fires. To provide a more uniform image as the moon phase changes, a reflectance product is generated using the moonlight algorithm from CIRA. The reflectance product is available twice per day from the ascending and descending passes of S-NPP. The DNB is obtained from servers at CIMSS and provided to NHC from SPoRT via the LDM. The CIRA moonlight code is applied at SPoRT to create the reflectance product before the data is posted for distribution. The imagery from the SPoRT LDM feed only includes data from direct readout systems at University of Wisconsin and along U.S. West coast, which provides coverage to only a small part of the Atlantic and East Pacific tropical cyclone basins. Longer latency DNB imagery was made available via the CIRA web page to complement the LDM data.

3.14 GOES-R RGB Dust Product (CIRA DEBRA-Dust)

The GOES-R Dynamic Enhancement Background Reduction Algorithm (DEBRA-Dust) is an MSG SEVIRI-based product designed to monitor the onset of lofted mineral dust events over the African interior and track plumes across the eastern/central Atlantic Ocean (to the extent of Meteosat Second Generation SEVIRI spatial coverage). DEBRA-Dust employs dynamic land surface emissivity and temperature background information to estimate the clear-sky signal of common dust-detection tests, and uses these values as a baseline for determining the presence of lofted dust. The result is a confidence factor (0=no dust, 1=confident dust) which, when presented as color-enhanced Red/Green/Blue imagery, provides a visually intuitive way of isolating dust from other elements of the complex scene, while suppressing land-surface artifacts. DEBRA-Dust complements the EUMETSAT RGB Dust product, attempting to refine/simplify identification of the salient features of interest.

The GOES-R DEBRA-Dust product is based on Meteosat Second Generation SEVIRI data. Although it is foremost a quantitative product (meaning that it can be thresholded on confidence factor value to isolate dust regions), it is presented in imagery form for this demonstration. Here, the areas of high dust confidence appear in yellow hue, with saturation values tied to the confidence factor strength (brightest yellow = highest confidence). To first order higher confidence factors correlate with optically thicker dust, but this is not a hard/fast rule and the foremost purpose of this product is a mask. A special version of DEBRA has been developed for this provisional demonstration which provides a more aggressive enhancement over water backgrounds. DEBRA-Dust products are generated every 15 minutes at CIRA and hosted online. If DEBRA becomes a formal demonstration product in the future then it will be further refined and converted into a format suitable for N-AWIPS and provided via ftp server or LDM.

3.15 GOES-R GLM Lightning Density (GLD-360 Lightning Density used as proxy)

The GLD-360 Lightning Density product provides an 8x8 km boxed average estimation of CG lightning activity within the Vaisala GLD-360 network. It takes the raw lightning observations from the Vaisala GLD-360 network and recombines them into a flash extent gridded field.
These data are then mapped to a GLM resolution of 8 km and are available at 2, 5, 15, and 30-minute refresh rate. With the flash data, when a flash enters a grid box, the flash count will be increased by one and no flash is counted more than once for a given grid box.

The GLD-360 Lightning Density product is meant to prepare forecasters to receive data at the spatial resolution of the GLM. It gives forecasters the opportunity to use and critique a demonstration of GLM type data to help improve future visualizations of these data and serves as reference for comparison with full GLM proxies and derived products. The GLD-360 lightning feed is used to create the 8x8 density grids at OPC. These grids are then made available to WPC, OPC, and SAB through the NCEP network for use in N-AWIPS.

3.16 GOES-R Tropical Overshooting Top Detection

The GOES-R Tropical Overshooting Tops (TOT) product uses infrared window channel imagery to identify domelike protrusions above cumulonimbus anvils associated with very strong updrafts. OTs are identified using a brightness temperature threshold method. Details can be found in Monette (2011). OTs can help to identify vortical hot towers, which are related to tropical cyclone formation (Montgomery et al. 2009) and intensification (Guimond et al. 2010). Real time OT timing and location over the tropical and subtropical Atlantic east of 55^{o}W based on 15-min Meteosat imagery was provided via a web page at CIMSS (http://cimss.ssec.wisc.edu/goes_r/proving-ground/nhc/ot/). GOES-East and GOES-West were used to identify TOTs over the western Atlantic and eastern Pacific. The TOT locations were also provided in N-AWIPS format so they could be overlaid on other products routinely utilized by NHC forecasters.

4. Evaluation Results

Product feedback was obtained using the mechanisms described in section 2. This feedback, related results, and NHC demonstration plans for 2016 are summarized below.

4.1 GOES-R Natural Color Imagery

Evaluation Strategy = Mature

The Natural Color product has proven valuable for public outreach, as well as feature identification such as cloud structure. The GOES-R version of the product is somewhat complex, utilizing a look-up table to estimate the green channel from neighboring channels. It may be necessary to first generate this product externally and then deliver it to NHC’s AWIPS systems, to provide time for local development at NHC. The imagery in Figure 3 provides an example of the product during Tropical Storm Ana, showcasing the changes in storm structure after making landfall in South Carolina.

Figure 3. Proxy (MODIS) GOES-R Natural Color imagery for Tropical Storm Ana before (left) and after (right) making landfall on 11 May 2015.

4.2 GOES-R RGB Air Mass Product

Evaluation Strategy = Mature

The RGB Air Mass product continues to be well utilized. Past training provided by Michael Folmer has helped forecasters better understand the application of this product. It is often mentioned by TAFB analysts in Tropical Weather Discussions in reference to the discrimination between moist tropical air masses and drier mid-latitude air masses, and is similarly used by HSU. A feedback form submitted this year mentioned the contrast in dry and moist mid-level environments relative to Tropical Storm Fred. A second feedback form highlighted the product's utility in analyzing the interaction of a mid-/upper-level trough with Tropical Storm Ida.

There have been critiques on the applicability to the tropics. It was indicated that it would be beneficial to develop an RGB Air Mass product with thresholds tuned to the tropics where ozone concentrations are lower, in comparison to the mid-latitudes for which the product was originally developed. However, the current product is useful during extratropical transition.

4.3 GOES-R RGB Dust Product (EUMETSAT Version)

Evaluation Strategy = Mature

Along with the RGB Air Mass product, the RGB Dust product continues to be one of the most highly utilized PG products. In addition to identifying regions of dust, the product is routinely used to assess moisture conditions at low-levels. This was indicated by several feedback forms during this year's demonstration, with references to Hurricane Danny, Hurricane Fred, and Tropical Storm Henri. Figure 4 shows an example of RGB Dust imagery for Hurricane Danny. Forecasters were able to determine that the dry/stable air (pink) surrounding the cyclone was blocked off by a perimeter of moist/unstable air, allowing the system to further intensify.

Since the RGB Dust product is considered a Mature PG product, the main focus has been to compare it with the CIRA DEBRA-Dust product (see section 4.14). Feedback suggests that while the RGB Dust product provides additional information to the presence of dust, this may come with a learning curve and require more training.

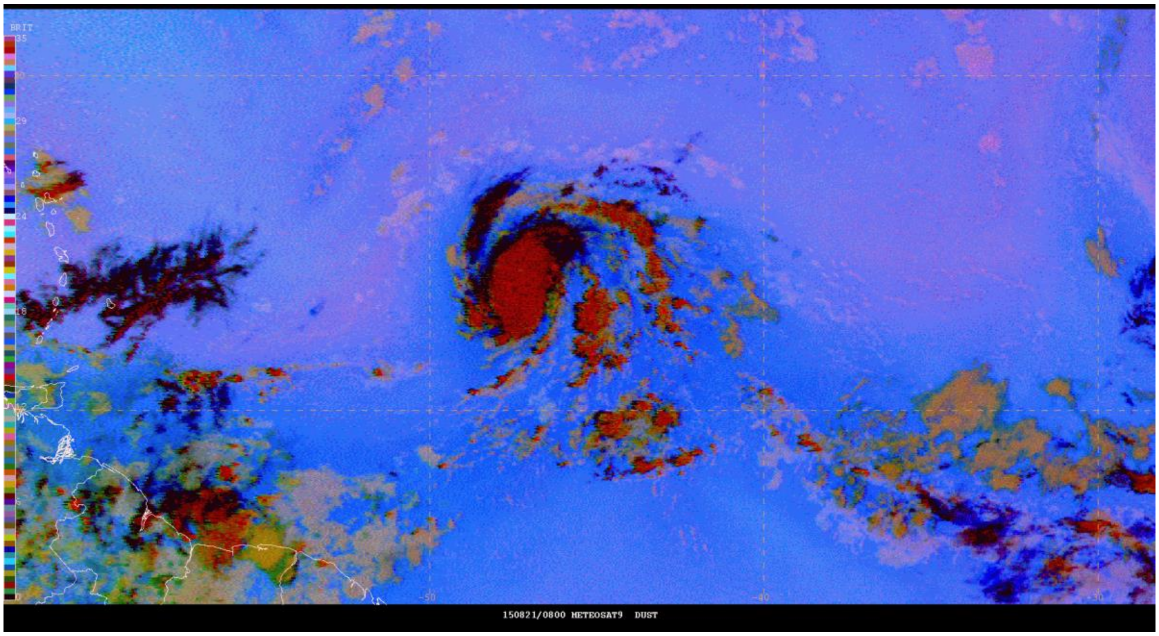


Figure 4. Proxy (SEVERI) RGB Dust imagery for Hurricane Danny on 21 August 2015.

4.4 GOES-R Saharan Air Layer (SAL) Product

Evaluation Strategy = Mature

The GOES-R SAL product is routinely used by both TAFB and HSU to identify dry and dusty air masses. This year it was noted that a major limitation of the SAL product is the possibility of overhead cirrus clouds or nearby moisture obscuring the signal. For example, moist outflow at the top of a system may block the view of a very dry signal underneath. For this reason, the SAL product is best used in conjunction with the RGB Dust and Air Mass products, and they were often mentioned together in forecaster feedback.

Figure 5 is an example of RGB SAL imagery for Hurricane Danny. This image was taken at the same time as the RGB Dust imagery in Figure 4, and shows how they might be used together to determine the boundary of the dry air mass and convection associated with the system. Feedback suggests the SAL product more clearly shows the separation in this instance. Training efforts for 2016 might want to focus on elaborating on the similarities and differences of the various NHC PG RBG products, their respective strengths and weaknesses, and examples of how multiple products may complement each other during analysis and forecasting.

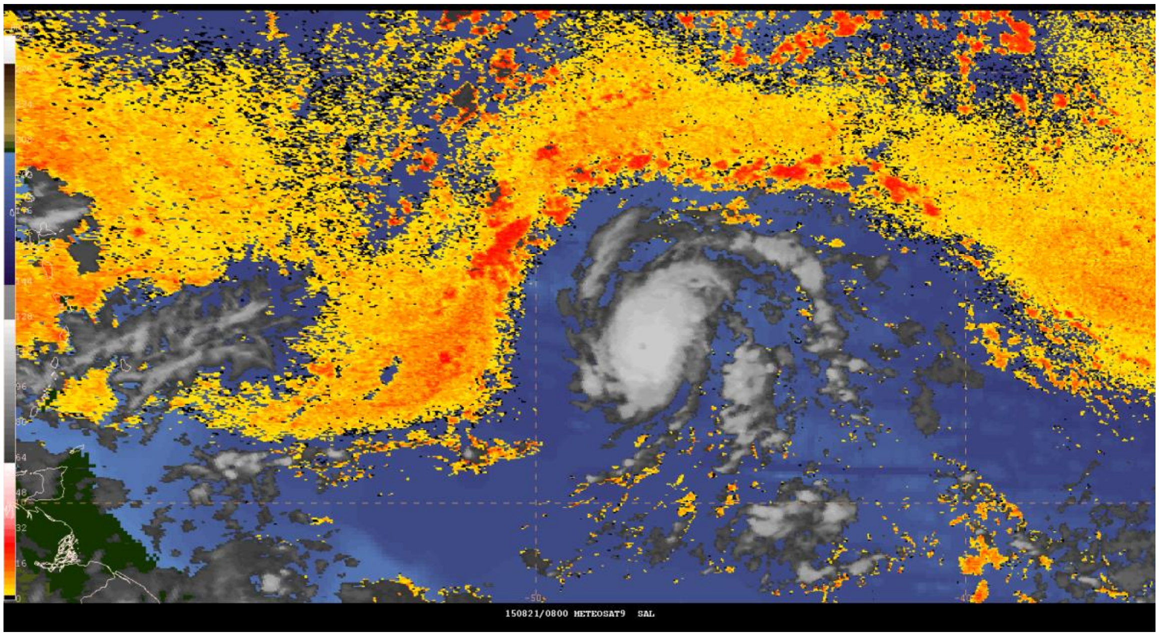


Figure 5. The RGB SAL product for Hurricane Danny on 21 August 2015.

4.5 GOES-R Pseudo Natural Color Imagery

Evaluation Strategy = Mature

Although no specific feedback was obtained in 2015, the GOES-R Pseudo Natural Color product could be a complement to the Natural Color product described in section 4.1. One benefit is that it is much easier to implement locally at NHC since its generation primarily involves image combinations and does not require a look up table. It would be used for the same purposes, primarily public outreach and limited feature identification.

4.6 GOES-R SRSO Imagery

Evaluation Strategy = Mature

The GOES-R Super Rapid Scan Operations product received a significant amount of positive feedback this year. Forecasters notice a marked improvement over 15-minute imagery. Quantitatively the higher time resolution data will lead to better model input, particularly in association with the wind field and associated changes in convergence, divergence, and vorticity. HSU feedback suggests key applications of rapid scan include the identification of center formation and in center-fixing systems that are weak, especially near sunrise. TAFB forecasters found the SRSO data useful for their tropical weather discussions, and helped document convection within tropical waves.

A full list of 2015 GOES-R SRSO periods can be found at http://cimss.ssec.wisc.edu/goes/srsor2015/GOES-14_SRSOR.html). A period of GOES-14 SRSO captured Hurricane Danny in the Atlantic from 21-22 August 2015. Figure 6 shows a snapshot from the resulting loop of 1-minute visible imagery. This imagery clearly shows the eye, surrounding cloud structure, and a SAL wrapping around the west side. When looped, details in the convective bursts within the eyewall can also be seen.

The main concern is accommodating the large data associated with and loading/displaying 1-minute imagery. Further discussion is needed on the optimal temporal resolution, which will be a compromise between higher resolution and reasonable frame count. It was suggested that 2-3 minute imagery may be optimal.

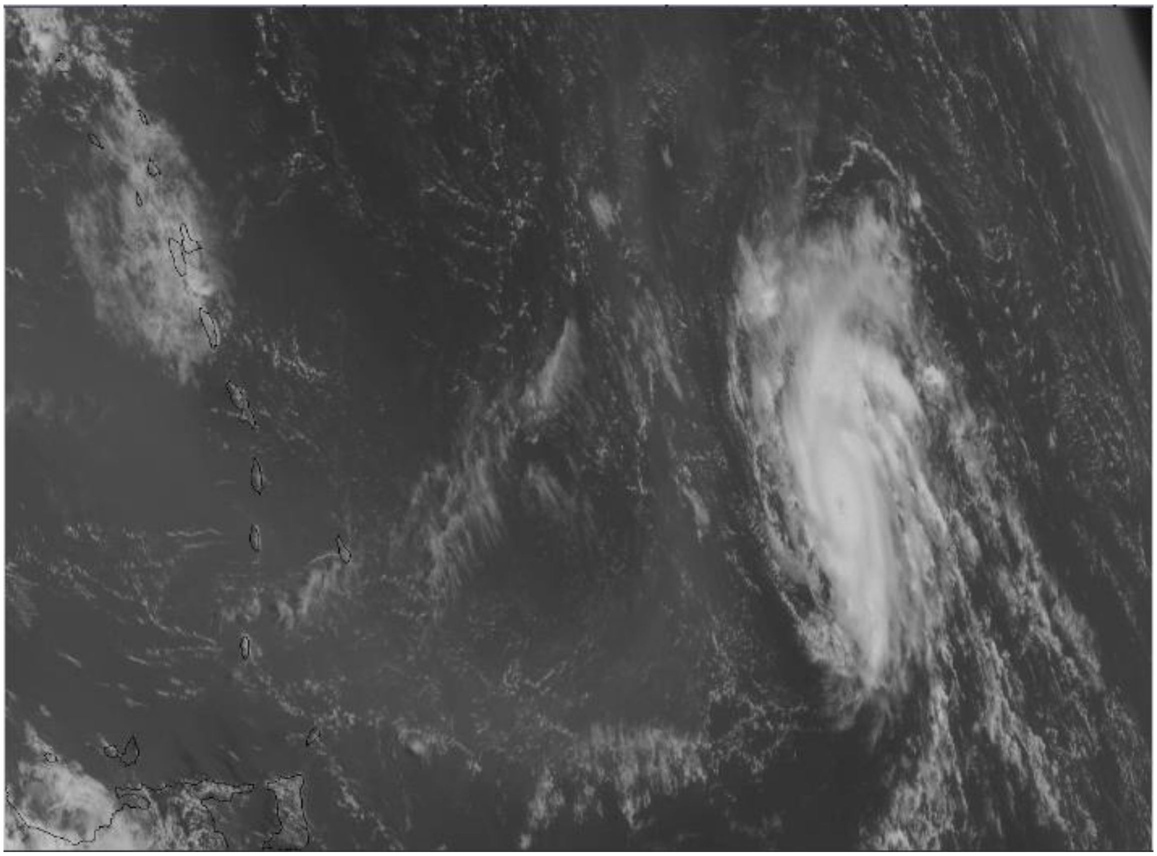


Figure 6. Snapshot from a GOES-14 SRSO visible imagery loop for Hurricane Danny on 21 August 2015.

4.7 GOES-R Hurricane Intensity Estimate (HIE)

Evaluation Strategy = Quantitative

The HIE product was generated from MSG and GOES-East and available to the NHC forecasters via a web page. Feedback from TAFB analysts indicate the ADT and HIE are used semi-regularly. In 2015, HIE estimates were available for 4 tropical cyclones spanning 34 distinct synoptic times. This relatively small sample is due to a lack of tropical cyclones in the HIE domain (see Figure 2a). HIE estimates and corresponding Best Track intensity values for all 2015 Atlantic cases are shown in Figure 7. The HIE had a mean absolute error of 6.8 kts in 2015 with a positive bias of 2.7 kts. The HIE consistently underestimated the intensity of Fred during its dissipation stage, which is consistent with reported ADT biases (Olander and Velden 2007, Figure 7). The HIE overestimated the peak intensities of Fred and Grace, with the largest overestimates occurring in the 1-2 days after the storms reached maximum intensity.

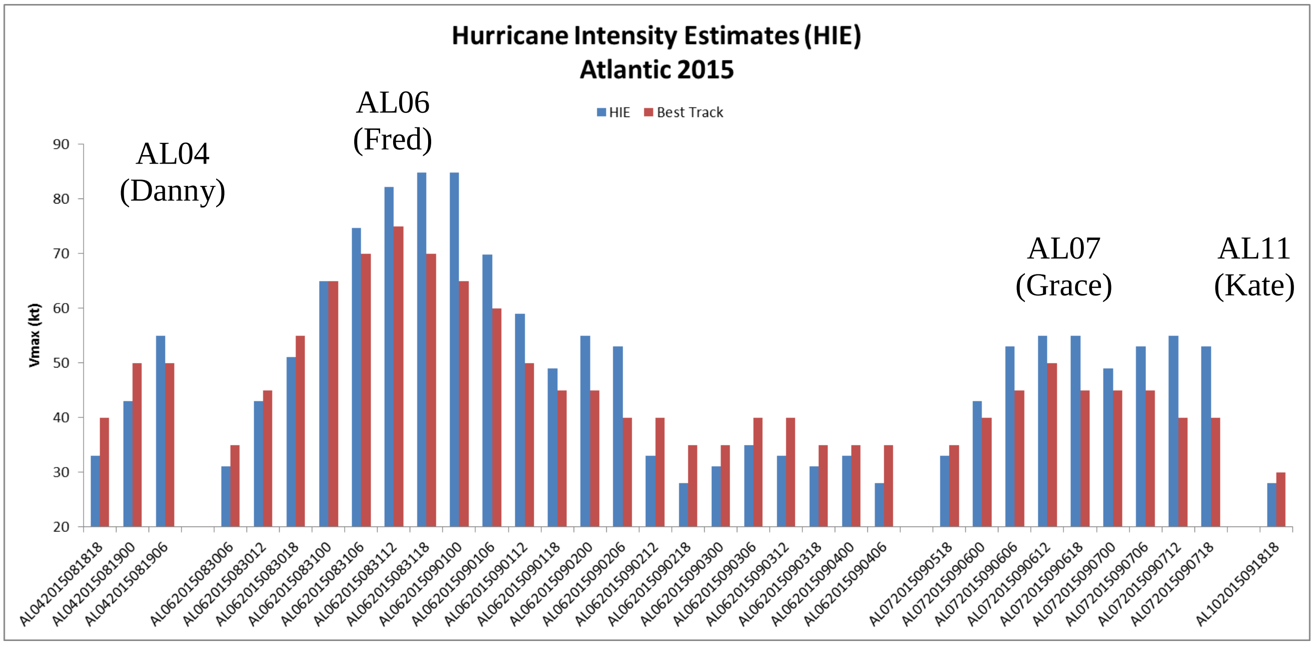


Figure 7. HIE estimates (blue) vs. Best Track intensities (red) for 2015 eastern Atlantic tropical cyclones, in knots.

4.8 GOES-R Lightning-based RII

Evaluation Strategy = Quantitative

As in previous years, the experimental lightning-based RII was run in real time for all cases in the Atlantic and eastern North Pacific and the output data was made available via ftp during the 2015 season. Two versions of the experimental RII were run; one that includes the lightning data and a version that is identical except that it does not include the lightning input. This allowed a direct evaluation of the impact of the lightning input. The coefficients of the RII show that an increase in inner-core lightning activity is often associated with increasing vertical shear and makes intensification less likely. Conversely, lightning in the rain band regions indicates intensification is more likely. This behavior was included in forecaster training on the lightning RII product. As described above in section 3.8, the quantitative RII product used the WWLLN data, while the NHC forecasters used the GLD-360 data in N-AWIPS for qualitative applications.

Examples of the two experimental versions of the RII are shown below. Figure 8 shows the RIIs and inner core and rainband lightning activity during the intensification of Hurricane Joaquin. At most times, the two versions of the RIIs were nearly the same. The largest deviations occur at times when the inner core lightning was quite a bit larger than rainband lightning, resulting in lower probability estimates for the lightning-based RII. The same is true for Hurricane Patricia (Figure 9). The times when the lightning-based RII probability is less than control are generally during or followed by periods where the rate of intensification slowed somewhat (e.g., 093000 and 100100 for Joaquin, 102206 for Patricia). However, this signal is neither clear nor consistent, suggesting further research is required to better isolate the relationship between TC lightning and rapid intensity change.

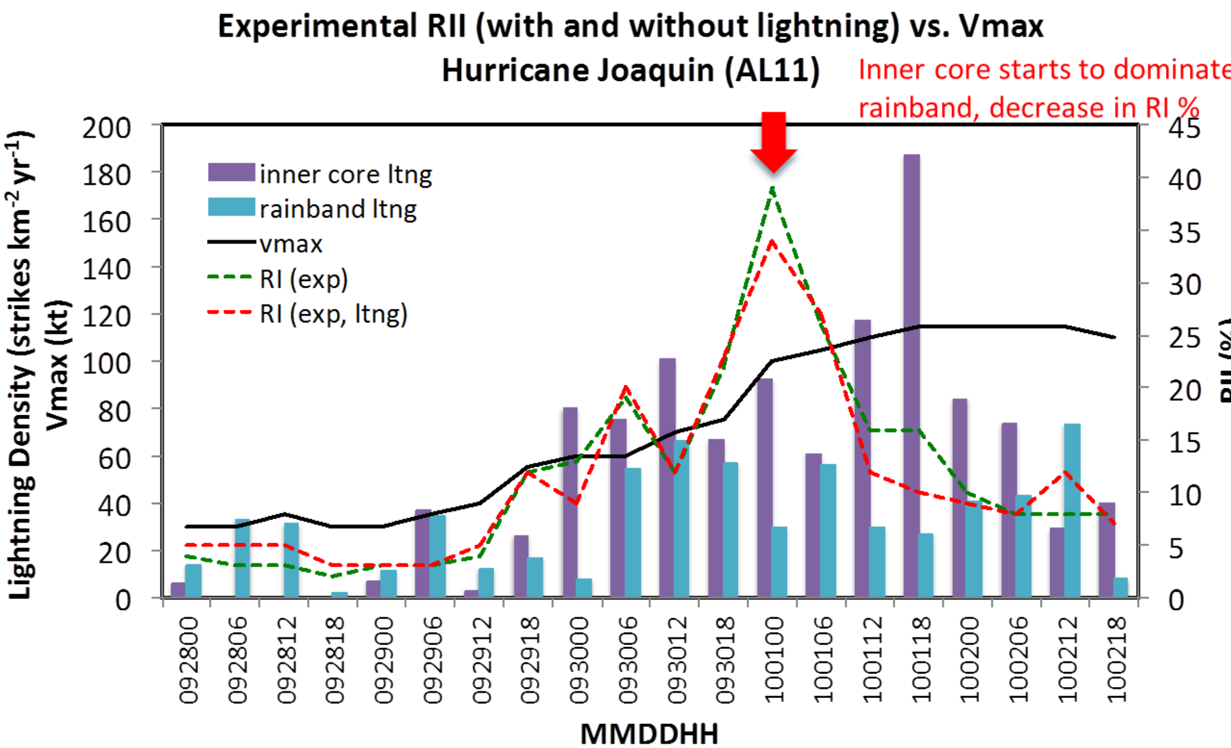


Figure 8. The RII with (green line) and without (red line) lightning-based predictors for Hurricane Joaquin. Observed vmax (black line) and inner core (purple bars) and rainband (blue bars) lightning density are also shown.

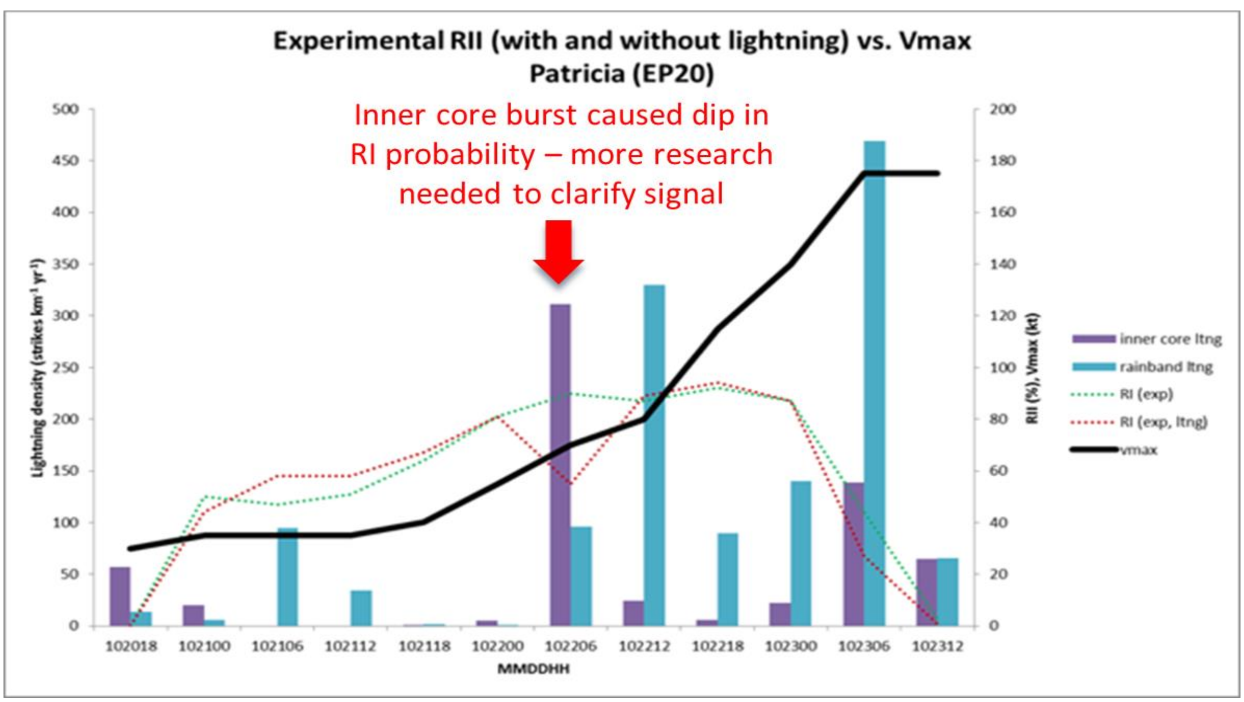


Figure 9. The RII with (green line) and without (red line) lightning-based predictors for Hurricane Patricia. Observed vmax (black line) and inner core (purple bars) and rainband (blue bars) lightning density are also shown.

Because the RII provides a quantitative estimate of the probability of RI, a quantitative product validation can be performed. Three metrics commonly used for probabilistic forecasts were utilized. These included the Bias, Brier Score and Threat Score (TS).

The Bias is usually calculated as the average of all forecasted probabilities divided by the observed percentage of RI cases in the verification sample. This provides an indication of whether RI is being over- or under-forecasted over a large number of cases.

The Brier Score is analogous to a Root Mean Square (RMS) error for probabilistic forecasts. It is the square root of the square of the difference between the predicted and observed probabilities, where the observed probability is 1 if RI occurred or 0 if RI did not occur for that case. This value is summed over all the forecast cases.

The Threat Score (TS) is calculated using

$$TS = N_{f\ and\ obs}/(N_f + N_{obs}) \qquad (1)$$

where N_f is the number of cases that were forecast to undergo RI, N_{obs} is the number of cases that were observed to undergo RI based on the NHC final best track, and $N_{f\ and\ obs}$ is the number of cases that were forecast to undergo RI and did undergo RI. The TS ranges between zero (no correct forecasts) and one (correct forecasts of all observed events with no false alarms). The TS depends on the probability threshold used to separate a forecast of a yes versus no event. For the verification, the TS was calculated for a range of thresholds from 0 to 100%, and the value that maximized the TS was utilized as a measure of the performance of the algorithm.

The Bias Error, BS and TS were calculated for lightning and no-lightning versions of the RII, and the percent improvement in each parameter was calculated for the Atlantic and East Pacific samples. The Atlantic (East Pacific) sample included 188 (501) cases. In the developmental sample about 8% (9%) of the Atlantic (East Pacific) cases were RI cases; in 2015, 6% (11%) were RI cases.

Figure 10 shows the percent improvement of the verification metrics due to the inclusion of the lightning input. For the 2015 Atlantic sample, the inclusion of the lightning data improved the optimal threat score but degraded the bias. However, these differences are very small (<2%) and the Atlantic sample was small and had fewer RI cases than average. The addition of lightning data improved the East Pacific Brier scores and threat scores and had little impact on the bias. As described above, the averaging areas of both the inner core and rainband regions were expanded for the 2014 season. This may have led to the degradations in the RII with the lightning since east Pacific tropical cyclones are generally smaller than Atlantic cyclones (Knaff et al. 2014). This result suggests that different averaging areas may be needed for each basin, or application of a more sophisticated algorithm that uses the IR imagery to provide an estimate of storm size, which can then be used to provide appropriate averaging areas on a case by case basis.

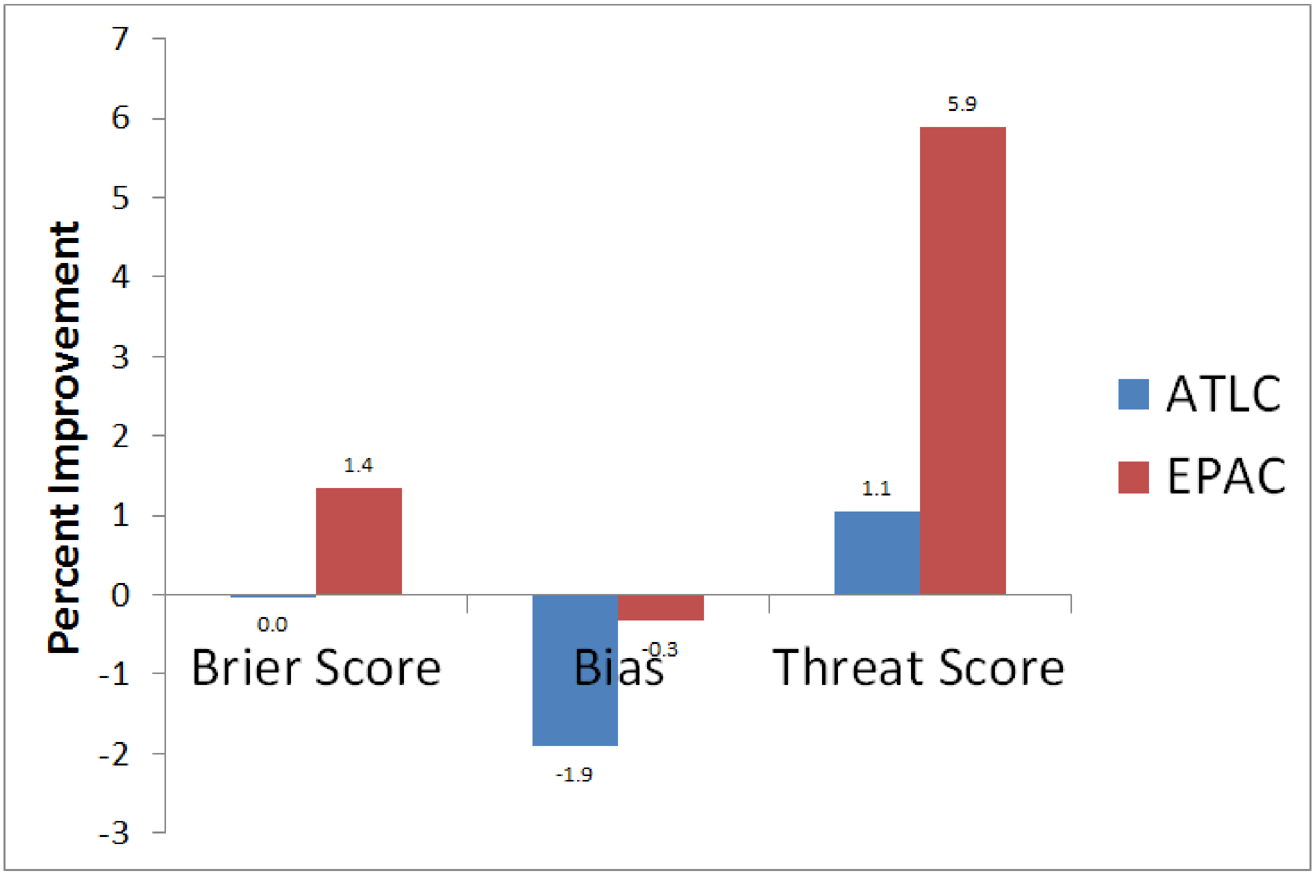


Figure 10. The percent improvement in the Brier Score, Bias and Threat Score when the lightning data was added to the RII for the 2015 Atlantic and East Pacific forecasts.

4.9 GOES-R RGB Daytime Microphysics

Evaluation Strategy = Introductory

The RGB Daytime Microphysics product is a newer product in the NHC PG, and feedback has been limited. It has been indicated that slight changes in the range would make the product more applicable to the tropics. In general there has been uncertainty as to if the product provides improvement over other products, or if there is a redundancy in information. HSU forecasters suggested that the RGB products being demonstrated are useful in analyzing and understanding the large-scale environment. On the other hand, without background knowledge and a framework for interpretation, they are unsure how to use and incorporate the product in TC analysis. This includes storm-scale features related to TC track, intensity, and structure. Looking forward, it may be beneficial to provide focused training and resources on RGB interpretation in relation to TCs.

4.10 GOES-R RGB Nighttime Microphysics

Evaluation Strategy = Introductory

The RGB Nighttime Microphysics product was new to the NHC PG in 2014. As such, HSU forecasters and TAFB analysts were still becoming familiar with this product during the 2015 season.

In general, it seems to be used comparably to the RGB Dust and RGB Air Mass products. Specific feedback (via online form) stated that the product was able to show a significant contrast in moisture on the east and west sides of Tropical Depression Eight (later Henri). This is seen in Figure 11, with a dry tongue wrapping inwards to the west.

As with RGB Daytime Microphysics, more experience is needed to understand the behavior of the product in some cases and tuning might be necessary to better represent tropical cyclone applications. It was further noted that the product utilizes the IR 3.9 channel, which is often quite noisy. This seems to affect the detail of the imagery at night making it difficult to identify storm-scale convective features, but still useful for identifying large scale moist air masses. An alternative product was mentioned that does not rely on the channel, RGB 24-Hour Microphysics developed by NASA SPoRT.

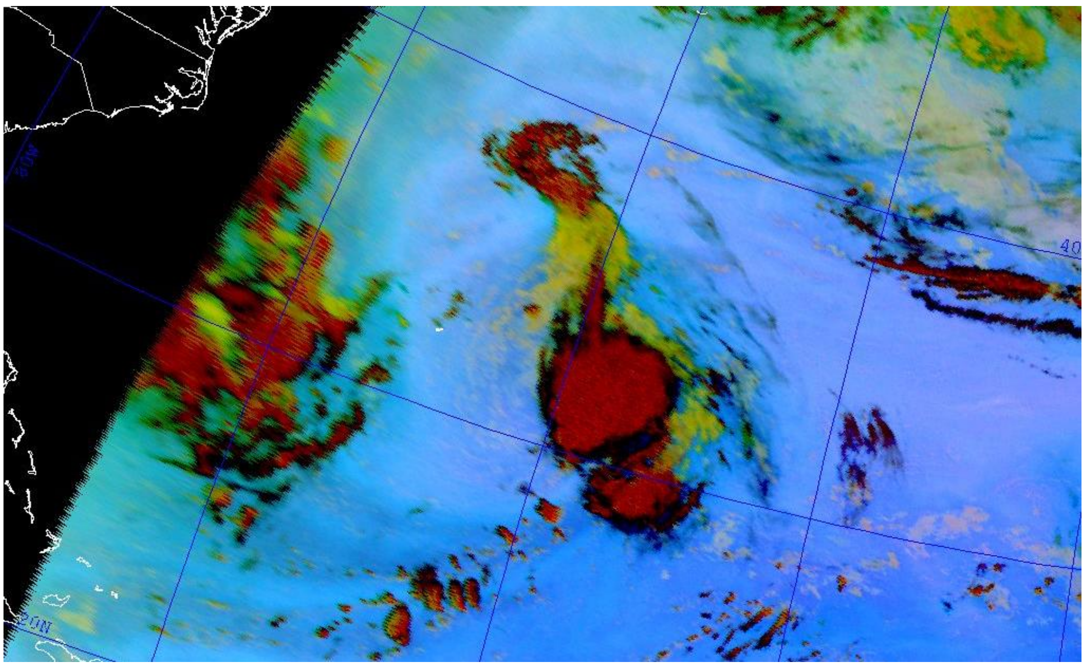


Figure 11. The RGB Nighttime Microphysics product for Tropical Depression Eight (later Henri) on 10 September 2015.

4.11 GOES-R RGB Daytime Convective Storms

Evaluation Strategy = Introductory

The RGB Daytime Convective Storms product is a newer product in the NHC PG, and feedback has been limited. As with RGB Daytime and Nighttime Microphysics products, more experience is needed to understand the behavior of the product in some cases and tuning might be necessary to better represent tropical cyclone applications. Future training efforts might focus on basic interpretation with examples specific to the tropics.

4.12 GOES-R Derived Motion Winds

Evaluation Strategy = Introductory

The HSU and TAFB were unable to display the GOES-R Derived Motion Winds product in NAWIPS this season. Consequently, no specific feedback was obtained. Michael Folmer is working with TSB staff to enable display of the GOES-R DMWs in 2016.

4.13 S-NPP VIIRS Day/Night Band

Evaluation Strategy = Introductory

The VIIRS Day/Night Band shows potential when there is a separation between the surface center and mid-level circulation, with no visible imagery available at night. This can happen in the presence of vertical wind shear. There were several mentions in Tropical Cyclone Discussions of the center being difficult to locate in infrared satellite imagery, particularly early in the morning. Figure 12 shows DNB imagery for Post-Tropical Cyclone Sandra (formerly a hurricane) as it approached the west coast of Mexico on 28 November 2015. The low level circulation was displaced to the west of the deepest convection, which is not clear in the IR image shown for comparison. This is an example of how the VIIRS DNB imagery can provide important information regarding TC structure at night that cannot be easily diagnosed with infrared-based imagery alone.

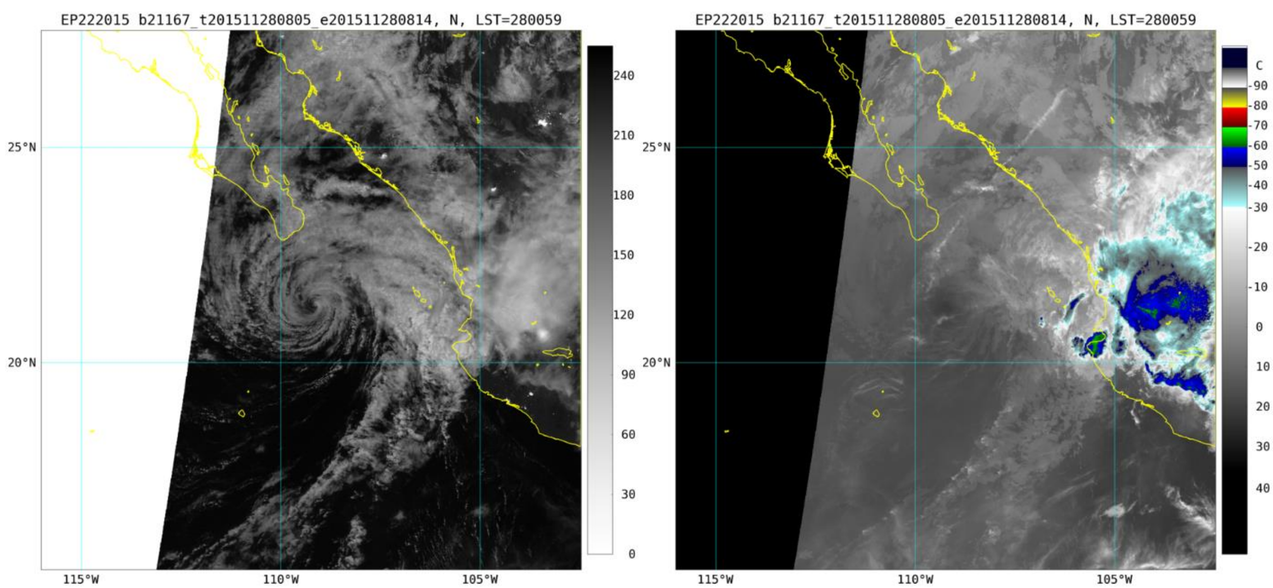


Figure 12. Day-night band imagery (left) compared to the standard IR image (right) for Hurricane Sandra on 28 November 2015.

4.14 GOES-R RGB Dust Product (CIRA DEBRA-Dust Version)

Evaluation Strategy = Comparison

As the GOES-R launch approaches, decisions will need to be made regarding the product sets to be routinely included on NHC AWIPS systems. The standard EUMETSAT Dust product has been demonstrated for several years, and has proven its utility for several HSU and TAFB applications. A more sophisticated product has been developed by CIRA, which shows promise. However, the new product is somewhat more difficult to implement. A decision needs to be made as to whether the enhancements are worth the additional complications.

The main goal for this GOES-R Future Capability product was to compare and contrast it with the EUMETSAT RGB Dust product. HSU feedback noted that the DEBRA-Dust product excels at identifying dust and dust boundaries. However, the EUMETSAT version also highlights large scale features such as tropical waves and moisture boundaries in addition to dust, which may be more useful depending on the type of analysis being performed. Feedback continues to indicate that the two products complement each other, and that DEBRA-Dust product is helpful with interpretation of the EUMETSAT product.

The two dust products are used together by TAFB to look at the moist/dry contrast at low levels. Although the EUMETSAT product provides additional information, TAFB feedback suggests that DEBRA-Dust is more useful when dust is exclusively important, i.e. a hazard for visibility with marine and aviation applications. Figure 13 shows an example comparing the two dust products during the time of Hurricane Fred. DEBRA-Dust clearly defines regions with high reliability of dust in yellow, while the EUMETSAT version indicate a larger region of dust in pink.

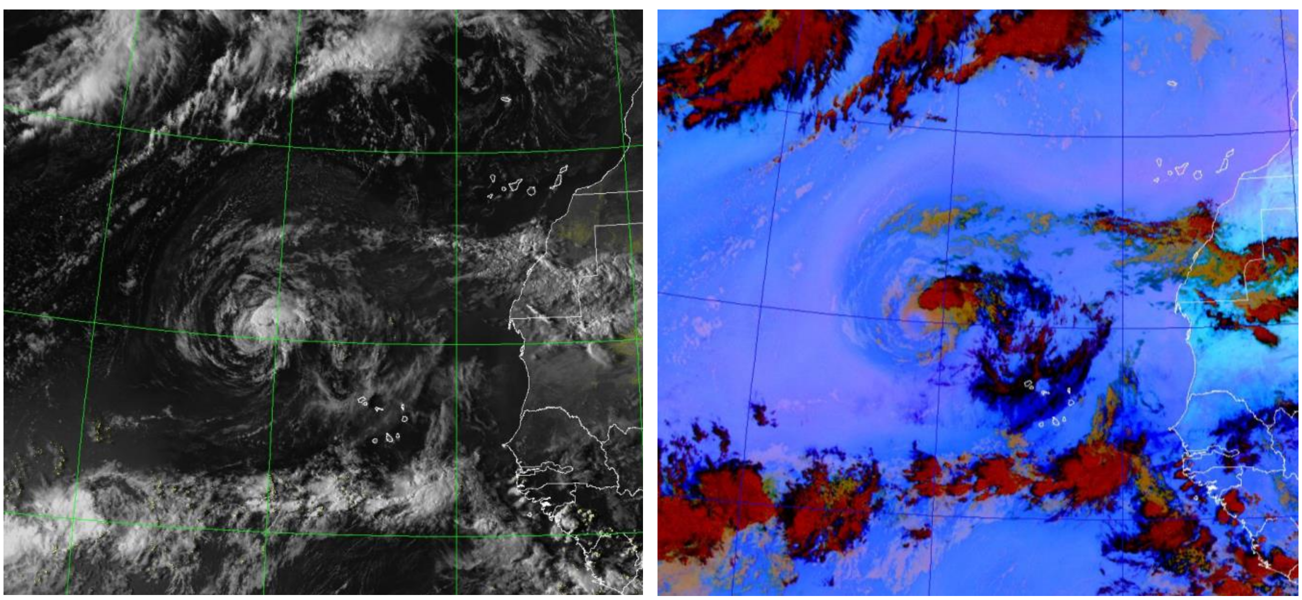


Figure 13. The DEBRA-Dust (left) and EUMETSAT (right) RGB dust products showing Hurricane Fred on 21 August 2015.

4.15 GOES-R GLM Lighting Detection (GLD-360 Lightning Density proxy)

Evaluation Strategy = Comparison

The GLD-360 Lightning Density product was routinely used is 2015, as an indicator of vigorous updrafts and more active areas of convection. HSU forecasters acknowledge the utility of the product during the tropical cyclone pre-genesis phase in identifying where the center is likely to consolidate. Feedback continues to address the observed relationships between 1) increases in inner-core lightning and increases in vertical shear and 2) increases in inner-core lightning and a halting of intensification or a delay in rapid intensification. These relationships have been documented in DeMaria et al. 2012. A more in-depth discussion of NHC PG feedback regarding lightning activity and RII can be found in section 4.8 on the Lightning-based RII. An example of the lightning density during Hurricane Joaquin is shown in Figure 14, though it was noted that Joaquin was not a classical case due to the intensification in persistent northerly shear. More basic research may be needed on the factors to be considered when looking at lightning, including shear and other environmental conditions.

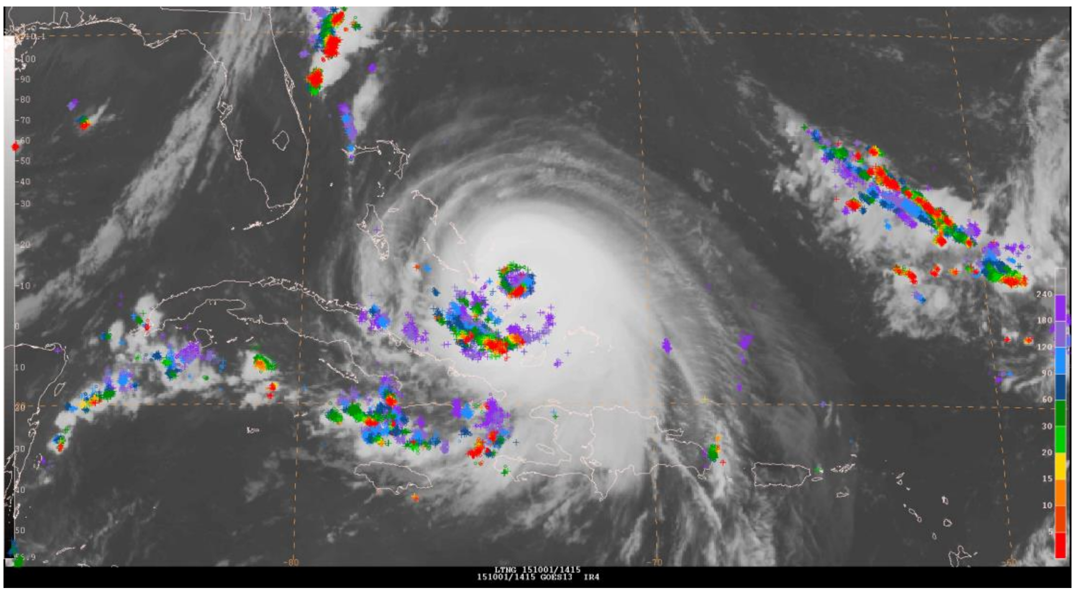


Figure 14. GLD-360 Lightning Density for Hurricane Joaquin on 1 October 2015.

4.16 GOES-R Tropical Overshooting Top Detection

Evaluation Strategy = Underutilized

The GOES-R Tropical Overshooting Top Detection product has been underutilized for the past few years. General HSU feedback suggests there is a lack of a consistent, observable relationship between TOTs and TC intensity change in real time. It was noted that the product may prove more useful in combination with another product, or in a quantitative format. TAFB analysts have found the TOT product useful, suggesting there are potential marine and aviation applications. They would be interested in seeing a related product that highlights the change in overshooting tops with time, which could hint at the potential for downdrafts.

4.17 Plans for 2016

The NOAA Satellite Proving Ground at the National Hurricane Center will continue in 2016, coinciding with the planned launch of GOES-R in the fall. This will be the last NHC PG before GOES-R data become available. During this time, the final selection of initial GOES-R products, future capabilities, and decision aids to be displayed at NHC will be determined. No new GOES-R products will be introduced in 2016. Obtaining feedback on the newer GOES-R proxy RGB products and the Derived Motion Winds will be a priority in the upcoming NHC PG, as will continuing to gather feedback that will help refine the NHC GOES-R initial product suite.

Two new JPSS capabilities will be introduced this year. The NUCAPS extratropical transition product will be evaluated for all potential ET cases in the Atlantic. Additionally, NUCAPS sounding products will be used to help validate moisture boundaries identified by the RGB SAL, airmass, and dust products. The use of ATMS/CrIS soundings to obtain storm environment temperature and moisture profiles will also be investigated. Several product adjustments and improvements will be made based on validation and feedback from past demonstrations. Development of AWIPS displays of PG products will continue.

Feedback in 2015 suggested that several products may be underutilized because the framework for interpretation is not well understood, particularly in regards the RGB products. To address this, a new action item for 2016 is to develop a series of quick reference guides tailored to tropical forecasting applications that will be made available to HSU forecasters and TAFB analysts. These will have a similar two-page format as the quick guides developed by NASA SPoRT, including a brief description of the product, specific examples that highlight main uses, and links to more comprehensive resources. The plan is to provide a document for each 2016 NHC PG product, in addition to direct comparisons of the products that are similar.

5. Performance and Success Measures

5.1 Relevance

Five of the NHC PG demonstration products will be moved to the next phase of texting in 2016.

HIE - through DOE-4 efforts, the NHC will be testing getting simulated HIE data through the operational data stream.

Lightning-based RII - the algorithm coefficients will be re-derived for 2016 to include cases from the last few years

Derived Motion Winds - capabilities have now been established to view the DMW vectors in N-AWIPS and AWIPS at NHC.

DEBRA-Dust - capabilities have now been established to view DEBRA-Dust in N-AWIPS at NHC. Forecasters will now be able to directly compare DEBRA-Dust with the EUMETSAT Dust RGB in the operational environment (i.e., without having to access a web page).

Day-Night Band - The availability of DNB imagery will be improved in 2016 with the addition of data from AOML Direct Readout. This should increase the opportunities forecasters will have to evaluate the DNB in real-time operations.

5.2 Quality

Many of the products in the NHC PG are qualitative in nature, and hence evaluations to date have focused on qualitative forecaster feedback via the online form and in-person discussions. Two of the products, the HIE and Lightning-based RII, provide quantitative estimates that are verified each year (see Sections 4.7 and 4.8). Currently, the impacts on workflow are also assessed through qualitative feedback. More quantitative metrics of workflow impacts and utility and performance of qualitative products will be investigated in 2016.

5.3 Efficiency/Effectiveness

Activities related to 15 of the 16 NHC PG were executed as planned in 2015. The one product that was not demonstrated as planned was the Derived Motion Winds, which took longer to display in NAWIPS than we had planned.

The NHC PG Participants are listed in the NHC PG Demonstration Plan (http://www.goes-r.gov/users/pg-activities-01.html). Participants include forecasters from NHC HSU and TAFB and product developers.

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