The 2013 Proving Ground Demonstration at the National Hurricane Center – Final Evaluation

Project Title: The 2013 GOES-R Proving Ground Demonstration at NHC Final Report

Organization: NOAA/NWS National Hurricane Center (NHC)

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

Duration of Evaluation: 01 Aug 2013 – 30 Nov 2013

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1. Executive Summary

Eleven prototype GOES-R products and one prototype JPSS product were demonstrated during the 2013 Satellite Proving Ground at the National Hurricane Center from Aug. 1st to Nov. 30th. Valuable forecaster experience and feedback were obtained. Nine of these products were demonstrated in the 2012 PG and three were new. The new products, which were implemented about a month after the demonstration began, included two new Red-Green-Blue (RGB) products, and the VIIRS day/night band.

The 2013 Atlantic hurricane season was very inactive, and the eastern North Pacific season had somewhat below normal activity, especially with regard to major hurricanes. This lack of tropical cyclone activity provided some limitations on product evaluation. However, considerable feedback on the utility of lightning data was obtained, and several RGB products (especially Air Mass and Dust) have now become fairly routinely utilized by part of NHC operations. Feedback was also obtained on the Hurricane Intensity Estimate (HIE) product including the utility of the higher refresh rate. In addition, a new Local Data Manager (LDM) feed was set up to NHC from SPoRT, which provided more efficient access to products. Feedback on the lightning-based rapid intensification index is being used to modify the algorithm for the 2014 season.

2. Introduction

The purpose of the GOES-R Proving Ground (PG) demonstration at the National Hurricane Center (NHC) is to provide NHC forecasters with an advance look at tropical cyclone related products for evaluation and feedback during the most active period of the Hurricane season (August 1 – November 30). Eleven GOES-R products and decision aids and 1 S-NPP product provided by NESDIS/STAR, CIRA, CIMSS, CIMAS, SPoRT and OAR were considered for evaluation at the NHC (Table 1). The Advanced Baseline Imager (ABI) products are being produced using proxy data from Meteosat, GOES, and MODIS, and the Geostationary Lightning Mapper (GLM) product is being produced from ground-based World Wide Lightning Location Network (WWLLN) data. NHC also has access to the Vaisala GLD360 lightning data in real time on their N-AWIPS systems as another proxy for the GLM.

Feedback on the utility of the GOES-R 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 mid-project review held at NHC on 17 Sep. 2013. The new feedback form was easy to use and 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 http://nasasport.wordpress.com and http://rammb.cira.colostate.edu/research/goes-r/proving_ground/blog.

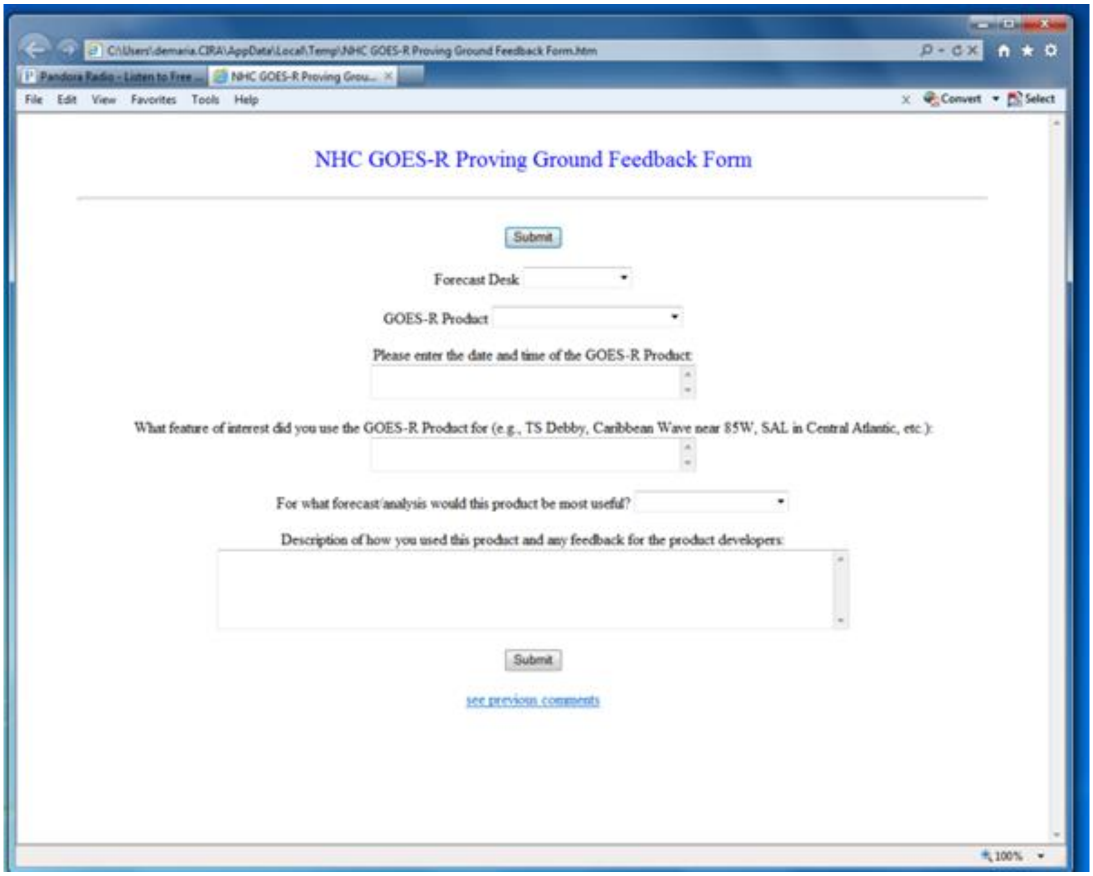
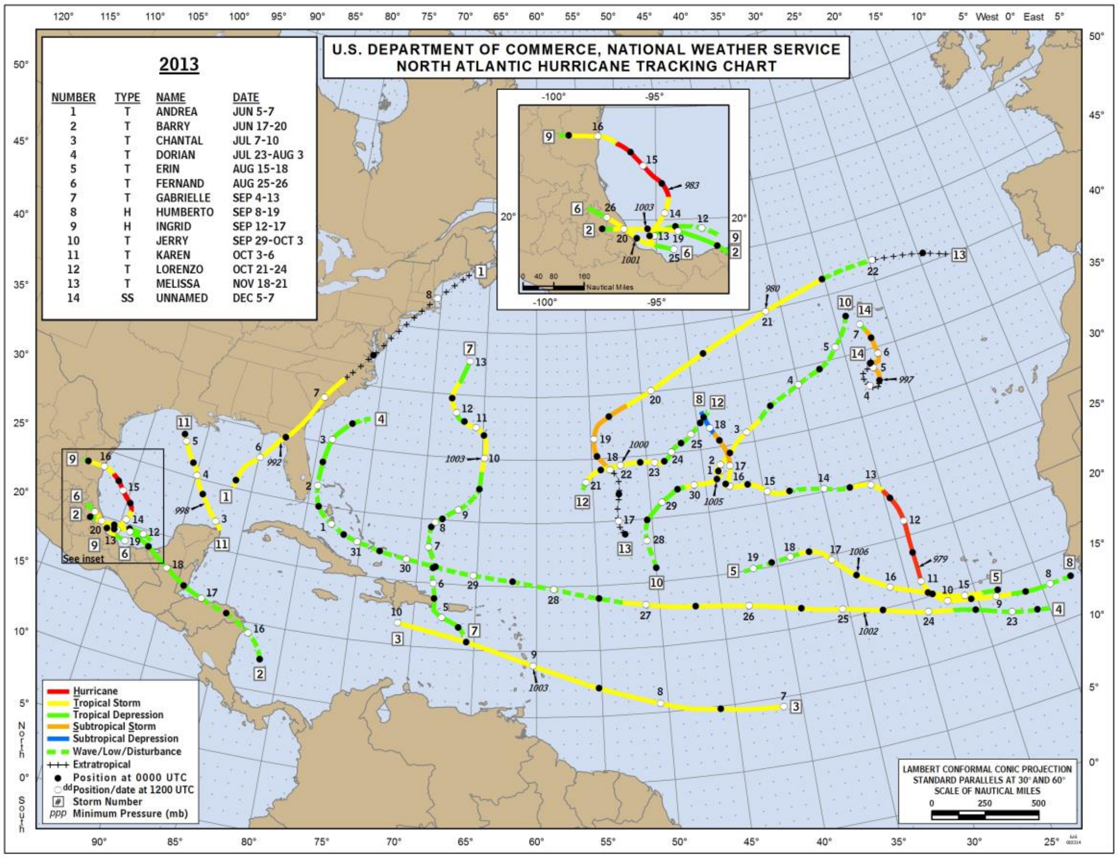


Figure 1. The feedback form used during the 2013 NHC Proving Ground.

The 2013 tropical cyclone activity is shown in Fig. 2 for the Atlantic and eastern North Pacific. The Atlantic season was average in terms of the number of named storms, but was the number of hurricanes (two) was far below average. There were no major hurricanes in the Atlantic and no periods of rapid intensification, which is especially unusual. The eastern North Pacific season was near normal in terms of the number of named storms and number of hurricanes. However, there was only one major hurricane in the eastern North Pacific, and below average periods of rapid intensification.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NORTH ATLANTIC HURRICANE TRACKING CHART
2013
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2 T BARRY JUN 17-20
3 T CHANTAL JUL 7-10
4 T DORIAN JUL 23-AUG 3
5 T ERIN AUG 15-18
6 T FERNAND AUG 25-26
7 T GABRIELLE SEP 4-13
8 H HUMBERTO SEP 8-19
9 H INGRID SEP 12-17
10 T JERRY SEP 29-OCT 3
11 T KAREN OCT 3-6
12 T LORENZO OCT 21-24
13 T MELISSA NOV 18-21
14 SS UNNAMED DEC 5-7
See inset
Nautical Miles
Hurricane
Tropical Storm
Tropical Depression
Subtropical Storm
Subtropical Depression
Wave/Low/Disturbance
Extratropical
Position at 0000 UTC
dd Position/date at 1200 UTC
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ppp Minimum Pressure (mb)
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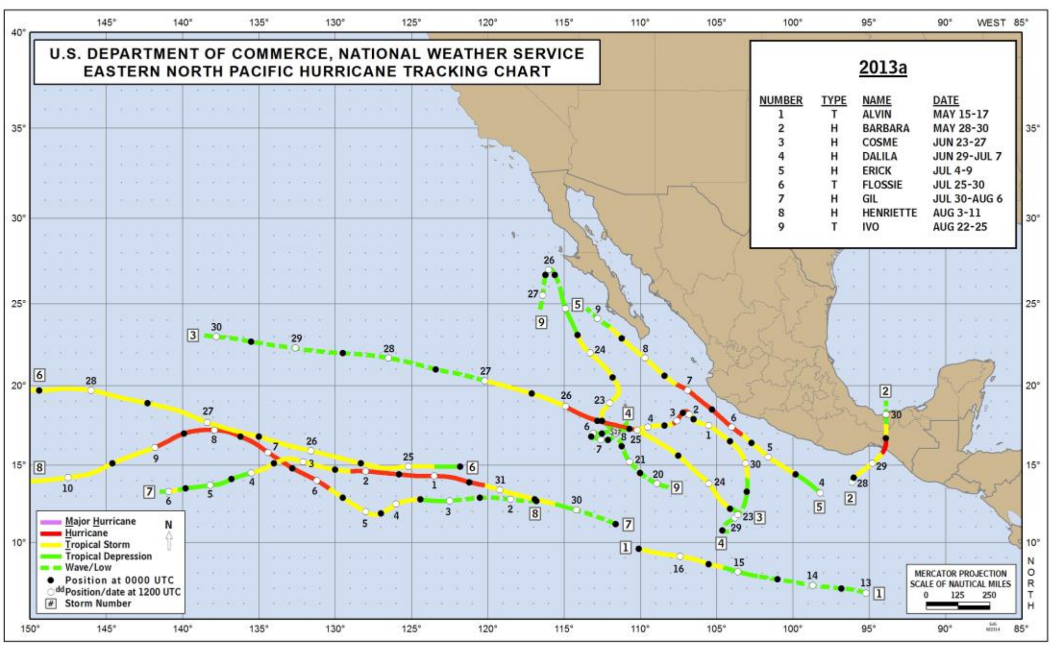
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6 T FLOSSIE JUL 25-30
7 H GIL JUL 30-AUG 6
8 H HENRIETTE AUG 3-11
9 T IVO AUG 22-25
Major Hurricane
Hurricane
Tropical Storm
Tropical Depression
Wave/Low
Position at 0000 UTC
dd Position/date at 1200 UTC
Storm Number
MERCATOR PROJECTION
SCALE OF NAUTICAL MILES
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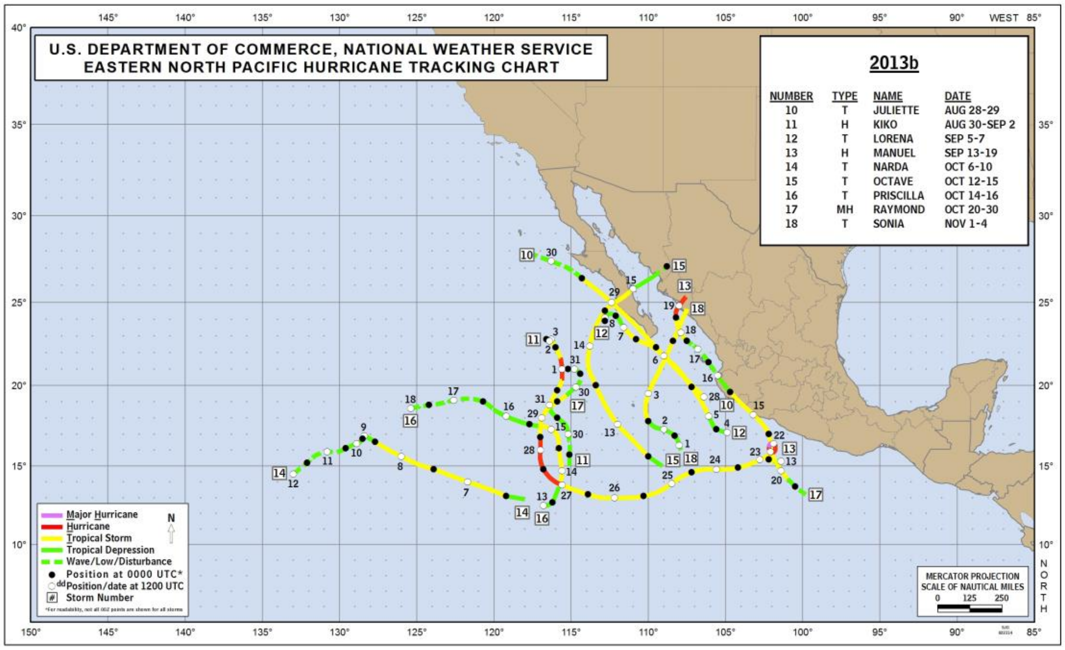

Figure 2. The 2013 season tropical cyclone tracks and intensities for the Atlantic (top) and eastern North Pacific (middle and bottom).

3. Products Evaluated

Table 1 summarizes the twelve products demonstrated in the 2013 Proving Ground. 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. Brief summaries of each product are provided below. Products 10-12 were new to the Proving Ground in 2013 while products 1-9 were continuing from the 2012 Proving Ground.

Table 1. The twelve GOES-R Products demonstrated in the 2013 NHC Proving Ground.

Product Name	Proxy Data	Product Type	Delivery Mechanism
1. Hurricane Intensity Estimate	SEVIRI, GOES – East Imager	Text	Web
2. Super Rapid Scan Imagery	GOES-East, -West and -14	Imagery	Web
3. Tropical Overshooting Tops	SEVIRI, GOES-East and West Imagers	Point values	N-AWIPS, web
4. RGB Air Mass	SEVIRI, GOES-	Imagery	N-AWIPS

	East and West sounder, MODIS		
5. RGB Dust	SEVIRI	Imagery	N-AWIPS
6. Saharan Air layer	SEVIRI	Imagery	N-AWIPS
7. Natural Color	MODIS	Imagery	Web
8. Pseudo Natural Color	SEVIRI	Imagery	N-AWIPS
9. Rapid Intensification Index	GOES-East and West Imagers, WWLLN	Text	Web
10. RGB Cloud Top Microphysics	SEVIRI	Imagery	N-AWIPS
11. RGB Convective Storms	SEVIRI	Imagery	N-AWIPS
12. VIIRS Day/Night Band	S-NPP VIIRS	Imagery	Web

3.1 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-min. Meteosat and GOES-East CONUS imagery, as a proxy to an ABI product demonstration. The HIE was run using 15 min GOES-East CONUS imagery for those systems west 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.

3.2 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 2013. 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 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 2013, 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.

3.3 Tropical Overshooting Top Detection

The 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.

3.4 Red Green Blue (RGB) Air Mass Product

The 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 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., dryer) 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 a new LDM feed from SPoRT.

3.5 RGB Dust Product

The 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 product depicts dust in magenta and purple colors over land during day and night, respectively. A dusty atmosphere can also be tracked the over 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). The RGB dust product was delivered by SPoRT in the same N-AWIPS format described in 3.4 for the air mass product.

3.6 Saharan Air Layer (SAL) Product

The Saharan Air Layer (SAL) product is another example of an 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. 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 via the same mechanism as the RGB air mass and dust products.

3.7 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. However, 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 bands. 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. 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 3.8.

3.8 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 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 via the same mechanism as the RGB air mass and dust products.

3.9 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.

3.10 RGB Daytime Cloud-top Microphysics

The RGB cloud-top microphysics product was new to the NHC GOES-R Proving Ground Demonstration in 2013. This product is an 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 Cloud-top 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 Cloud-top 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 Cloud-top Microphysics product was delivered by SPoRT in the same N-AWIPS format described in 3.4 for the air mass product.

3.11 RGB Daytime Convective Storms

The RGB Daytime Convective Storms product was new to the NHC GOES-R Proving Ground Demonstration in 2013. This product is an 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 was delivered by SPoRT in the same N-AWIPS format described in 3.4 for the air mass product.

3.12 VIIRS Day/Night Band

The VIIRS Day-Night Band (DNB) on S-NPP is a new low light sensing capabilities that 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 via a SPoRT ftp server. The CIRA moonlight code is applied at SPoRT to create the reflectance product before the data is posted for distribution.

4. Results

Product feedback was obtained using the mechanisms described in section 2. This feedback, related results and plans for 2014 are summarized below.

4.1 Hurricane Intensity Estimate (HIE)

The HIE product was generated from MSG and GOES-East and available to the NHC forecasters via a web page. HSU forecasters indicated that the higher refresh rate of the HIE allowed for quicker identification of the developing eye with Hurricane Humberto. Around the same time, they also noted the HIE appeared to have a high bias, and was quite a bit higher than the ADT, for Hurricane Ingrid.

Because of the very small sample size and lack of hurricanes due to the inactive Atlantic season, NHC forecasters did not perform a systematic evaluation of the HIE as in past years.

4.2 SRSO Imagery

Despite the potential availability of SRSOR data from GOES-14, there were no SRSO cases due to a slow season and satellite availability.

4.3 Tropical Overshooting Top Detection

HSU forecasters indicated the Tropical Overshooting Top (TOT) product was useful for identifying a region of bursting convection in TS Juliette. At this time, the center of TS Juliette was passing over the southern end of the Baja peninsula (Figure 3). The product identified TOTs in the convective region just to the south of the center and the intensity estimate was maintained at 40 kt.

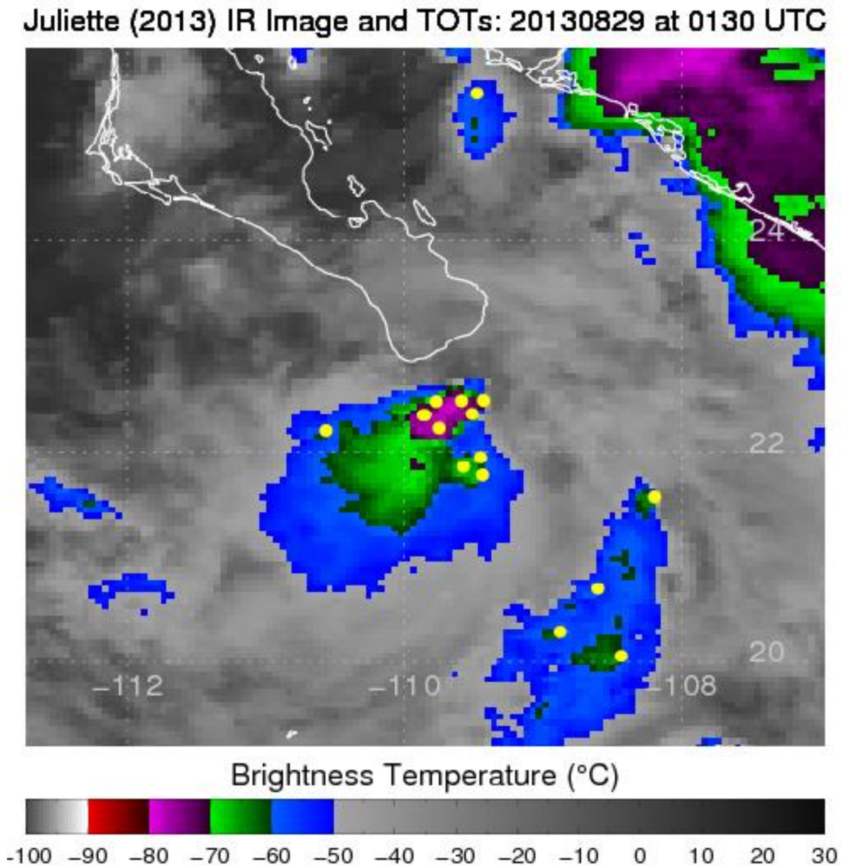

Figure 3. TOT product for TS Juliette as it was passing near the southern tip of Baja. TOTs (yellow dots) helped identify an increase in deep convective activity near the TS center.

More basic research is needed to understand the relationships between TOTs and intensification. There was no obvious signal during the 2013 season. To determine if there is any predictive information in the TOTs, S. Monet from UW/CIMSS is providing the Atlantic product back to 2005 so it can be tested as a predictor in the experimental RII.

4.4 RGB Air Mass Product

The RGB Air Mass product continues to be one of the most highly utilized PG products. The training provided by Michael Folmer has helped forecasters better understand the application of this product.

HSU forecasters found the RGB Air Mass product useful for identifying dry air impinging on TS Erin, suggesting intensification was less likely. Figure 4 shows an example of the SEVIRI version of the Air Mass product for TS Erin, which was moving towards the west/northwest in the NE Atlantic at this time. The reddish-orange area to the northwest of the storm indicated a region of drier subtropical air in the storm's path. A loop of this and other cases are available from http://rammb.cira.colostate.edu/research/tropical_cyclones/air_mass/cases.asp

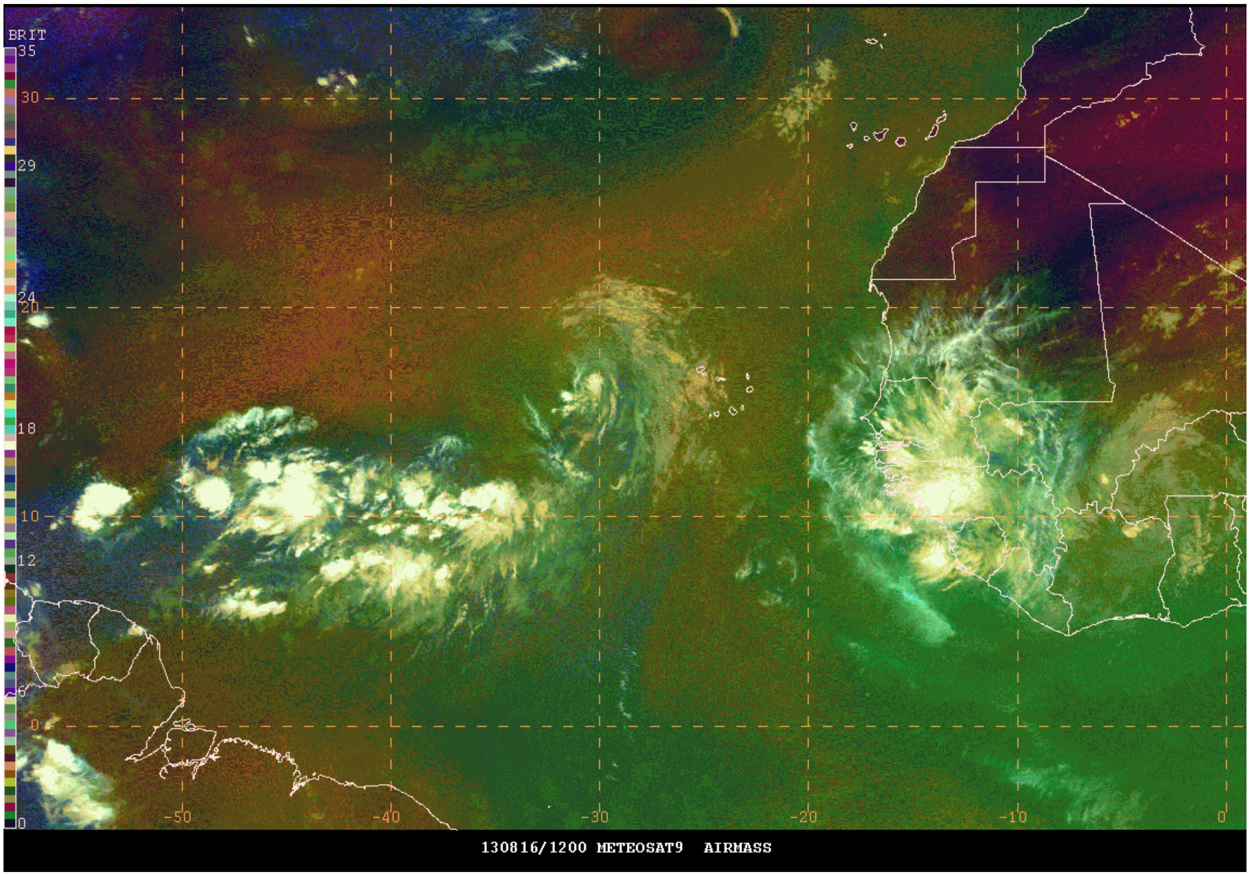

Figure 4. An example of the Air Mass product at 1200 UTC on 13 August 2013 for TS Erin.

4.5 RGB Dust Product

Along with the RGB Air Mass Product, The RGB Dust product continues to be one of the most highly utilized PG products. However, no specific feedback was obtained during the 2013 season.

4.6 SAL Product

The SAL product continued to be available in N-AWIPS format this year, although no specific feedback was obtained in 2013.

4.7 GOES-R Natural Color Imagery

The routine generation of the Natural Color product continues to be useful for the product developers. The MODIS version routinely has sun glint problems near the center of the data swath, but that will usually not be a problem with GOES-R. The product would be better utilized if it was made available in N-AWIPS. This possibility will be investigated for future seasons. Figure shows an example of the product during Hurricane Humberto.

The exposure to the Natural Color Imagery has led to some discussion at NHC regarding how this product would be produced in real time. AWIPS2 will be the primary display system at NHC during the GOES-R era, but, because of its complexity on the Natural Color algorithm, this product can not be created directly on that system. Plans are being discussed to generate the product at NHC using their satellite ingest system and then supplied to AWIPS2 as part of their non-SBN data stream.

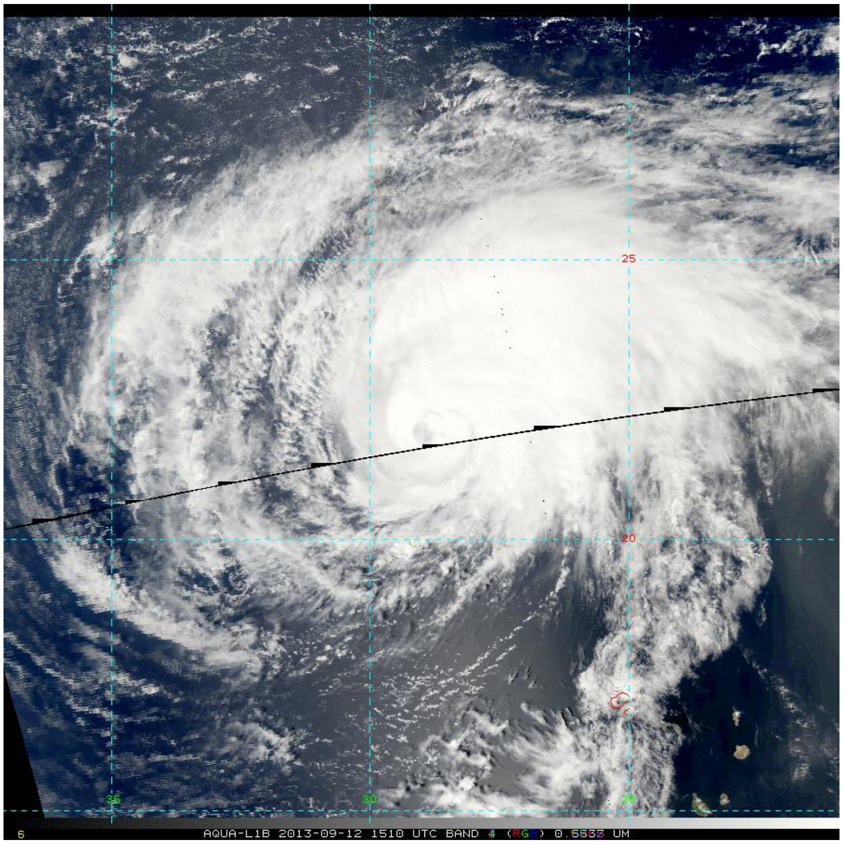

Figure 5. Proxy (MODIS) GOES-R Natural Color imagery for Hurricane Humberto on 12 Sep 2013.

4.8 Pseudo Natural Color Imagery

During the 2012 PG HSU forecasters noted that the latency of this product is longer than the other SEVIRI products. Jason Dunion worked with SPoRT to investigate this problem and, through script optimizations, reduced the latency of this product from t=+44 min to t=+32 min. It is possible that the product latency can be further reduced by making changes to the procedure being used to acquire and display these images at NHC. This will be investigated in 2014. No specific feedback on this product was obtained in 2013.

4.9 Lightning-based RII

A considerable amount of feedback was obtained in 2013 on the quantitative lightning product, and the qualitative interpretation of the lightning location data. This was partially because the lightning product developer (M. DeMaria) was on a six week work detail as the acting NHC Technology and Support Branch Chief during the main part of the 2013 hurricane season, and spent time working directly with forecasters.

The experimental RII was run in real time for all cases in the Atlantic and eastern North Pacific during the 2013 season. Two versions of the experimental version 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 section3, the quantitative RII product used the WWLLN data, while the NHC forecasters used the GLD-360 data in N-AWIPS for qualitative applications.

An unanticipated application of the lightning location data occurred during an outage of GOES-east in May of 2013. Meteosat data was used to replace GOES-east, but left a gap in some composite GOES-west, GOES-east products. Marine forecasters utilized the lighting locations to provide continuity of convective features in the imagery gap. An example is shown in Fig. 6, where the lightning data suggested that the convection seen in the imagery in the eastern Bahamas extended westward towards the Florida coast in the imagery gap region, and strong convection was also located near Louisiana.

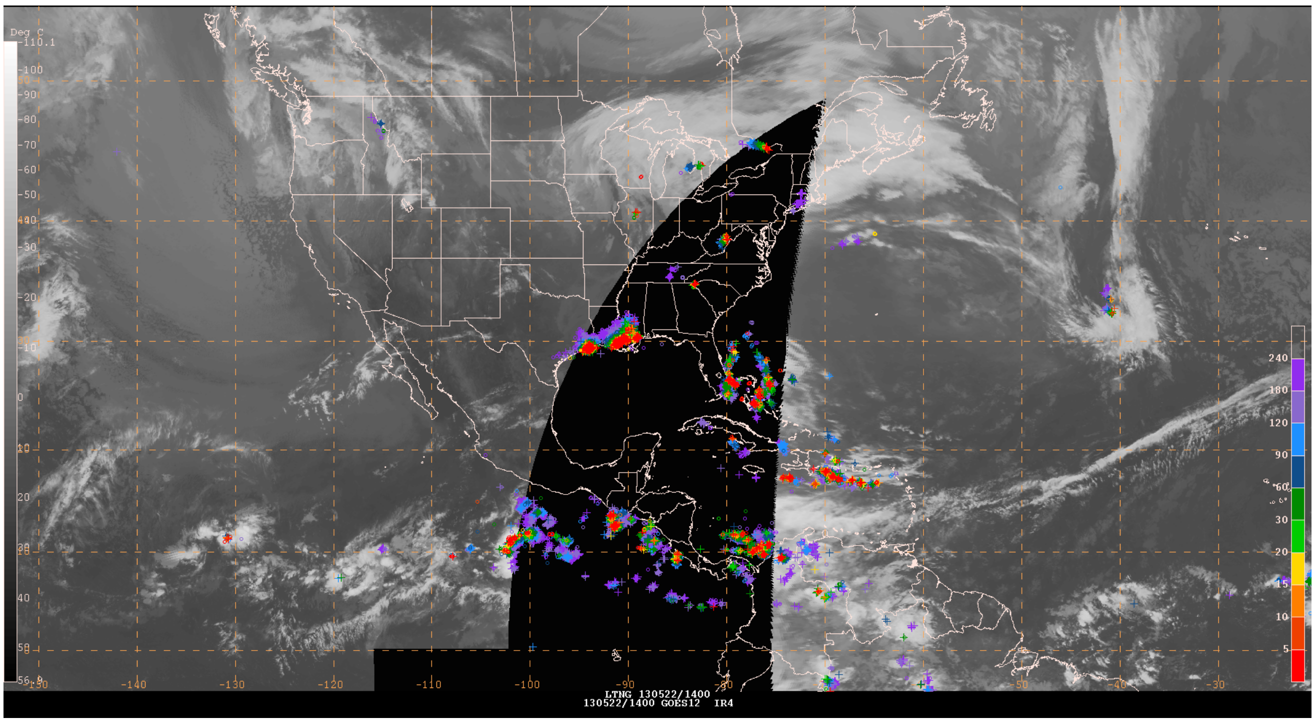

Figure 6. A composite GOES-W/MSG visible image during the GOES-East outage on May 22. The GLD-360 lightning locations in the previous two hours are show by the colored points, where the color indicates the time of the strike locations relative to the time of the image. The color bar is labeled in minutes.

The lightning data was also utilized as an indicator of interaction of tropical cyclones with vertical shear. In the operational forecast discussion text product for TD 11 on 30 September 2013 the HSU forecaster noted that "…There has been a noticeable increase in lightning activity during the past couple of hours…which is often indicative of increasing vertical wind shear." A similar observation was made in TS Chantal just prior to dissipation (Figure 7). At this time TS Chantal was experiencing considerable vertical wind shear and was interacting with land. The lightning distribution shows large inner core lightning and little rainband lightning during this dissipation period, which is consistent with the predictors in quantitative RII lightning data.

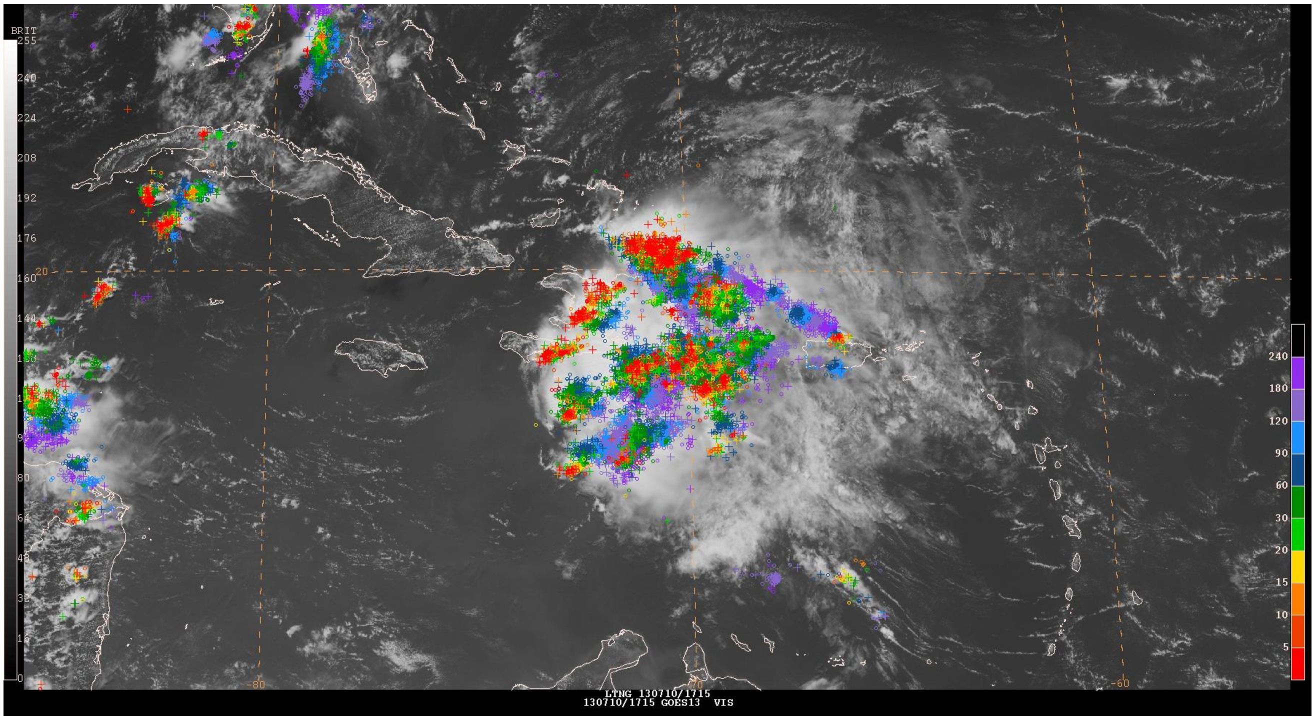

Figure 7. GLD360 lightning density plotted on a visible image of TS Chantal just prior to dissipation.

HSU forecasters noted that an inner core lightning outbreak lowered the SHIPS RII probability estimate at 012 and 18 UTC on 20 October 2013 as Hurricane Raymond was entering a rapid intensification period. As described above, the radial interval for the inner core lightning was increased from 0-100 km to 0-200 km in the updated version of the algorithm. This redefinition was primarily based on Atlantic results. Raymond was a fairly small tropical cyclone, so this change needs to be re-evaluated for the 2014 season. A different definition of inner core lightning might be needed for the East Pacific, which tends to have smaller tropical cyclones.

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. However, as will be described below, the Atlantic sample had no RI cases in 2013, so the Bias is undefined. Therefore, the Bias Error was calculated instead, which is the average of the forecasted probabilities minus the observed percentage of RI cases.

The Brier Score is analogous to a Root Mean Square (RMS) error for probabilistic forecasts. It is the square root 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 is calculated using

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

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. Because there were no Atlantic RI cases, Nf in (1) is zero, so the TS is zero for that case, no matter what probability threshold is used to separate the RI and non-RI forecasts.

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 173 (290) cases. There were no Atlantic cases that underwent RI, and 13 East Pacific cases. In the developmental sample about 8% (9%) of the Atlantic (East Pacific) cases where RI cases, but in 2013, 0% (4.5%) were RI cases.

Figure 8 shows the percent improvement of the verification metrics due to the inclusion of the lightning input. The lightning data generally reduced the probability of RI, which resulted in an improvement in the Bias Error in both basins. The Brier Score results were mixed with an improvement in the Atlantic, and a slight degradation in the East Pacific. However, the optimal Threat Score improved by more than 12% for the East Pacific. As described above, the Threat Score was zero for both the lightning and no-lightning for the Atlantic due to the lack observed RI cases, so the percent improvement was zero. These results show that the lightning input generally improved the RI forecasts in both basins, even in a very inactive year like 2013.

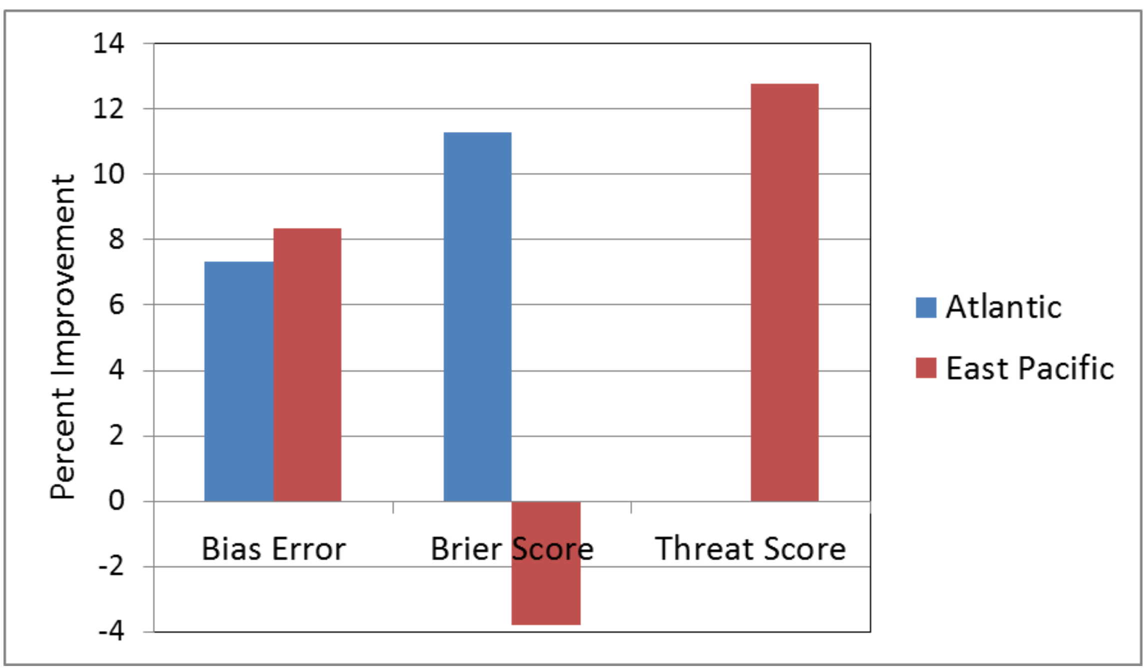

Figure 8. The percent improvement in the Bias Error, Brier Score and Threat Score when the lightning data was added to the RII for the 2013 Atlantic and East Pacific forecasts.

4.10 RGB Cloud-top Microphysics

The RGB Cloud-top Microphysics product was new to the NHC PG in 2013. Although no formal feedback was given, HSU forecasters spent time getting familiar with this and the RGB Daytime Convective Storms product.

4.11 RGB Daytime Convective Storms

The RGB Daytime Convective Storms product was also new to the NHC PG in 2013. HSU forecasters were getting familiar with this product during the 2013 season, comparing it with other products (e.g., RGB Air Mass) with which they had more experience. Forecasters noted the sheared central convection in TS Jerry (Fig. 9) showing up as bright orange to yellow and fading to red/pink downshear of the center.

HSU forecasters noted a processing/enhancement artifact that was occurring near sunrise and sunset in this product. This feedback was relayed to developers who are working on fixing this issue for next season.

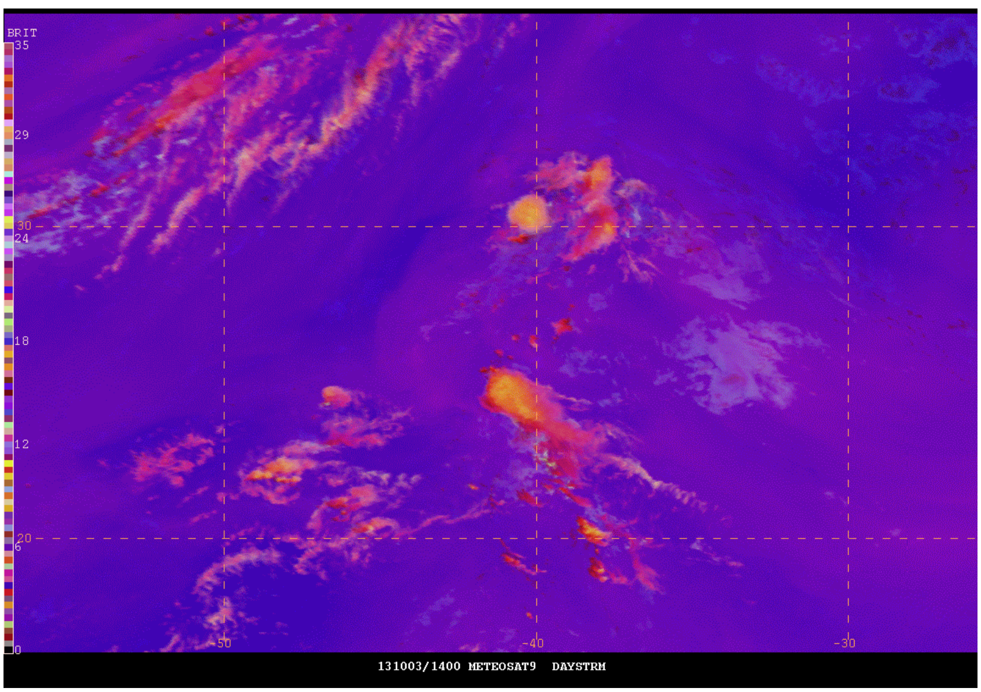

Figure 9. RGB Daytime Convection Storms product for TS Jerry during its dissipation over low SSTs and moderate vertical shear.

4.12 VIIRS Day/Night Band

Most of the effort with this product was on the technological aspects of getting the imager available in N-AWIPS. This accomplished on Sept 15 and the data was made available during the rest of the demonstration. Figure 10 below shows one of the first VIIRS DNB images on NHC's N-AWIPS systems. The remnants of Hurricane Manual can seen in the lower left corner of the image.

The VIIRS imagery was made available from the CIMSS direct read out, and from a ground station in the Pacific Northwest. These provided only very limited coverage over the Atlantic and east Pacific tropical cyclone regions. NHC forecasters were very interested in seeing the VIIRS imagery for a late season tropical cyclone (Melissa) that formed in the Central Atlantic (see the track in Fig. 2). Unfortunately, this was too far east for the CIMSS direct readout data. An effort will be made for 2014 to increase the coverage of the data, even if it is with longer latency than is available from the CIMSS direct readout site.

4.13 Additional Results

As alluded to above, an LDM feed was established between NHC and SPoRT shortly after the 2013 demonstration began. This simplified the delivery of many of the products, including the new RGB products and the VIIRS imagery. In addition, the LDM feed is more efficient than the current ftp methods that were used for product transmission, so the overall bandwidth requirements decreased, despite new products being added. A request was also recently approved to establish LDM feeds to CIRA and CIMSS, which will may help reduce the latency of some products, and provide access to new products.

Although not a planned part of the 2013 PG, lightning density contours were demonstrated in September during Hurricane Humberto during a visit to NHC by M. Folmer. HSU forecasters indicated these contours should be an enhancement over the individual lightning strike data and should be quite useful for quantifying the area of active deep convection. It was suggested that the contours should be filtered/smoothed slightly to remove the noisy pixelated appearance. This product might be included in the 2014 demonstration.

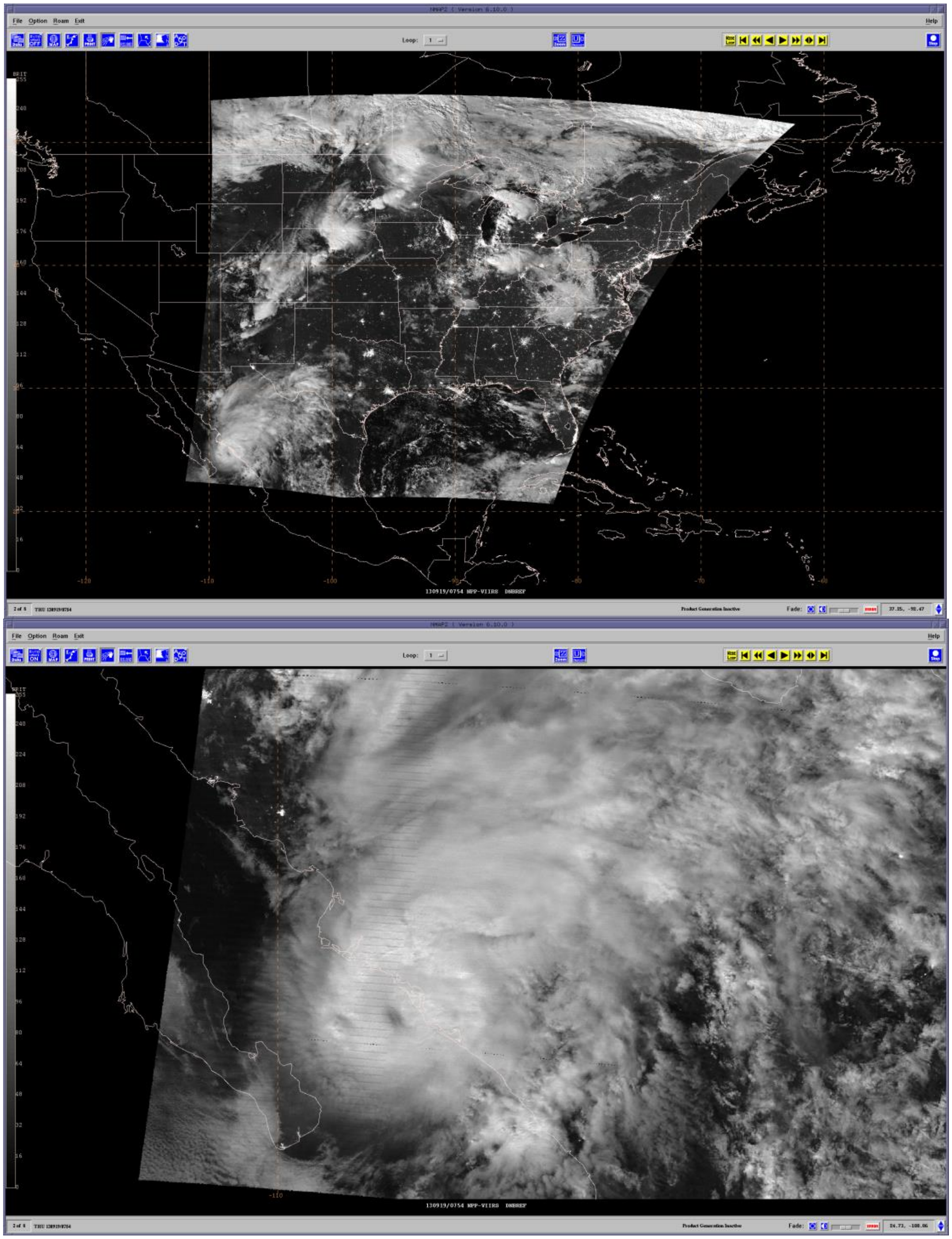

Figure 10. DNB imagery of TS Manuel as is made landfall along the west coast of Mexico around 1200 UTC on 15 September 2013.

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4.14 Plans for 2014

The NHC PG will continue in 2014. A. Schumacher (CIRA) is the new part-time satellite liaison for NHC/HSU. The 2014 NHC PG will continue to look for quantitative evaluations, such as those methods already established for the HIE and Lightning RII. In addition, the VIIRS domain will be expanded by using addition direct readout sites.

One issue that has been identified during recent NHC PGs is that too many products are being evaluated. As described in section 4, some products did receive any direct feedback. This issue will be addressed in 2014. Suggestions for addressing this issue include concentrating on a subset of products for specific forecast desks. Another option would be to rotate in new products. New products for 2014 may include ATMS temperature and moisture retrievals, GOES-R atmospheric motion vectors, aerosol optical depth, and lightning density.

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