The 2012 Proving Ground Demonstration at the National Hurricane Center – Final Evaluation

Project Title: The 2012 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: 01Aug 2012 – 30 Nov 2012

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1. Executive Summary

Nine prototype GOES-R products were demonstrated during the 2012 Proving Ground at the National Hurricane Center from Aug. 1st to Nov. 30th. Valuable forecaster experience and feedback was obtained. The Hurricane Intensity Estimate (HIE), Tropical Overshooting Tops (TOT) and Natural Color products are being improved based on feedback obtained during the 2012 experiment. The availability of GOES-14 provided several excellent periods of 1-min Super Rapid Scan Operations (SRSO) imagery that cannot usually be obtained due to constraints on the operational GOES satellites. These SRSO data are being utilized to test and improve the GOES-R Atmospheric Motion Vector (AMV) algorithms. Based on forecaster feedback, multi-spectral imagery products are now becoming routinely used in NHC operations, including Red-Green-Blue (RGB) products. A verification of the experimental version of the Rapid Intensification Index showed that lightning input improved the Threat Score by 5 to 7% in the Atlantic and east Pacific basins. Plans are underway to expand the NHC Proving Ground to include some Suomi-NPP products in 2013.

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 peak of the 2012 Hurricane season (August 1 – November 30). Nine GOES-R products and decision aids provided by NESDIS/STAR, CIRA, CIMSS, CIMAS, SPoRT and OAR were evaluated 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. Although the same nine products were demonstrated in 2012 as in 2011, more of them were available in N-AWIPS format this year thanks to coordination between the product providers. These included which included NESDIS/STAR, CIRA/CSU, NASA/SPoRT, UW/CIMSS, OAR/HRD, UM/CIMAS, CIMSS and CICS/UM.

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 11 Sep. 2012. 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 is also being 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.

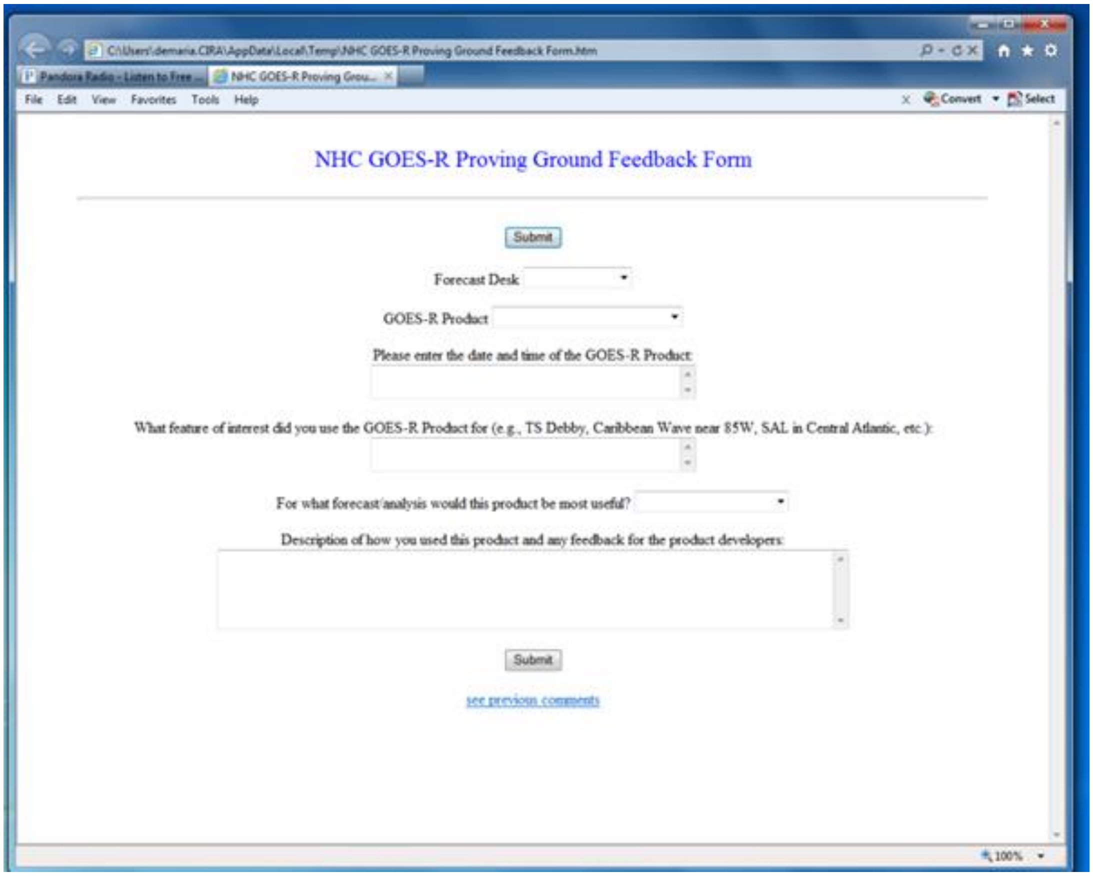
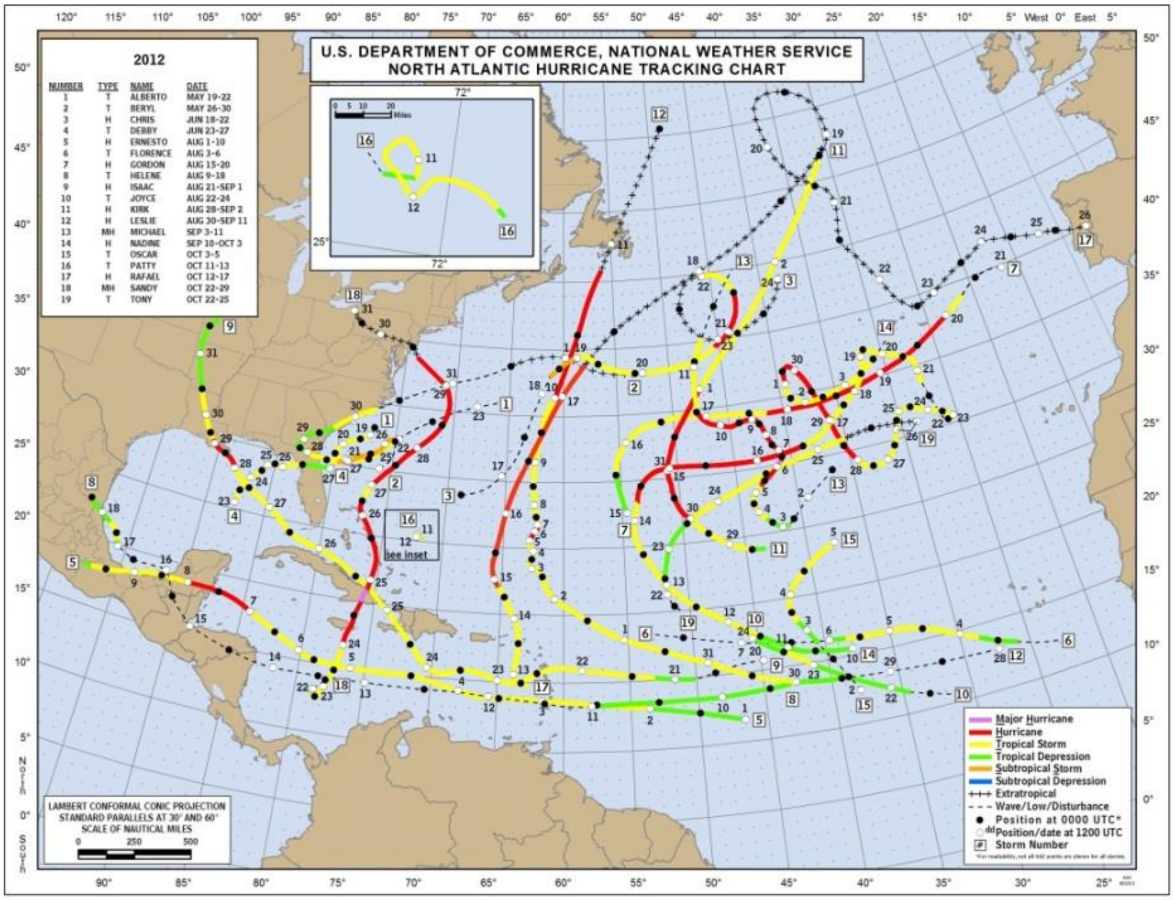


Figure 1. The feedback form used during the 2012 NHC Proving Ground.

The 2012 tropical cyclone activity is shown in Fig. 2 for the Atlantic and eastern North Pacific. The ABI-like products were only available in the central and eastern Atlantic, but the GLM rapid intensification product was also available in the east Pacific. The Atlantic season was active in terms of named storms, but most of the activity was relatively far north. There were only two short lived major hurricanes in the Atlantic and few periods of rapid intensification. The east Pacific season was near normal. In terms of societal impact, the most significant cyclone of the season was Hurricane Sandy which made landfall in eastern Cuba as a major hurricane and again along the New Jersey coast as an extra-tropical cyclone.


U.S. DEPARTMENT OF COMMERCE, NATIONAL WEATHER SERVICE
NORTH ATLANTIC HURRICANE TRACKING CHART
2012
NUMBER TYPE NAME DATE
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2 T BERYL MAY 26-30
3 H CHRIS JUN 18-22
4 T DEBBY JUN 23-27
5 H ERNESTO AUG 1-10
6 T FLORENCE AUG 3-6
7 H GORDON AUG 15-20
8 T HELENE AUG 9-18
9 H ISAAC AUG 21-SEP 1
10 T JOYCE AUG 22-24
11 H KIRK AUG 28-SEP 2
12 H LESLIE AUG 30-SEP 11
13 MH MICHAEL SEP 3-11
14 H NADINE SEP 10-OCT 3
15 T OSCAR OCT 3-5
16 T PATTY OCT 11-13
17 H RAFAEL OCT 12-17
18 MH SANDY OCT 22-29
19 T TONY OCT 22-25
See inset
LAMBERT CONFORMAL CONIC PROJECTION
STANDARD PARALLELS AT 30° AND 60°
SCALE OF NAUTICAL MILES
Major Hurricane
Hurricane
Tropical Storm
Tropical Depression
Subtropical Storm
Subtropical Depression
Extratropical
Wave/Low/Disturbance
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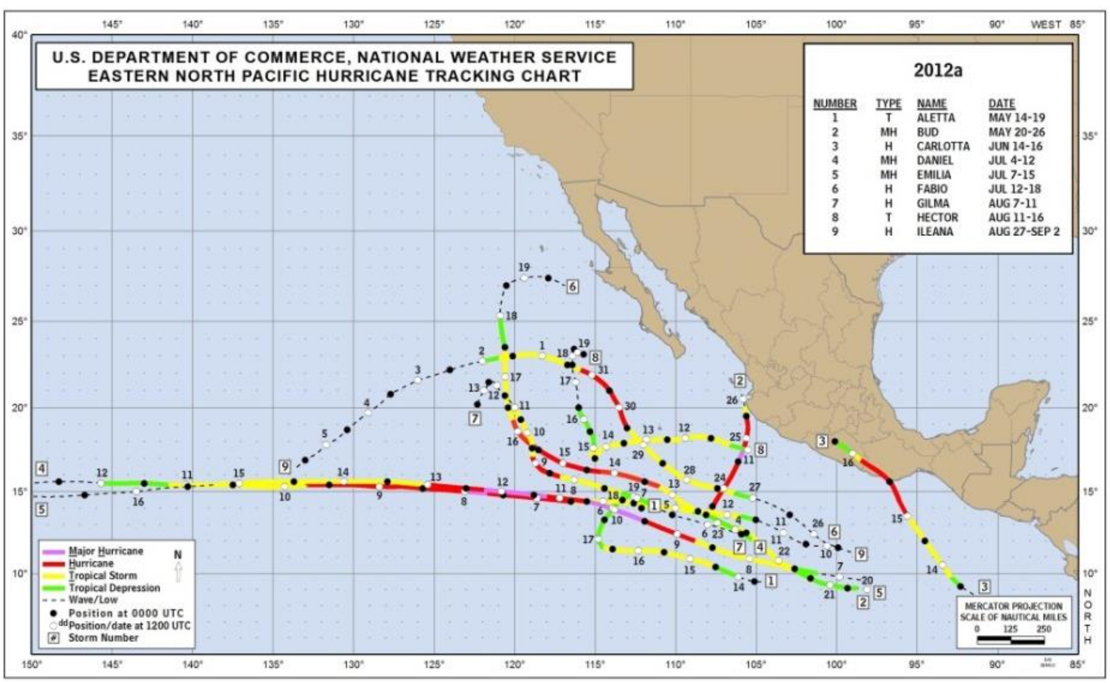
Position/date at 1200 UTC
Storm Number


U.S. DEPARTMENT OF COMMERCE, NATIONAL WEATHER SERVICE
EASTERN NORTH PACIFIC HURRICANE TRACKING CHART
2012a
NUMBER TYPE NAME DATE
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2 MH BUD MAY 20-26
3 H CARLOTTA JUN 14-16
4 MH DANIEL JUL 4-12
5 MH EMILIA JUL 7-15
6 H FABIO JUL 12-18
7 H GILMA AUG 7-11
8 T HECTOR AUG 11-16
9 H ILEANA AUG 27-SEP 2
Major Hurricane
Hurricane
Tropical Storm
Tropical Depression
Wave/Low
Position at 0000 UTC
Position/date at 1200 UTC
Storm Number
MERCATOR PROJECTION
SCALE OF NAUTICAL MILES

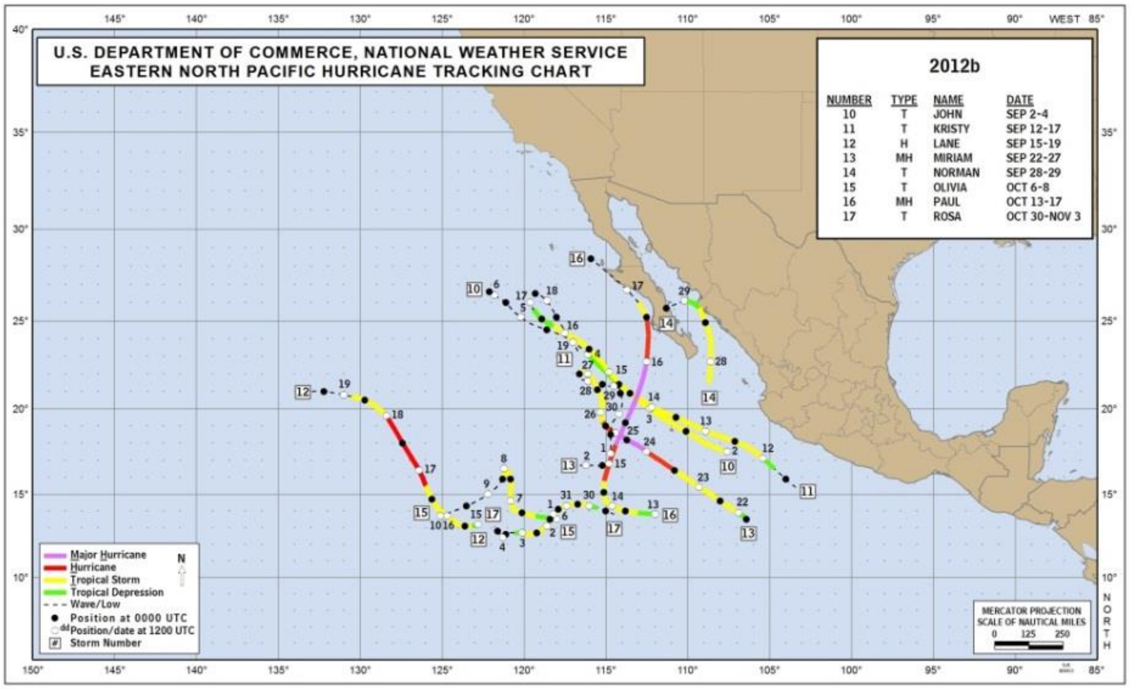

Figure 2. The 2012 season tropical cyclone tracks and intensities for the Atlantic (top) and eastern North Pacific (middle and botton).

3. Products Evaluated

Table 1 summarizes the nine products demonstrated in the 2012 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. Further details on each product are provided below.

Table 1. The nine GOES-R Products demonstrated in the 2012 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-East and West sounder, MODIS	Imagery	N-AWIPS
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

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 2012. 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 2011 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.

Beginning in mid-August 2012, GOES-14 was brought out of storage for routine readiness testing. Permission was obtained to use that satellite for SRSO. Because this satellite was not part of the operational suite, it did not have the constraints described above. Thus, the availability of GOES-14 provided numerous opportunities to obtain long periods of SRSO data, which is described in greater detail in section 4.

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 be provided via a web page at CIMSS. 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 posted on an ftp server for download by NHC.

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 ≥ 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 (0-100 km from the center) and rain band region (200-300 km from the center) calculated over 6 hr time periods. 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 also 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.

4. Results

Feedback on each product was obtained using the mechanisms described in section 2. This feedback, related results and plans for 2013 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 HIE was very responsive for Hurricane Michael due to the more rapid updating than the ADT, and was used to upgrade it to a major hurricane. They also noted that the HIE intensity estimates tended to be on the high side compared to other methods, especially when a storm first develops an eye. The ADT also has that tendency. The HIE also appeared to have a high bias for Isaac, but that was at a time when the ratio of surface winds to flight level winds was smaller than normal, similar to Irene in 2011 and Igor in 2010.

Following the mid-project review, there was a question about what constraints are built into the HIE compared to the ADT. Chris Velden clarified that there are no differences in constraints between the CIMSS ADT and the HIE. The only differences are that the HIE is operating on 15-min imagery, and of course the viewing angle when HIE is using MSG and the ADT is using GOES.

J. Beven from NHC has performed a systematic verification of the HIE results from the 2012 season. Results show that the overall stats for the HIE/ADT were not as good in 2012 than in 2011. This was due mainly to the hybrid portion of Hurricane Sandy's life cycle, when large errors occurred in all Dvorak-based satellite intensity estimates. The 2012 results show that the estimates from the eye patterns need some adjustment due to a high bias. The NHC has been performing an evaluation of the constraints of the Dvorak Technique. The results of that study may improve the use of constraints in future versions of the HIE/ADT.

4.2 SRSO Imagery

The availability of GOES-14 provided numerous opportunities to obtain SRSO imagery. Because GOES-14 was not in operations it was possible to obtain 28 images per half hour. Table 2 summarizes all the SRSO cases collected during the PG. An example of a loop for Hurricane Sandy is available from http://www.ssec.wisc.edu/data/1min/hurricane_sandy/.

The HSU forecasters indicated that there is a mismatch between the time scale of the vortex evolution and the SRSO data, so the value of higher temporal resolution beyond routine 15-min imagery is not clear for that application. Both TAFB and HSU forecasters indicated that there is utility for center fixing, especially for weaker systems, and obtaining intensity and center fixes closer to synoptic times. The SRSO data have greater utility for monitoring changes in convective activity, especially for storms such as Hurricane Isaac when it was in the central Gulf of Mexico, where the inner core circulation is the formative stage. TAFB forecasters found the SRSO data useful for their tropical weather discussions, and helped document convection within tropical waves.

HSU and TAFB forecasters indicated that the full value of the SRSO data will realized when it is fully exploited in atmospheric motion vector algorithms and then assimilated into hurricane forecast models. This work is underway through support by the GOES-R program office and Hurricane Forecast Improvement Project.

Table 2. SRSO data collected during the 2012 NHC Proving Ground.

Storm Name	Date(s)	Starting lat/lon	Ending lat/lon
Helene	Aug 18	23 ^{o}N/97 ^{o}W	-
Isaac	Aug 23-Aug 31	18 ^{o}N/68 ^{o}W	35 ^{o}N/88 ^{o}W
Leslie	Sep 07	27 ^{o}N/63 ^{o}W	-
Sandy	Oct 25-Oct 31	25 ^{o}N/76 ^{o}W	41 ^{o}N/78 ^{o}W

4.3 Tropical Overshooting Top Detection

HSU forecasters indicated that the TOT product seemed to work well in the outer bands of Ernesto, but not near the center where vigorous turrets were observed in visible and IR imagery. This may have to do with the 9 K brightness temperature threshold being too high in regions with thick upper-level cirrus. This problem was also noticed during Nadine. The product also sometimes falsely identifies OTs in thin cirrus. The product developers at CIMSS are using this feedback to refine the algorithm.

TAFB indicated that the TOT product was useful for documenting waning convection in a tropical wave. Hugh Cobb suggested that TAFB forecasters should make an effort to overlay the TOT locations on IR and visible imagery during tropical cyclone Dvorak classifications to better understand the relationship between TOTs and trends with tropical convection.

More basic research is needed to understand the relationships between TOTs and intensification. There was no obvious signal during the 2012 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 helped forecasters better understand the application of this product. The HSU forecasters found it useful for analyzing the moisture structure in Subtropical Storm Beryl, identification of dry air wrapping around Hurricane Gordon and monitoring the evolution of a trough upstream of that cyclone. The product was also useful for identifying air mass boundaries and interaction with upper level potential vorticity anomalies during Nadine. Special dropwindsondes from the NASA Global Hawk were obtained around Nadine, which are being used to better understand the Air Mass product. Also, an extensive case study of Hurricane Sandy is being performed, which includes an analysis of the Air Mass product during that cyclone's complicated interactions with mid-latitude systems and extra-tropical transition.

Figure 3 shows an example of the SEVIRI version of the Air Mass product for Hurricane Gordon, which was rapidly accelerating towards the east in the NE Atlantic at this time. The SW to NE oriented reddish region to west and SW of the storm indicated an upper level short wave that had overtaken Gordon by this time and helped to reduce its intensity. A loop of this and other cases are available from http://rammb.cira.colostate.edu/research/tropical_cyclones/air_mass/cases.asp

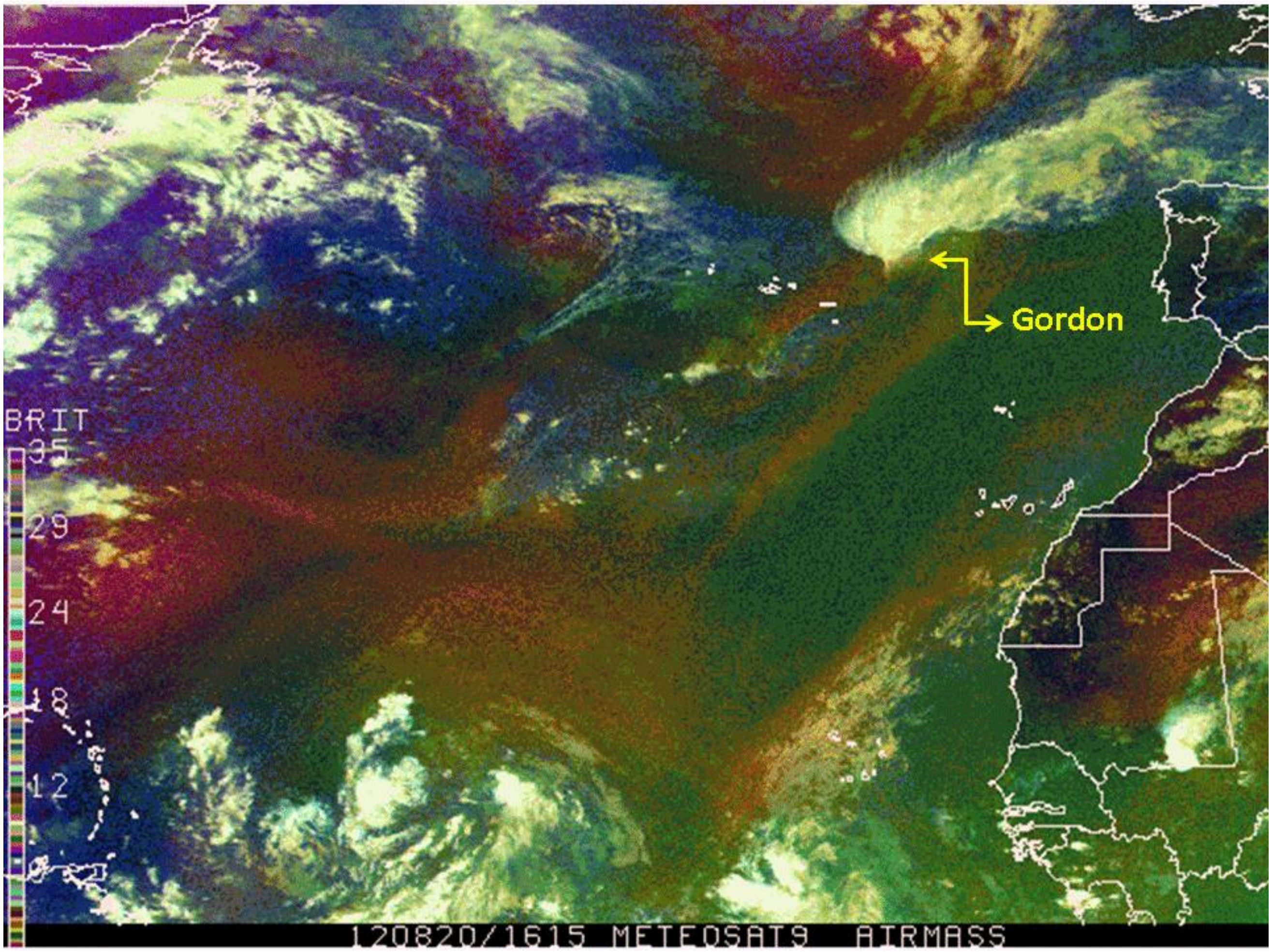

Figure3. An example of the Air Mass product at 1615 UTC on 20 August 2012 for Hurricane Gordon.

TAFB forecasters used the product in the marine analysis of tropical lows, and as supplemental guidance for location of the center of Tropical Depression 10. TAFB also utilized the Air Mass product with the analysis of a low near the Azores, which help to confirm that the system was still cold core due to the low tropopause heights near the low center.

More experience is still needed to understand the behavior of the product in some cases, and tuning might be needed to better represent tropical cyclone applications. For example, the evolution of the product for Hurricane Gordon when it reached the subtropics was complicated, with the product indicating dry air in regions where there was still likely moist air in the low levels. There may also be some ambiguity between regions of stratospheric air and lofted dust.

Jack Beven presented some examples of the product at a recent mesoscale workshop, and Lance Bosart from SUNYA suggested that the product may be useful for studying potential vorticity (PV) filamentation. This is important for understanding the interaction between upper troughs and tropical cyclones. Generally speaking, when the PV associated with a trough becomes filamented it can sometimes fracture into a smaller low latitude section to the SW of the storm, while the main part of the feature moves on to the east. This configuration is more favorable for intensification than the case where the PV maintains its structure to the NW of a TC.

4.5 RGB Dust Product

The RGB Dust product is now used routinely by TAFB forecasters as input to their Tropical Weather Discussion product. It was especially useful for helping to diagnose the atmospheric stability in the early stages of Tropical Storm Florence. TAFB is considering developing a new graphical public product to depict areas of dust. In the interim, the RGB Dust Product will be useful guidance in the depiction of dust in their Graphicasts.

4.6 SAL Product

The availability of the SAL product in N-AWIPS format this year increased its utility. TAFB found it helpful in the identification of dust near Tropical Depression Six, which later became Florence. They also use it routinely in their Atlantic Tropical Weather Discussion product, and sometimes as input to their tropical surface analysis. The SAL would also provide useful input for the new TAFB Dust Product mentioned above. There was some question about whether the SAL product detects dry or dusty regions. According to Jason Dunion, the product primarily detects dry regions in the lower to middle levels of the atmosphere that may or may not be dusty. However, the presence of dust does act to enhance the split window signal in the imagery.

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 2013.

4.8 Pseudo Natural Color Imagery

The availability of the Pseudo Natural Color product in N-AWIPS format this year increased its utility. This product was used in conjunction with the Dust and SAL products.

HSU forecasters noted that the image is too dark near the terminator, and that perhaps a correction could be applied. Based on this feedback, Jason Dunion worked with CIMSS to adjust the terminator detection algorithm which reduced the areas of darkness along the sunlit side of the terminator edge.

Also, the latency of this product is longer than the other SEVIRI products. Jason Dunion should work with SPoRT to investigate this problem.

4.9 Lightning-based RII

The experimental RII was run in real time for all cases in the Atlantic and eastern North Pacific during the 2012 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 RII provides an estimate of the probability of rapid intensification. These probabilistic forecasts were evaluated using a Threat Score (TS), where a specified probability was used to separate a “yes” forecast from a “no” forecast. The TS is then 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. Figure 4 shows the percent improvement of the maximum TS when the lightning data was included compared to the version without the lightning input. The figure shows that the lightning data improved the TS by about 5% for the Atlantic and 13% for the eastern North Pacific. These improvements show that the lightning input is providing independent information to the RII. A larger evaluation is planned with three years of data. A method to evaluate statistical significance of the differences between the lightning and no-lightning versions will be determined at that time.

The experimental version of the RII was compared with the operational RII run by NHC. These results showed the operational version has a very large high bias compared with observations. Thus, the operational RII over-estimates the probability of RII in both basins. The experimental version of the RII does not have this problem. The PG developers will coordinate with HRD to see if this issue can be resolved, which would lead to improvements in the operational RII.

HSU and TAFB forecasters also have the ability to overlay the lightning locations from the ground-based Vaisala GLD360 network on satellite imagery and other products in N-AWIPS. The GLD360 is qualitatively similar to that from the WWLLN data used the RII algorithm. By overlaying the lightning flash locations on satellite imagery, the forecasters can get a better idea of distribution of the lightning distributions, which complements the quantitative RII product. For example, lighting near the storm center generally lowers the probability of RII because this is usually associated with an increase in vertical shear. If the lightning and convective distributions are very asymmetric relative to the storm center, this provides confirmation that the cause of the inner core lightning increase is due to shear. Conversely, lighting in the outer bands increases the probability of rapid intensification. Figure 5 shows an example of a 6 hr composite of lightning locations for Hurricane Sandy during its rapid intensification phase. The lightning distribution is consistent with the quantitative RII, with very little inner core lightning but very larger rain band lighting.

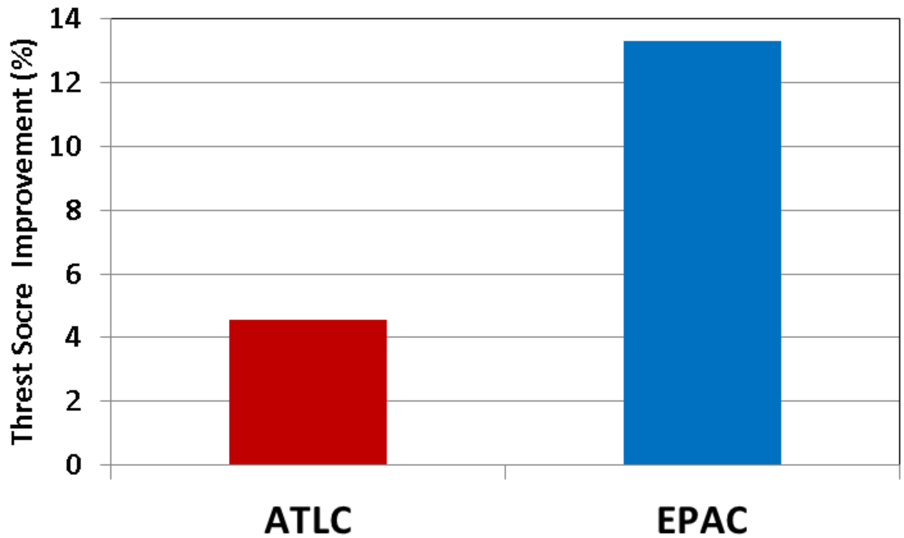

Figure 4. The percent improvement in the Threat Score of the rapid intensification index product due to the inclusion of the lightning data during the 2012 Hurricane Season. The evaluation included 340 RI forecasts in the Atlantic and 278 in the eastern North Pacific.

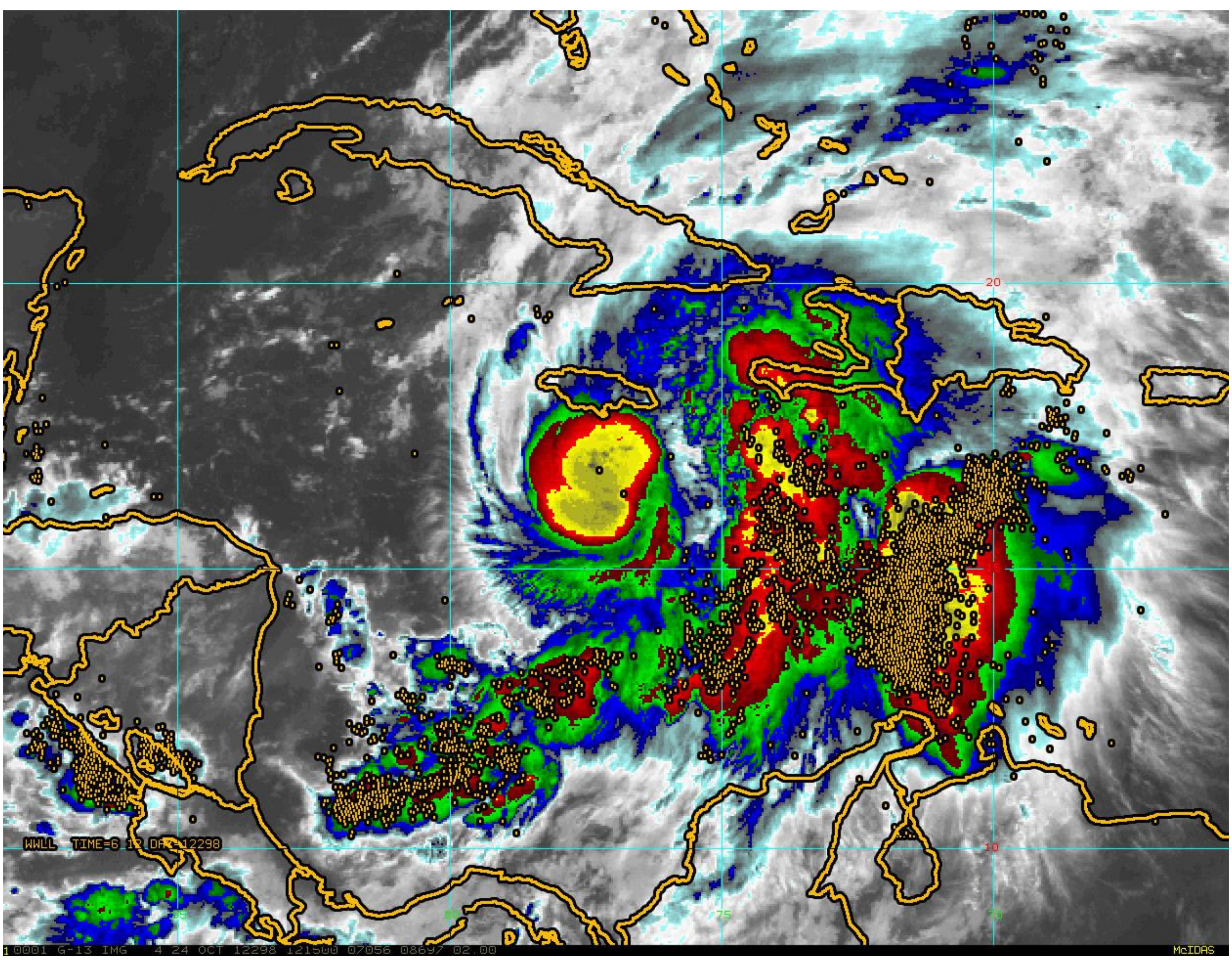

Figure 5. Lightning locations (gold points) plotted on an IR image of Hurricane Sandy just as it was entering a period of rapid intensification.

4.10 Additional Results

As described in section 4.5, the NASA HS3 field experiment was performed in August through October of 2012. Several in situ datasets were obtained from this experiment were collected, which should be useful for comparison of the GOES-R experimental products, and for development of training material. The NHC PG products were also made available to the field experiment operations center through a web page at CIRA (see http://rammb.cira.colostate.edu/research/tropical_cyclone/tc_proving_ground/).

The infrastructure set up for the NHC Proving Ground was leveraged to provide NHC with additional products not directly related to GOES-R. SPoRT provided microwave imagery from several Low Earth Orbiting (LEO) satellites in N-AWIPS format. HSU forecasters indicated that this capability was a significant improvement to their operational environment, since this real time imagery had previously only been available via the web. Figure 6 shows Hurricane Specialist Lixion Avila demonstrating the real time microwave imagery on one of their N-AWIPS systems.

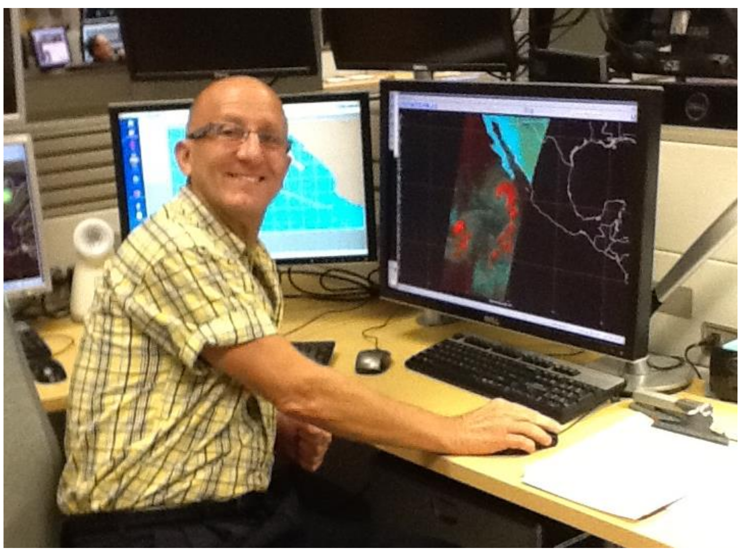

Figure 6. Hurricane Specialist Lixion Avila demonstrating the display of real time microwave imagery on NHC's N-AWIPS system.

4.11 Plans for 2013

The NHC PG will continue in 2013, and several new products might be added. These include new RGB products that provide information on cloud top structure, an improved RGB dust product, combined LEO-GEO products, and imagery from the Suomi-NPP satellite. The highest priority NPP product is day-night band imagery. The new products will be distributed to NHC through SPoRT, similar to most of the current PG products.

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