RADAR OPERATIONS CENTER

ECP 511 2D Velocity Dealiasing Field Test

Final Report

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ABSTRACT: A field test of a new two-dimensional velocity dealiasing algorithm (2DVDA) for the WSR-88D was scheduled to coincide with the 2011 hurricane season and included 8 coastal and 5 non-coastal sites. The test could not be completed as originally intended due to problems with the software modifications needed to run the algorithm at field sites. Instead, non-operational RPGs within the ROC's Applications Branch were configured to record data from 8 WSR-88Ds as Hurricane Irene traveled up the eastern U.S. seaboard August 25-28, 2011. Sites included in the Irene study were Miami, FL, Melbourne, FL, Charleston, SC, Wilmington, NC, Morehead City, NC, Wakefield, VA, Sterling, VA, and Upton, NY. For the ½° azimuthal resolution velocity products at or below 1.5° elevation, the legacy Velocity Dealiasing Algorithm (VDA) had an error rate of 11.98% while the new 2DVDA had an error rate of 0.85%. For the 1° azimuthal resolution velocity products, the legacy VDA had an error rate of 11.17% while the 2DVDA had an error rate of 1.28%. This report compares the velocity dealiasing results between the two algorithms for data from Hurricane Irene and provides examples. It examines the impact of the 2DVDA on kinematic algorithms. In particular, the Mesocyclone Detection Algorithm has a 45% reduction in false detections due to better handling of noisy velocity data. Velocity data from Hurricane Ike (2008) shows that 2DVDA-dealiased velocities have about a 1 m/s increase in magnitude for velocities above the Nyquist velocity. Finally, the report includes examples of the legacy VDA dealiasing errors in clutter from the Amarillo, TX WSR-88D that the 2DVDA was able to handle correctly.

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1. INTRODUCTION

The original goal and intent of the 2-Dimensional Velocity Dealiasing Algorithm (2DVDA) field test was to provide Radar Operations Center (ROC) Applications Branch meteorologists a chance to independently evaluate the performance of the new algorithm and to give forecasters in the field hands-on experience. Conducting a field test before full deployment is desirable as it provides real time experience with new technology and can gain support for new technology from operational users if it can be shown to be superior to older technology, which, in this case was the legacy Velocity Dealiasing Algorithm (VDA). Thirteen sites were recruited to participate in the field test. From the Weather Service's Central Region they included Des Moines, IA (KDMX), Goodland, KS (KGLD), and Pueblo, CO (KPUX); from the Eastern Region they included Burlington, VT (KCXX) and Wilmington, NC (KLTX); from the Southern Region they included Brownsville, TX (KBRO), Corpus Christi, TX (KCRP), Key West, FL (KBYX), Lake Charles, LA (KLCH), Miami, FL (KAMX), and Tallahassee, FL (KTLH); and from the Western Region they included Boise, ID (KCBX) and Great Falls, MT (KTFX). The test was to begin in mid-August 2012 and run through the end of the year. As discussed in Section 2 we were not able to complete the field test as originally planned.

2. REASONS FOR ABORTING THE FIELD TEST

To facilitate development and testing, a version of the 2DVDA software has been incorporated into the RPG software in a non-operational mode for the past couple of years. That is, while field sites have no way to activate the algorithm, developers using non-operational RPGs can run and test the 2DVDA. The most advanced version was slated for fielding in the summer of 2012 in ORPG Software Build 13 with the goal of making it operational at that time. To facilitate the field test for the summer/fall of 2011 we needed to implement the RPG Build 13 version of the 2DVDA into Build 12.2 RPG software that was already fielded. A software modification kit was assembled that included a new azimuthal recombination algorithm and installation directives to run one instance of the velocity dealiasing software for super resolution ½° products on one RPG processor (A) and a second instance of the velocity dealiasing software for 1° resolution products on the second RPG processor (B). After sites installed the modifications, at least three separate problems were observed: 1) the task to transmit Level 2 Archive data via the LDM feed aborted itself; 2) both instances of the velocity dealiasing algorithm ended up installed on the same RPG processor; and 3) the recombination algorithm was non-compliant with coding standards in that it allowed a radial to be tagged with an azimuth of 360° whereas coding standards require the azimuth to be set to 0°. The first problem caused the WSR-88D NWS sites to not be able to send their Level 2 Archive data to NCDC for archival. The second problem resulted in failures in one or both instances of the velocity dealiasing algorithm when significant weather was present. The Des Moines WSR-88D site in particular was adversely impacted. They uninstalled the software modifications but hadn't disabled the 2DVDA and so with the modified software removed were unable to turn off the 2DVDA. Consequently the velocity dealiasing algorithms failed with significant weather in the county warning area. Only after putting the radar into VCP 121, which uses the Multiple PRF Dealiasing algorithm, were they able to stay up. The third problem resulted in data at 359° being smeared azimuthally through tens of degrees to the first radial in the scan which may not have been at north. The NCAR/RAP radar data web site was one site with corrupted velocity data. Any one of the three problems would have been sufficient to abort the field test. The third problem was the first one noticed. Within two days of observing the smearing in the velocity data, the test director aborted the field test and asked all sites to uninstall the software kit. Ten of 13 sites had installed the modification kit. To ensure there were no residual problems, the ROC director opted to have the affected sites reinstall Software Build 12.2. Because the test bed WSR-88D (KCRI) was already being modified to have dual polarization, ROC test bed equipment was no longer available for testing corrections to the software kit so no attempt was made to restart the field test.

3. RESTRUCTURED TEST

As mentioned in Section 1 there were two components to the field test. One was exposure of the new algorithm to operational users which, for reasons described in Section 2, we were not able to complete. The other component was to evaluate the performance of the 2DVDA using data from the WSR-88D field test sites using non-operational Radar Product Generator software within the Applications Branch. As this portion of the field test simply required Level II data feeds into the ROC, the errors in the kit mailed to the field sites had no impact. Coincidentally, as the test team was assessing how to proceed with the test, Hurricane Irene developed in the Atlantic Ocean just to the east of the Caribbean Sea with a projected track that would take it up the eastern US seaboard. The test director decided to reconfigure the non-operational RPGs in the Applications Branch to support data collection from radar sites along the East Coast. The results of this test were presented at the AMS's 30th Conference on Hurricanes and Tropical Meteorology held in Ponte Vedra Beach, Florida April 15-20, 2012. Much of that material is reproduced in this report. The original manuscript and presentation are available at the following URL: [https://ams.confex.com/ams/30Hurricane/webprogram/Paper205076.html.](https://ams.confex.com/ams/30Hurricane/webprogram/Paper205076.html) The 2DVDA's impact on kinematic algorithms is included in this report as well as a brief histogram comparison from Hurricane Ike. Lastly, we include in this report results from testing the 2DVDA on Amarillo, TX WSR-88D velocity data during an episode where the site experienced dealiasing errors in ground clutter with strong storms present.

4. HURRICANE IRENE ANALYSIS

From August 25 through August 28, 2011 Hurricane Irene traveled up the eastern U.S. seaboard. During this period, velocity products were generated in real time from live Level 2 data feeds using multiple pairs of non-operational Radar Product Generator (RPG) platforms in the ROC Applications Branch. One of each RPG pair used the legacy VDA while the second RPG used the 2DVDA. Files containing the products were saved for review afterwards. Data from the following WSR-88Ds were included in the evaluation: KAMX (Miami, FL), KMLB (Melbourne, FL), KCLX (Charleston, SC), KLTX (Wilmington, NC), KMHX (Morehead City, NC), KAKQ (Wakefield, VA), KLWX (Sterling, VA), and KOKX (Upton, NY). Figure 1 shows, geographically, the radars included in the evaluation; Table 1 shows the number of volumes of data for the radars and the volume coverage patterns. For KLWX and KLTX, data gaps in time were filled in by retrieving Level 2 Archive data from the National Climatic Data Center and replaying the data**.**

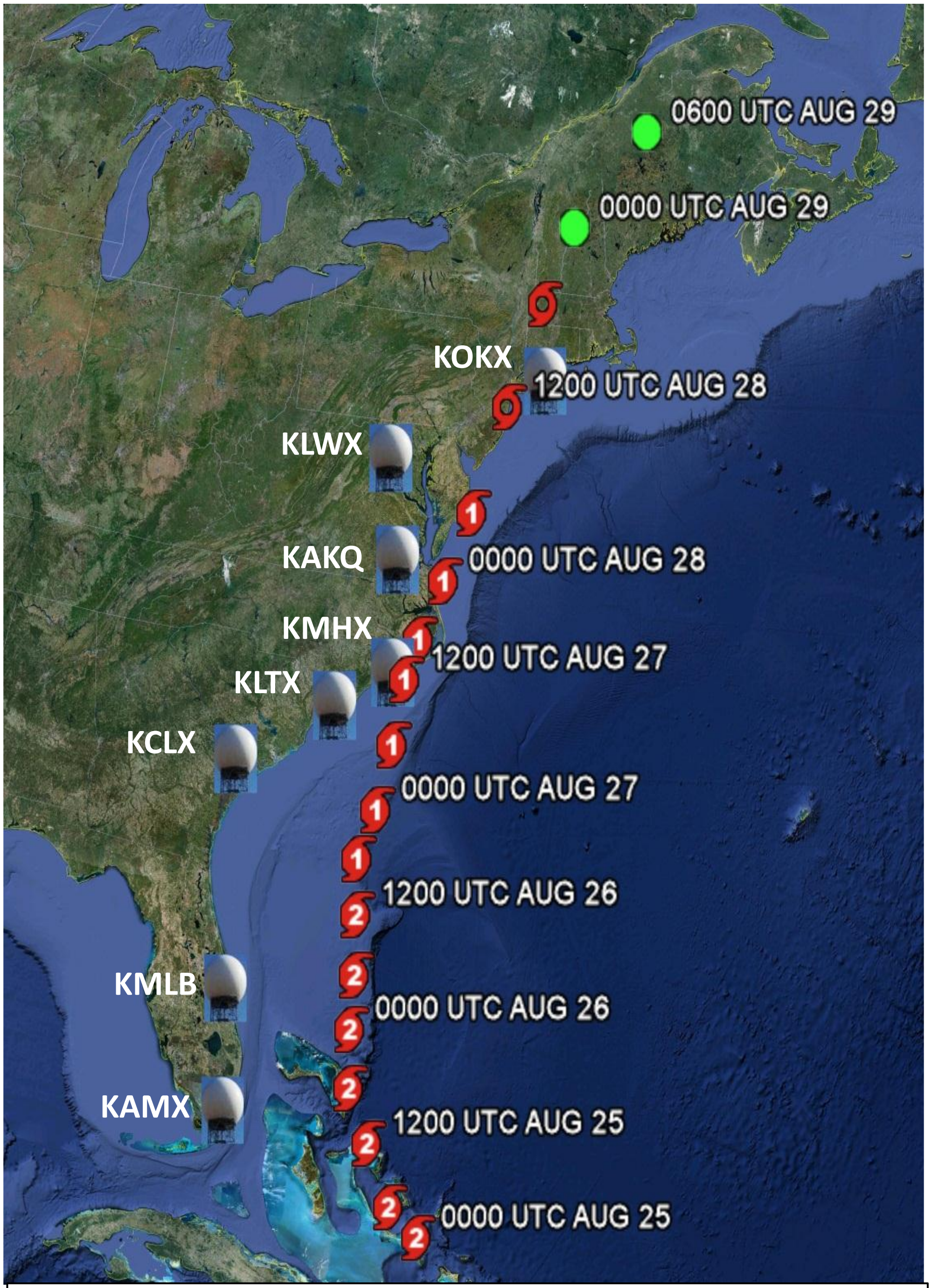

Figure 1. This figure shows a graphical depiction of WSR-88D sites used in the analysis and Irene's track. Solid red circulation symbols indicate when Irene was a hurricane. The open circulations symbols show when Irene was a tropical storm, and the green symbols show the location of Irene as a depression. The track positions are shown at six hour intervals; Irene's hurricane strength is printed over the solid red circulation symbols.

	No. of Volumes		
Site	**12/212**	**21/221**	**Total**
KAMX	109	74	183
KMLB	0	68	68
KCLX	229	0	229
KLTX	209	0	209
KMHX	94	77	171
KAKQ	267	0	267
KLWX	332	0	332
KOKX	231	0	231
Total	**1471**	**219**	**1690**

Table 1. WSR-88D sites, Volume coverage patterns and number of volume scans used in the Hurricane Irene analysis

4.1. Methodology

Unlike previous studies by Arthur Witt, Rodger Brown, and Zhongqi Jing (2009, hereafter WBJ09) and Langlieb and Tribout (2010, hereafter LT10) that compared the goodness of the 2DVDA to the VDA by examining velocity products in great detail and tabulating defects or errors in velocity dealiasing, we displayed a full-range image of each velocity product and simply tabulated whether or not velocity dealiasing errors were observed. Like LT10 we characterized the size of the errors as small (~1 to 100 km^2), medium (~100 to 10,000 km^2), or large (>10,000 km^2). Because it is rare that any velocity field is completely free of errors due to ground clutter, moving targets, blockage, interference, noise in second trip, etc., we did not tabulate very small, random errors deemed not operationally significant. Like WBJ09 we included in our analysis super resolution (SR) velocity products (½° resolution in azimuth) for elevation angles at or below 1.5° elevation and 1° resolution products from all elevations.

Sites most often used VCP 12 or 212 (1471 volumes) while VCPs 21 or 221 were used less frequently (219 volumes). Results were tabulated by radar and by elevation angle. The specific elevation angles (cuts) for the VCPs and their pairing are shown in Table 2. In this table the elevation angles have been grouped by scan (waveform) type: split cuts, batch cuts, and contiguous Doppler (CD) cuts. In split cuts, a surveillance scan with a low PRF is followed by a scan with a high PRF scan to obtain Doppler data. Batch cuts alternate pulses at a low PRF with pulses at a high PRF on a radial-by-radial basis. For both the split cuts and the batch cuts, the low-PRF reflectivity data are used to range unfold the Doppler data. Contiguous Doppler cuts use only a high PRF to obtain both reflectivity and Doppler data because range folding is not an issue.

The number of products evaluated for each elevation angle (or paired elevation angles) is simply the total number of volume scans. For instance, at 0.5° elevation a total of 1690 SR velocity products were evaluated while at 0.9° elevation only 1471 SR products were evaluated. The total number of products evaluated for each algorithm was 9702, 9702, and 8012 for split, batch, and CD cuts, respectively. Note split cuts include both ½° and 1° resolution products.

VCPs	**Split Cuts**			**Batch Cuts**						**Contiguous Doppler Cuts**				
12/212	0.5°	0.9°	1.3°	1.8°	2.4°	3.1°	4.0°	5.1°	6.4°	8.0°	10.0°	12.5°	15.6°	19.5°
21/221	0.5°		1.45°		2.4°	3.35°	4.3°		6.0°		9.9°		14.6°	19.5°

Table 2. Pairing of elevation angles between the VCPs to facilitate statistical analysis.

4.2. Irene Base Velocity Comparison Results

For all sites and all elevations the 2DVDA consistently had fewer errors than did the legacy VDA. Table 3 shows the frequency of errors for all sites by elevation for the SR products in split cuts. The total number of SR errors for the legacy VDA is 581 while the 2DVDA had only 41 which is more than an order of magnitude fewer. The average error rate (100 x total error count/(total number of products)) is 11.98% for the legacy VDA and 0.85% for the 2DVDA.

		½ Deg Super Resolution Split Cuts							
		Legacy VDA Error Count				2DVDA Error Count			
VCP	# of Vols	0.5°	0.9°	1.3°/1.45°	Total	0.5°	0.9°	1.3°/1.45°	Total
21/221	219	20	-	13	33	1	-	1	2
12/212	1471	286	180	82	548	19	13	7	39
Total	1690	306	180	95	581	20	13	8	41

Table 3. Number of velocity products with errors for the legacy VDA and the 2DVDA for ½° resolution split cuts by elevation for Hurricane Irene.

Table 4 shows the split cut dealiasing results for the 1° resolution velocity products. The error rates between the ½° and 1° resolution products are roughly comparable. The legacy VDA frequency of dealiasing errors is slightly lower for the 1° vs. the ½° resolution products (542 vs. 581). There is ~50% increase in dealiasing errors for the 2DVDA for the 1° resolution products over the ½° resolution products (62 vs. 41). Still, the 2DVDA average error rate of 1.28% is almost an order of magnitude smaller than the legacy VDA's average error rate of 11.17%. Table 5 shows the number of errors for the batch and contiguous Doppler cuts.

		1 Deg Resolution Split Cuts							
		Legacy VDA Error Count				2DVDA Error Count			
VCP	# of Vols	0.5°	0.9°	1.3°/1.45°	Total	0.5°	0.9°	1.3°/1.45°	Total
21/221	219	17	-	10	27	0	-	0	0
12/212	1471	269	161	85	515	26	21	15	62
Total	1690	286	161	95	542	26	21	15	62

Table 4. Number of velocity products with errors for the legacy VDA and the 2DVDA for 1° resolution split cuts by elevation for Hurricane Irene.

For the batch cuts the dealiasing errors are mostly confined to the lowest two elevation angles at 1.8 and 2.4° for either dealiasing algorithm. Overall, there is ¼ the number of dealiasing errors in the 2DVDA products over the legacy VDA products (17 vs. 70). The legacy VDA average error rate is ~0.72% and the 2DVDA average error rate is ~0.18%. The number of products with errors and the average error rates are exceedingly small for the CD elevation cuts due, primarily, to our method of evaluation. Although, there was generally little return in the higher elevation cuts, large-scale images of the velocity products show dealiasing artifacts due to side lobe contamination.

We also looked at the frequency of errors by radar site. Table 6 shows the number of products by site for split, batch, and CD cuts. (Refer to Table 1 for the number of volume scans of each type of VCP for each site.) The site with the fewest products examined was KMLB (748) while the site with the largest number of products examined was KLWX (5644); the average number of products per site was about 3400. Some factors that limited the number of products examined from each site included distance of Hurricane Irene from a radar, use of VCP 121, and the use of sectorized PRFs. For split cuts (Table 7) the frequency of velocity dealiasing errors between the ½° super-resolution and 1° resolution products using the legacy VDA is roughly comparable and proportional to the number of products analyzed.

		Error Count: Legacy VDA / *2DVDA*						
Batch	Elevation cut	1.8°	2.4°	3.35°/3.1°	4.3°/4.0°	5.1°	6.0°/6.4°	**Total**
Batch	Error Count	**25 / *10***	**31 / *6***	**7 / *1***	**3 / *0***	**4 / *0***	**0 / *0***	**70 / 17**
CD	Elevation cut	8.0°	9.9°/10.0°	12.5°	14.6°/15.6°	19.5°	-	**Total**
CD	Error Count	**4 / *1***	**3 / *2***	**4 / *1***	**7 / *4***	**3 / *0***	-	**21 / *8***

Table 5. Number of velocity products with errors elevation angle and waveform for Hurricane Irene. Each "Error Count" cell in the table shows the number of legacy VDA products with errors followed by the number of 2DVDA products with errors.

Site	**KAMX**	**KMLB**	**KCLX**	**KLTX**	**KMHX**	**KAKQ**	**KLWX**	**KOKX**	**Total**
# of Split Products	950	272	1374	1254	872	1602	1992	1386	**9702**
# of Batch Products	950	272	1374	1254	872	1602	1992	1386	**9702**
# of CD Products	767	204	1145	1045	701	1335	1660	1155	**8012**
Total # of Products	**2667**	**748**	**3893**	**3553**	**2445**	**4539**	**5644**	**3927**	**27416**

Table 6. Number of products examined by waveform (split, batch, contiguous Doppler) and by site for Hurricane Irene.

Error Count: Legacy VDA / *2DVDA*								
	KAMX	**KMLB**	**KCLX**	**KLTX**	**KMHX**	**KAKQ**	**KLWX**	**KOKX**
½° Res Split Cuts	27 / *1*	17 / *1*	53 / *11*	116 / *15*	41 / *1*	125 / *0*	77 / *2*	125 / *10*
1° Res Split Cuts	36 / *2*	14 / *0*	67 / *7*	105 / *23*	42 / *0*	139 / *1*	63 / *4*	76 / *25*
Batch Cuts	0 / *0*	1 / *0*	5 / *0*	6 / *6*	22 / *0*	17 / *3*	2 / *2*	11 / *3*
CD Cuts	0 / *0*	0 / *0*	9 / *0*	0 / *0*	4 / *0*	0 / *0*	0 / *0*	8 / *8*

Table 7. Number of velocity products with errors by WSR-88D site and by waveform. Each cell in the table shows the number of legacy VDA products with errors followed by the number of 2DVDA products with errors.

Although the 2DVDA had consistently fewer dealiasing errors for all the sites than the legacy VDA, it had a somewhat higher frequency of errors for the 1° resolution products for KLTX (23 errors) and KOKX (25 errors) compared to the other sites. KLTX velocity products exhibited small errors in fragmented eye-wall bands. For KOKX, ground clutter artifacts were occasionally large enough to be seen in a full-range product. These were mainly speckles of velocities placed in the wrong Nyquist co-interval ($2V_N$). In the batch cuts, the number of legacy VDA errors for KMHX stands out. These errors occur mostly as wedges within the ground clutter preceding the onset of the outer bands or in isolated patches at the farthest range of the velocity product. The CD cuts had few errors for either algorithm (21 for VDA and 12 for 2DVDA). The nature of the errors was similar to those seen in the batch cuts near the radar. That is, wedge-shaped errors were present in the VDA products while small side-lobe contaminated errors were present in the 2DVDA products. While much better than the legacy VDA, the 2DVDA is not perfect.

4.3 Irene Discussion and Examples

Both WBJ09 and LT10 included weather events other than hurricanes in their studies. Besides velocity products from Hurricane Ike (2008), WBJ09 evaluated frontal boundaries in clear air (VCP 31), a squall line with super cells, and general thunderstorms. LT10 evaluated velocity products containing tornadic and/or mesocyclones signatures, squall lines, and gust fronts. Both studies concluded that the 2DVDA was superior to the legacy VDA in reducing velocity dealiasing errors for all types of weather events examined. Of particular interest was the performance of the 2DVDA on Hurricane Irene in contrast to the performance observed by LT10. LT10 analyzed 201 velocity products with 1° azimuthal resolution at 0.5° elevation for hurricanes Rita (2005), Gustav (2008), and Ike (2008). They found the legacy VDA had 185 dealiasing errors while the 2DVDA had only five dealiasing errors. (Their results are summarized in Table 8.) Note that in their analysis a velocity product could have more than one error if the errors were non-contiguous. The corresponding number of errors for each technique for Hurricane Irene from Table 4 shows that the legacy VDA had 286 products with dealiasing errors while the 2DVDA had only 26 products with dealiasing errors.

	Hurricane		
	Rita – 9/24/2005	Gustav – 9/1/2008	Ike – 9/13/2008
Site WSR-88D	Lake Charles, LA (KLCH)	Slidell, LA (KLIX)	Houston, TX (KHGX)
# of Products	62	39	100
Err Cnt VDA/2DVDA	42 / *4*	37 / *0*	106 / *1*
VDA Error Size	0 Lge; 2 Med; 40 Sm	6 Lge; 8 Med; 23 Sm	18 Lge;16 Med; 72 Sm
2DVDA Error Size	0 Lge; 0 Med; 4 Sm	0 Lge; 0 Med; 0 Sm	0 Lge; 0 Med; 1 Sm

Table 8. Summary of error counts and sizes for legacy VDA and 2DVDA for three hurricanes from LT10.

Also striking, was the difference in the number of legacy VDA products with large errors. LT10 tabulated 24 large errors (personal communication). By contrast, for Hurricane Irene we saw only two legacy VDA-dealiased velocity products with a large dealiasing error. In both our study and the earlier LT10 study, the 2DVDA had no large dealiasing errors. Figure 2 shows an example of a large VDA dealiasing error seen at KOKX for Hurricane Irene. Figure 3 shows another example of a large velocity dealiasing error produced by the legacy VDA seen at KAKQ. These dealiasing errors are like those seen by LT10. LT10 counted 26 medium-sized errors for the legacy VDA and no medium-sized errors for the 2DVDA. For the legacy VDA, we observed 16 medium-sized errors with Hurricane Irene, nine from KAKQ and seven from KLTX. For the 2DVDA we observed just one medium-sized from KLTX. Figure 4 shows a comparison of the velocity products from KLTX for the legacy VDA and the 2DVDA which had the medium-sized error which was the largest dealiasing error we saw for the 2DVDA. In this instance, the legacy VDA had no trouble dealiasing the band near the eye.

The improved performance of the 2DVDA over the legacy VDA is not as pronounced for Hurricane Irene as it was for the three hurricanes analyzed by LT10. From the National Hurricane Center’s Tropical Cyclone Reports [available online at http://www.nhc.noaa.gov/pastall.shtml#tcr] we surmise Irene was not as strong as the other hurricanes when it made landfall. Also, Irene had an extensive rain shield ahead of it. That is, for the times periods we analyzed, there were few breaks in echo coverage along radials between the rain bands. Thus, Irene was more easily dealiased by the legacy VDA. Irene traveled parallel to and at some distance from the radars as it traveled up Florida’s east coast. Later, Irene moved obliquely towards the radars upon initial landfall and only directly towards the radars after it had weakened. By contrast, the three hurricanes examined by LT10 were stronger and moved directly towards the radars during the periods they analyzed.

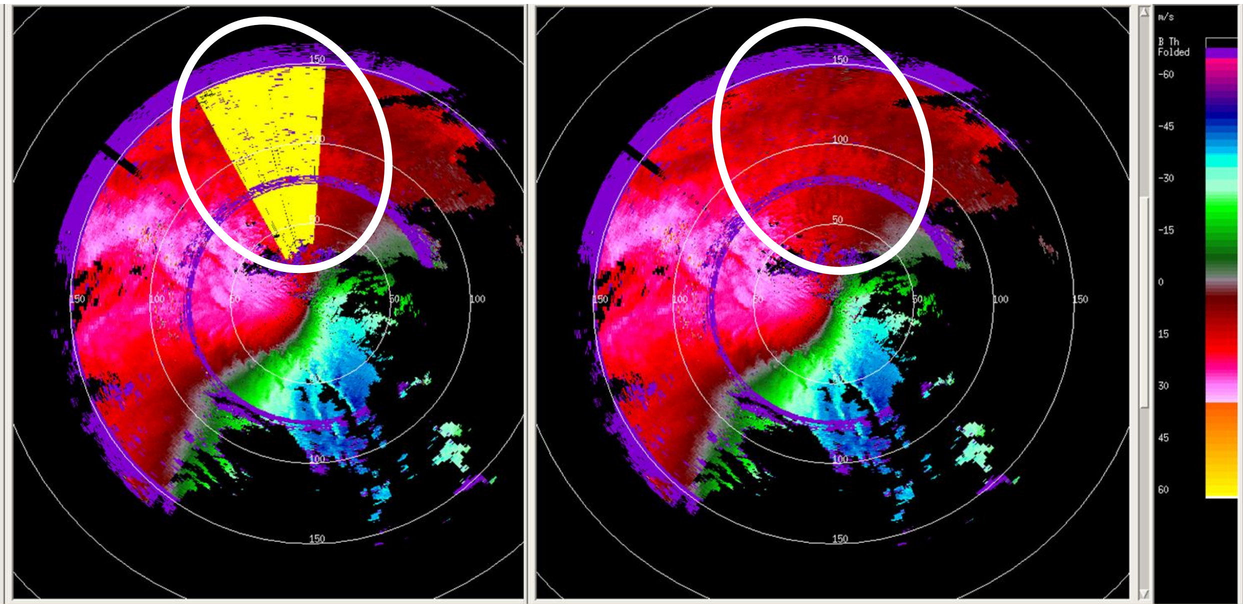

Figure 2. Hurricane Irene August 28, 2012 from Upton, NY WSR-88D (KOKX) at 07:21Z at 0.5 deg elevation. Circulation center is 150 n mi south-southwest of radar. Legacy VDA dealiased ½ deg azimuthal resolution velocity product is on the left, the 2DVDA dealiased product is on the right. Note large yellow wedge of incorrectly dealiased velocities for the legacy VDA (see white ovals). Range rings are every 50 n mi.

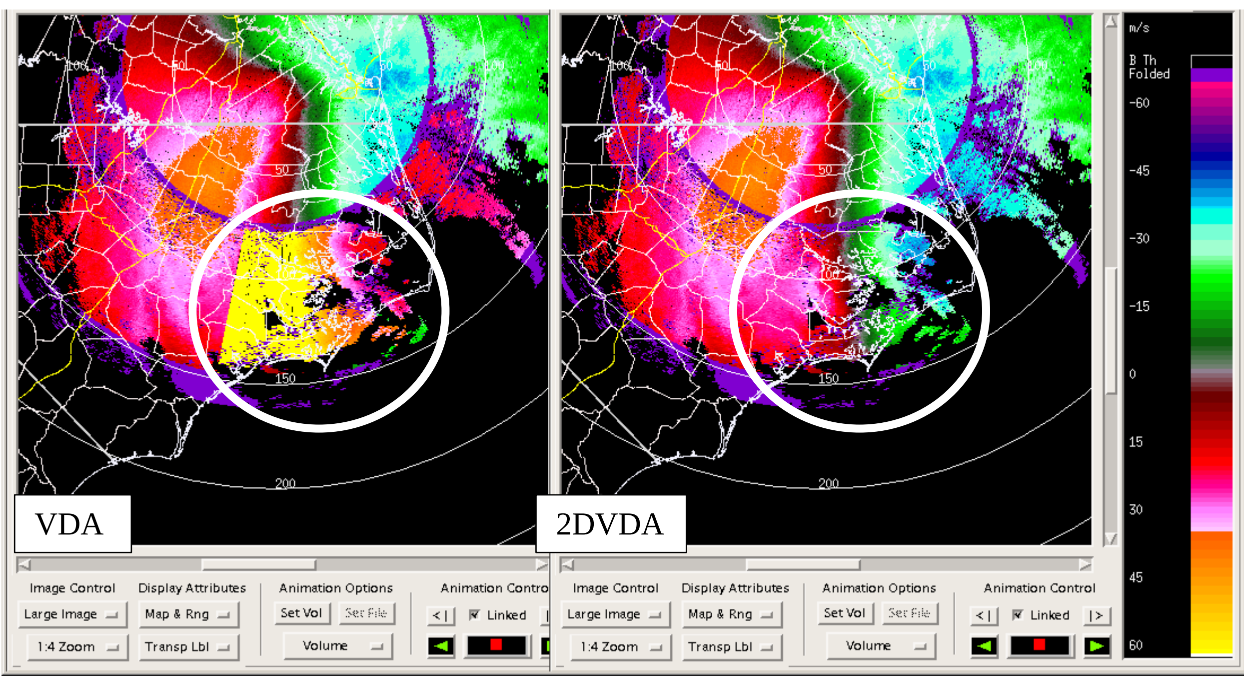

Figure 3. Hurricane Irene August 27, 2011 from Wakefield, VA WSR-88D (KAKQ) at 15:23Z at 0.5 deg elevation. Circulation center is about 115 n mi south of the radar. The legacy VDA dealiased ½ deg azimuthal resolution product is on the left; the 2DVDA dealiased product is on the right. Note large yellow area south of radar in second trip for the legacy VDA that is incorrectly dealiased (see white circles). Range rings are every 50 n mi.

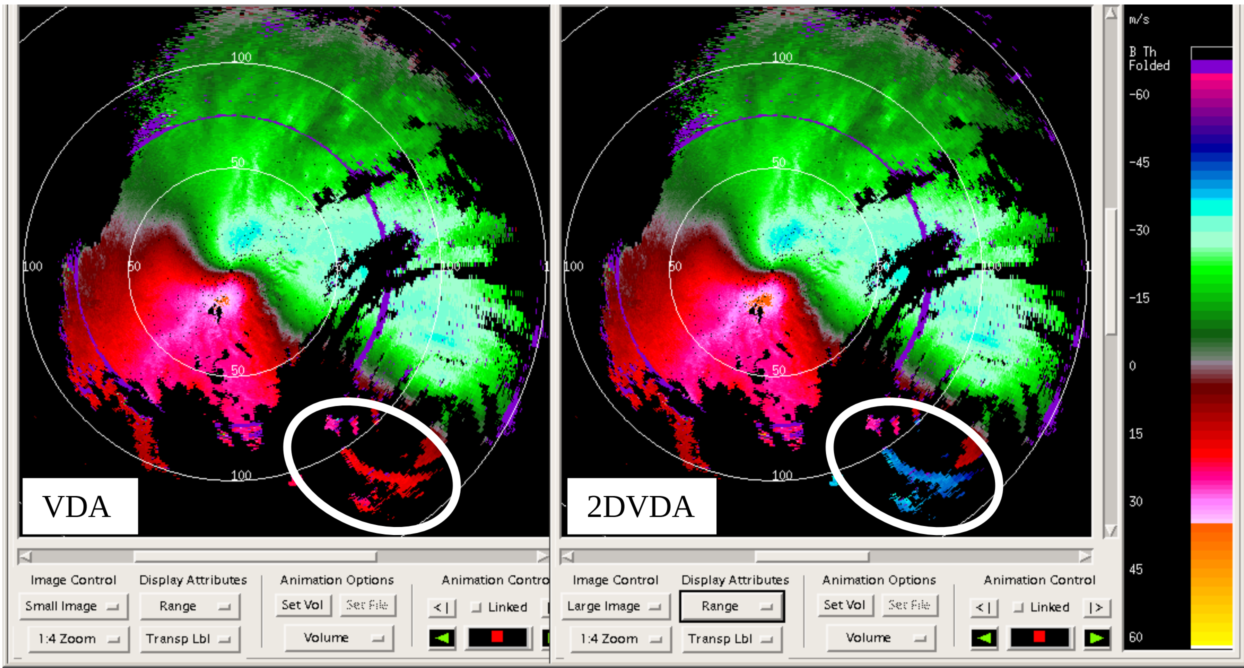

Figure 4. Hurricane Irene August 27, 2011 from Wilmington, NC WSR-88D (KLTX) at 04:05Z at 1.3 deg elevation. Circulation center is about 125 n mi southeast of the radar. The legacy VDA dealiased 1 deg resolution product is on the left; the 2DVDA dealiased product is on the right. Note the blue inbound incorrectly dealiased fragmented eye wall in the 2DVDA panel (see white ovals). Range rings are every 50 n mi.

5. KINEMATIC ALGORITHM EVALUATIONS

Data from Hurricane Irene were used to compare velocity dealiasing effects on Enhanced Velocity Azimuth Display (VAD) Wind Profile (EVWP) Algorithm (being fielded in the RPG Build 13.0 software), the Mesocyclone Detection Algorithm (MDA), and Tornado Detection Algorithm (TDA). For the EVWP, data from KLTX (Wilmington, NC) and KAKQ (Wakefield, VA) were analyzed. For the MDA and TDA algorithms, data from KLTX, KAKQ, and KOKX were analyzed.

5.1 Enhanced VAD Wind Profile Algorithm

About 6.5 hours of data (15:23Z to 22:05Z) from August 27, 2011 from KAKQ were examined for differences between EVWP products generated from velocity data dealiased by the VDA and velocity products dealiased by the 2DVDA. Over this time period, the only differences noted occurred at 21:56Z with the winds reported at 25 kft. The VAD algorithm, using 2DVDA dealiased velocity data, computed a wind speed of 47 kts and using the legacy VDA dealiased velocity data, computed a wind speed 50 kts. The corresponding directions were 48° and 47°, respectively while the RMS values were 4.2 kts and 4.4 kts, respectively. For this observation, the legacy VDA wind speed fit the vertical profile slightly better than the 2DVDA wind speed. The differences in the wind direction and RMS values were trivial. None of the differences were deemed operationally significant.

About 6 hours of KLTX data (21:02Z to 02:56Z) from August 26-27, 2012 were examined for differences between the EVWP products generated from the legacy VDA and the 2DVDA dealiased data. For this data set many more differences were observed; none were deemed operationally significant. Figure 5a shows a EVWP product for the 2DVDA and Figure 5b is the corresponding EVWP product for the legacy VDA. Each product spans 11 volume scans from 23:52Z to 00:37Z. An example of a difference is at 13 kft at 00:14Z where the wind barb is displayed in red for the 2DVDA EVWP product and yellow for the legacy VDA EVWP product. At 3 kft the 2DVDA wind barbs are shown in green for 23:52Z and 23:56Z and in yellow for the corresponding EVWP generated from the legacy VDA. Other minor differences between the products are left to the reader to identify.

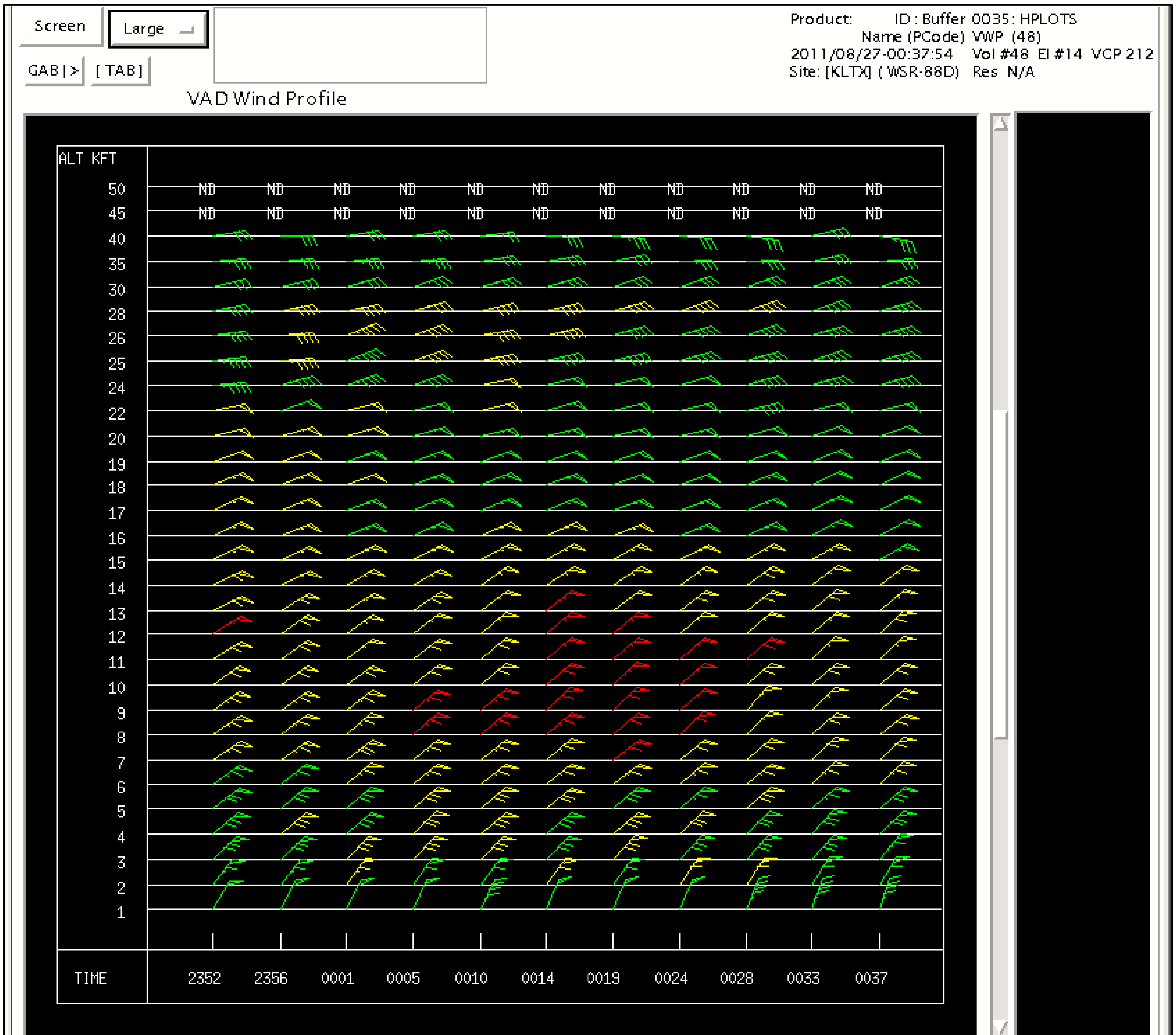

Figure 5a. EVWP product generated from 2DVDA-dealiased velocity data for KLTX on August 27, 2011 at 00:37Z. Barbs show direction from which the wind is blowing for a particular time and height. A green barb indicates an RMS value between 0 and 4 kts, yellow indicates an RMS value from 4 to 8 kts, and a red barb indicates an RMS value of 8 to 12 kts.

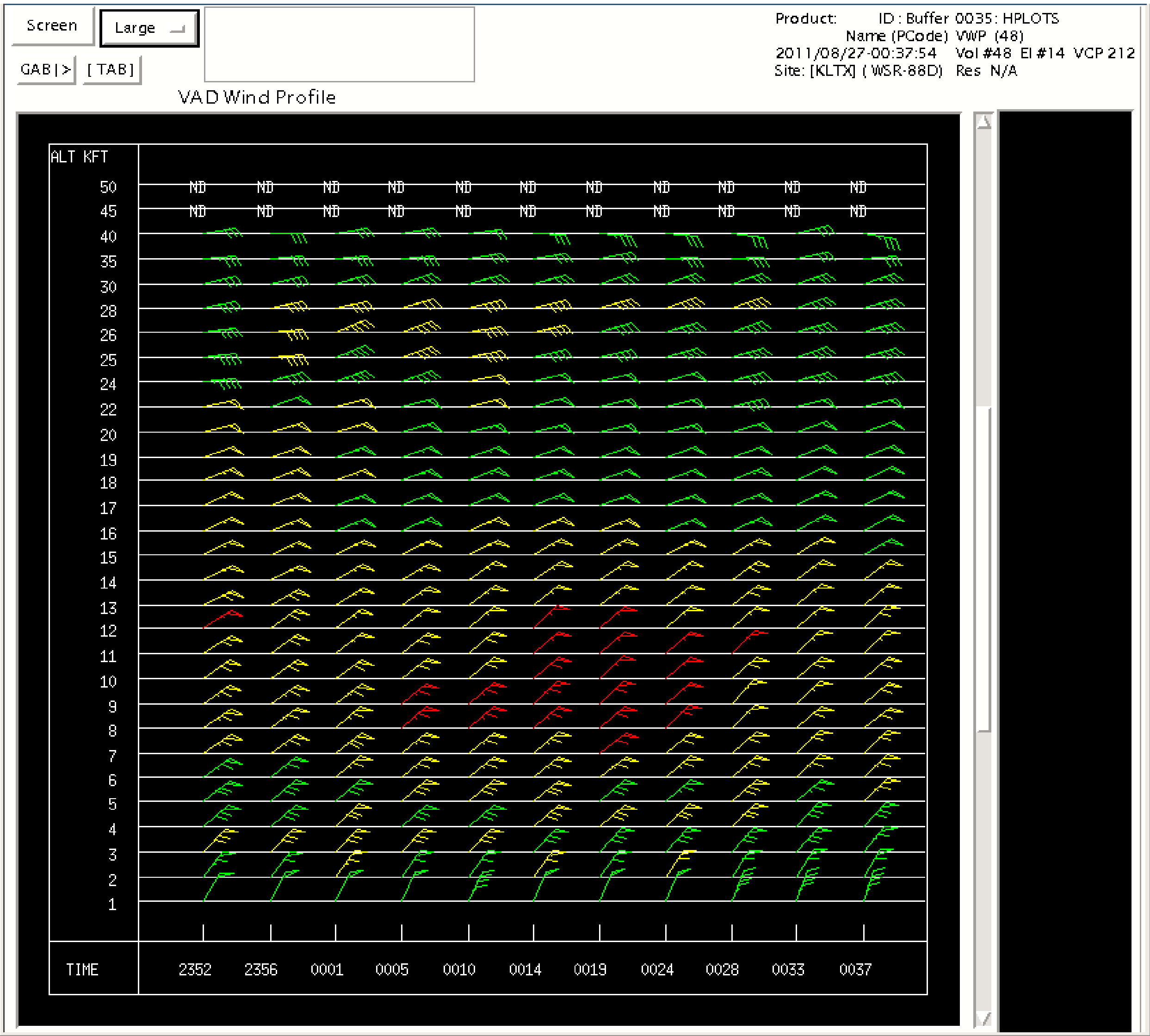

Figure 5b. Same product as Figure 5a but generated from velocity data dealiased by the legacy VDA.

We also looked at differences in the vertical profiles for 00:19Z for wind speed, direction, and RMS. Figures 6a shows the wind speed profile comparison and Figure 6b shows the RMS profile. (The wind directions did not vary and so are not shown.) The information for the vertical profiles plotted in Figures 6a and 6b are taken from the tabular portion of the VWP product which contains wind estimates from heights not shown in the graphical profiles in Figures 5a-b. Differences in speed are seen at 1.2, 1.8, 2.0, 2.6, and 3.0 kft while for RMS values, differences are observed at 1.2, 1.8, 2.6, 3.0, 5.0, 13.0, 14.0, and 15.0 kft. The largest velocity difference is 2 kts (69 vs. 67) at 2.6 kft. The largest RMS difference is 1.1 kts (4.2 vs. 3.1) at 3.0 kft. The clustering of RMS values at heights below 5.0 kft suggests the values were computed from different elevation angles and, hence, different ranges from the radar. For instance, for the 3.0 kft winds, the EVWP used the 2DVDA-dealiased velocity data from the 1.8° elevation angle at a range of 14.10 n mi while it used the legacy VDA-dealiased velocity data from the 2.4° elevation angle at a range of 10.88 n mi.

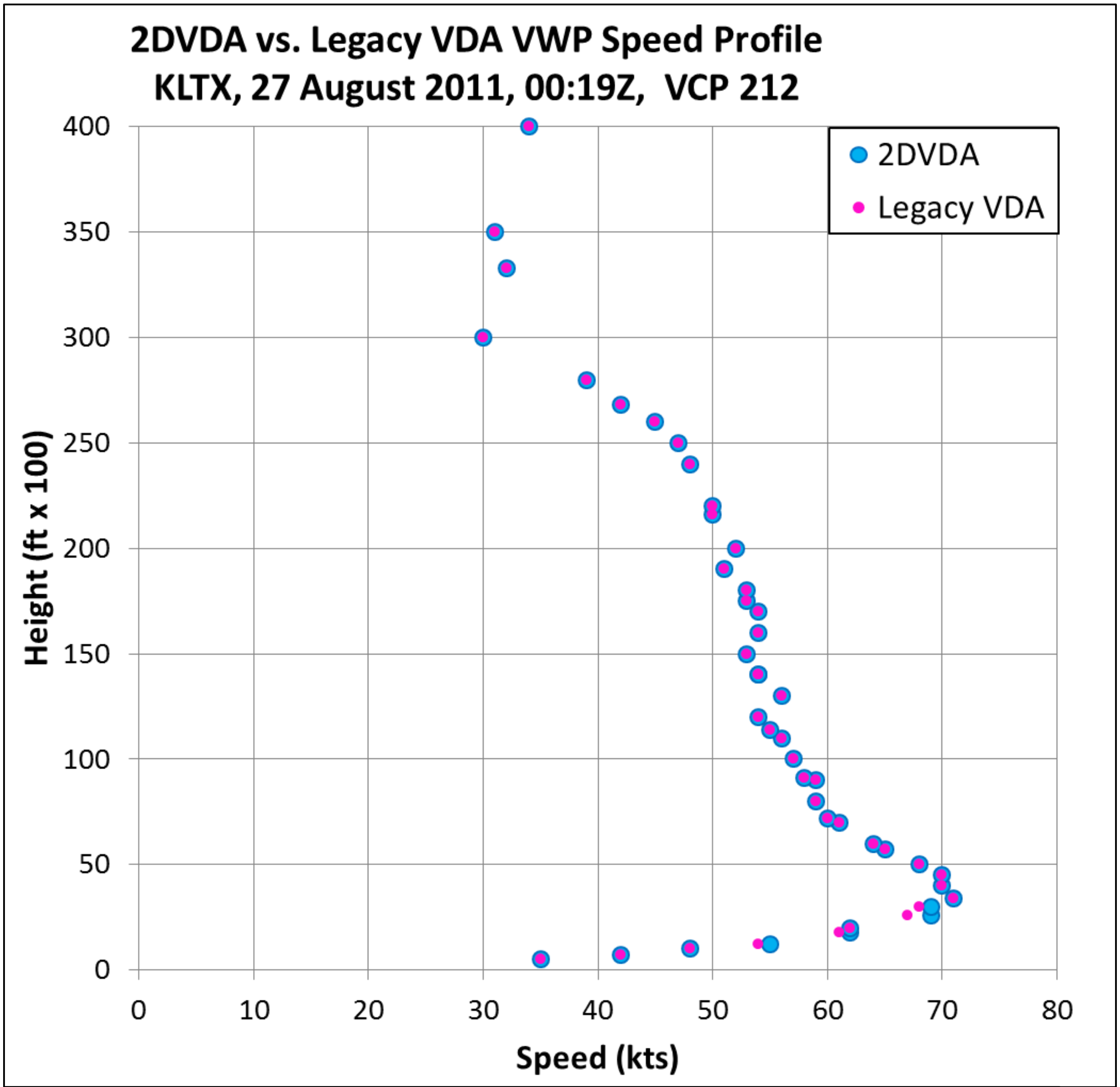

Figure 6a. Vertical profile of wind speeds computed the VAD algorithm for heights requested by the VWP product from KLTX on August 27, 2011 at 00:19Z for KLTX. Blue dots show winds computed from 2DVDA-dealiased velocity data and magenta dots show wind speeds computed using legacy VDA-dealiased velocity data.

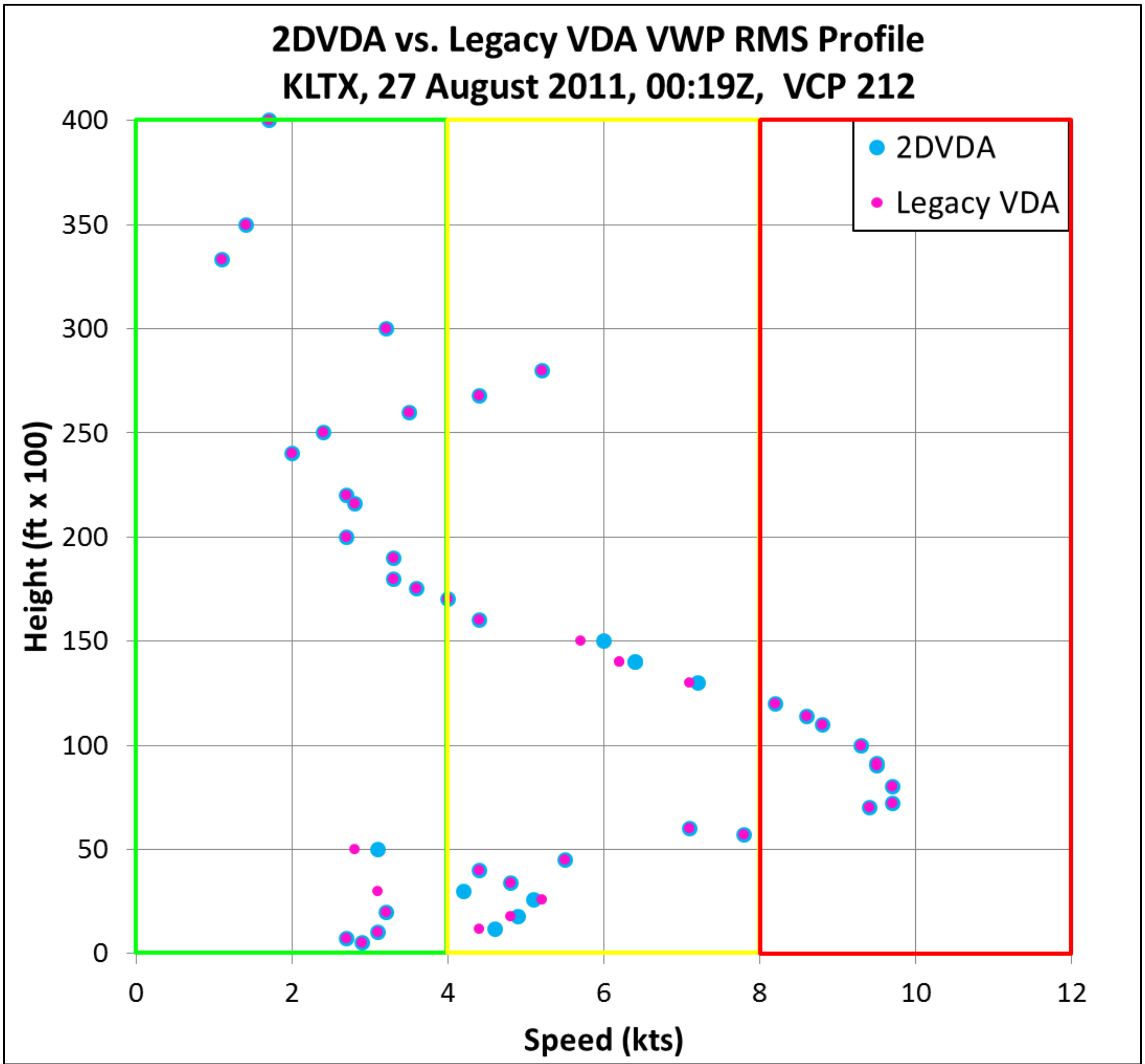

Figure 6b. Same as Figure 6a except the RMS values are plotted. The green, yellow, and red colored boxes correspond to wind barb color coding in Figures 5a-b.

Finally, we looked at time series plots of wind speed, direction, and RMS values for selected heights. For KLTX we plotted data from 3.0 and 15.0 kft. Only minor, none operationally significant differences were observed for this data as shown in Figure 7. At either height, the largest differences in direction were 2° azimuth or less. Velocity differences were 2 kts or less. RMS values differed by as much as 2 kts and, thus, were somewhat larger relative to the magnitude of the values, especially at the 3.0 kft height (not shown).

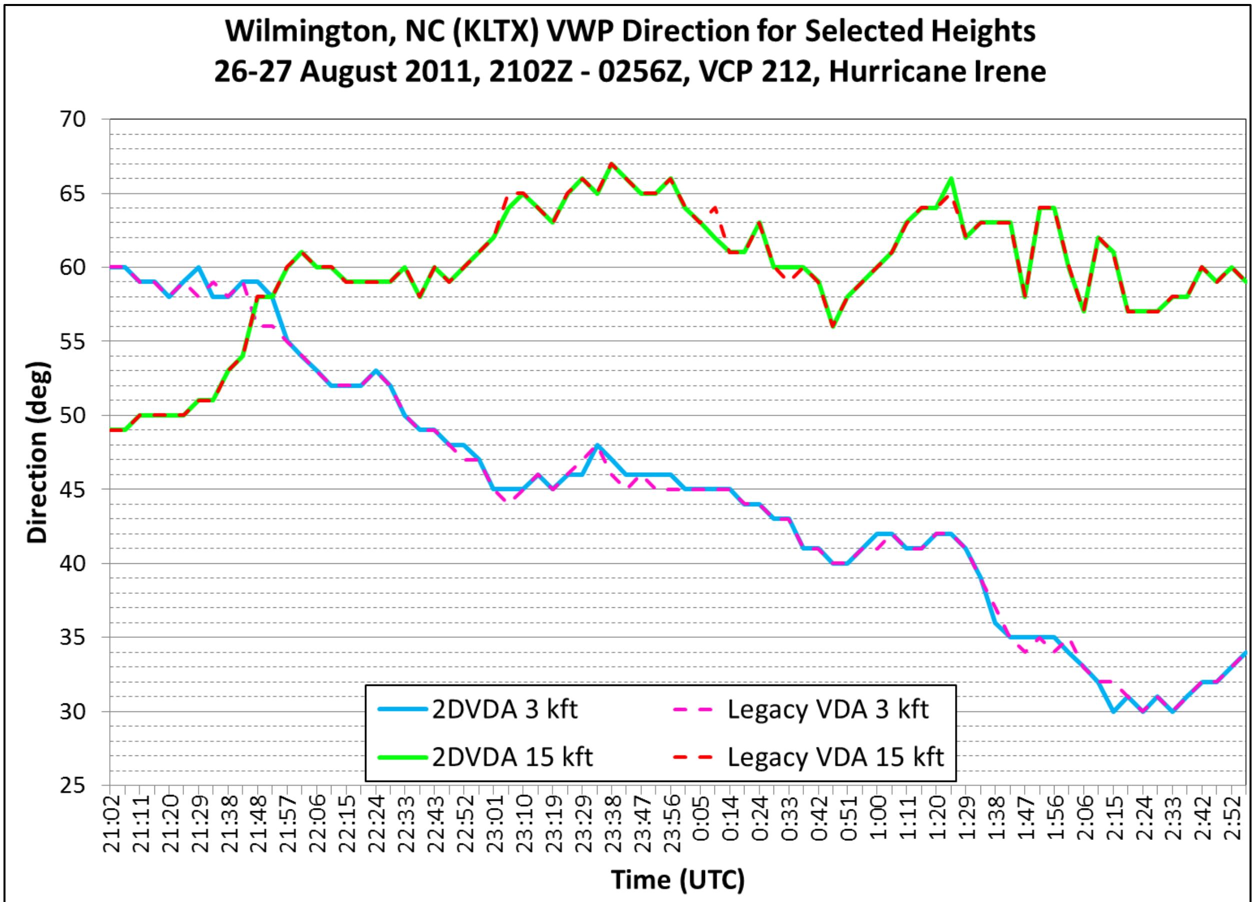

Figure 7. Time series for the wind direction 3 kft and 15 kft for KLTX for August 26-27, 2011 from 21Z to 03Z. Wind direction computed by the VAD from velocity dealiased using the 2DVDA shown in solid blue and green; the wind direction computed by the VAD from the legacy VDA dealiased velocity data shown as dashed magenta and red.

5.2 Mesocyclone Detection Algorithm

We examined differences between the Mesocyclone Detection Algorithm (MDA) output when using velocity dealiased or using the 2DVDA or the legacy VDA from Hurricane Irene. Over 21 hours of data included the following 3 sites: KLTX, August 26-27, 2011, 21:15Z to 02:56Z; KAKQ, August 27, 2011, 15:23Z to 22:04Z; and KOKX, August 28, 2011, 07:11Z to 14:58Z. Scatterplots of the locations found using either dealiasing algorithm showed that the majority occurred just beyond the start of 2^{nd} trip echo. Each site was in VCP 212, a VCP that uses the SZ-2 range unfolding technique to recover weak trip echo. Often, the velocity data in weak trip echo is noisy and prone to dealiasing errors by the legacy VDA. Figure 8 shows a scatterplot from KAKQ of MDA detections using legacy VDA dealiased velocity data (shown in cyan) overlaid with MDA detections using 2DVDA dealiased velocity data. Both algorithms show a surfeit of detections just beyond 75 n mi (139 km). The chart in Figure 9 shows the number of mesocyclones detected for each case. The MDA, using legacy VDA dealiased velocity data, found 870 mesocyclones for the 3 cases but only 470 mesocyclones using the 2DVDA dealiased velocity data, a reduction of nearly 46%. We conclude the 2DVDA is better at correcting noisy velocities by the appropriate Nyquist co-interval $2V_N$.

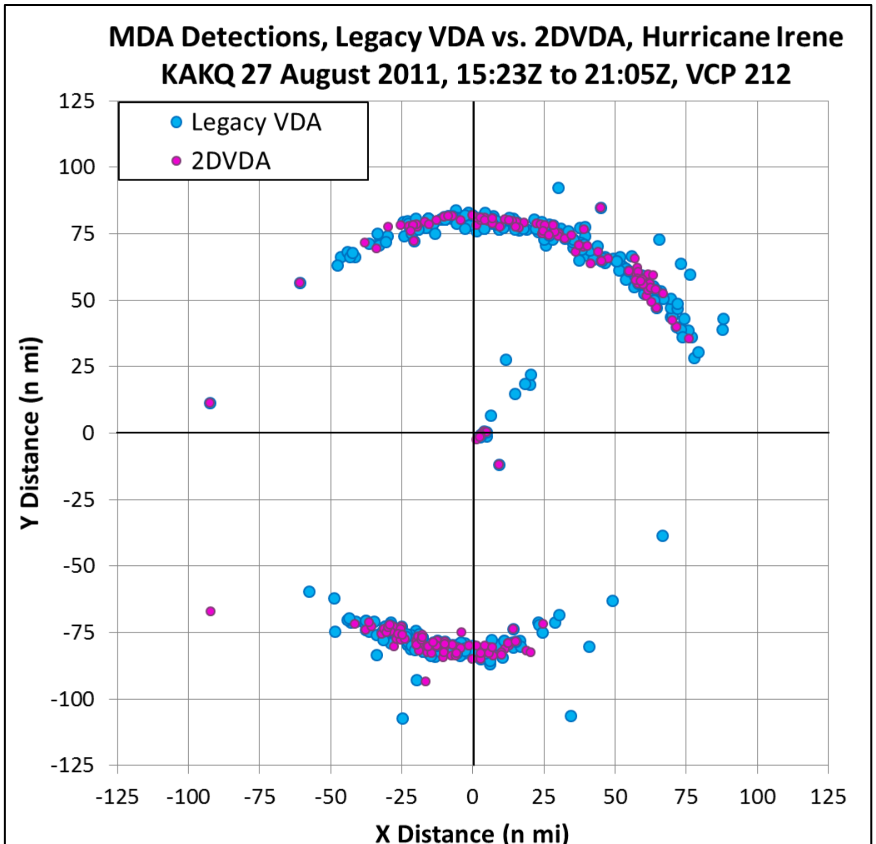

Figure 8. Scatterplot of mesocyclones detected using velocity data dealiased by the legacy VDA (cyan) and those detected using velocity data dealiased by the 2DVDA (magenta) for KAKQ August 27, 2011 from 15:23Z to 21:05Z.

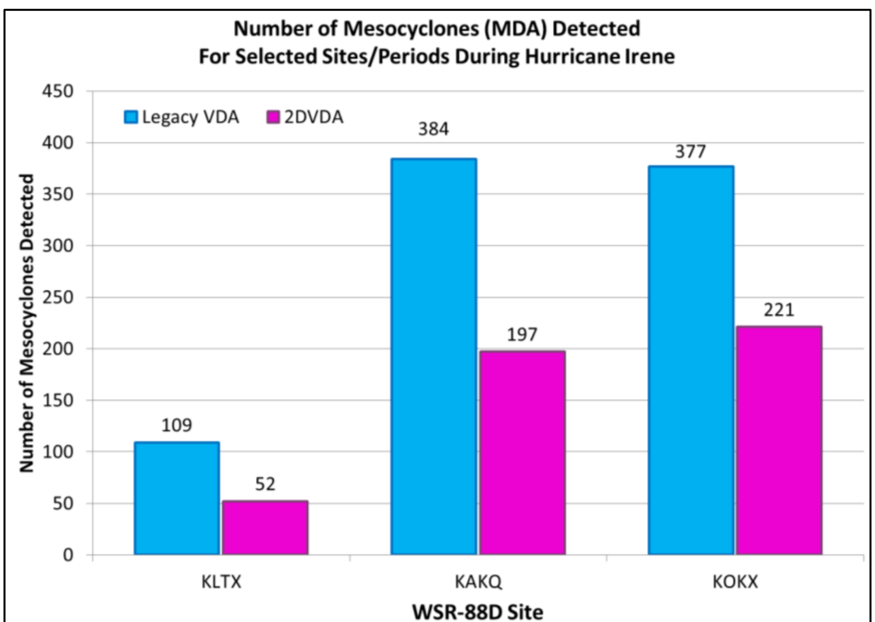

Figure 9. Bar chart showing the number of mesocyclones detected by the MDA using velocity data dealiased by the legacy VDA (cyan) and the 2DVDA (magenta) for KLTX, KAKQ, and KOKX.

5.3 Tornado Detection Algorithm

The same data sets as were used for the MDA detection comparison were used for the Tornado Detection Algorithm analysis except that an extra 10.5 hours from KAKQ were included. The total period of time for KAKQ was 05:03Z to 22:04Z. For KLTX there no Tornado Vortex Signatures (TVSs) reported by the TDA using data dealiased by either the 2DVDA or the legacy VDA. For KAKQ there were 3 TVSs and for KOKX there were 2 TVSs detected by the TDA using velocity dealiased by each algorithm. In all 5 instances, the TVS locations matched. Figure 10 shows the side-by-side comparison of velocity dealiased by the 2DVDA (left) and the legacy VDA (right) from KAKQ August 27, 2011 at 12:32Z at 0.5 deg elevation using 1° azimuthal resolution data.

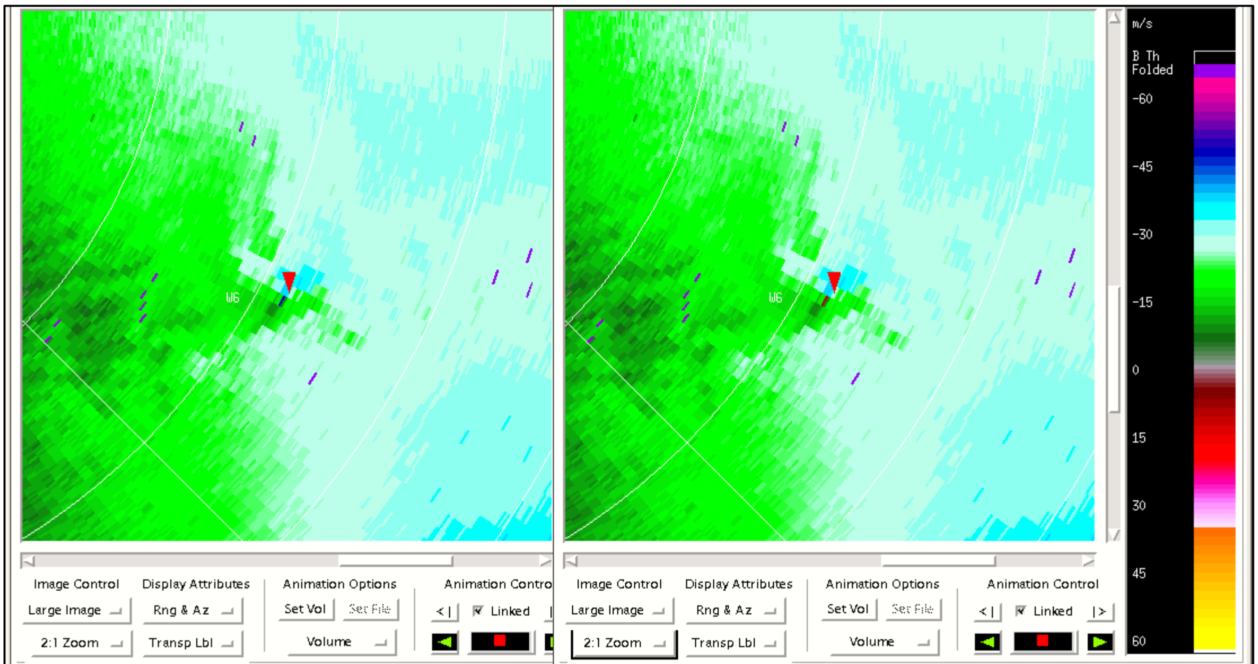

Figure 10. Results of the Tornado Detection Algorithm from KAKQ August 27, 2011, 12:32Z at 0.5 deg elevation with azimuthal resolution of 1 deg. 2DVDA dealiased velocity data is on the left, legacy VDA dealiased velocity data is on the right. The red inverted triangle shows the location of the TVS in each velocity field.

6. HURRICANE IKE COMPARISON

Because Hurricane Irene was only a weak Category 1 hurricane as it made landfall, the radial component of the wind required little velocity dealiasing. Previously, the LT10 study demonstrated the efficacy of the 2DVDA at correctly dealiasing winds in stronger hurricanes but did not address the differences between that algorithm and the legacy VDA for values at and above the Nyquist velocity V_N. The legacy VDA truncates V_N while the 2DVDA rounds V_N to the nearest 0.5 m s^{-1}. This causes velocities in the 2DVDA that exceed $\pm V_N$ to be higher in magnitude by 1 m s^{-1} than the velocities for the legacy VDA. Figure 11 shows a side-by-side comparison of velocity data from the Houston, TX WSR-88D (KHGX). The left image was dealiased using the legacy VDA while the image on the right was dealiased using the 2DVDA. The effect is seen in regions of strong inbound and outbound velocities . Velocities below V_N match. Figure 12 shows velocity histograms for a region from 45° through 225° azimuth out

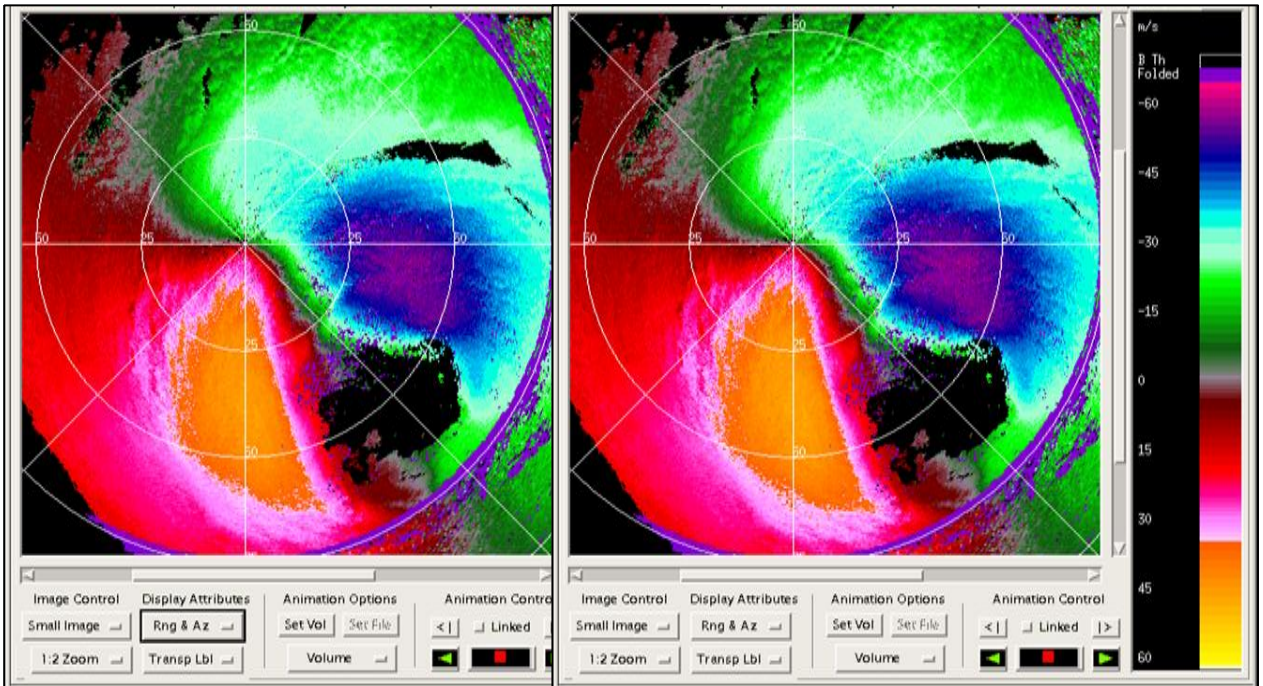

Figure 11. Super resolution velocity of Hurricane Ike seen from the Houston, TX WSR-88D (KHGX) September 13, 2008 at 04:39Z images at 0.5° elevation. Image on left has been dealiased using the legacy VDA; the image on the right has been dealiased using the 2DVDA. Note the expanded areas of strong outbound velocities shown in orange and strong inbound velocities shown in purple in the image on the right.

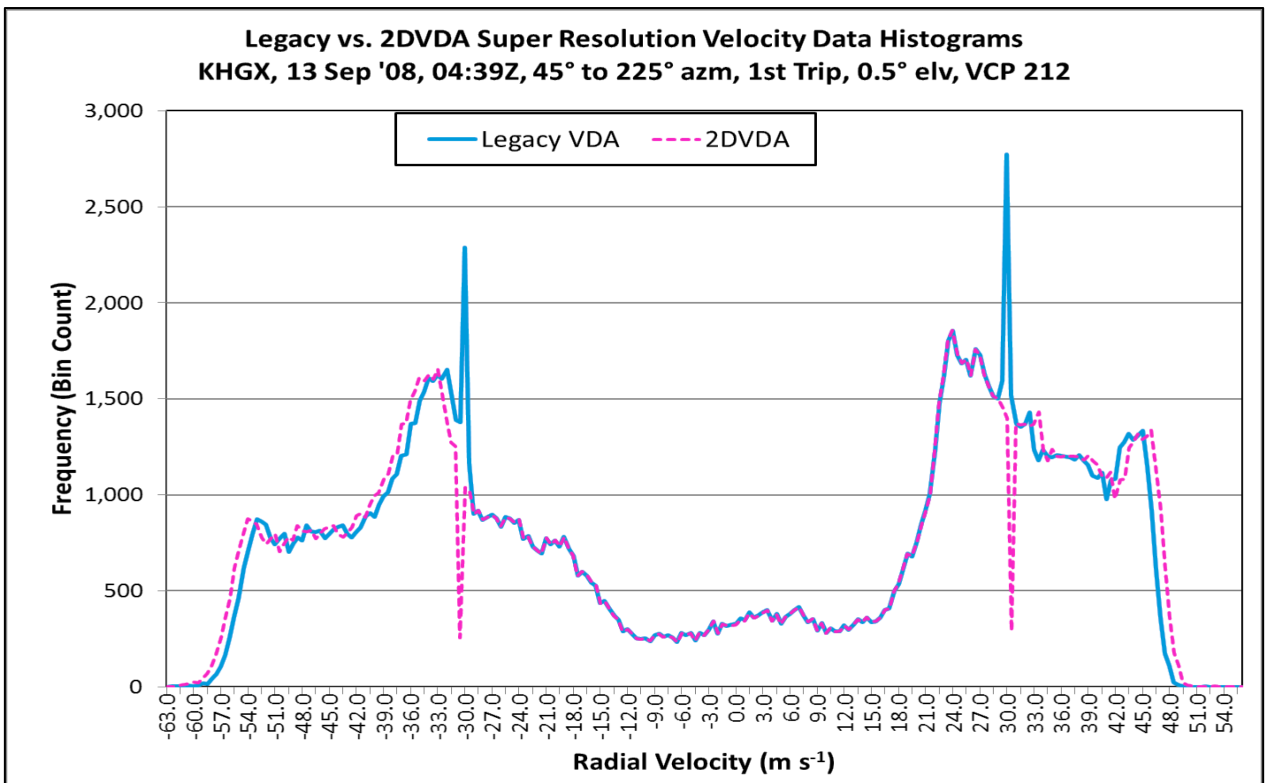

Figure 12. Histogram comparisons of legacy VDA and 2DVDA for velocity data from Figure 11. Region included is shown in title. Note the upward spike in velocities near V_N for the legacy VDA data (cyan) and the downward spike near V_N for the 2DVDA dealiased velocities (magenta). The 2DVDA raises dealiased velocities by 1 m s^{-1} for velocities above V_N and lowers dealiased velocities by -1 m s^{-1} for velocities below $–V_N$.

to 135 km, the end of 1st trip. The legacy VDA show an unexpected increase in the number of velocity bins with a value about $\pm V_N$ while the 2DVDA shows an unexpected decrease in the number of velocity bins about $\pm V_N$. Inside $\pm V_N$ the histograms match while outside $\pm V_N$ the 2DVDA histogram is displaced outward by 1 m s^{-1} relative to the legacy VDA histogram.

7. AMARILLO (KAMA) ANALYSIS

On August 25, 2011 the Amarillo, TX WSO contacted the ROC Hotline concerning velocity dealiasing errors they were observing while using VCPs 12 and 212. They reported having dealiasing errors on both August 23, 2012 and August 25, 2012 and provided velocity product images captured from their Advanced Weather Information Processing System (AWIPS) illustrating the problem. The Hotline asked the Applications Branch to investigate the dealiasing problem via a Request for Technical Information (RTI) #51896. The Applications Branch ordered Level II Archive data for the earlier date, August 23-24, 2011 for the period 21Z to 00Z. Data were played back using the legacy VDA and then again using the 2DVDA. The legacy VDA produced the same errors as were seen in the images provided by the Amarillo WSO. Velocity products generated from the 2DVDA cleared up the large errors. It did not reduce small dealiasing errors due to vehicular traffic along major thoroughfares. Figure 13 at 22:07Z shows an AWIPS velocity product on the left dealiased using the legacy VDA, and on the right, the corresponding 2DVDA dealiased velocity product from the RPG display tool cvg. A large region between about 135° and 285° azimuth and originating from the radar was incorrectly dealiased as strong, inbound velocities VDA (shown in blue) by the legacy but dealiased correctly by the 2DVDA. Both the legacy VDA and the 2DVDA have noisy velocities along major thoroughfares.

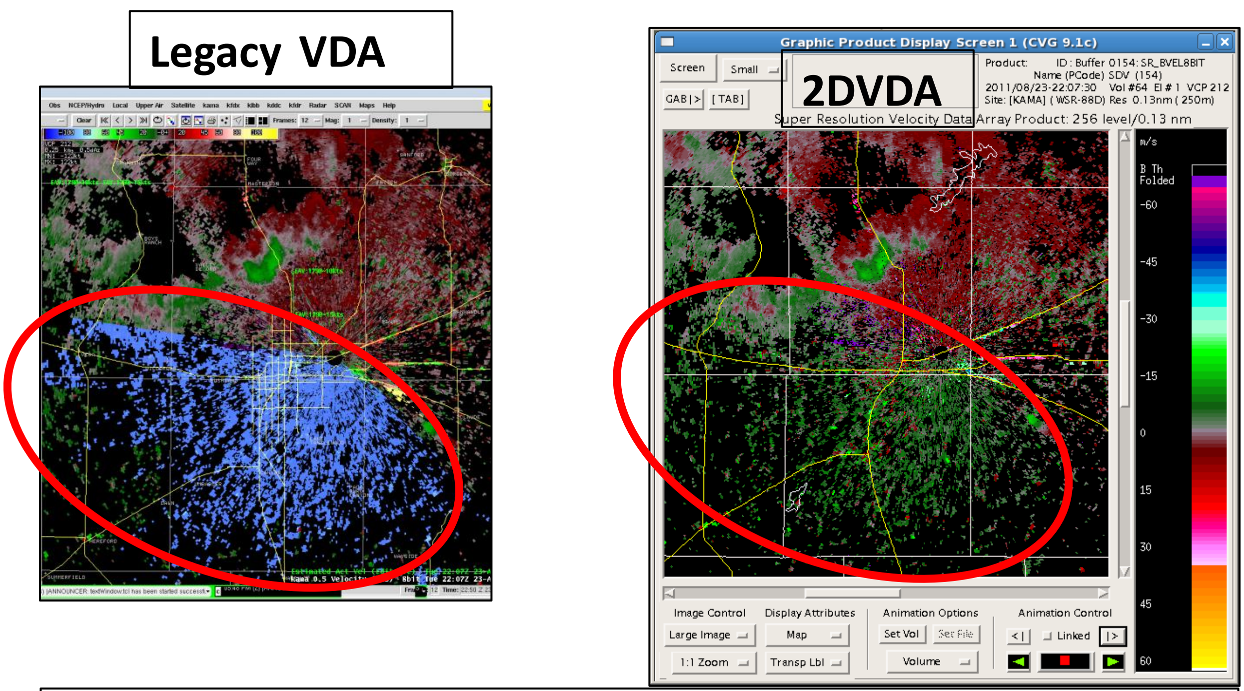

Figure 13. KAMA super resolution velocity data from August 23, 2011 at 22:07Z at 0.5 deg elevation. On left is an AWIPS image that has been incorrectly dealiased by the legacy VDA and on the right the same velocity data that has been correctly dealiased by the 2DVDA.

Besides the errors at the 0.5° elevation angle with super-resolution velocity data, the legacy VDA introduced errors in the 1° resolution velocity products both at the 0.5° elevation angle and at higher elevation angles. The 2DVDA correctly dealiased the same velocity data. Figure 14 shows a comparison of velocity data at 21:12Z at 6.4° elevation. The left image was dealiased by the legacy VDA and the right image was dealiased by the 2DVDA. The legacy VDA has incorrectly dealiased a large area from about 300° through 125°.

The legacy VDA dealiasing errors are due to a combination of factors. 1) VCPs 12 and 212 have a reduced number of samples from which to calculate base reflectivity data which affects clutter mitigation; 2) There is contamination from vehicular traffic that is contributing to the errors at the 0.5° elevation angle (the 2DVDA does a better job of keeping these errors from spreading than does the legacy VDA); and 3) Based on the noisy velocities and high spectrum width values at the start of many radials, the radar may need tuning.

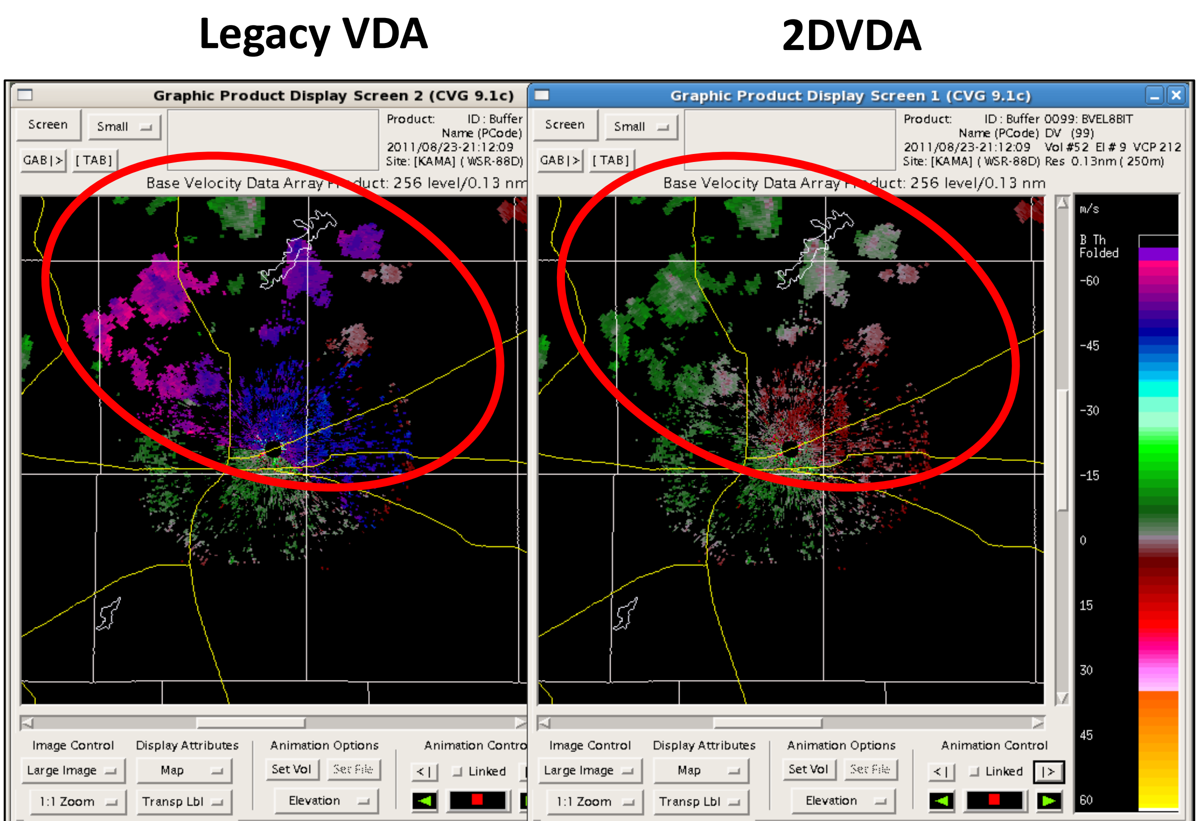

Figure 14. KAMA super resolution velocity data from August 23, 2011 at 21:12Z at 6.4° elevation. On left is an AWIPS image that has been incorrectly dealiased by the legacy VDA and on the right the same velocity data that has been correctly dealiased by the 2DVDA.

8. RESTRICTIONS ON THE USE OF 2DVDA

There are three conditions under which the 2DVDA cannot be used: 1) a site uses different PRFs in a scan; 2) a site opts to use 1 m s^{-1} resolution data; or 3) a site chooses to use VCP121 and the MPDA. For either of the first two conditions the RPG software automatically deselects the 2DVDA and switches to the legacy VDA. The third option, use of VCP 121, completely removes the possibility of using the 2DVDA because the MPDA is a yet another velocity dealiasing algorithm. Sites will have the option of toggling off the 2DVDA if they so choose. In this case, the RPG reverts to the legacy VDA as the primary dealiasing algorithm.

9. SUMMARY

The new 2-Dimensional Velocity Dealiasing Algorithm (2DVDA), slated for deployment starting in the fall of 2012, clearly reduced the frequency and severity of velocity dealiasing errors over the legacy VDA for Hurricane Irene data. At low elevation angles there was an order of magnitude reduction in the frequency of velocity dealiasing errors for Irene. At higher elevation angles the reduction in dealiasing errors was not as pronounced although the likelihood of having a dealiasing error is much lower to begin with. Differences in winds displayed in the VAD Wind Profile (VWP) product due to the 2DVDA were trivial. The same number of TVSs was detected with velocity data dealiased by either the legacy VDA or the 2DVDA. However, the number of mesocyclones detected by the MDA in Hurricane Irene for 3 sites was reduced by 45%. The mesocyclones were the result of noisy velocity data at the start of 2nd trip in VCP 212 and were not true circulations. Histograms of velocity data from KHGX for Hurricane Ike, a stronger hurricane at landfall than Irene, show the 2DVDA dealiases velocities about 1 m s^{-1} higher in magnitude than the legacy VDA for velocities above V_N. The 2DVDA eliminated dealiasing errors due to noisy velocities for the KAMA WSR-88D. This study supports the conclusions of both WBJ09 and LT10 that the 2DVDA is superior to the legacy VDA.

10. ACKNOWLEDGMENTS

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