P2.15

A Data Quality Comparison of the WSR-88D Legacy Radar Data Acquisition (RDA) to the Open RDA (ORDA), in a Challenging Clutter Regime

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1. INTRODUCTION

Shortly after the WSR-88D was installed in Phoenix, AZ, it was discovered that the location posed significant data quality challenges. The first complaint called in to the Operational Support Facility occurred on March 31st, 1993 with the subject, "Clutter Suppression Insufficient." In the closing comments of the ticket, the engineer studying the problem wrote, "… it was determined that the return from the surrounding mountains exceeds the capability of the clutter suppression hardware." Since then, the WSR-88D Hotline has received numerous calls documenting problems related to clutter suppression, precipitation estimation, radar calibration, mountain blockage, poor velocity estimates, etc.

During testing and evaluation of the Open Radar Data Acquisition (ORDA) and the new Gaussian Model Adaptive Processing (GMAP) clutter suppression solution, the Radar Operations Center (ROC) sought out "difficult" situations under which to conduct tests. ROC Hotline meteorologists and technicians were aware of the problems imposed by terrain on the Phoenix radar (KIWA) radar products, and the site was added to the list of sites to visit. This work presents a summary of the operational comparison of the legacy RDA and the ORDA in this difficult clutter regime.

2. GEOGRAPHY, LOCATION, CHALLENGES

Figure 1 is an exaggerated relief map, showing the terrain around the KIWA site. The red pointer indicates the radar location, the superimposed red circle has a radius of 10 miles, and the view is toward the north. The radar is located on Williams Gateway Airport, immediately adjacent to four busy metropolitan areas. The cities of Mesa, Scottsdale, Tempe, and Phoenix lie to the Northwest of the radar on a gradually rising slope. The airport is in a low area with rising terrain in nearly every direction. Figure 2 is an exaggerated cross section, centered on the radar, with a radius of 100 miles. The cross section was cut such that Northwest is to the left, and Southeast is on the right; the viewer is looking toward the Northeast. The cross section shown in Figure 3 is perpendicular to the first with the viewer looking toward the Northwest. In both cases, the radar location is depicted by the cursor and the vertical blue line.

If the "bowl" in which the radar is located does not present enough challenges, the airport adds to the list of potential problem sources. Figure 4 is a "Google™ Earth" map which shows the location of the radar relative to the airport and several other man-made obstructions (tower, hanger, etc.). The radar is immediately adjacent to a busy road and a railroad track that runs from northwest to southeast, passing within one mile south of the radar site (white line in Figure 4). Further, at least two Federal Aviation Administration (FAA) Air Surveillance Radars (ASRs) are located on the air field; one is within one mile.

Figure 1-Phoenix Radar Site

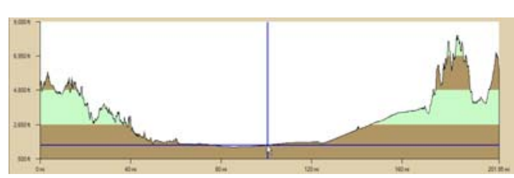

Figure 2-Northwest to Southeast Cross Section

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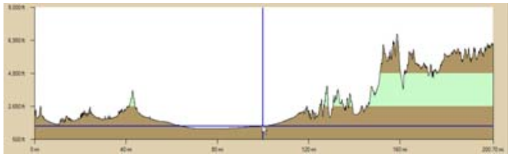

Figure 3-Southwest to Northeast Cross Section

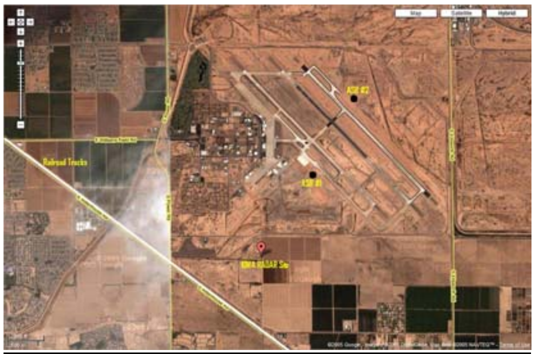

Figure 4-Google™ Earth Map Presentation of Radar Site

3. DATA QUALITY PROBLEMS RESULTING FROM RADAR SITING

The most frequent complaint from Weather Forecast Office (WFO) Phoenix forecasters, almost from the time the radar was installed, was that residual clutter was a persistent problem. Residual clutter results when the clutter filters are unable to entirely remove the returned power from ground targets, resulting in insufficient suppression. The Operational Support Facility (now the Radar Operations Center (ROC)) engineers documented this fact in Hotline Assistance Request #2747 stating, "… it was determined that the return from the surrounding mountains exceeds the capability of the clutter suppression hardware." Not only does residual clutter interfere with operations, but the data is memorialized in the national archives. Figure 5 shows the residual clutter pattern which has been present for the last 12 years while using the legacy Infinite Impulse Response (IIR) clutter filter.

3.1 *Base Data*

It is well known that residual clutter biases the reflectivity estimates high, and the velocity estimates low, while spectrum width (SW) products may be affected in various ways due to beam geometry and the size of the target. Figure 5 shows the three base moments for one legacy volume scan of Volume Control Pattern (VCP) 32. There is no precipitation in the area. The site is filtering clutter using the bypass map, yet it is obvious that a great deal of clutter remains. The velocity product provides significantly more detail about what is going on. The linear regions with relatively high velocities assigned represent traffic on highways. The light grey color denotes zero velocity which is evidence that much of the echo shown in the reflectivity product, is actually due to anomalous beam propagation. Finally, the SW product is very noisy, as one would expect in a situation in which there are legitimate scatterers, vehicles, biological returns, and terrain in a single sample volume.

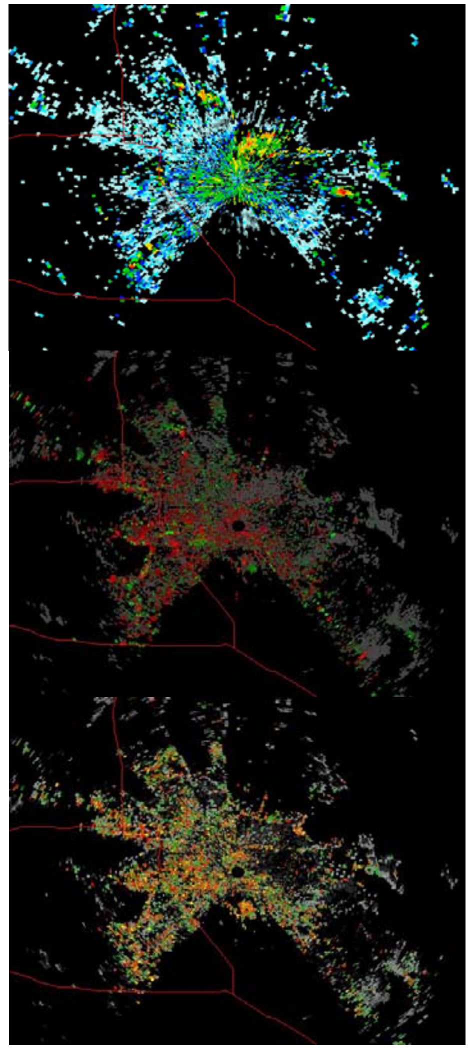

Figure 5- Residual Clutter shown on Reflectivity (top); Velocity (middle); and Spectrum Width (bottom)

3.2 *Algorithms*

Given this difficult clutter regime, reflectivity based algorithms, in general, will have a positive bias. Precipitation products are related to base reflectivity via the Z-R Relationship, so any residual clutter contaminates precipitation estimates (Figure 6). Further, the clutter may cause precipitation algorithms to begin collection too early or end too late, which will also cause the estimates to be biased high. Operators who take steps to mitigate this problem can easily end up making changes to precipitation algorithm parameters which could make the situation worse.

Velocity estimates are power weighted, and since residual clutter is often highly reflective, the velocity algorithms will be impacted. One algorithm which is regularly used by operators is the Velocity Azimuth Display Wind Profile (VWP) (Figure 7). Residual clutter/anomalous beam propagation affects the VWP in several ways. Where the ground is detected, depending on the display system, the VWP may show “ND” for no data, a blank, or a “zero” which indicates the system detects targets, but those targets are stationary. Under ducting/anomalous propagation conditions, even if wind estimates are available, they often are of poor quality as indicated by the barb colors (red and yellow). The VWP from the volume scan (Figure 7) is of little use to operators since the data is contaminated by ground targets; however, it does relay one important piece of information: the data is of poor quality and operators can expect all velocity-based products, including those from the Mesocyclone and Tornado Detection algorithms, to be suspect.

Figure 8 is an echo tops product. These data are used extensively by the FAA and the Department of Defense (DoD). In the example, the weather tops seem to follow the terrain, and at times, even the highways. There is no weather; however, operators unfamiliar with the KIWA terrain and residual clutter it produces may make poor operational decisions based on these products.

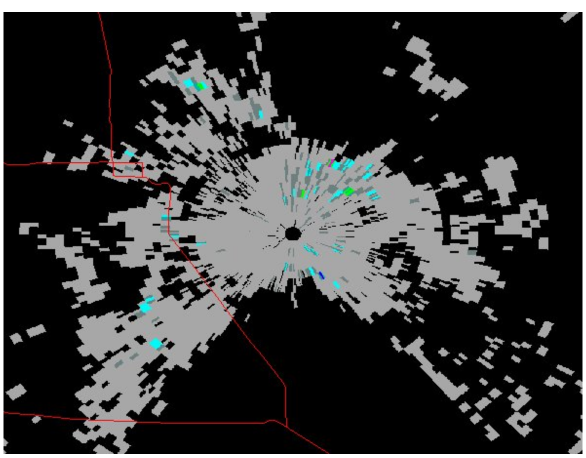

Figure 6-Precipitation Estimates Contaminated by Residual Clutter

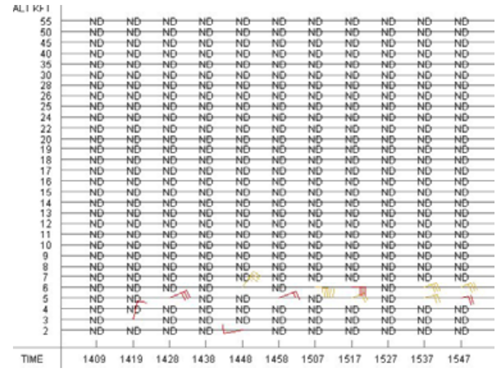

Figure 7-Velocity Azimuth Display Wind Profile

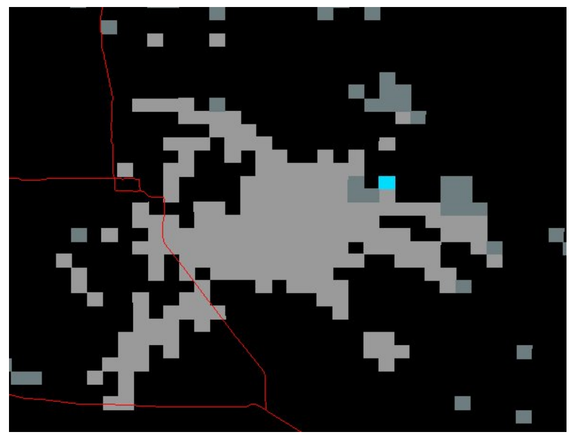

Figure 8-Echo Tops

4. SYSTEM ASSESSMENT/DATA COLLECTION

As part of the on-going effort to fully understand the persistent residual clutter and possible interference issues at the KIWA radar site, the ROC implemented a two phase site visit plan. The first site visit employed two Operations Branch personnel; an electronics technician and a data quality meteorologist. The plan called for the technician to work with the site technician to optimize the site from a hardware perspective while the meteorologist operated the radar, analyzed products, and worked with the radar focal point and staff members to “tweak” the RPG and algorithms. The goal was to remove as many variables as possible in preparation for the second trip.

The second phase was implemented by a team from ROC Engineering. This team’s task was collecting data from the legacy RDA and a Portable ORDA (hereafter referred to as “Porta ORDA”) system.

The summary of execution and findings from these two investigative trips are provided in the next two subsections.

4.1 *Visit 1 - Site Assessment and Calibration*

Upon arriving at the site, the team began diagnosing the data quality problems and as expected, nearly all of those problems were the result of residual clutter and radar siting. Figures 9 and 10 were obtained during the middle of the day; clutter suppression in use at the time was the bypass map filtering high. The reflectivity product showed several areas of relatively higher returned power (residual clutter), close to the radar. There is also a region of relatively higher reflectivity at the southeast edge of the product. The velocity image (Figure 10) vividly shows the contributions of vehicular traffic and terrain to the products. Traffic-contaminated estimates show up as continuous, linear regions of relatively higher velocities. The ground return is displayed as areas of grey, the color for zero velocity. The circled area in Figure 10 shows that the echo to the southeast, which is apparent in reflectivity, is the result of the beam hitting terrain. Regions of little or no data are apparent, and are due to terrain blockage south and northeast of the radar. These terrain-related problems become obvious when overlaying the terrain map with the velocity image, as shown in Figure 11. The bypass map (Figure 12) shows that this area is terrain; however, the legacy clutter filter was unable to remove all of the clutter power in this region.

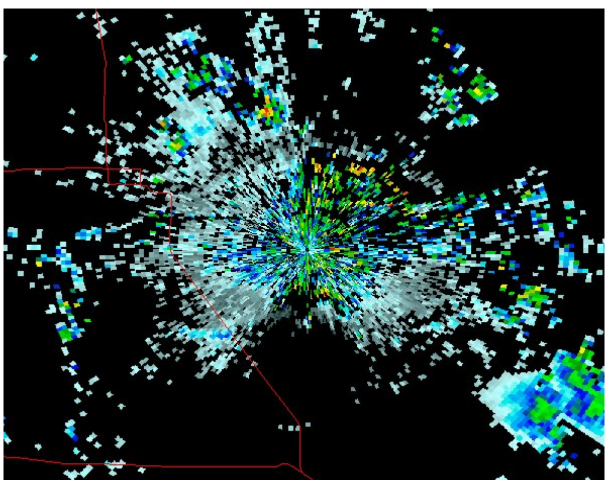

Figure 9-Base Reflectivity

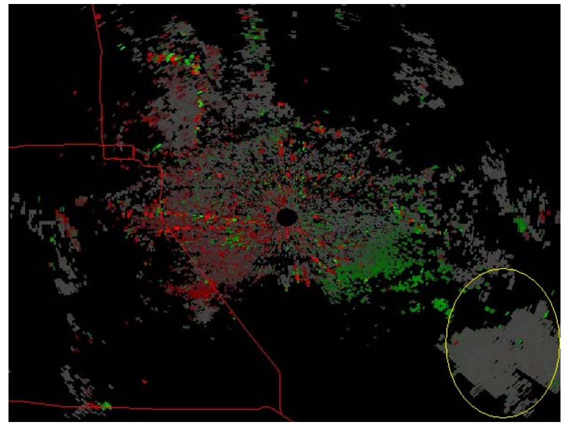

Figure 10-Base Velocity

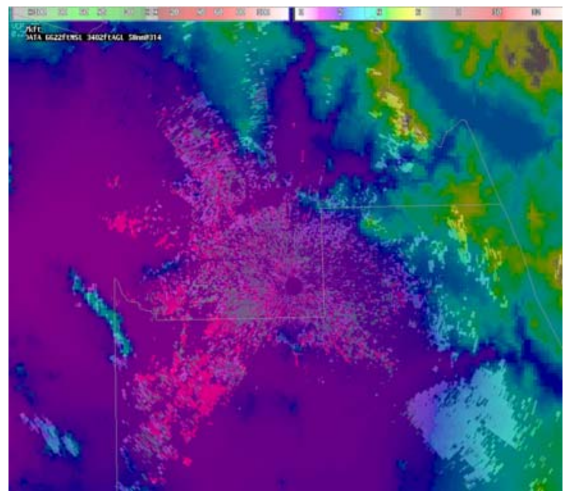

Figure 11-Base Velocity Terrain Map Overlay

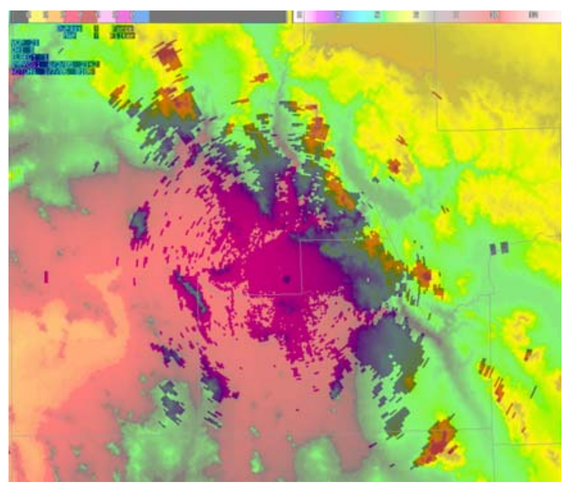

Figure 12-Bypass Map and Terrain Map Overlay

4.2 *Visit 2 – Data Collection with ORDA*

For the data collection visit, the ROC sent a three person team to KIWA to collect Level I (time series data), Level II (base data), and Level IV (product data). This process included installing the Porta ORDA, an RPG, and an Open Principal User Processor (OPUP) at the KIWA WSR-88D site. The Porta ORDA and other test assets comprise a self-contained system; therefore, none of the on-site equipment was removed or modified. ROC personnel used this configuration to analyze product data and to collect and record data levels I, II, and IV. There were several benefits to collecting data in this way. First, technicians could switch between the legacy and open systems within minutes, allowing little time for the atmosphere to change. Therefore, meaningful comparisons could be made between legacy and ORDA data. Second, the test data did not go to the Advanced Weather Interactive Processing System (AWIPS) and therefore was not sent to the National Climatic Data Center (NCDC). Third, collection with both of the systems (legacy and ORDA) made use of the same antenna, transmitter, and critical path, thereby greatly reducing possible variables to consider. Finally, the test was completely transparent to the WFO operators, as the radar was controlled using the ROC-provided RPG at the RDA site.

A representative comparison of the two RDA systems is provided in Figures 13 and 14. The notes taken by the team described this comparison; "The ORDA performed extremely well in suppressing and censoring the mountain returns around the KIWA site. Large areas of residual clutter return in excess of 30 dBZ were routinely apparent in the data collected with the legacy RDA. However, data collected by ORDA showed very little residual clutter in excess of 25 dBZ. Even though the near field clutter targets associated with local buildings and traffic continue be evident in the ORDA generated data, the ability of ORDA/GMAP to more adequately remove the high-power clutter targets from the local terrain should improve KIWA precipitation estimates."

Figure 13 shows the residual clutter pattern present after processing by the legacy IIR clutter filter. The image shown in Figure 14 was collected with the ORDA using the GMAP clutter filter; these two images were collected within minutes of each other using the KIWA radar. It is obvious that the GMAP clutter filter removes significantly more power from the clutter targets than the legacy filter.

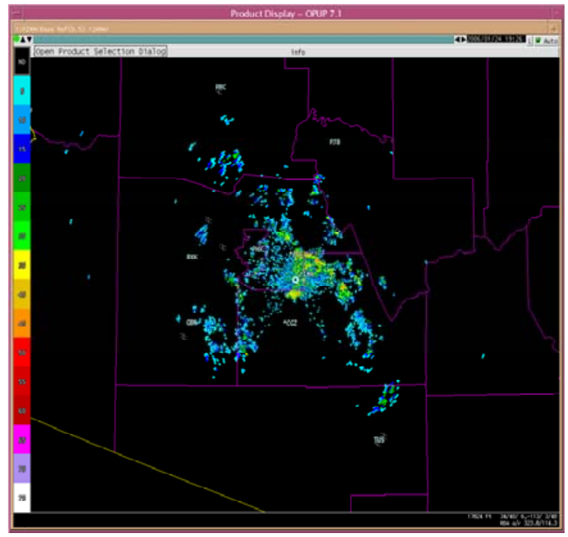

Figure 13-Legacy Base Reflectivity

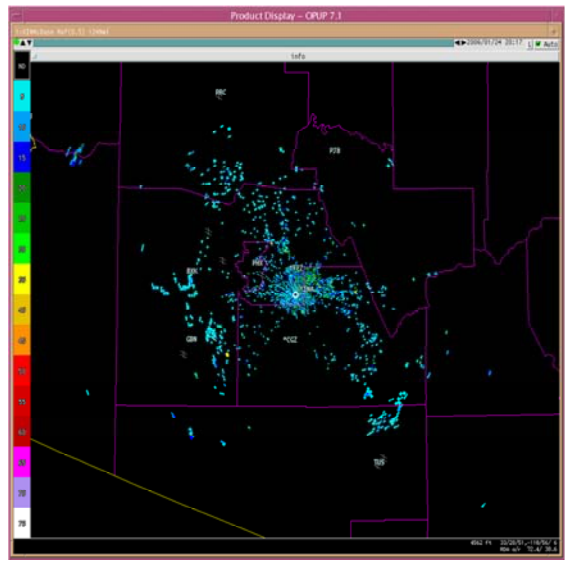

Figure 14-ORDA Base Reflectivity

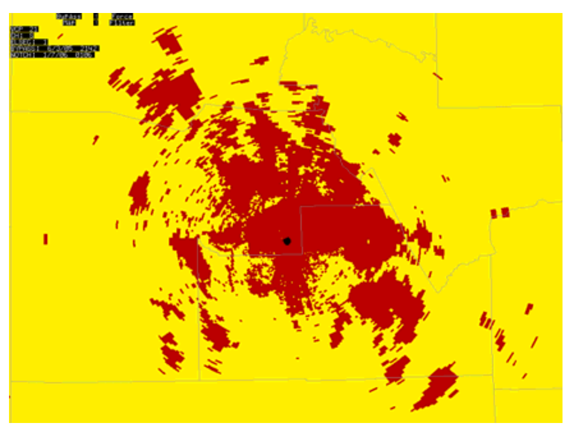

Figure 15-Legacy Bypass Map (AWIPS)

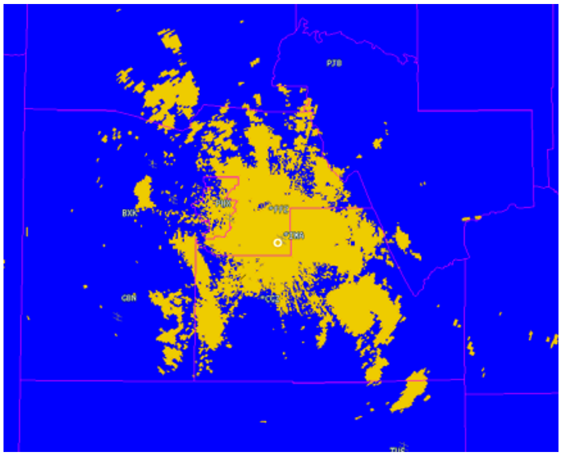

Figure 16-ORDA Bypass Map (OPUP)

5. CONCLUSIONS

The improvement in data quality that ORDA brings to the WSR-88D network is measurable. The system is quieter which results in a more sensitive radar. Though GMAP has been found to be very aggressive under some circumstances, sites which previously had to contend with terrain-induced residual clutter appreciate the added suppression. Additionally, GMAP brings the capability of replacing "weather-like" data that once was lost to the censoring process in the legacy system. Many sites have reported significantly better detection of clear air echoes, fine lines, thunderstorm outflows, etc. That is a direct result of utilizing a more sensitive radar along with a clutter suppression solution which rebuilds portions of the removed weather echo in areas which are clutter filtered.

Another advantage of ORDA is the increased resolution of the bypass map. ORDA bypass maps have a horizontal resolution of 1 degree x 1km, whereas the legacy bypass map has a resolution of 1.4 degrees x 1km (Chrisman and Ray, 2005).

Figure 15 is a KIWA legacy bypass map, captured from AWIPS and Figure 16 is a KIWA ORDA bypass map captured using an OPUP. The finer detail of the ORDA-produced bypass map is evident in the OPUP image.

Other advantages of the ORDA bypass map generation process, which are not immediately obvious, include a shorter time to generate a map (less than 10 minutes) and improved control over the generation of the map using the applicable adaptable parameters.

The legacy system allowed only two elevation segment definitions, resulting in only two bypass maps being used to filter all tilts. In contrast, when Build 9.0 is released to field sites (Spring or Summer 2007), the ORDA will allow a total of five elevation segment definitions supporting five bypass maps. This added versatility will allow sites to more finely tailor clutter suppression for each site. (Chrisman and Ray, 2007).

Experience gained from numerous investigations at field sites has shown the utility of overlaying either products or the bypass map with the high resolution terrain map. Making use of these simple techniques will often unravel the "mystery" of unexplained echoes an operator sees in the radar imagery. A reflectivity product combined with the terrain map shows an operator which echoes correspond to terrain and which to weather. Swapping the reflectivity for the velocity product allows one to see which zero velocity areas are actually terrain. This allows operators to see exactly when and where beam ducting is occurring. By adding high resolution highway maps to the velocity data, an operator can easily identify some targets as vehicles. Finally, using the terrain map and the clutter bypass map together, assists technicians and meteorologists in determining the quality of the bypass map.

6. ACKNOWLEDGEMENTS

All facets of research and testing such as discussed in this work simply cannot be adequately addressed in a test environment. If not for the regions and sites which are willing to open their offices to ROC personnel, operational development of NEXRAD software and hardware would be much more difficult. The authors would like to thank the Phoenix staff, and specifically Doug Green, Hector Vasquez, Mike Schumacher, and Frank Stewart for providing technical and meteorological advice and assistance during the field tests. Jimmy Roper and Paul Krenek (ROC Electronics Maintenance Section) as well as Olen Boydstun (ROC Engineering) provided technical guidance and advice during their respective site visits.

(Note: The views expressed are those of the authors and do not necessarily represent those of the National Weather Service.)

7. REFERENCES

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