3.6 USING ORPG TO ENHANCE NEXRAD PRODUCTS TO SUPPORT FAA CRITICAL SYSTEMS

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1. INTRODUCTION†

The initial release of a new operational open architecture is currently being phased into the national WSR-88D (NEXRAD) radar network. This new Common Operations and Development Environment (CODE) includes the Open Radar Product Generator (ORPG) that replaces the existing NEXRAD Radar Product Generator. The new ORPG includes all the algorithms of the RPG it replaces. Future algorithms designed for use within NEXRAD also will be processed by the ORPG.

CODE can also be used in a research capacity to significantly enhance the process of ORPG meteorological algorithm development. When used independently of a NEXRAD installation, CODE/ORPG provides multiple playback options for accessing real-time base data streams. This allows development and testing of new algorithms under the same environment an algorithm would encounter in an operational setting. This establishes a flow relationship from algorithm development through operational implementation within the common environment of CODE/ORPG.

A six-month Build cycle for future CODE/ORPG releases has been established. An algorithm developed in a research CODE/ORPG capacity has an opportunity, at six-month intervals, to garner agency approval and undergo final preparation for operational release. The NEXRAD Radar Operations Center (ROC) needs about eight months preparation time from algorithm submission until release of the next CODE/ORPG version. For instance, Build 2 is to be released September 30, 2002. Algorithms for Build 2 inclusion had to be submitted by January 31, 2002. It will take about three months after the release for the entire NEXRAD network to be updated. The deadline for Build 3 submission is in July 2002 with a release date set in March 2003.

Multiple Federal Aviation Administration (FAA) critical systems rely on products from NEXRAD algorithms. These projects include ITWS (Integrated Terminal Weather System), MIAWS (Medium Intensity Airport Weather System), WARP (Weather and Radar Processing), and CIWS (Corridor Integrated Weather System). Some of the NEXRAD products used include severe storm information, composite reflectivity factor depictions, and velocity data.

In this paper, we discuss new algorithms and modifications to existing algorithms earmarked for the first few releases of the CODE/ORPG that produce products of importance to these FAA systems. They include modifications to the existing Anomalous Propagation Edited Composite Reflectivity algorithm released during Build 1 upgrades, a new high resolution, digital VIL (Vertically Integrated Liquid) algorithm slated for Build 2, and a Data Quality Assurance algorithm anticipated for Build 3.

2. BUILD 1: AP EDIT ALGORITHM

Large vertical gradients of refraction in the atmosphere, caused primarily by temperature and humidity, lead to clutter contamination of weather radars. This contamination is known as anomalous propagation or AP (Huschke, 1989). AP typically is observed as erroneously high reflectivity factor at lower tilt elevations of a radar volume scan. A trained radar meteorologist can decipher the AP at these lower tilts in many instances. On many occasions, the AP is less obvious and co-exists with legitimate weather returns making for much more difficult analysis conditions.

An important NEXRAD product used is the composite reflectivity (comprefl). It provides a mapping of the maximum reflectivity factor found within a layer of the radar volume. Typically, higher reflectivity factor implies stronger weather. Information of this sort can be scrutinized by ATC to determine areas aircraft should avoid due to inclement weather. As noted, anomalous propagation can manifest itself as higher reflectivity factor values. Thus, any comprefl product is susceptible to AP breakthrough and contaminated results if not edited out.

To address the AP contamination problem, MIT/Lincoln Laboratory (LL) developed an AP Edit/Removal comprefl algorithm (APR). The APR relies on the three radar moments for AP identification and removal: reflectivity factor, radial velocity, and spectrum width. A version of this algorithm was included in the suite of NEXRAD algorithms prior to the development of the CODE/ORPG. It became apparent that the NEXRAD APR produces less desirable AP removal than the prototype algorithm tested at Lincoln Laboratory using external workstations running off NEXRAD base data.

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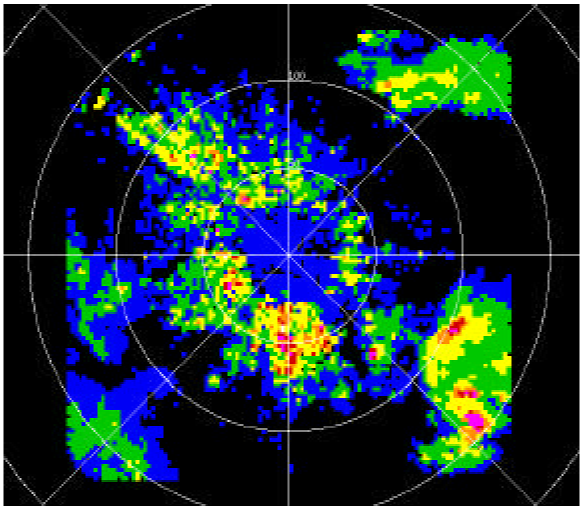


Figure 1. The pre-Build 1 ORPG AP Edited Composite Reflectivity Product. This is a case from Amarillo, TX from 05/25/94 at 0317 UTC. See text for discussion.

The APR tests the radial gates with sufficiently high reflectivity factor for the combined occurrence of small radial velocity and low spectrum width. Those gates meeting the Doppler test's criteria are deemed contaminated with AP. This approach fails for a finite number of gates to identify AP requiring the need for additional filtering.

We have shown that the fundamental difference between the LL and NEXRAD APR implementations is in the use of median and scatter order statistics filters. The preferred performance of the LL APR is due to its sole use of the scatter filter. The scatter filter scours away AP residue of a target range gate based on previously identified AP in neighboring gates in both range and azimuth. Unfortunately, the NEXRAD APR does not have an explicit scatter filter. Fortunately, a combination of adaptation parameter changes was found that does improve the AP removal performance of the NEXRAD APR. Some of the parameters changed effectively make the median filter a de facto scatter filter. These parameter changes for the APR have been implemented with Build 1 of CODE/ORPG.

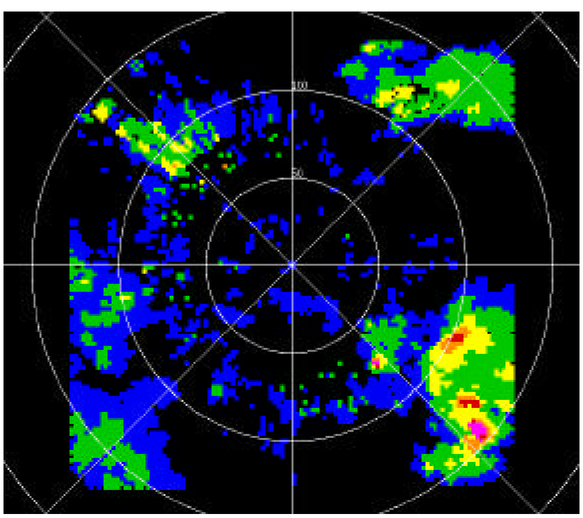


Figure 2. This is the same Amarillo case as in Figure 1. Here, the new Build 1 APR parameter changes have been made. See text for discussion.

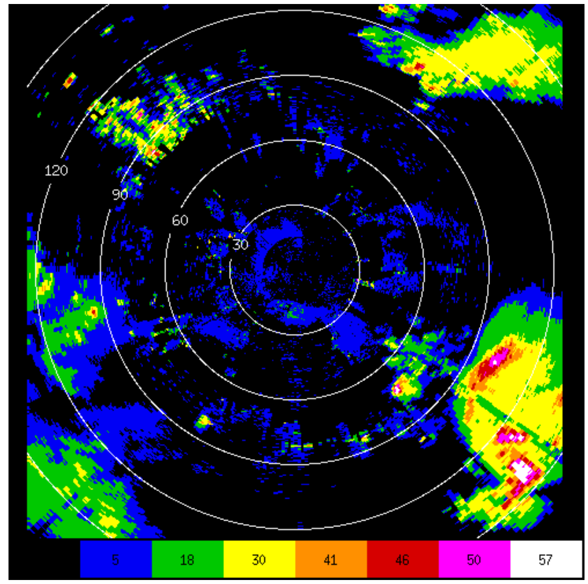


Figure 3. This is the same Amarillo case as in Figures 1 and 2. Here, the results for the LL APR are shown. The spatial resolution is higher than that of the other two figures. The reflectivity factor scale (in dBZ) applies to all three figures. See text for discussion.

As an example, Figure 1 depicts the pre-Build 1 APR comprefl product for an Amarillo, TX case. The resolution of the data is 4x4 km to a distance of 230 km (124 nmi) from the radar. A severe case of AP to beyond 90 km (49 nmi) from the radar is observed with legitimate weather beyond about 185 km (100 nmi) except to the northwest. Figure 2 shows the results for the same case with the changed parameters now in the Build 1 release. It is apparent that a significant reduction in the coverage and intensity of the AP is observed. For reference, Figure 3 shows the AP Edited comprefl for the same case as processed by the LL APR.

Obviously, the Build 1 APR product's AP removal compares well to that of the LL APR and is superior to the pre-Build 1 NEXRAD APR product. However, the algorithm is limited by requiring all three radar moments. Thus, the products in Figures 1, 2, and 3 all show AP breakthrough to the northwest beyond 115 km (62 nmi) where at least one of the radar moments was not available. In addition, as a cost for improved AP removal from the NEXRAD APR, the data are somewhat more smoothed beyond 115 km (62 nmi).

3. BUILD 2: HIGH RESOLUTION DIGITAL VIL

In general, a depiction of vertically integrated liquid water content (VIL) is preferred over the comprefl for ATC concerns. This is because VIL is less susceptible to AP and it provides a depiction of the integrated, three-dimensional (3D) structure of the atmosphere instead of a mapping of maximum values within that radar volume. Such a mapping can lead to bright band contamination of the comprefl and susceptibility to other artifacts. In addition, an assessment of the 3D nature of precipitation, such as with VIL, may be more directly related to storm vigor than is a point maximum value.

A NEXRAD VIL product has been available for years. However, it is limited in spatial resolution (4 km), range (230 km), and data levels (16). It also does not accumulate VIL from gates with reflectivity factor below 18 dBZ. There is a need for a high resolution VIL product that is unencumbered by the above limitations. For instance, the Terminal Convective Weather Forecast project utilizes VIL as it looks to provide forecast lead times eventually to two hours. This forecast information would be targeted to the FAA critical systems mentioned earlier.

For Build 2 of CODE/ORPG, a High Resolution Digital VIL algorithm (HRVIL) has been submitted to the NEXRAD ROC by MIT/LL. This algorithm provides the range (460 km) needed to monitor upwind convection and the fine resolution (1^{o} by 1 km with 254 data levels and no 18 dBZ restriction) to monitor incipient weather for potential development. The benefits of the polar-formatted HRVIL product are illustrated through comparison of Figure 4 with Figure 5 for a case of convective weather observed on May 18, 2000 at 1712 UTC with the Cleveland NEXRAD.

The comprefl product (top, Figure 4) includes AP breakthrough near the radar (center of image) that is accentuated by the product's 4 km resolution. It should be noted that, in this case, the APR removes that AP from its comprefl product. This comprefl was chosen to highlight that the VIL products de-emphasize AP. The bottom image in Figure 4 shows the current VIL product depiction of this weather using the HRVIL color scheme (refer to the left-side color bar). The current VIL product is limited to half the range of the comprefl (230 km or 124 nmi) and depicts the impact of the 18 dBZ threshold. In Figure 5, the improved coverage and structural detail possible with the Build 2, HRVIL product contrasts with the products depicted in Figure 4. Both the current VIL and HRVIL products show decreased sensitivity to the AP seen in the comprefl. However, the HRVIL product, by virtue of its better resolution, improves on the de-emphasis of AP seen with the current VIL product.

Two new AP Edited comprefl products introduced in CODE/ORPG are to be used in the FAA's ITWS system to substitute for comprefl products. They, too, benefit from the adaptation parameter changes made for the APR. The one product is identical to the top image in

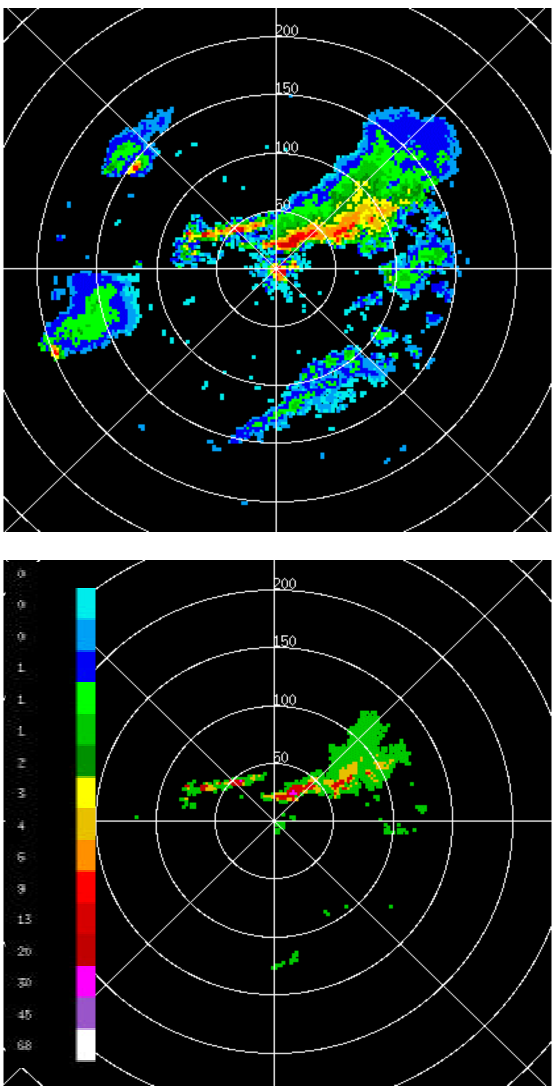


Figure 4. A comparison of the comprefl (top) and current NEXRAD VIL product (bottom) is shown for a case from the KCLE NEXRAD on 05/18/00 at 1712 UTC. Notice the AP breakthrough in the comprefl and the reduced coverage in the VIL. See the text for discussion.

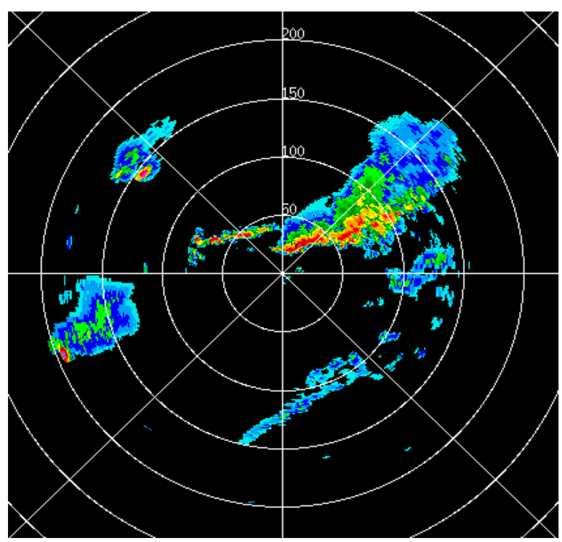
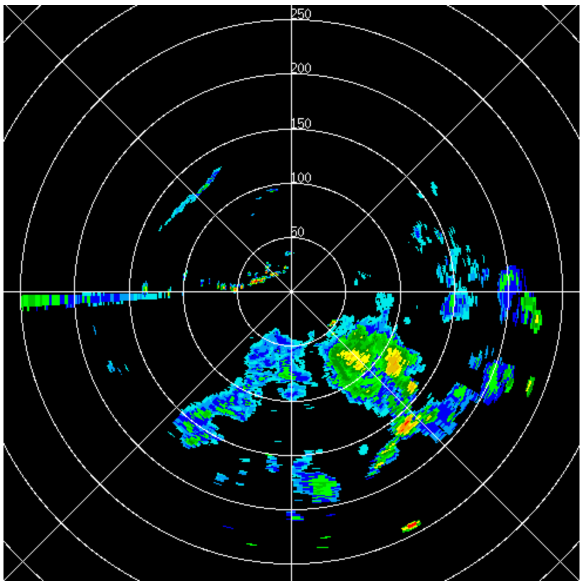


Figure 5. This depicts the new Build 2 High Resolution VIL product for the same case as in Figure 4. Notice VIL coverage beyond 230 km (124 nmi) and the finer structural detail. See the text for discussion.

Figure 4 less the AP at the radar center. HRVIL's spatial resolution is superior to that. The second product (not shown) extends to just 230 km (124 nmi) but with 1 km resolution. Again, HRVIL has superior spatial resolution by virtue of its polar (1^o x 1 km) format. This advantage would be most pronounced at short distances from the radar. Lastly, HRVIL's digital data level resolution is much greater than the 16 levels of these new products.

4. BUILD 3+

HRVIL utilizes the base reflectivity factor data provided within the ORPG without additional quality assurance checks. As shown, VIL generally de-emphasizes AP. Artifacts in the radar data such as sun strobes and bull's-eyes, that exhibit a constant power function, may not be de-emphasized, however. The top image of Figure 6 shows HRVIL with an artifact sunset strobe about due west of the radar. Currently, all reflectivity factor based products in NEXRAD are vulnerable to these artifacts.



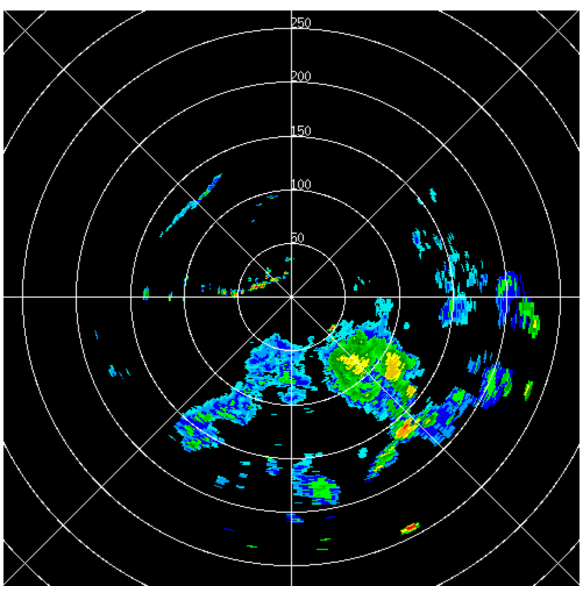


Figure 6. The top image is the new Build 2 High Resolution VIL product for a case from the KMLB NEXRAD on 09/27/01 at 2306 UTC featuring a sunset strobe artifact to the west of the radar. The bottom image is the same product with the Artifact Detection preprocessor applied to successfully remove the sunset strobe artifact. See the text for discussion.

MIT/LL is developing a Data Quality Assurance (DQA) algorithm in the research CODE/ORPG environment for submission into the Build 3 release cycle. The intent is to provide this DQA data as a substitute input for base reflectivity factor in HRVIL. It would also be available for use in future algorithms. One part of the DQA will focus on the detection and removal of constant power signal artifacts. These artifacts are characterized by a steadily increasing reflectivity factor along a radial. The lower image in Figure 6 is a prototype Build 3 HRVIL with DQA preprocessing that properly removes the sunset strobe artifact seen in the top image of Figure 6.

While AP is not a major contaminant of VIL, the DQA will include an AP editor. It is intended that this editor will include the full scatter filter methodology of the LL APR. Recall that the APR is vulnerable to lack of all three radar moments. We are evaluating whether the techniques of Steiner and Smith (2001), that only use the reflectivity factor's "texture" to type for AP, can mitigate some of that vulnerability to the APR. If expectations are realized, the DQA will serve as a powerful data quality check of the reflectivity factor data and provide these data for use with other algorithms. It is also possible that the DQA may be fitted to provide a new DQA Edited comprefl product in Build 3 or 4 to supercede the AP Edited comprefl products of today's current CODE/ORPG release.

5. SUMMARY

The advent of CODE/ORPG has allowed for a rapid advancement of some needed modifications to and addition of NEXRAD algorithms for the betterment of critical FAA systems. That they were developed within the same compute environment as the operational NEXRADs has made this advancement possible. Examples were described here to illustrate the benefits soon to be realized. MIT/LL plans to continue to develop algorithms to benefit these FAA systems, for instance, with the incorporation of the Machine Intelligent Gust Front Algorithm (MIGFA).

6. REFERENCES

Huschke, R.E., 1989: Glossary of Meteorology, 5th Edition, American Meteorological Society, Boston, MA, pp. 638.

Steiner, M. and J.A. Smith, 2001: Use of Three-Dimensional Reflectivity Structure for Automated Radar Data Quality Control, submitted to the Journal of Atmospheric and Oceanic Technology.