14.12 NEW PRODUCTS FOR THE NEXRAD ORPG TO SUPPORT FAA CRITICAL SYSTEMS*

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1. INTRODUCTION†

A number of Federal Aviation Administration (FAA) critical systems rely on products from the NEXRAD (WSR-88D) suite of algorithms. These systems include MIAWS (Medium Intensity Airport Weather System), ITWS (Integrated Terminal Weather System), CIWS (Corridor Integrated Weather System), and WARP (Weather and Radar Processing). With the advent of the NEXRAD Open Radar Product Generator (ORPG), a six-month build cycle has been established for the incorporation of new or improved algorithms. This build cycle provides the mechanism for the integration of new products into the algorithm suite tailored to the needs of these FAA systems now and into the future.

The FAA has tasked the Massachusetts Institute of Technology's Lincoln Laboratory (MIT/LL) with developing algorithms for the ORPG to address their systems' needs. Many of these algorithms will also prove useful to other users of NEXRAD products such as the National Weather Service and the Department of Defense. MIT/LL has created a network of ten ORPGs, or an ORPGnet, to use for the purpose of developing, testing, and implementing new algorithms targeted to specific builds. The benefits of the ORPGnet will be discussed in more detail later in this paper.

MIT/LL has provided improvements to existing algorithms or developed new algorithms for the first three build cycles of the ORPG (Istok *et al.*, 2002; Smalley and Bennett, 2002). Development of more algorithms is currently in progress for upcoming build cycles. In addition to describing ORPGnet, this paper will focus on its use in the development of a new Data Quality Assurance (DQA) algorithm, an improved High Resolution VIL (HRVIL) algorithm, and progress on the development of the enhanced Echo Tops (EET) algorithm; as well as the symbiotic relationship of these algorithms to the FAA critical systems.

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2. ORPGnet

The ORPGnet consists of 10 CODE/ORPG clone systems linked together. The Common Operations and Development Environment (CODE) includes the Open Radar Product Generator (ORPG) that generates algorithm products. Use of these systems provides the same environment for algorithm operations as found with the operational ORPGs. This allows for development and testing of new algorithms in the same environment an algorithm would encounter operationally. This establishes an advantageous flow relationship from algorithm development through operational implementation within a common environment.

Figure 1 is useful for visualizing the MIT/LL ORPGnet. Four of the ORPGnet systems are located at MIT/LL headquartered in Lexington, MA. These four systems form the core of the development center where algorithms are developed for and implemented into the ORPG environment. Part of the development process includes examination of algorithm products created from past weather. A number of utilities are available for playback of various versions of NEXRAD Archive II base data: from tape or disk files in standard or LDM formats. Additionally, MIT/LL operates the CIWS demonstation project for the FAA. The ORPG clones at the development center have access to base data from 26 NEXRAD radars from the Midwest to the East Coast of the United States ingested for CIWS.

The remaining six systems of the ORPGnet are dispersed among four ITWS-prototype field sites that MIT/LL operates for the FAA. Those sites are located in Dallas, Memphis, Orlando, and New York and receive live base data from nearby operational ORPG NEXRADs. In the case of New York, three NEXRADs are utilized that are also included as part of CIWS. Each field ORPG clone is dedicated to a specific NEXRAD data stream. The primary mission of the six field ORPG clones is to provide the algorithms under development at MIT/LL exposure to continuous input of weather for analysis and testing. This method should expose algorithms to a greater variety of weather over a shorter period. Multiple versions of an algorithm can be run simultaneously on an ORPG clone to allow quick review of products created from the same data to aid in the analysis process.

MIT/LL is using the ORPGnet to develop new products from well-tested algorithms but there have been ancillary benefits as well. Diagnostic tools have been created that could benefit other algorithm

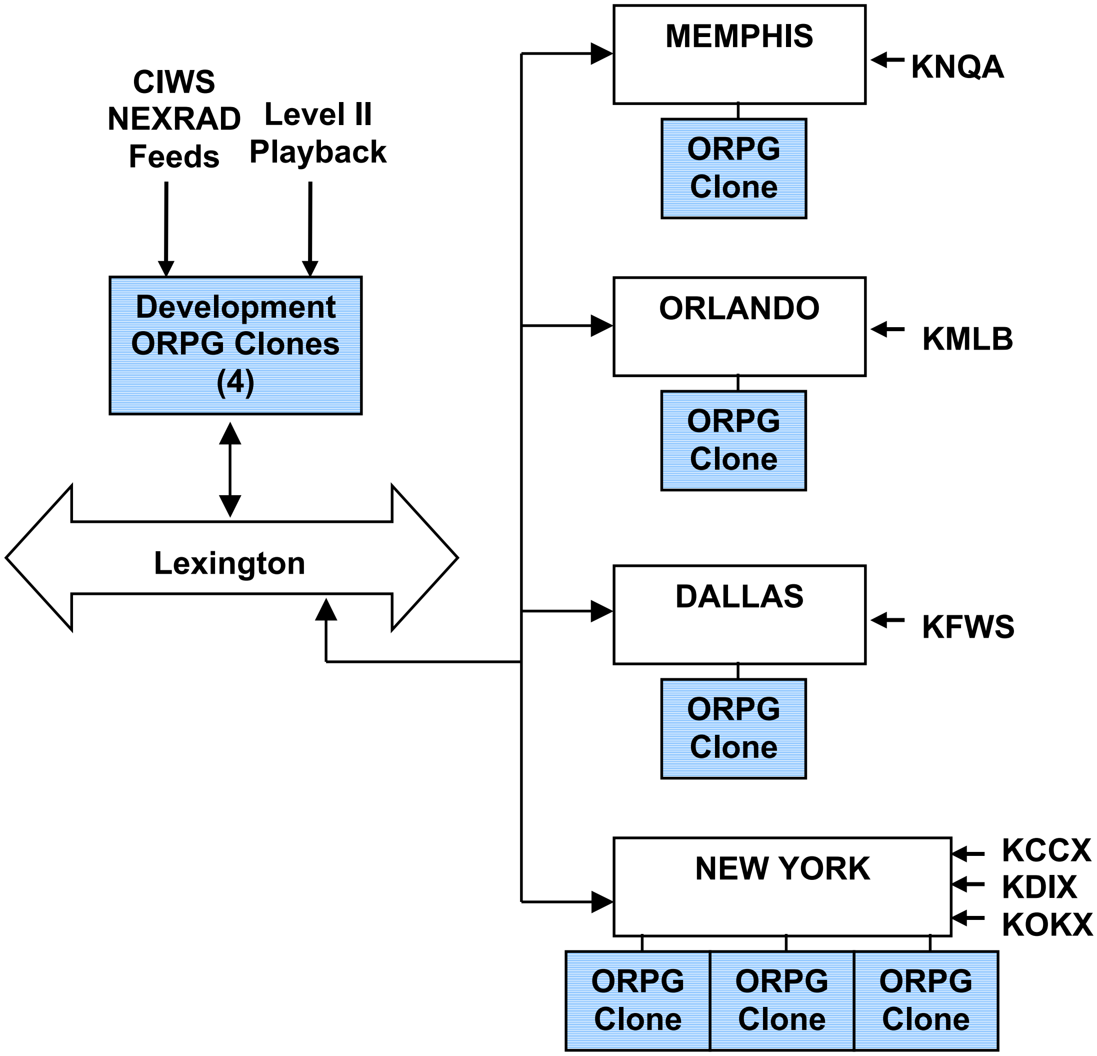

Figure 1. This is a schematic of the ORPGnet. The left-hand portion of ORPGnet is the algorithm development center consisting of four systems. The remaining six systems comprise the set of field ORPG clones for algorithm evaluation.

developers and will be cataloged by the NEXRAD ROC (Radar Operations Center). The ROC has provided a Class 1 user emulator tool. MIAWS is a Class 1 user that anticipates replacing composite reflectivity products with the Build 3 version of the High Resolution VIL (HRVIL) product developed at MIT/LL and running on ORPGnet. By using the emulator tool on ORPGnet, MIAWS is able to advance engineer and test its next software release well ahead of the operational release of Build 3 HRVIL. A cooperative relationship has been fostered between the NEXRAD ROC and institutions involved in ORPG algorithm development.

The field site ORPG clones have provided some added conveniences at the ITWS prototype sites. The ORPG clone base data display allows continuous viewing of the radar data sweep in a PPI format. The hail, mesocyclone, and tornado vortex signature storm products are being generated by the ORPG clones and passed to the ITWS prototype situation displays. Depending on the site, some of these products are passed on to the customer.

The ORPGnet enables MIT/LL to operate a robust program of algorithm development for the national NEXRAD ORPG network. This development has historical ties with the pre-ORPG NEXRAD that currently benefits ORPG and important FAA systems such as ITWS, MIAWS, and CIWS. The next few sections will illustrate these connections as relating to new algorithm products.

3. DATA QUALITY ASSURANCE (DQA)

MIT/LL developed a Data Quality Assurance (DQA) algorithm for the ORPG Build 3 release (late March 2003) to provide other algorithms with the base reflectivity factor data edited for anomalous propagation (AP) and artifacts detected (AD). The first use of the DQA edited reflectivity factor data is for the upgraded Build 3 High Resolution VIL (HRVIL) algorithm. The HRVIL will be discussed in the next section.

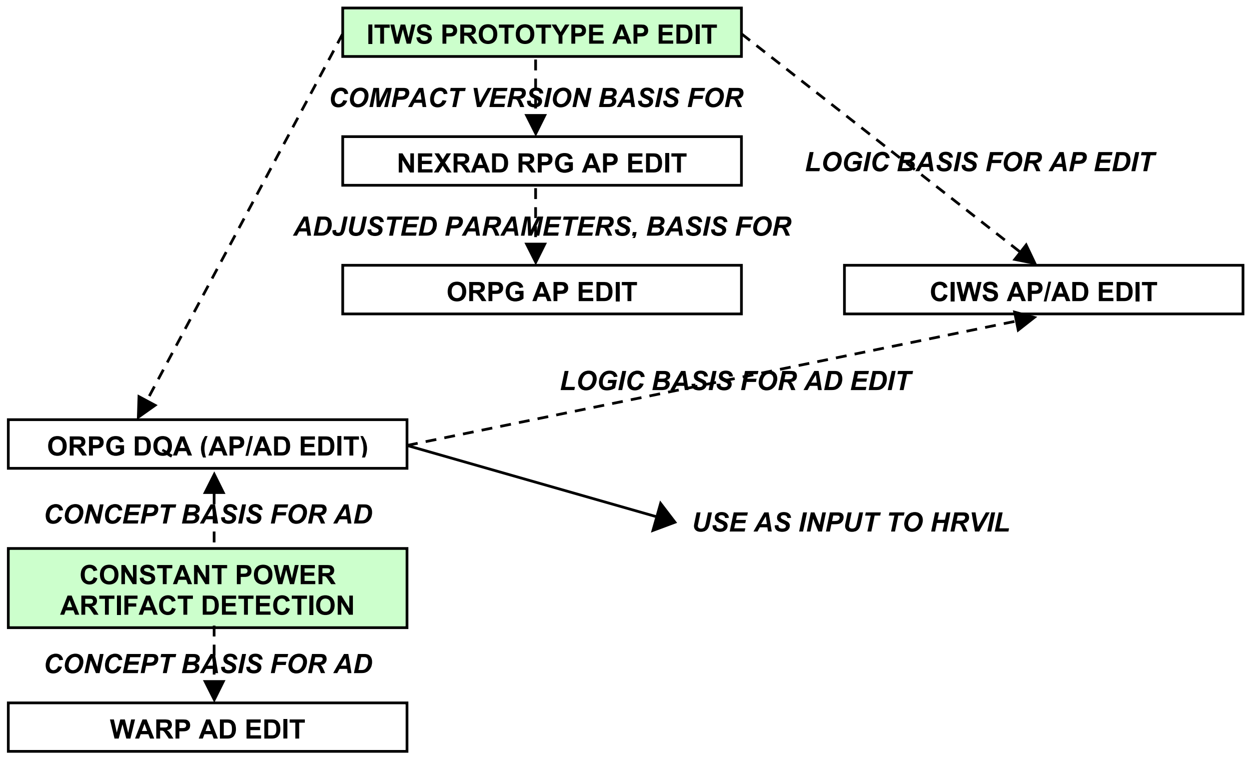

Figure 2. This is a schematic of the interrelationship of the Data Quality Assurance algorithm with some of the FAA systems. More details can be found in Section 3.

As noted, the DQA algorithm has two components: AP edit/removal and AD edit/removal. Figure 2 illustrates the flow and development of these components through NEXRAD and some of the FAA systems. The AP edit component was developed at MIT/LL and used in ITWS. It relies on both Doppler moments plus the reflectivity factor data to determine the presence of AP within a radar volume segregated into analysis regions. In addition, order statistic filters are applied. This version has become the basis for the AP editing in CIWS and the DQA algorithm.

The original AP edit techniques also served as the basis for the legacy NEXRAD RPG (that predates the ORPG) with some interpretive differences. Those differences, primarily the use of the order statistic filters, reduced the effectiveness of the AP edit process. With the advent of the ORPG, the adaptation parameters for this legacy version of AP editing were adjusted to improve performance but with the cost of data smoothing.

Radar artifacts also contaminate the NEXRAD data and their detection and removal has never been addressed. The development of the DQA algorithm presented a natural opportunity to address this omission. A common class of artifacts affecting the NEXRAD data is due to constant power contamination. These artifacts are manifested in the reflectivity factor data primarily as bull's-eyes and sun strobes. They exhibit increasing reflectivity factor along a radial with distance from the radar. Their removal is beneficial to any radar product utilizing the reflectivity factor data.

The concept of constant power signature artifact detection and removal has been utilized in DQA on a tilt –by-tilt basis. This approach has been adopted for use in CIWS. WARP also applies an artifact detection scheme to their products. The DQA edited reflectivity factor data provides superior quality assurance checking in a combination not previously available in NEXRAD. Its development both benefited from systems past and now benefits current and future systems.

4. HIGH RESOLUTION VIL (HRVIL)

In many instances, a depiction of vertically integrated liquid water content (VIL) is preferred over composite reflectivity products for air traffic control concerns. VIL is less susceptible to AP breakthrough and provides a depiction of the integrated, three-dimensional (3D) structure of the atmosphere. This 3D assessment of the precipitation structure is considered more directly related to storm vigor.

A NEXRAD VIL product has been available for years. As seen in Figure 3, the original VIL algorithm from the legacy NEXRAD RPG is the basis for the VIL algorithms in the ORPG as well as for ITWS and CIWS. For many of the FAA systems mentioned, a higher resolution VIL depiction was desirable. The High Resolution VIL (HRVIL) algorithm was developed to address this need. The final product from HRVIL is a candidate for use in ITWS and WARP as a replacement for the original VIL. Additionally, MIAWS is anticipating switching to HRVIL as a substitute for composite reflectivity when the product is available operationally.

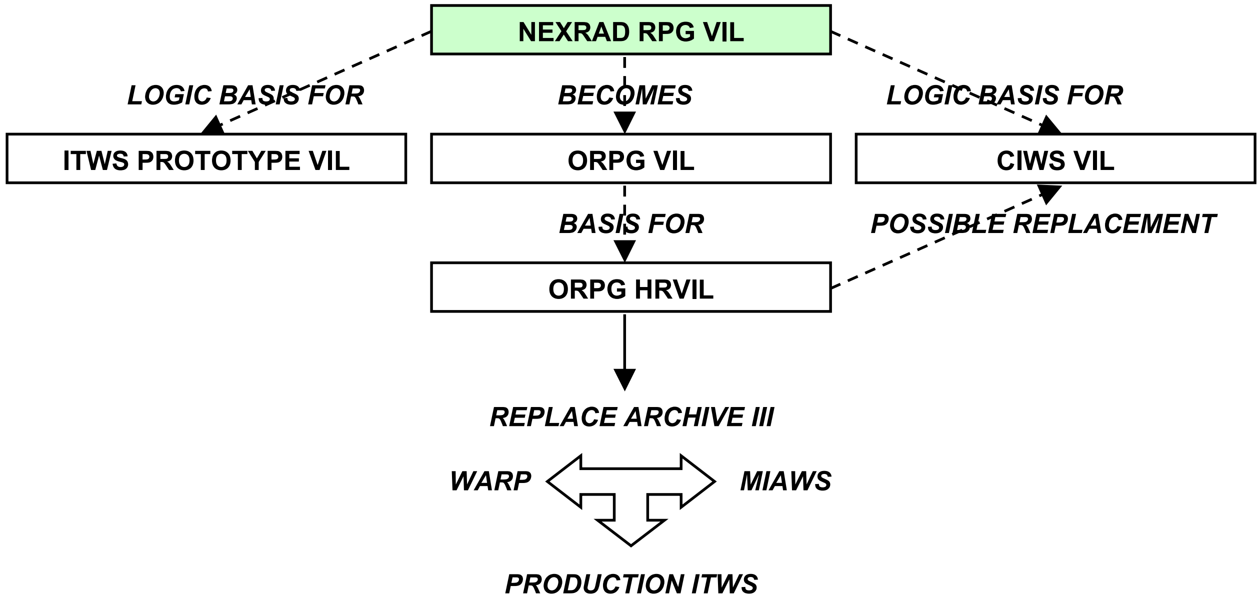

Figure 3. This is a schematic of the interrelationship of the High Resolution VIL algorithm with some of the FAA systems. More details can be found in Section 4.

HRVIL was developed for the Build 2 release of the operational ORPG. The algorithm provides the range (460 km vs. 230 km for VIL) needed to monitor upwind convection. It also provides the fine resolution (1° by 1 km with 254 data levels and no 18 dBZ minimum restriction vs. a 4x4 km Cartesian grid with 16 data levels and an 18 dBZ minimum threshold) to monitor incipient weather for potential development. The benefits of the HRVIL product are illustrated in Figure 4 for convective weather observed on May 18, 2000 at 1712 UTC with the Cleveland, OH NEXRAD. The original NEXRAD VIL product is on the left and the HRVIL product is on the right. The HRVIL product clearly contains more information by virtue of the longer range, higher resolution (finer structural detail), and inclusion of weaker reflectivity factor in its computations.

Figure 5 is provided to illustrate the benefits to HRVIL of using the DQA edited reflectivity factor instead of the unedited reflectivity factor in its computations. This case is from the Melbourne, FL NEXRAD on September 27, 2001 at 2306 UTC and includes a sunset strobe artifact to the west. On the right, the strobe has been removed by the DQA editing process making for an improved HRVIL product. Typically, the sunrise and sunset strobe sequences are evident within the radar volume over the course of about one hour. Thus, many volumes are affected. Bull's-eye and starburst artifacts are also readily removed yielding improved HRVIL. As

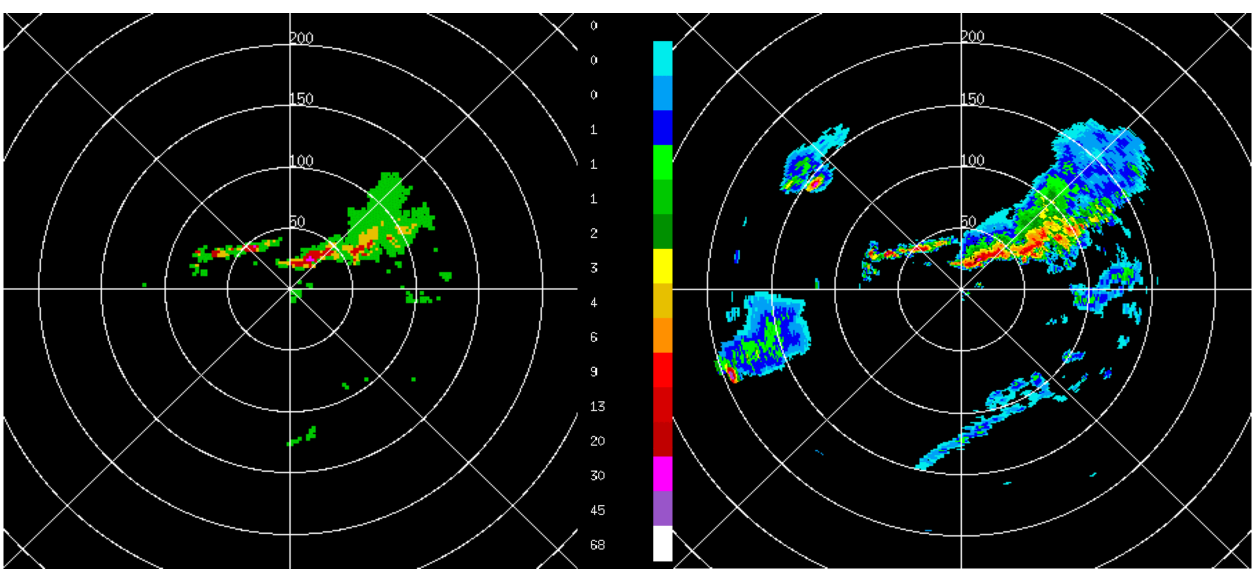

Figure 4. This is a comparison of the legacy (lower resolution) VIL on the left with the High Resolution VIL on the right. Refer to Section 4 for discussion.

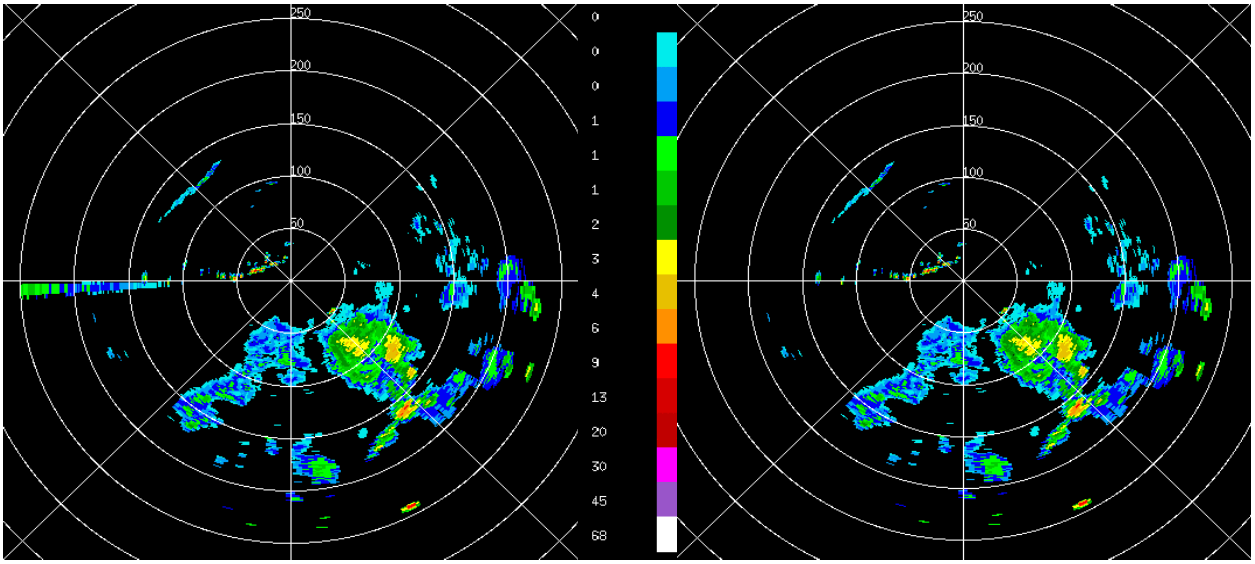

Figure 5. This is a comparison of the Build 2 HRVIL on the left without the benefit of DQA edited data and the Build 3 HRVIL on the right that utilizes the DQA edited data. Refer to Section 4 for discussion.

with the development of the DQA algorithm, the HRVIL algorithm has evolved beneficially from its early roots.

5. ENHANCED ECHO TOPS (EET)

An accurate depiction of the echo tops structure is a primary concern in the aviation industry. Echo top altitude plus time trending is significant. It is often preferable for en route aircraft to fly over the tops of storms. Figure 6 indicates that a NEXRAD echo tops product has been available pre-ORPG. Unfortunately, the sampling method employed for this product results in a noted saw tooth depiction. That is, an oscillation in the altitude of the echo tops. Additionally, it suffers from coarse resolution not suitable for today's aviation needs.

This legacy echo tops algorithm served as the basis for the same in ITWS, CIWS, and ORPG with the noted shortcomings conserved. The Enhanced Echo Tops (EET) algorithm was requested to address the primary

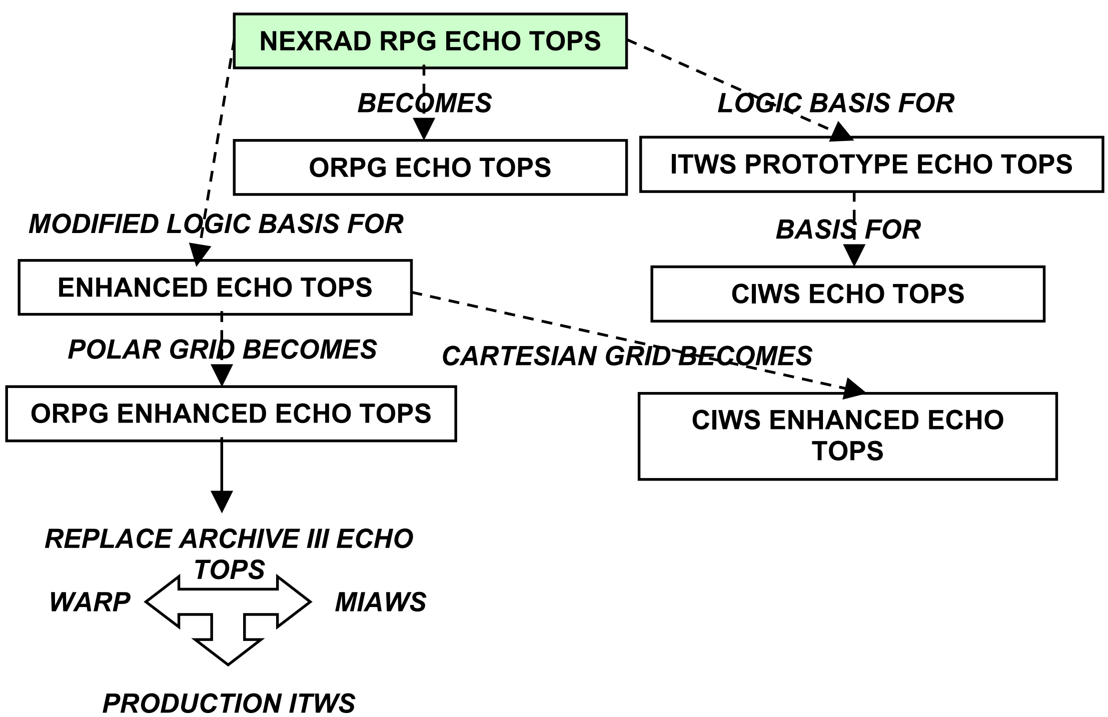

Figure 6. This is a schematic of the interrelationship of components of the Enhanced Echo Tops algorithm with some of the FAA systems. More details can be found in Section 5.

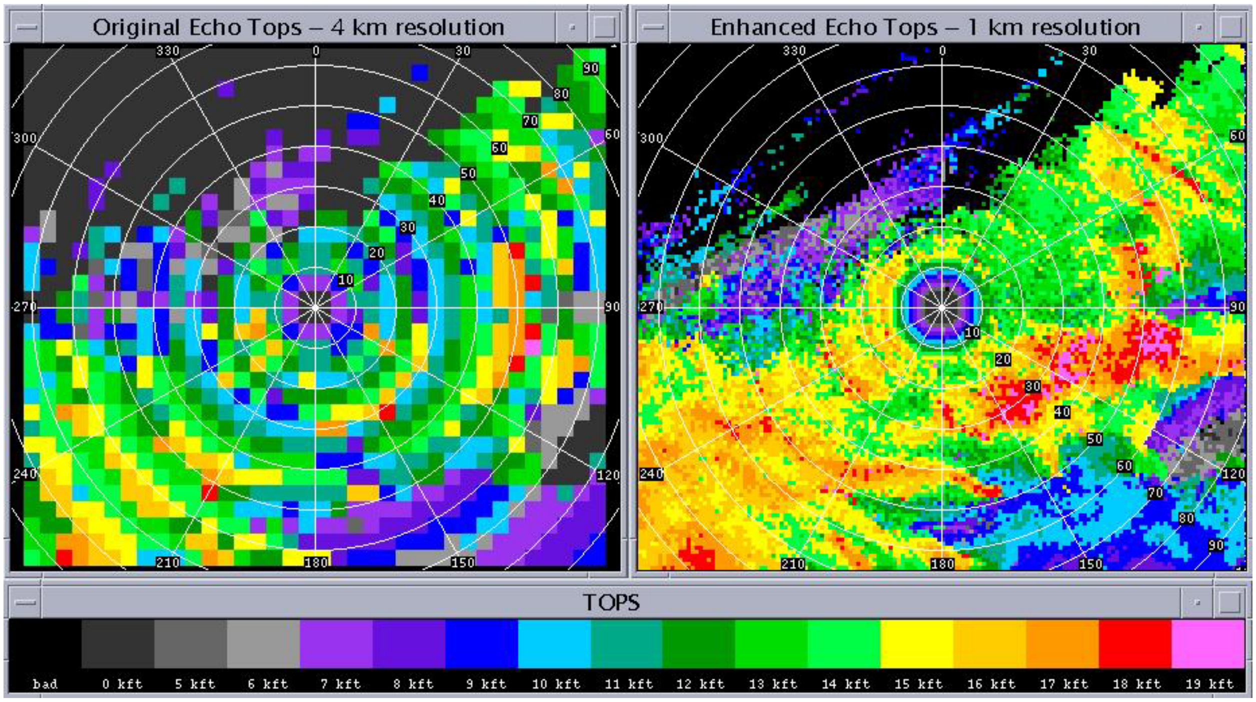

Figure 7. A comparative approach to echo tops is presented. The right side image is the enhanced echo top product of the same weather as depicted by the traditional echo tops algorithm (left image). Refer to Section 5 for more details.

limitations of the original algorithm. The EET algorithm is the first specifically planned from the design phase to serve as the echo top algorithm for both CIWS (as a Cartesian product) and ORPG (as a polar product). It will provide higher spatial resolution than the original as well as one kft data accuracy (vs. five kft) that coincides with new FAA Reduced Vertical Separation Minimums. The EET product will be a valid candidate for replacement of the original echo tops product in WARP, MIAWS, and ITWS.

Figure 7 illustrates the improvement possible with the EET product. The case is from the Chicago, IL NEXRAD on January 30, 2002 at 1049 UTC. The saw tooth artifact of the original echo tops product is most pronounced to the southwest of the radar (left image) and successfully mitigated in the EET product (right image). In addition, a broad area southeast of the radar is depicted with much higher detail and resolution with the EET product. Like DQA and HRVIL, the EET algorithm has benefited from the legacy of a past product to lead to a more advanced product serving current and future systems.

6. SUMMARY

CODE/ORPG has allowed MIT/LL to provide needed modifications to and addition of NEXRAD algorithms for the betterment of critical FAA systems. This is being done with ORPGnet that allows for multi-algorithm development and testing with an extensive meteorological exposure. It has been shown how DQA, HRVIL, and EET algorithms will provide improved products to benefit current and new FAA systems as well as the meteorological community in general due to their incorporation in the operational NEXRAD ORPGs. The interrelationship between these new algorithms with the original algorithms that predated them was also demonstrated. MIT/LL anticipates further improvements to DQA for future builds as well as the incorporation of the Machine Intelligent Gust Front Algorithm (MIGFA) into the ORPG.

7. REFERENCES

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