# P5B.1 NEXRAD PRODUCT IMPROVEMENT—IMPLEMENTING NEW SCIENCE

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## 1. INTRODUCTION

This is an exciting new era for NEXRAD radar applications development. Network deployment of the WSR-88D Open Systems Radar Product Generator (RPG) was completed in August 2002. The expansion capacity of this system upgrade is enabling the operational implementation of new scientific applications to improve the forecast and warning missions of the NEXRAD agencies.

The Common Operations and Development Environment (CODE), developed to streamline the transfer of technology into the WSR-88D operational baseline (Saffle et al., 1998) is being used to implement and demonstrate enhancements to the WSR-88D.

The National Weather Service (NWS) and the Federal Aviation Administration (FAA) have identified and prioritized future NEXRAD system capabilities (Saffle et al., 2003) and have formed software engineering groups to implement agency-specific scientific enhancements.

The WSR-88D software development and maintenance paradigm was refined to incorporate the concepts of NEXRAD applications being developed and evaluated by several organizations using CODE on RPG clones, and the decoupling of techniques development from the software release cycle.

With this paradigm shift along with the Open RPG design and CODE, agency-sponsored mature applications are being integrated into the WSR-88D baseline following an efficient process, schedule milestones are being met, WSR-88D software containing greater functional improvements is being released every six-months, and the quality of the deployed system remains high.

Through the NEXRAD Product Improvement Program, software engineering of agency-specific scientific enhancements is being conducted at the NWS Office of Science and Technology (OST) Systems Engineering Center (SEC), NWS Office of Hydrologic Development (OHD), and MIT/Lincoln Laboratory. The SEC and OHD implement NWS specific-applications, Lincoln Lab implements FAA specific-applications, and there is collaboration on applications of joint interest. Although the Air Force Weather Agency (AFWA) has not yet sponsored development of new applications, request and display of the NWS and FAA-sponsored enhancements are available to the AFWA Open Principle User Position (OPUP) system.

This paper describes the functionality of the enhancements deployed in 2002 and 2003 and the process by which these enhancements were developed, tested and deployed.

## 2. FUNCTIONALITY

Functional enhancements have been deployed in RPG Builds 1, 1.2, 2, 3 and development is progressing for future builds scheduled for release every six months. Enhancements developed by the NWS for RPG Builds 1.2, 2, 3, and 4 are described later in this paper.

Deployment of the RPG Builds 1.2, 2, and 3 began in March 2002, September 2002, and March 2003. Build 4 and 5 deployments are scheduled for September 2003, and March 2004. Deployment of the AWIPS Builds 5.2.1, 5.2.2, and OB1 began in May 2002, October 2002, and February 2003. Operational Build 2 and 3 (OB2 and OB3) deployments are scheduled for July 2003, and February 2004. It can take up to three months before all fielded systems are running a new software build.

Enhancements developed by Lincoln Laboratory for the FAA are described in Smalley and Bennett (2003). These enhancements consist of a data quality assurance (DQA) algorithm and two new products. The DQA algorithm detects and edits data contaminated by AP clutter and constant power artifacts which appear as bull's-eyes, sun-strobes, and starbursts. The new products consist of a high resolution VIL product and an enhanced high resolution echo tops product. The high-res VIL product contains more information due to its longer range, higher resolution, inclusion of weaker reflectivity data, and benefits through use of DQA to clean up the input data. The objective of the enhanced echo tops product is to provide higher spatial resolution data and reduce the saw toothed effect that is often evident in the standard Echo Tops product. The display of these products on AWIPS is planned for OB3.

### 2.1 Full Resolution Base Products

Full resolution base reflectivity and velocity products were provided with RPG Build 1.2 and are displayable with AWIPS Build 5.2.1. These products are at the same resolution and coverage area as the RDA base data. Consequently, they are very large (160-330 Kbytes) and so the high speed RPG-AWIPS TCP/IP product distribution

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interface is needed to acquire them in a timely manner. In RPG Build 2 these products became replayable, meaning that a product will be generated and distributed immediately upon one-time request. The capability to remove a specified storm motion from the full resolution base velocity product was initially provided in AWIPS OB1 and improved in OB2. Given the 4-times increase in range resolution and the 16-times increase in the velocity data resolution, these high resolution products will improve the visual identification of mesocyclone and tornado vortex signatures.

**2.2 Super-ob Product**

The Super-ob (SO) product is derived by averaging Doppler velocities in small sectors (cells 5 km by 6 degree azimuth) on each elevation angle over a period of one hour. The SO product is generated at 30 minutes past the hour and extends out to 100 km radius from the radar. Individual Super-ob cells are registered in space and time by averaging the position of each base data velocity bin contributing to each Super-ob cell. The following attributes are derived for each Super-ob cell: latitude, longitude, altitude, time deviation, azimuth, elevation, average Doppler velocity, and standard deviation of velocity. The data compression efficiency of the Super-ob is greater than 1500 to 1. For example, in a widespread severe weather event, the SO product is around 112 kilobytes, while one-hour of base data can exceed 165 Megabytes.

As described by Alpert et al. (2003), along with other remotely sensed and conventional observations, Super-obs will provide a high resolution wind component in the analysis cycling system. Super-ob products from each WSR-88D are flowing to the National Centers for Environmental Prediction (NCEP) and testing with the Meso-eta and Global models has begun.

**2.3 Radar-Rainfall Bias**

The NWS has been computing the difference between radar and rain gage measurements of rainfall in order to remedy the bias that is sometimes present in radar derived rainfall products. With RPG Build 2 and AWIPS Build 5.2.2, this radar-rain gage mean field bias factor is automatically sent from each WFO AWIPS to the corresponding NEXRAD RPG. The Supplemental Precipitation Data (SPD) product contains the AWIPS computed radar-gage mean field bias value. A software switch provides the RPG user an option to apply the radar-gage bias to the precipitation accumulation products. When applied, the accumulation data in the NEXRAD precipitation products (all but the Digital Precipitation Array (DPA) product) is multiplied by the radar-gage bias value. The bias-applied flag value and the bias value used are both contained in the header and/or alphanumeric portions of the precipitation products. This adjustment is intended to remove systematic biases in the NEXRAD precipitation products caused by radar calibration problems and variations in rainfall characteristics.

**2.4 REC and Clutter Likelihood Products**

The RPG Build 2 Radar Echo Classifier (REC) implements the Anomalous Propagation (AP) detection algorithm described by Kessinger and VanAndel (2001). The REC outputs AP/clutter likelihood arrays which are then used to generate Clutter Likelihood Reflectivity (CLR) and Doppler (CLD) Products. These new radar products are displayable on AWIPS OB1 and depict the likelihood the corresponding base data is contaminated by ground clutter due to AP. When displayed in combination with a base product, the user will see which data is suspect. It is expected these products will help users determine in which regions to invoke clutter suppression, which data to not trust, and to develop experience and confidence with the algorithm. In build RPG 5, the AP/clutter likelihood array will be used by the precipitation pre-processing algorithm to edit data suspected to be AP/clutter. This should improve the data quality in the Hybrid Scan products, Radar Coded Message product, and the precipitation products.

**2.5 User Selectable Layer Reflectivity Product**

The User Selectable Layer Reflectivity (ULR) product in RPG Build 3 addresses several limitations of the standard Layer Composite Reflectivity product. A user specifies the boundaries of the layer (1000 ft minimum thickness) through the product request. The RPG can simultaneously generate up to 10 products with different combinations of boundaries. This product is replayable, meaning that a product will be generated immediately upon one-time request. The ULR product extends to 230km range, has a spatial resolution of 1 km by 1 degree, and is formatted similar to standard base products (i.e., radial, 4-bit, run-length-encoded). Similar to other 16-level reflectivity products, the width of data levels are 5 dBZ, but only between 5 and 55 dBZ. There are two extra 5 dBZ data levels between -5 and +5 dBZ. On the low end there is a data level for below -5 dBZ, and on the upper end, a data level for above 55 dBZ. In addition, there is a data level for below Signal-Noise ratio threshold. Finally, there is a data level for where the layer is unsampled because of the larger angular intervals between upper elevation scans or where all of the scans are above or below the layer. The ULR product will have many uses since it can be generated at whatever layer is relevant to the meteorological situation. For example, requesting a layer just above the 0-degree isotherm can show icing potential, at the convective initiation level to detect the onset of convection, or above certain altitudes to highlight the tallest storms.

**2.6 VWP Product and Hodograph Display**

The alphanumeric part of the Velocity-Azimuth-Display (VAD) Wind Profile (VWP) product is modified in RPG Build 3 to report the complete set of wind data derived by the VAD algorithm during the volume scan. The VWP graphic product contains wind data at 30 specific altitudes.

These altitudes are used to derive specific slant ranges and elevation angles for the VAD algorithm analysis. The algorithm also derives a wind estimate at a constant range (at the optimum range) for each elevation angle and a wind estimate at one-third the optimum range on the two lowest elevation cuts. The low-elevation short-range estimates are done to improve the performance of velocity dealiasing at low altitudes. The constant range wind estimates are done to compute divergence and vertical velocity on a scale twice the optimum range (Rabin and Zrnic, 1980). The alphanumeric part of the VWP product will contain the complete set of wind data in a tabular format. Where winds are available and parameters applicable, the table contains the altitude, wind speed and direction, vertical velocity, divergence, RMS value, analysis slant range and elevation angle. In AWIPS OB1, this wind data is used to provide a Hodograph display.

### 2.7 Digital Storm Total Precipitation Product

The Digital Storm Total Precipitation (DSP) product in RPG Build 3 has the same spatial and temporal resolution as the standard Storm Total Precipitation product, except 8-bits are used to encode rainfall accumulation quantities. The resolution of the DSP rainfall data is a function of the maximum rainfall accumulation. When the maximum accumulation is less than 2.55 inches, the resolution is 0.01 inches, when the maximum is between 2.56 and 5.10 inches the resolution is 0.02 inches, and so forth for larger accumulations. The DSP product is tentatively planned to be incorporated into AWIPS OB3. Likely AWIPS uses include the Multi-Sensor Precipitation Estimator (MPE), Flash Flood Monitoring and Prediction (FFMP), or as a graphic display.

### 2.8 Improved Precipitation Accumulation Algorithm

In RPG Build 4, the precipitation accumulation algorithm was modified to support new Volume Coverage Patterns (VCP) planned for RPG Build 5. The modification results in higher precision rainfall accumulation calculations, which is needed for the faster VCPs. There is no change to the product format. However, the areal coverage of very light rainfall will increase since the minimum reflectivity used to accumulate rainfall is reduced.

### 2.9 Mesocyclone Rapid Update Product

The Mesocyclone Rapid Update (MRU) product in Build 4 contains the same information as the standard mesocyclone (M) product but instead of waiting until the end of volume scan, the MRU is available at the end of each elevation scan. The MRU product combines current Mesocyclone algorithm data (based on the elevations that have been completed thus far in the current volume scan), with Mesocyclone and Storm Track Algorithm information from the previous volume scan.

The average motion of all storm cells from the previous volume scan is used to compute a forecast position at the current volume scan time of each feature from the previous volume scan. An attempt is then made to match features from the previous volume scan to features in the current volume scan. Current 3D features which are not matched to a feature from the previous volume scan, are assigned a status of New. Current features inherit the attributes (associated storm ID, feature type, maximum tangential shear, height of maximum tangential shear, top height, base azimuth, base range, base height, azimuth diameter, range diameter)of the matched previous feature. The position attributes (base azimuth, range, and height) of a matched previous feature are updated to the current detection. Whereas, the position attributes of an unmatched previous feature, are set to the extrapolated forecast position. Unmatched previous features are assigned a status of Extrapolated. Strength attributes (feature type and maximum tangential shear) are updated if they increase in magnitude. Features with increasing strength attributes are assigned a status of Increasing. All other matched features are assigned a status of Persistent. Any information updated with current volume data is clearly identified.

The MRU product is available with AWIPS OB2. The product display is very similar to the standard Mesocyclone product with a few important differences. The graphic overlay symbol for extrapolated features look like typical Mesocyclone symbols but instead a dashed perimeter is used. Extrapolated features may appear on lower scans for elevated features, when a feature is dissipating, or if the feature motion is very different from the average storm motion. The AWIPS user is provided an option to suppress display of extrapolated features. Another important difference is that the MRU graphic alphanumeric and text displays contain a caret (^) symbol next to updated information. Since MRU products obtained later in the volume scan are based on a more complete volume scan, AWIPS provides an option to always display the latest MRU received from the volume scan. In figure 1, notice how well the 1.5 degree MRU product compares with the end of volume M product. In this case, the radar was in VCP 11

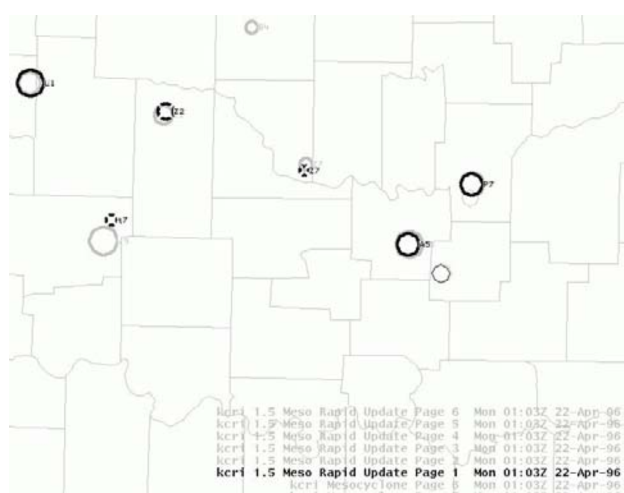


Figure 1. Comparison of the 1.5 deg MRU product (black) with the standard end-of-volume M product (grey).

and the MRU product was generated 80 seconds into the volume scan, or 3 minutes and 40 seconds sooner than the standard mesocyclone product.

## 3. SOFTWARE DEVELOPMENT ENVIRONMENT

The baseline RPG software runs on affordable hardware platforms. WSR-88D base data is available from the archives at the National Climatic Data Center (NCDC), live via the Craft demonstration project (Droegemeier, 2002), and directly from sites through the Base Data Distribution Server(BDDS)(Johnson et al., 1999). CODE (Ganger, 2002) combines the RPG baseline software, with tools to aid development, and a Web-based suite of documentation. Scripts configure the RPG to any of the network WSR-88D's. RPG clones (a workstation running RPG software on WSR-88D base data from one of the available sources) are in use by several organizations to support applications software development, demonstrations of future capabilities, and to support testing of other systems.

## 4. CAPABILITY ENHANCEMENT PROCESS

The steps for inserting enhancements into the WSR-88D baseline follow a three-phase process: technique development, software implementation, and integration.

Technique development is where ideas are prototyped and validated. If researchers use the CODE they can focus on the science of an application, instead of also developing systems to handle and pre-process WSR-88D base data. Ideas which are shown to meet an operational need are evaluated and prioritized by NEXRAD agencies and target deployment schedules are established.

Based on target schedules, implementation is performed by software engineers following a systematic development process. Prototype software is reused if possible, but often software is developed following the typical steps of requirements, design, code, and unit test.

At six-month intervals, implementing organizations deliver completed scientific packages to the Radar Operations Center (ROC). The ROC integrates each delivered software package and infrastructure changes, into the RPG operational baseline, tests the new software and deploys a new software load nine-months later.

## 5. SUMMARY

Recent accomplishments of the NEXRAD Product Improvement program have been reviewed in this paper. Functional enhancements have been identified and prioritized by the NEXRAD agencies and implementation time-lines have been established. The process to transfer developed techniques to the operational WSR-88D baseline has been refined. The Open RPG is deployed and CODE is providing an environment for efficient development and implementation of functional enhancements. Software engineering groups, formed to implement agency-specific applications, have delivered several functional enhancements which are being deployed at six-month intervals. These enhancements are improving the forecast and warning missions of the NEXRAD agencies.

The NEXRAD enhancements deployed in 2002 and 2003 provide increased resolution over several standard NEXRAD products; improve the accuracy of rainfall accumulation products; provide information to control clutter filters during AP conditions; distill Doppler velocity data to a size and frequency which can be ingested by NCEP operational models; edit data contaminated by artifacts and AP/clutter; and provide more timely updates of algorithm information. These recent accomplishments are just the beginning of a series of improvements scheduled to be deployed over the next several years.

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