C:\Users\files\PPS_paper.ams (for 14th IIPS conf. at Jan 97 AMS Meeting) 10/10/9

FA7.9 EVOLUTION OF THE NEXRAD PRECIPITATION PROCESSING SYSTEM (PPS) IN THE OPEN SYSTEMS ERA

Dennis Miller*, D.J. Seo, Jay P. Breidenbach and Richard Fulton

National Weather Service, Office of Hydrology
Hydrologic Research Laboratory
Silver Spring, MD 20910

1.0 INTRODUCTION

WSR-88D radar-derived rainfall estimates are generated by the Precipitation Processing Subsystem (PPS) within the NEXRAD algorithm set. As the NEXRAD system transitions from a proprietary Concurrent computer architecture to a UNIX-based Open Systems environment, several important enhancements to the PPS will be made. In addition, the Open Systems environment and associated Applications Programming Interface (API) will make it easier to quickly transition new algorithms from research-only to operational use.

2.0 OPEN SYSTEMS ENVIRONMENT

The upcoming, WSR-88D Build 10 will be the last RPG build hosted on the proprietary, Concurrent architecture. Thereafter, as the system transitions to a UNIX, workstation-based environment, the incorporation of algorithms, products, and other applications from the research community should be greatly facilitated. This is both because the operational environment of the "Open" RPG (ORPG) will be much closer to that used by most developers, and because a Common Operations and Development Environment (CODE) is being implemented, as part of the Open Systems transition program, to specifically create an infrastructure which will bridge the gap between development environments and the operational environment of NEXRAD [Saffle, 1997].

CODE will utilize both an Application Programming Interface (API) and a Visual Programming Tool (VPT) to enable users to interface with the NEXRAD system. The API will provide multiple layers of programming services that a user with more sophisticated programming skills or a more ambitious agenda can utilize for design, development and integration. The VPT will provide a graphic interface by which a perhaps less-experienced user can access reusable program modules for use in experimentation or development.

*Corresponding author address: Dennis A. Miller, NWS Office of Hydrology, Hydrologic Research Laboratory, 1325 East-West Hwy, Silver Spring, MD 20910; e-mail: Dennis.Miller@noaa.gov.

Presently, a UNIX-Workstation based version of the Stage-1 PPS sub-function of the RPG is in existence at the Hydrologic Research Lab (HRL) of the Office of Hydrology (OH) [Fulton, 1993]. It has been used for research and experimentation on new algorithms, and to initiate changes to the operational, NEXRAD system under approved change requests (CCRs) during the two most recent build cycles (i.e., Builds 9 & 10) on the Concurrent-based WSR-88D. It is the intention of HRL to upgrade this in-house system to make it compatible with the CODE environment of the Open RPG, and to continue to use it as a launching platform for the incorporation of new and modified algorithms and products into the operational, ORPG.

3.0 EARLY ENHANCEMENTS TO THE PPS IN THE ORPG

With several new display products having been implemented within the PPS during recent Concurrent builds (graphical User Selectable Precipitation Accumulation product; digital and graphical Hybrid Scan Reflectivity products) and with several known bugs having been addressed, the emphasis in the near future will be on algorithmic updates to improve precipitation estimates.

The process by which rain gage reports are used to adjust radar-based precipitation estimates in real time has undergone a thorough review at HRL during the past year, and a new Bias Adjustment algorithm has been developed (described below) which has already been approved for implementation during Open Build 1 (presently scheduled for deployment by the end of the year 1999). Because of the simplified manner in which the new algorithm utilizes rain gage reports, a complementary change can be implemented to restructure the gage database architecture within the PPS and expand its capacity from the present 50 to 200, or more, gages per RPG. The change request to undertake this re-engineering will be implemented in one of the builds shortly following Open Build 1, if not in Build 1 itself.

Also, two prototype algorithms presently under development at HRL have shown good results, and are likely candidates for implementation in one of the early, follow-up Open builds. The first procedure is a real-time adjustment of rainfall estimates to correct for range-dependent biases due to non-uniform reflectivity gradients in the vertical and incomplete beam filling at long ranges. The second procedure is for real-time bright-band detection and height estimation.

As described below, both these algorithms will require access to full volumetric reflectivity data, which is not presently available to the PPS. These and future algorithms will likely require a complete restructuring of the Precipitation Preprocessing algorithm of the PPS. This restructuring will build a reflectivity hybrid scan from complete volume scans of base reflectivity data stored in RAM, rather than from individual, incoming radials in real time, as is done currently. Access to full, volumetric reflectivity will be provided in the ORPG, under one of the APIs.

3.1 NEW REAL-TIME, MEAN FIELD, BIAS ADJUSTMENT ALGORITHM

Although it has never actually been run operationally, the existing procedure for gage-based correction to radar-based rainfall estimates within the Stage-1 PPS, which is based upon a gage-to-gage distance weighting scheme and a slope-only least-squares minimization process within a Kalman Filter approach, is known to have deficiencies, particularly in maintaining a stable, long-term estimate of the bias and in achieving mass balance in the presence of non-linear errors in radar-rainfall estimates. And, due to the way it must utilize the gage database, it is computationally expensive, and exponentially more so if new gages are added.

In order to address these deficiencies, a new algorithm to determine a mean, gage-based bias correction to the radar-estimated rainfall field (i.e., one multiplicative value to be applied uniformly throughout the radar umbrella) has been formulated [Seo, 1997]. The method, which utilizes a static model with no predictive equations within a general, Kalman filter approach, has minimal parameter estimation requirements and is less susceptible to non-linear variations in the radar-rainfall data than the existing algorithm, despite its relative simplicity. And, due to its elimination of the gage-to-gage distance dependency requirement, it will allow considerably more gage reports to be utilized in real time than the existing method, further enhancing the likelihood of accurate determination of the bias.

For each hour, the method determines a best-fit line with both slope and intercept, utilizing all gage-radar pairs

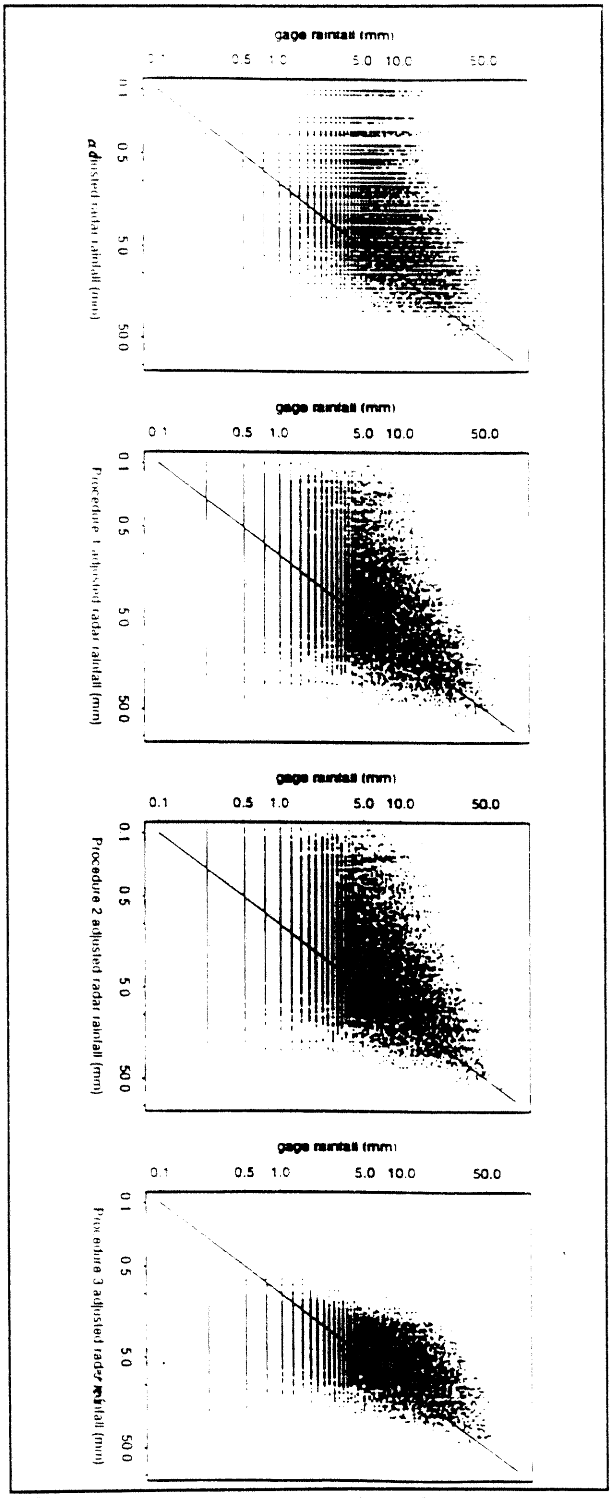

Figure 1: Scatter plots in logarithmic scale between gage rainfall and bias-unadjusted radar rainfall, and between gage rainfall and bias-adjusted radar rainfall from Procedures 1, 2 & 3, from Twin Lakes (KTLX), with ½ gage network used for adjustment and ½ for verification, and memory span parameter set to 100 hours.

with both positive gage and radar readings for a user-specified number of hours into the past. Each pair's contribution is weighted as a function of its age, as determined by a user-specified weighting function. The slope and intercept are then converted to a single, multiplicative bias, based on the definition of mean-field bias (i.e., the long-term integrated sum of all non-zero gage reports is equal to that of all non-zero, bias-corrected radar estimates at the corresponding locations).

Figure 1, a scatter plot in logarithmic scale, reveals the relationship between gage reports and unadjusted radar estimates (panel a), or radar estimates adjusted by either of three methods (panels b, c & d), from off-line simulations performed on two years of Archive-II data (1994, 1995) from Twin Lakes, OK. It can be seen that the newly-proposed algorithm (Procedure 1, panel b) achieves considerably better mass balance throughout the range of gage reports than found with unadjusted gage reports, or with reports adjusted by either of two other experimental methods.

The weighting parameter must be chosen optimally to achieve a balance between near time and climatological effects. This parameter will be determined on a site-by-site basis and, like other WSR-88D adaptable parameters, will vary seasonably and regionally.

3.2 PROTOTYPE REAL-TIME, RANGE-DEPENDENT, BIAS ADJUSTMENT ALGORITHM

The above algorithm, however, does nothing to address known, systematic causes of range-dependent biases, such as the interception of the bright band layer or beam overshooting at far ranges. A prototype algorithm to do that, in real time, is presently under development at HRL [Seo, 1997].

The basic approach is to utilize the vertical profile of reflectivity near the radar, where it can be fully measured, to determine relationships between apparent radar rainfall at various levels aloft against that at a lower, "target" altitude. Then, assuming that the vertical reflectivity profile is homogeneous throughout the radar coverage area and that signal attenuation with distance is negligible, these relationships are applied at farther ranges, after application of a spatial filter to account for differences in scale with range (i.e., beam filling), to estimate rainfall rates at the target altitude, which is now below the base radar beam (usually 0.5°). The target altitude is a constant height above ground level (AGL), optimally chosen just above where ground clutter and beam blockage are problematic, and at the level where the Z-R relationships are considered to be most valid.

In the example shown in Figure 2, the 'reference range', where the target altitude intercepts the axis of the base tilt, is 60 km and the target altitude is approximately .75 km. Using the nominal elevation angles of the lowest five tilts of Volume Coverage Patterns (VCPs) 11 and 21 (i.e., 0.5, 1.45, 2.4, 3.35 and 4.3 degrees), relationships are determined at the reference range between each of elevations two through five against elevation one (i.e., 'Bins' 2-5 vs. 'Bin' 1, in the illustration). Then, at the discrete ranges where the central axis of tilt 1 is at the same altitude as elevations 2-5 at the reference range (i.e., approximately 120, 160, 200 & 230 km, respectively), the tilt 1 value is used as the 'upper' bin in determining the rainfall rates at the target altitude, below. Between these discrete ranges, relationships between the upper and lower levels are determined via

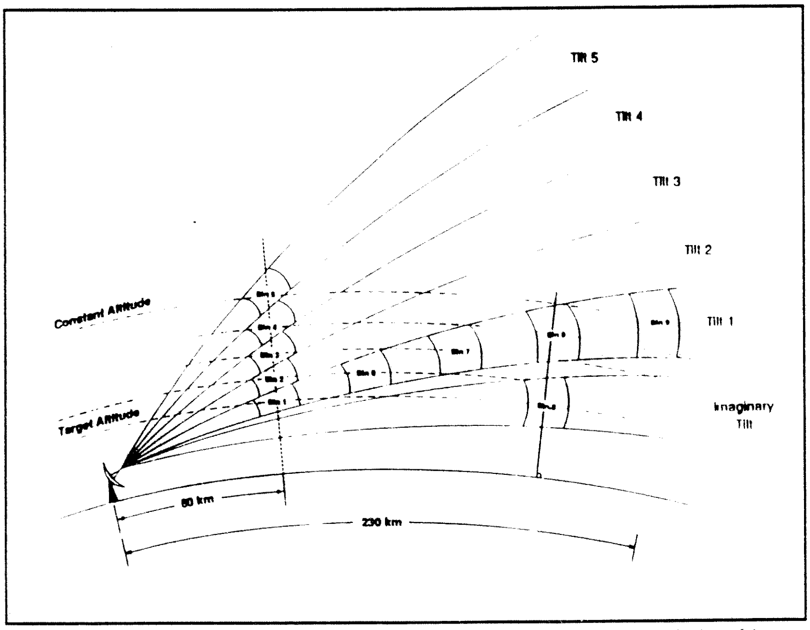

Figure 2: Schematic of sampling geometry: Rain rate relationships determined at Reference Range (60 km) applied at farther ranges, where Tilt 1 intercepts constant altitude lines, from Tilt 1 to imaginary tilt (below) at Target Altitude.

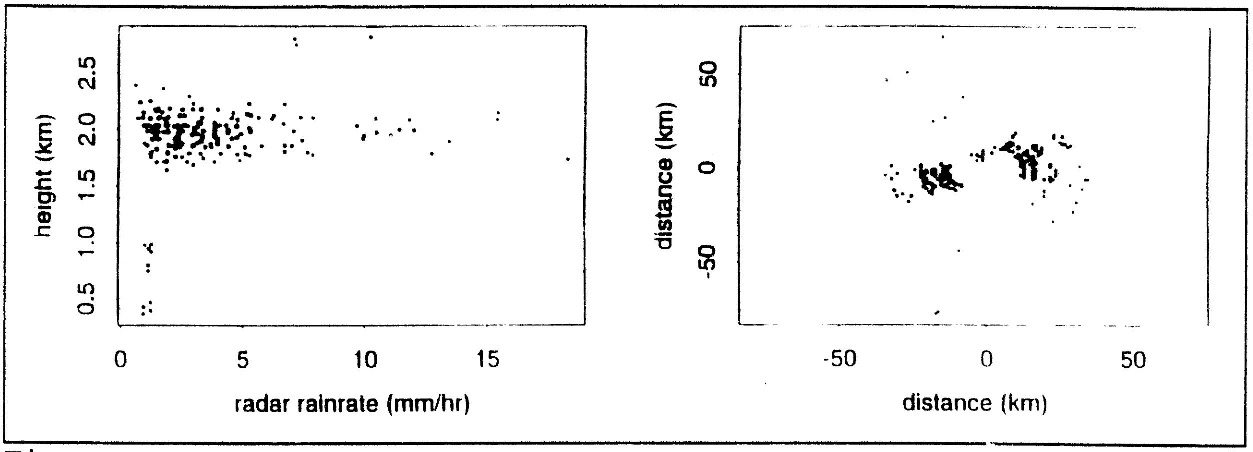

Figure 3: Scatter plot between averaged height of suspected bright band and apparent radar rainrate (upper); suspected bright band boxes mapped onto earth's surface, centered at radar (lower).

horizontal interpolation. At any discrete location at any time, a rainfall estimate can thus be inferred provided the measured reflectivity is non-negligible (nothing can be done where complete beam overshooting has occurred).

3.3 PROTOTYPE REAL-TIME, BRIGHT BAND DETECTION AND HEIGHT ESTIMATION ALGORITHM

Another prototype algorithm based on WSR-88D sampling geometry has shown good preliminary results. Conceptually similar to the approach taken by Smith [1986] but fine-tuned and adapted to the sampling characteristics of the WSR-88D, the method is predicated on the assumptions that the bright band layer forms a distinct peak in the vertical reflectivity profile which can be discerned in the profiles of individual radials, and that the layer has sufficient homogeneity and breadth that vertically-adjacent radials in the WSR-88D scanning strategy (which are less than 1 degree apart, at lower levels) will detect maxima at approximately the same height if a bright band is truly present.

The processing basically proceeds as follows [Seo, 1997]: in each radial of each of the lowest five elevation cuts, after the conversion of reflectivity to rainrate and the performance of averaging over the areas of grid squares, the two largest, averaged rainrates are identified, along with their corresponding, averaged heights. The two maxima are then compared among each pair of vertically-adjacent radials (i.e., four comparisons for each of elevations 1 vs. 2, 2 vs. 3, 3 vs. 4 and 4 vs. 5). For each pair in which the heights are within a threshold distance of one another (approximating the thickness of the bright band layer), a "couplet" is identified [after Smith, 1986]. In the presence of true bright band conditions, these couplets, when viewed in a scatter plot (as seen in Figure 3) will form clusters that are visually recognizable, in their near-common height and their annular appearance when projected onto the earth's surface, as bright bands.

Finally, some quality control procedures are applied on the standard deviations of the heights of the couplets, their mean rainrates, and their absolute numbers, in order to determine whether or not a bright band is, indeed present and if so, what its areal extent and height are.

4.0 REFERENCES

Fulton, P., 1993: Precipitation Processing System Stage I - HRL Ported Version User's Document. [Available from NWS/OH/HRL, 1325 East-West Hwy., W/OH1, Silver Spring, MD., 20910]

Saffle, R., J. Cappelletti, W. Carrigg, T. Ganger, M. Jain, D. Miller, and S. Smith, 1997: Accelerating the Integration of New Meteorological Algorithms into the WSR-88D - the Common Operations and Development Environment, Preprints of the 14th International Conference on IIPS, Phoenix, AZ., January 1988.

Seo, D.J., R. Fulton, and J. Breidenbach, 1997: Final Report for June 1 1996 to May 31 1997 Interagency Memorandum of Understanding Among the NEXRAD Program, WSR-88D OSF, and the NWS/OH Hydrologic Research Laboratory. [Available from NWS/OH/HRL, 1325 East-West Hwy., W/OH1, Silver Spring, MD., 20910]

Smith, C.J., 1986: The Reduction of Errors Caused by Bright Bands in Quantitative Rainfall Measurements Made Using Radar. J. Amos. Ocean. Technology, 3, 129-141.

November 12, 1997

NOTIFICATION OF PROCUREMENT ACTION

TO: Requisitioner Elaine Hauschildt
DOC/NOAA/NWS/Office of Hydrology, Research Lab.
SSMC2, Sta. 8346

FROM: Lawrence B. Frazier, Chief
Small Purchase Branch

This is to advise you that your procurement under your requisition number NWWC0000800022 has been received by my office on the above date. This procurement is being processed by Jean Hairston, telephone 301/713-0856.

cc: Procurement file

eh822