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COMPARISON OF WSR-88D PRECIPITATION ESTIMATES WITH GAGE DATA FOR PHOENIX, ARIZONA AND BOISE, IDAHO

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Introduction

The precipitation estimates provided by the WSR-88D are a powerful tool for forecasters to utilize in real time. This Technical Attachment (TA) provides a preliminary verification of the performance of the precipitation processing subsystem (PPS) and the bias adjustment algorithm in the West. This study was accomplished by comparing radar estimated precipitation to ground truth gage data. The radar sites evaluated were Phoenix, Arizona (KIWA) and Boise, Idaho (KCBX). These sites were the only ones having Level II data at the time of this evaluation. A broad range of Level II data was available for the Phoenix radar site (June 1993 - March 1995); hence, eight cases were chosen. Boise, Idaho had Level II data for a two-month period (February 1995 - March 1995), as a result only three cases were chosen from the available period. Thus, a total of eleven precipitation events are discussed in this TA. All evaluation procedures were consistent with the process described by the Operational Support Facility (Kelly 1994).

PPS Review

The PPS contains four main algorithms: (1) preprocessing, (2) precipitation rate, (3) precipitation accumulation, and (4) bias adjustment. These algorithms refine and perform various quality control checks on the reflectivity base data prior to product generation. The interaction of these algorithms is depicted in Fig. 1. This evaluation compares a 24-hour precipitation total product produced by the

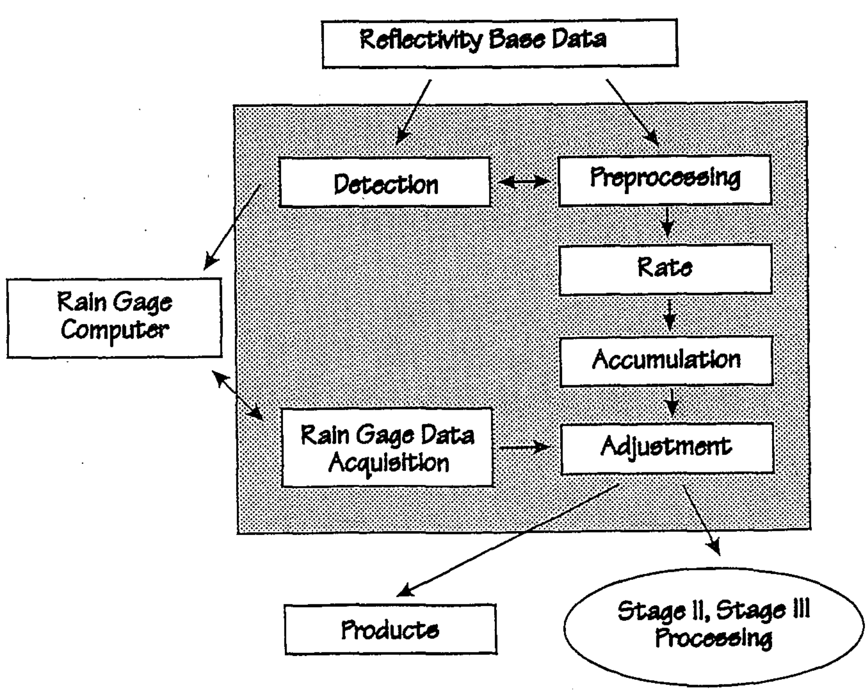

Figure 1 - WSR-88D Precipitation Processing Subsystem data flow diagram (OTB 1993).

complete precipitation subsystem. During this product generation, the bias adjustment is set to one, which eliminates any bias modifications in the final product. Bias calculations can then be performed outside the actual PPS for an analysis of their effectiveness.

Methodology Used

All gage data measurements used in this evaluation originated from cooperative stations. Approximately 90 stations reside under each radar's area of concern. Correlating a 24-hour accumulation period, beginning at 00Z, to a site's observation time eliminates many of these sites. After this filtering process, only 31 cooperative stations in Idaho and 24 in Arizona were acceptable.

Radar precipitation estimates were generated by processing Level II data tapes through the PPS software running on an HP 755. These 24-hour products were sent to the OSF, who extracted the data corresponding to each gage location. This extracted data was in a 5x5 matrix form centered on the gage location. The data surrounding the actual location is used to reduce radar precipitation advection and gage siting errors. In this evaluation, only the inner 3x3 matrix was used to obtain the best fit radar estimate. A best fit method uses the value which is closest to the gage measurement within these nine bins. All calculations and comparisons used this best fit value.

The specific calculations used in this study are:

Average error:

$$E = \frac{1}{N} \sum_{i=1}^{N} \left| \frac{G_i - R_i}{G_i} \right| * 100 \qquad (1)$$

N = number of gage radar pairs
G = a particular gage value
R = the radar estimate for that particular gage

Average error with mean radar bias removed:

$$E = \frac{1}{N} \sum_{i=1}^{N} \left| \frac{G_i - (B * R_i)}{G_i} \right| * 100 \qquad (2)$$

B = bias adjustment.
Two biases can be calculated:

Bias 1:

$$B_1 = \frac{\sum_{i=1}^{N} G_i}{\sum_{i=1}^{N} R_i} \tag{3}$$

Bias 2:

$$B_2 = \frac{1}{N} \sum_{i=1}^{N} \frac{G_i}{R_i} \tag{4}$$

The average error calculation provides a percentage deviation of the radar estimate from the gage. Bias adjustments are inserted into the average error equation to remove a mean bias from the estimate. The bias calculation is an integral part of the adjustment algorithm, and an active area of development in the WSR-88D software. The actual bias calculation done in the PPS is different than the one performed in this study. The WSR-88D bias adjustment employs a Kalman filter technique not dealt with here; however, this evaluation does examine the general bias adjustment approach for radars in the West. A large portion of the PPS enhancements expected in Build 9.0 deal with the bias adjustment calculation. Ideally, when each radar precipitation estimate is multiplied by the bias, the error will approach zero. As you can see, the bias is assumed to be a constant value across the entire field. This constant bias assumption is the common point between this study and the actual WSR-88D PPS.

Bias 1 (Equation 3) has a weight assigned to each observation proportional to the gage amount. In other words, it places more emphasis on higher precipitation events. On the other hand, in bias 2 (Equation 4) all comparisons receive equal weight. As a result, it favors low precipitation events.

Comparisons

Figures 2 and 3 depict the average error and bias adjustment calculations for KIWA and KCBX radars. Several important facts can be drawn from these diagrams:

1. The average error of the radar precipitation estimate is 50% or greater.

2. The bias adjustments rarely improve the precipitation estimate. In only three

cases out of the eleven did bias 1 slightly improve the estimate, and in only one case did bias 2 show any improvement.

3. The bias adjustments can dramatically **degrade** the precipitation estimate. Specific examples are shown in Fig. 2 where the bias 2 adjustment actually increased the error by over 150%.

Plotting the error versus range (Fig. 4) shows that a range dependency does exists. The farther the estimate is from the radar, the more likely it will have a larger error. When a scatter plot of gage versus radar data is generated from the entire evaluation (Fig. 5) two conclusions can be drawn: (a) the radar predominately underestimates precipitation, and (b) many times the radar does not generate precipitation when amounts were measured at the gage.

Summary

In summary, this evaluation looked at a combination of stratiform and convective precipitation events occurring under the KIWA and KCBX radar umbrellas to evaluate the accuracy of the Precipitation Processing Subsystem (PPS) products. Two significant findings were discovered:

1. The precipitation product contains significant errors prior to any bias adjustments. The average error is 73% for the 273 data points used.

2. The bias adjustment algorithm in the PPS does not significantly improve the radar precipitation estimate. In fact, the bias adjustment can increase the errors by up to 150%.

The bias adjustment algorithm is an area of active development in the software. However, the wide variation between gage and precipitation estimates illustrates that applying a mean bias correction across the entire field is not necessarily effective in improving radar estimates. Fortunately, the bias adjustment portion of the PPS can be disabled on a site-by-site basis, per approval of your Unit Radar Committee.

This study suggests that other methods for improving the PPS should be researched, rather than attempting to minimize the error through a mean bias correction.

References

Kelly, Scott D., 1994: Procedures for Forecast Offices to Perform Gage-Radar Comparisons. WSR-88D Users' Conference preprint.

OTB, 1993: WSR-88D Operations Training Student Guide. Operational Support Facility, Operations Training Branch, Norman, Oklahoma.

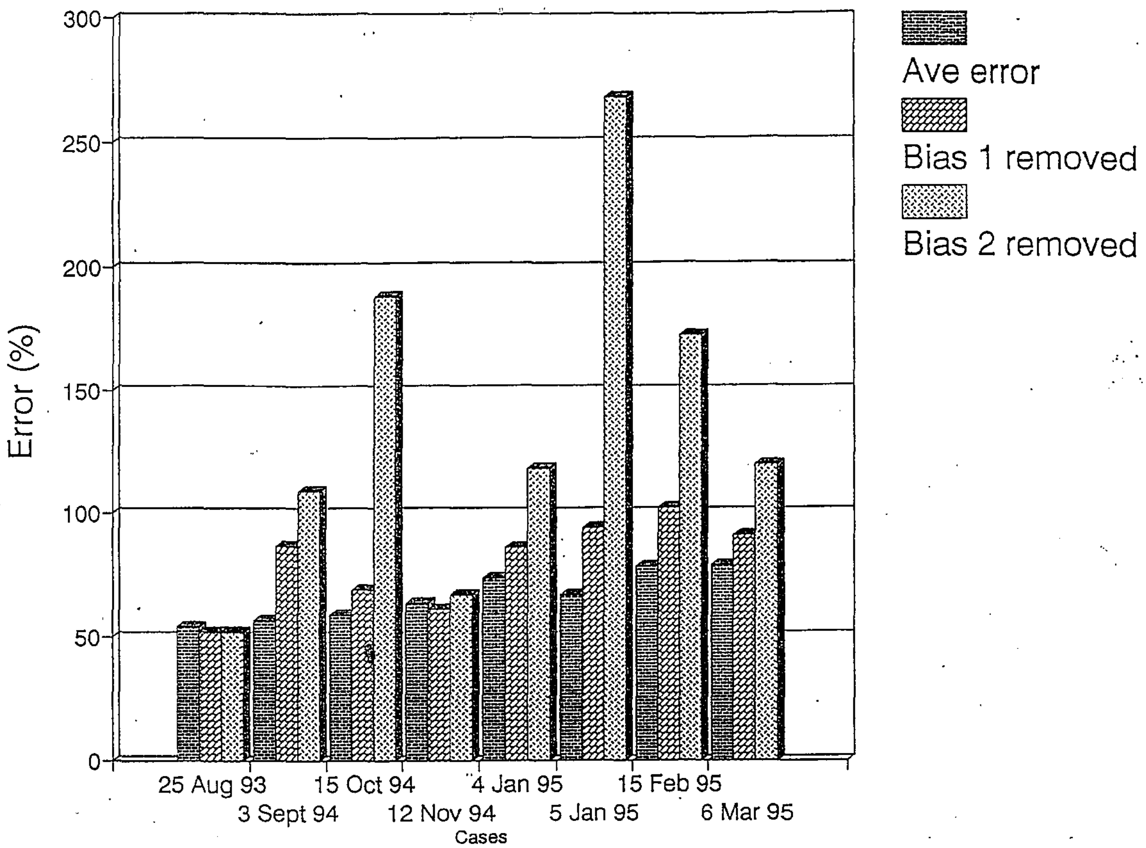

Figure 2. Distribution of error for each case examined in Arizona (KIWA).

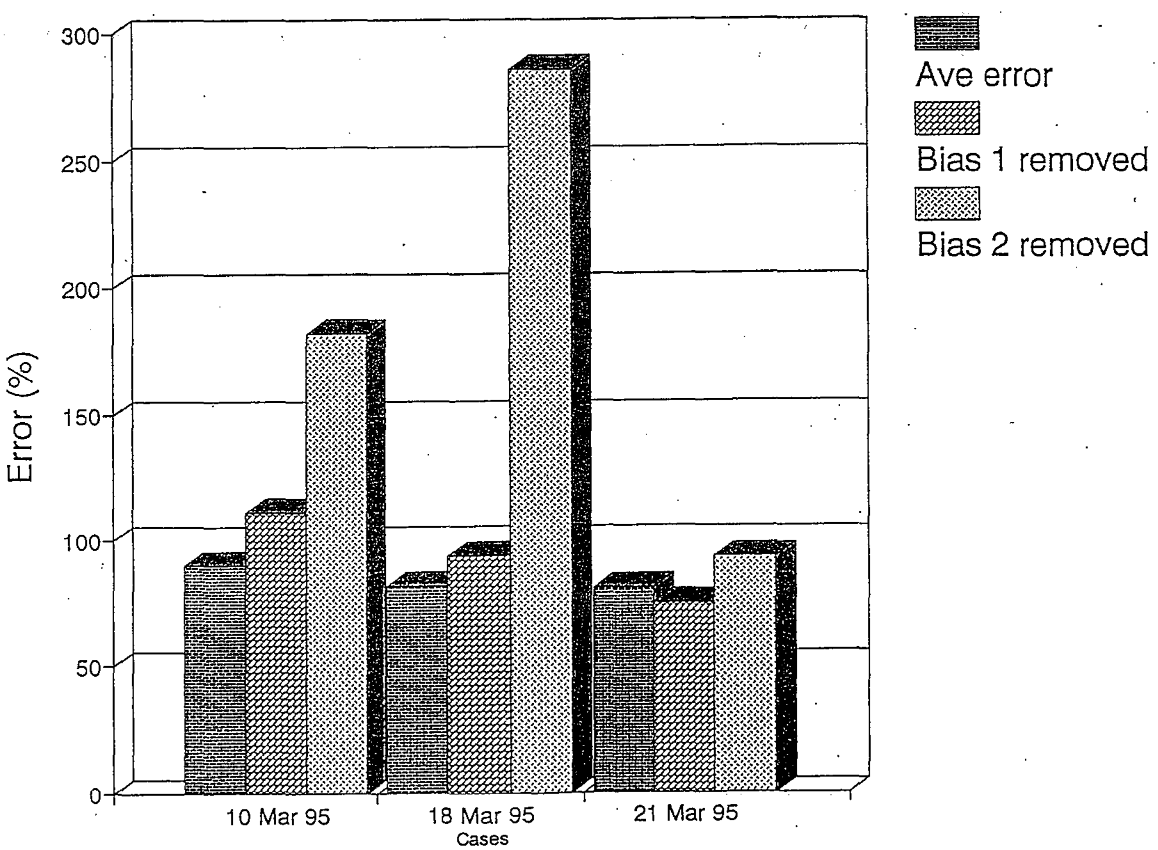

Figure 3. Distribution of error for each case Examined in Idaho (KCBX).

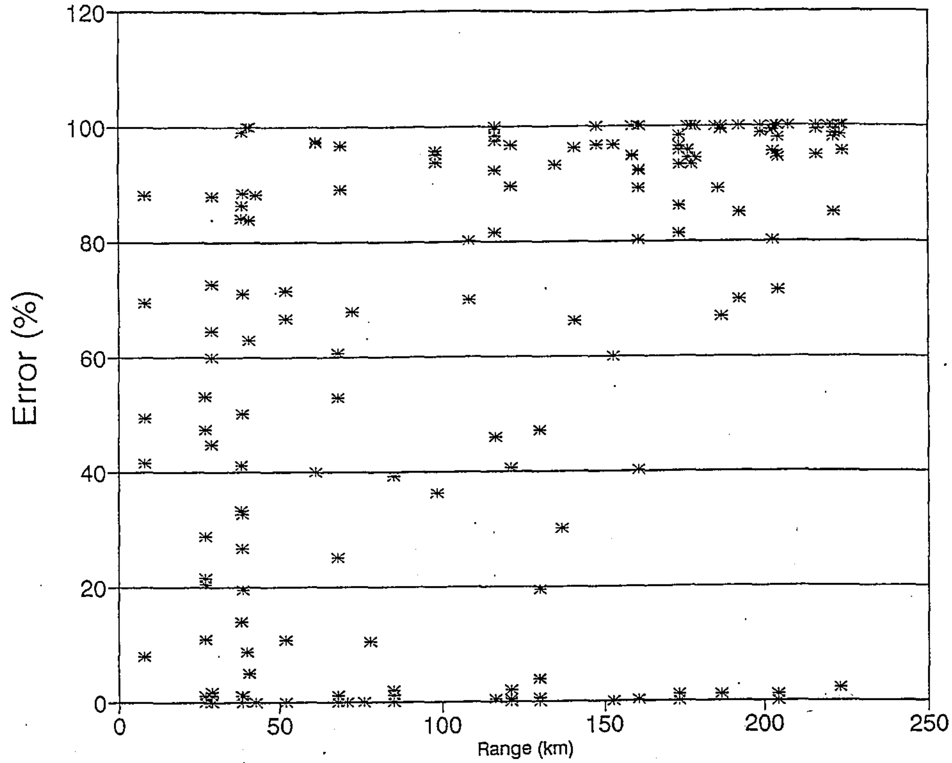

Figure 4. Plot of range verses error for Entire evaluation.

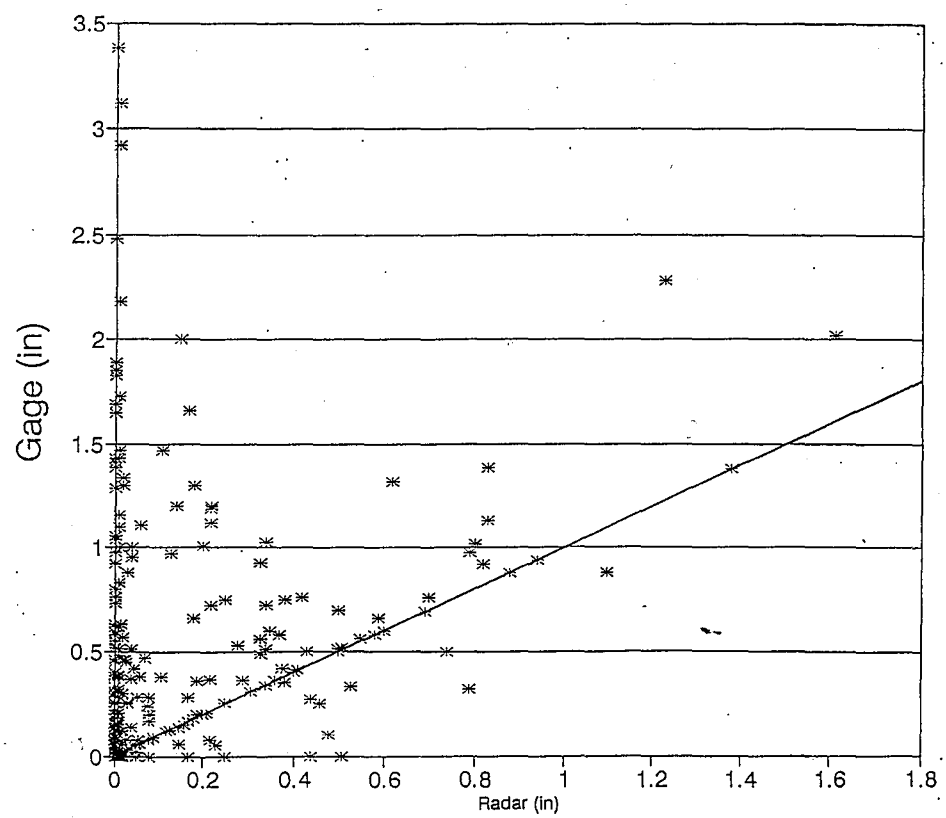

Figure 5. Scatter plot of gage verses radar For entire evaluation.