10.5 VERIFICATION OF NSSL'S MULTISENSOR PRECIPITATION ESTIMATION TECHNIQUES IN ARIZONA

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1. INTRODUCTION

Accurate estimates of precipitation type and amount are important for water management at the Salt River Project (SRP) located in Arizona. The primary focus of water operations at the SRP is management of reservoirs on the Salt and Verde Rivers. Knowledge of precipitation accumulating in watersheds (WSs) has historically been provided by a network of rain gauges located throughout and adjacent to the WSs. While gauge data are considered ground truth, they do not provide temporally or spatially continuous coverage of precipitation falling into the WSs. Also, gauge measurements may not be representative of the character of the precipitation on a case-by-case basis. Finally, one or more gauges may have reporting errors.

To overcome these deficiencies, the National Severe Storms Laboratory (NSSL), in partnership with the SRP, has developed and deployed a multisensor (MS) system designed to provide widespread quantitative precipitation estimates. The Quantitative Precipitation Estimation and Segregation Using Multiple Sensors (QPE SUMS) system (Gourley et al. 2001) combines satellite, numerical model, multiple radar, lightning, surface data, and rain gauge data to provide a number of precipitation products, including precipitation type and multi-hour accumulations.

As an example of its uniqueness to specific problems encountered in Arizona, QPE SUMS employs a brightband identification (BBID) algorithm that identifies situations that result in gross overestimates in traditional radar-only products. Overestimation is prevented by employing a methodology of using the correlation between satellite infrared (IR) cloud top temperatures and calculated precipitation rates. In addition to improving the magnitude of precipitation estimates, the satellite technique also greatly increases the coverage area.

While QPE SUMS has been employed in Arizona for several years, a systematic study of its performance has not been conducted (mainly due to lack of significant precipitation events). This paper provides a preliminary evaluation of QPE SUMS products for the 13-14 February 2003 event. An overview and description of key components and parameters of QPE SUMS are provided in section 2. Section 3 provides background on the SRP domain including the Salt and Verde WSs and associated gauges used for verification. Section 4 describes verification methodology and results. A summary and future work plans are given in section 5.

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2. QPE SUMS DESCRIPTION

A summary of the main components of QPE SUMS is provided in this section. The major components include a quality control (QC) process, determination of precipitation type and corresponding radar derived rates, a satellite-radar regression, and finally a multi-hour accumulation. Precipitation type and rates are computed in polar coordinates for each radar and then combined on a Cartesian grid. The products and diagnostics are also displayed on this common grid.

Data for each radar are first checked for ground clutter and anomalous propagation (AP) echoes. There are several persistent clutter problems in Arizona: the Harcuvar Mountains northwest of KIWA; White Mountains southeast of KFSX; and localized ground clutter near all radars, especially KIWA and KYUX. Excessive accumulations can result from these sources but are not addressed specifically in this paper. Subsequent to QC, precipitation rates and types are computed. First a convective - stratiform test is done. In stratiform precipitation, the horizontal range limit of "good" data is determined by an environmental sounding, NCEP's RUC2 model data or the BBID algorithm. Below either the 0^{o}C level or brightband, "good" rain is assumed and the corresponding Z-R relation is used to determine rates. Alternatively, beyond the horizontal range of the 0^{o}C level or brightband, "bad" rain is assumed. Within a certain distance above the brightband, "good" snow is assumed and the snow Z-S relation is used to determine rates. Henceforth, RAD is used to refer to accumulations from the radar-only algorithm. The multi-sensor (MS) algorithm entails the application of regression equations based on satellite IR temperatures and radar rain/snow rates. In the MS algorithm, the RUC2 is used to define the horizontal rain/snow line and different rain/snow regressions can be used.

3. ANALYSIS SETTING

The focus of this evaluation of QPE SUMS is on the Salt and Verde WSs located in central Arizona. Fig. 1 shows the WSs, gauge and radar locations. Note the uneven distribution of gauges in the WSs. Vast portions of the WSs lack gauges, particularly the northwest portion of the Verde and southeast portion of the Salt, highlighting the need for supplemental precipitation data.

Figure 1 also depicts the complex terrain in central Arizona that results in radar beam blockage,

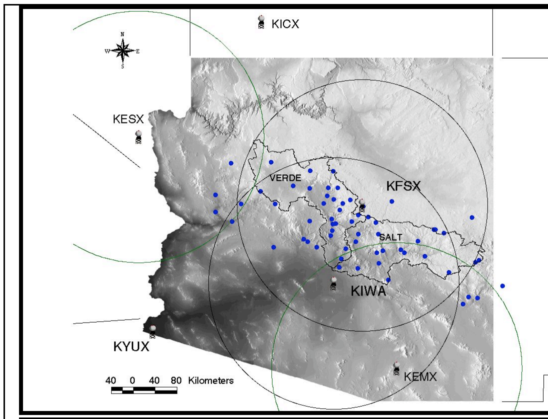


Figure 1. Topography of Arizona with KESX, KICX, KFSX, KIWA, KYUX, and KEMX WSR-88Ds, Salt (eastern-most) and Verde (western-most) watersheds and locations of gauges used in the study overlaid.

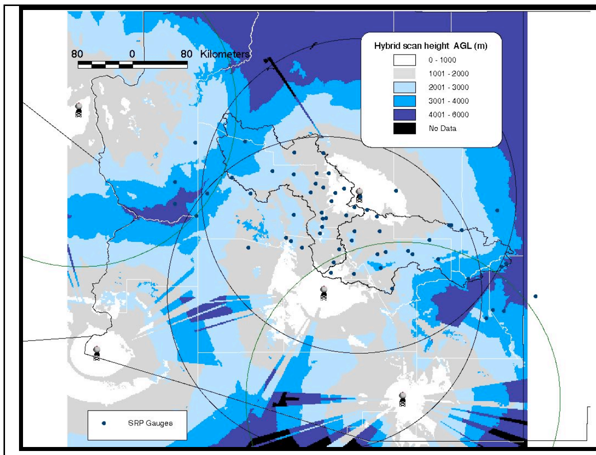


Figure 2 Composite of hybrid scan heights for several WSR-88Ds in Arizona. The Salt and Verde watersheds and locations of gauges used in the study are shown on the WSs.

Table 1. Performance statistics for QPESUMS accumulations for 13 February 2003.

	Gauge	RAD	MS
Mean	0.56	0.75	0.60
Standard Deviation	0.39	0.68	0.26
Correlation coefficient		0.40	0.22
Bias (G/R)		0.75	0.94
rmse		0.65	0.42

enhanced regions of AP, and incomplete coverage. Reflectivity data used to derive precipitation rates is ideally obtained from the elevation angle closest to the surface. However due to the complex terrain this cannot always be achieved.

Figure 2 shows a composite of the heights of the hybrid scan tilts above ground level (AGL) for the radars. Because each radar has a unique blockage pattern, the actual radar coverage (collocated bin) is highly variable spatially. There is very little coverage with hybrid tilts within 1000 m AGL over the two WSs. Twenty six gauges have no radar coverage within 2000 m AGL and six gauges have no coverage within 3000 m AGL. Coverage becomes dramatically worse over the northwest and southeast portions of the WSs. Under optimal circumstances, KFSX covers about the two thirds of the Salt and Verde WSs while KIWA covers about a third. If a radar ceases to operate for any period then coverage switches to an alternative radar that is further away, reducing the quality of data. In situations when the freezing level is above KIWA and below KFSX, the transition between precipitation types can be difficult to resolve.

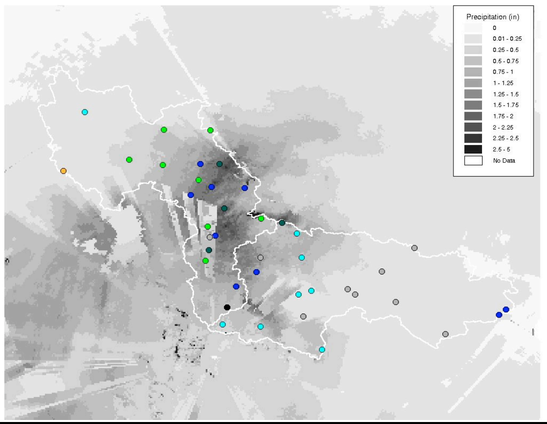
4. VERIFICATION

Verification is done by comparing RAD and MS 24 h total accumulations with collocated gauge amounts and calculating descriptive statistics including bias, root mean square error (rmse), and correlation coefficient (ccoef). All calculations are in units of inches. Bias shows how the sum of all gauge reports compares with collocated 24 h accumulations. The rmse summarizes the degree of scatter for each estimate associated with the random error and the ccoef indicates the relationship between the estimators and gauges. Bias closest to 1, rmse closest to 0 and ccoef closest to 1 all indicate optimum agreement with gauges. Also, a comparison is made between the “area-averaged” (all QPE SUMS points over the WSs; AREA) and the “gauge-averaged” (QPE SUMS points collocated with gauges; GP) amounts of precipitation for each of the Salt and Verde WSs.

4.1 13 February 2003 event

The rain-snow event of 13 – 14 February was the first significant event in several years. Two-day totals exceeded 2 inches at some gauge locations. This event was characterized by a significant contribution of precipitation from stratiform clouds. In addition, the existence of a low-altitude brightband provided an opportunity to examine the MS component of QPE SUMS. Figure 3a shows 24 h RAD accumulations during the period 1200 UTC 12 February to 1200 UTC 13 February. The most notable feature is the area of high reflectivity from brightband contamination over the east side of the Verde WS compared to the low values over the west side. There was little accumulation over the Salt WS. The MS results (Fig. 3b) indicate reduced overestimation in problem areas identified in Fig. 3a. Also, the noticeable height discontinuities between KIWA and KFSX (light-dark discontinuities in the eastern Verde WS caused by beam blockage near the Phoenix radar) are smoothed out by the MS approach.

a)



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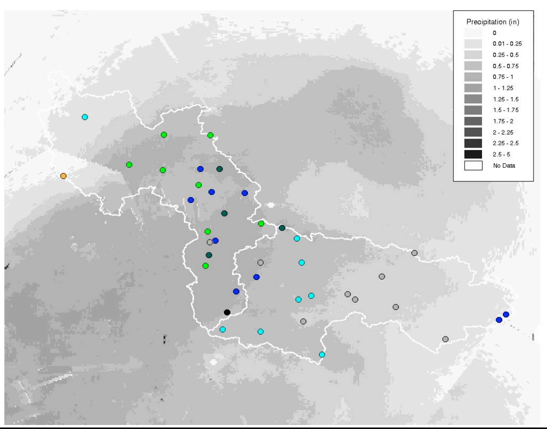


Figure 3. QPE SUMS 24 accumulation ending 1200 UTC on 13 February 2003 of a) RAD and b) MS algorithms. Gauge data and the Salt and Verde watersheds are shown.

Table 2. Averages of gauge and QPESUMS 2 accumulations for 13 February 2003.

Watershed	Gauge	RAD GP	RAD Area	MS GP	MS Area
Salt	0.33	0.42	0.36	0.5	0.44
Verde	0.79	1.07	0.65	0.71	0.58

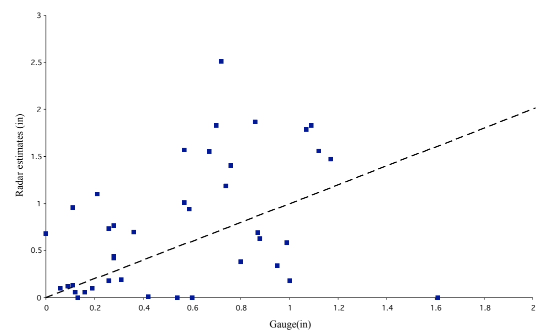
As previously stated, the WSs have poor radar and gauge coverage on the northwest and southeast tips. For instance, two gauges that are located at the tip of the southeast Salt WS recorded large accumulations yet do not lie within 230 km of any radar. Furthermore, the radar beam heights are over 3500 m AGL at each of the gauge locations resulting in severe underestimation. Similarly, the QPE is underestimated in the northwest Verde WS. The MS and RAD-gauge 24 h data pairs are visualized via scatter plots shown in Fig. 4 and associated statistics are shown in Table 1. The mean gauge accumulation over the 24 h period is 0.56 in with the mean of the RAD estimates being ~1/3 higher than the gauge mean. The ccoef between RAD estimates and gauge accumulations is .4 and the bias is .75. Figure 4b again shows the improvement resulting from using the MS approach, primarily in that the brightband contamination has been largely removed. Although the ccoef is only .22, the average of collocated grid-gauge points is 0.6 in.

Since an attractive aspect of QPE SUMS is that it provides greater spatial coverage than gauges, "area averages" were calculated for each basin (Table 2). The area averages are generally lower than the grid-gauge averages for both WSs. Ultimately, these averages should be correlated with stream flow data to verify the area average accuracy.

5. SUMMARY AND DISCUSSION

Verification of NSSL's QPE SUMS algorithm in Arizona was done for 13 February 2003. Focus was on performance over the Salt and Verde WSs. Brightband contamination was expected and evident in the radar-only results. The MS algorithm results were significantly better, mitigating overestimation of precipitation rates in the brightband regions.

a)



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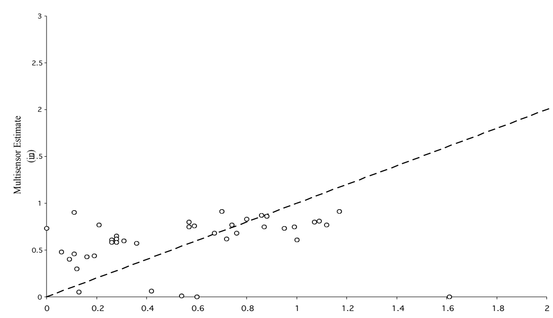

Figure 4. Scatter plots of QPE SUMS vs. gauge 24 hr accumulations on 13 February from a) RAD and b) MS algorithms.

These results illustrate the challenges that face QPE in complex terrain and shallow stratiform storms. For example, while the Phoenix radar is blocked over most of the lower Salt and Verde WSs, the Flagstaff radar is atop a ridge on the Mogillon Rim and the lowest elevation angle scans high above the surface in the WSs.

Additional verification work is being done on several additional significant events that occurred during the winter of 2002-2003 in Arizona. Several of these events included periods of heavy snowfall. This will allow testing of the "segregation" component of QPE SUMS that differentiates between rain and snow (water equivalent).

6. REFERENCES

Gourley, J. J., J. Zhang, R. A. Maddox, C. M. Calvert, and K. W. Howard, 2001: A real-time precipitation monitoring algorithm - Quantitative Precipitation Estimation and Segregation Using Multiple Sensors (QPE SUMS). Preprints, Symp. on Precipitation Extremes: Prediction, Impacts, and Responses, Albuquerque, Amer. Meteor. Soc., 57-60.