120 ASSESMENT OF MULTISENSOR QUANTITATIVE PRECIPITATION ESTIMATION IN THE RUSSIAN RIVER BASIN

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1. INTRODUCTION

The use of weather sensing radar measurements along with corresponding gauge data seek to provide reliable estimates of rainfall rate and accumulation. This information is essential for forecasters to issue flood warnings and for improved situational awareness. Radar rainfall estimators have a number of advantages over gauges including the ability to observe precipitation over wider areas within shorter timeframes and providing advanced warning of impending precipitation events. The radar reflectivity-rainfall (Z-R) relations are traditionally used for quantitative precipitation estimation (QPE).

This study aims to evaluate the impact of a commercial C-band radar for QPE in an area of poor NEXRAD radar coverage and to determine the relative performance of different QPE methods. The primary area of interest in this study is concentrated around the National Oceanic and Atmospheric Administration (NOAA) Hydrometeorology Testbed (HMT) in the Russian River basin north of San Francisco, CA (Figure 1). This watershed covers approximately 1500 square miles and has an annual average discharge of around 1,600,000 acre-feet. In this mountainous terrain, the challenge of obtaining reliable QPE's is limited by beam blockage and overshooting (Maddox et al. 2002), and orographic enhancement (Kitchen et al. 1994). Even if a perfect empirical Z-R relation can be applied, the accuracy is subject to factors such as: radar calibration, ground clutter, attenuation, beam blockages, bright bands and anomalous propagation, etc. (Fulton et al. 1998). In development of Z-R algorithms, rain gauges provide ground truth to the estimation of Z-R coefficients for a given region. In this study, radar data is taken from the surrounding NEXRAD WSR-88D radars (KMUX, KDAX, KBHX, and KBBX) as well as the C-band TV station radar KPIX. The KPIX radar scans the same area of interest but, unlike the NEXRADs, is closer and has a nearly unobstructed view of the Russian River basin. Rain gauge data from the California Data Exchange Center (CDEC) was used for ingest into QPE processing, and the rain gauges used for validation came from the NOAA HMT and Sonoma County winery gauges (Figure 2).

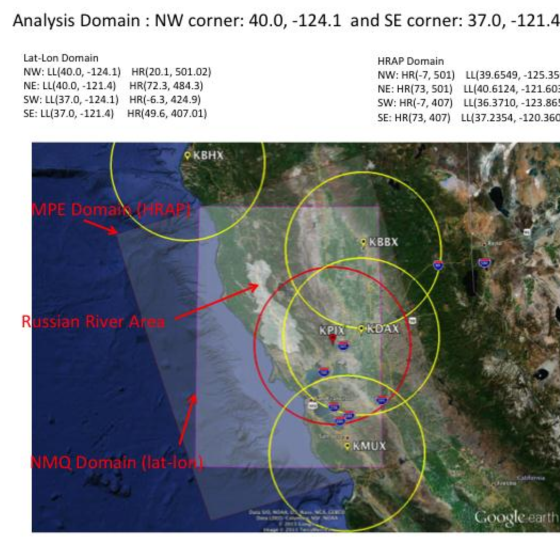

Figure 1. Domain of analysis covering the Russian River Basin with 100km range rings.

Ten days of rain events during the months of March and December of 2012 were considered. This analysis evaluates the performance of precipitation estimation from the National Mosaic and QPE (NMQ – also known as the Multi-Radar Multi Sensor System) algorithm package, which is developed by the National Severe Storms Laboratory (NSSL) (Zhang et al. 2011) and the Multisensor Precipitation Estimator (MPE)

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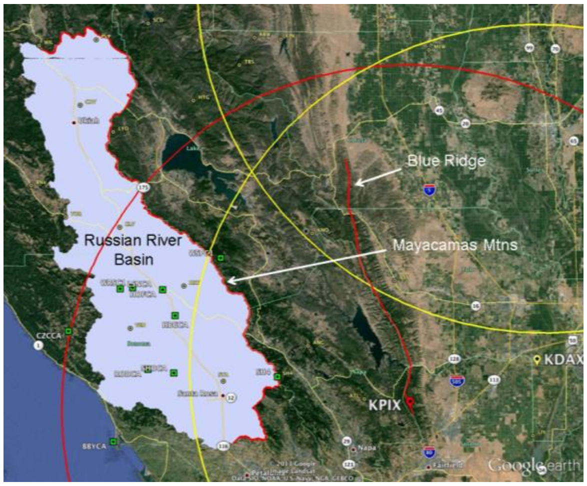

Figure 2. Radar and gauge locations surrounding the Russian River basin. Analysis gauges are yellow and validation gauges are green.

developed for use within the Advanced Weather Interactive Processing System (AWIPS) (Seo 1998). Independent of these QPE processing packages, a simple KPIX QPE analysis is created using KPIX reflectivity to derive rainfall amounts.

2. METHODOLOGY

The QPE precipitation fields, generated by NMQ, evaluated in this analysis include: gauge only, multiple radar-only, and multiple radar with VPR and gauge correction. Along with radar input, 52 gauges are used by NMQ for gauge analysis. The computed QPE output are gridded into common latitude-longitude coordinates and compared to an independent

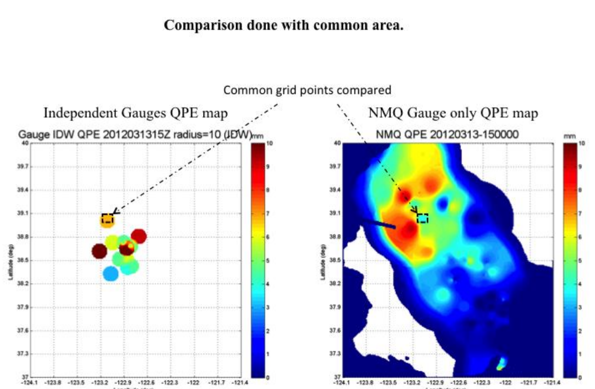

Figure 3. Statistics computed comparing common latitude-longitude grid points between NMQ QPE map and Independent Gauges QPE maps.

validation gauge set consisting of 10 gauges (Figure 2.). The domain of interest for this study is shown in Figure 1. The independent HMT/Sonoma winery gauge QPE is created by gridding the hourly gauge data into lat-lon using inverse distance weighting (IDW) and is calculated as (Simanton et al. 1980),

$$F(x,y) = \sum_{i=0}^{n} w_i f_i \quad (1)$$

$$w_i = \frac{\frac{1}{d_i^b}}{\sum_{i=0}^{n} \frac{1}{d_i^b}} \quad (2)$$

where f_i = gauge value, b = power parameter, d = distance from interpolation point to gauge, and i is the gauge number. Statistics are calculated by comparing the common grid points from the NMQ output with the independent gauge IDW QPE grid using b=2 and a 2km radius of influence. In addition to the NMQ QPEs derived using the four NEXRAD radars (KDAX, KMUX, KBHX, and KBBX – see Fig. 1), a Simple KPIX QPE was derived using the reflectivity fields from the KPIX radar. The Martner Z-R relation ($Z=44R^{1.91}$) was used since it was derived in the CA coastal mountain range in the vicinity of the analysis region (Martner et al. 2008).

MPE QPE fields were produced using Digital Precipitation Array (DPA) files that use the same radar set and gauge data input as mentioned above for NMQ. This QPE processing, takes advantage of the PRISM (Parameter-elevation Regressions on Independent Slopes Model) climate mapping system for scaling the multisensory estimates in MPE. The MPE output generated follows the 4km by 4km grid used by the Hydrologic Rainfall Analysis Project (HRAP) grid system. The HRAP grid is then converted to lat-lon grid and then compared to the independent gauge data. The same IDW scheme, as mentioned in equation (1) and (2), was used to re-interpolate the MPE products to 1km by 1km grids for cross comparison with NMQ measurements.

Along with NMQ/MPE QPE, statistics were also calculated on the simple KPIX QPE field. This QPE is calculated using the Martner Z-R relationship. This technique determines rainfall rate from reflectivity, similar to NMQ and MPE. However, no VPR or gauge information is used in order to minimize the complexity in the analysis. The radar reflectivity measurements are gridded to a 0.01 degree lat-lon grid covering the domain of interest using 4/3 earth radius model. The rainfall QPE hourly amounts are obtained by summing the rainfall amount between each consecutive radar scan.

3. ANALYSIS

Statistics of interest for this study focused on the correlation coefficient, normalized mean bias and the normalized standard error which are calculated by comparing the common grid points between the NMQ QPE fields and the independent gauge QPE fields where the angle brackets are the sample average, R_R is the QPE estimate, and R_G is the independent gauge measurement.

$$CC = \frac{<(R_R - <R_R>)(R_G - <R_G>)>}{\sqrt[2]{<(R_R - <R_R>)^2>}\sqrt[2]{<(R_G - <R_G>)^2>}} \quad (3)$$

$$< e >_N = \frac{<R_R - R_G>}{<R_G>} \quad (4)$$

$$NSE = \frac{<|R_R - R_G|>}{<R_G>} \quad (5)$$

In order to minimize the impacts of non-rainfall events, a threshold criterion was used to ensure the statistics were representative of the heavier rain events, which are of more concern for flooding purposes. In any given 6 hour period (00-06,06-12,12-18,18-24), the average of the validation gauge totals has to exceed the threshold (0.1"). For example, assume that the threshold was exceeded during 00-06z and 06-12z but not exceeded from 12-18z and 18-24z. That means, for that day, there would be (12) 1hr accumulations, (4) 3hr accumulations , (2) 6hr accumulations, and (1) 12hr accumulation to generate stats, based on the 00-12z accumulation period. There would be no 24hr accumulations for this day

Table 1 shows the 1 hour accumulation statistics between simple KPIX QPE, NMQ QPE's and MPE QPE's versus the independent gauge QPE considering 10 days of data. The NMQ QPE products shown are gauge only, radar only, radar with VPR, and radar with VPR and gauge correction. The radar input is varied for all of these products. These cases are NMQ using NEXRAD only, NMQ using KPIX only, and NMQ using NEXRAD and KPIX. MPE QPE's show the gmosaic, mmosaic, and rmosaic Table 2 gives the 6 hour accumulation periods for same estimated QPE's, also over 10 days of data.

Using the threshold of 0.1 inch, the daily statistics for 1 hour rainfall accumulation can be seen in Figures 6, 7, and 8 for normalized mean bias, normalized standard error, and correlation coefficient respectively. The red indicates NMQ gauge only, black is NMQ radar only, green shows NMQ with VPR and gauge correction, blue plots the simple KPIX QPE, and

Hr	QPE Product	KPIX	NSE	Norm Bias
1	Gauge only	NMQ KPIX only	56.7777	-2.0071
1	Radar only	NMQ KPIX only	84.3084	5.3928
1	Radar with VPR	NMQ KPIX only	75.903	-29.9844
1	Radar with VPR & GC	NMQ KPIX only	51.7236	7.0345
1	Gauge only	NMQ NEXRAD and KPIX	57.3865	-7.2824
1	Radar only	NMQ NEXRAD and KPIX	72.4809	-16.0402
1	Radar with VPR	NMQ NEXRAD and KPIX	72.7167	-37.3771
1	Radar with VPR & GC	NMQ NEXRAD and KPIX	52.5811	2.5628
1	Gauge only	NMQ NEXRAD w/o KPIX	56.968	-11.8563
1	Radar only	NMQ NEXRAD w/o KPIX	77.0071	-61.415
1	Radar with VPR	NMQ NEXRAD w/o KPIX	75.0376	-54.7066
1	Radar with VPR & GC	NMQ NEXRAD w/o KPIX	56.4591	-0.21
1	Simple KPIX QPE	KPIX	58.827	-0.5673
1	MPE QPE gmosaic	MPE using KPIX	64.9267	-9.4007
1	MPE QPE mmosaic	MPE using KPIX	58.7046	-6.6845
1	MPE QPE rmosaic	MPE using KPIX	56.6824	-17.971

Table 1. 1 hour QPE 10 day statistics showing Normalized Mean Bias and Normlized Standard Error.

Hr	QPE Product	KPIX	NSE	Norm Bias
6	Gauge only	NMQ KPIX only	42.3909	-2.8205
6	Radar only	NMQ KPIX only	55.8853	5.8397
6	Radar with VPR	NMQ KPIX only	56.9385	-30.8999
6	Radar with VPR & GC	NMQ KPIX only	38.4307	6.2428
6	Gauge only	NMQ NEXRAD and KPIX	41.8054	-7.9287
6	Radar only	NMQ NEXRAD and KPIX	49.2954	-16.3351
6	Radar with VPR	NMQ NEXRAD and KPIX	56.057	-38.5129
6	Radar with VPR & GC	NMQ NEXRAD and KPIX	38.3443	1.8735
6	Gauge only	NMQ NEXRAD w/o KPIX	41.7548	-10.9525
6	Radar only	NMQ NEXRAD w/o KPIX	66.9503	-63.4299
6	Radar with VPR	NMQ NEXRAD w/o KPIX	62.096	-56.4652
6	Radar with VPR & GC	NMQ NEXRAD w/o KPIX	40.4948	-1.4118
6	Simple KPIX QPE	KPIX	45.4208	2.8135
6	MPE QPE gmosaic	MPE using KPIX	49.9659	-10.9677
6	MPE QPE mmosaic	MPE using KPIX	43.2946	-7.5436
6	MPE QPE rmosaic	MPE using KPIX	46.7665	-28.2764

Table 2. 6 hour QPE 10 day statistics showing Normalized Mean Bias and Normlized Standard Error.

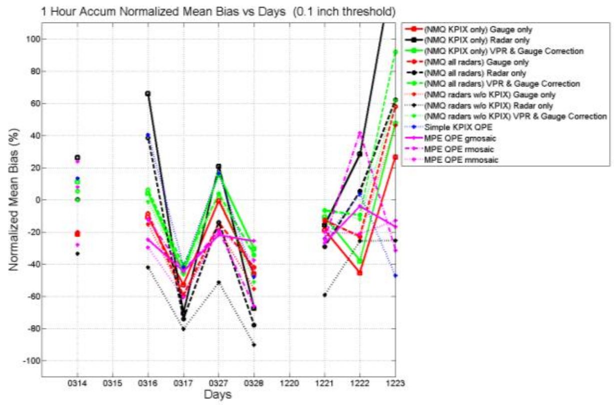

Figure 4. Daily 1 hour accumulation normalized mean bias for each day using a 0.1 inch threshold.

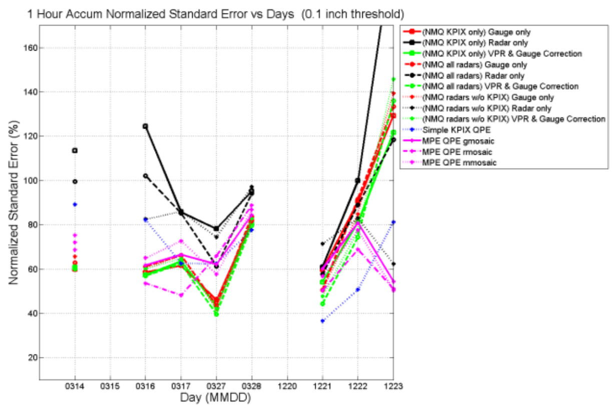

Figure 5. Daily 1 hour accumulation normalized standard error for each day using a 0.1 inch threshold.

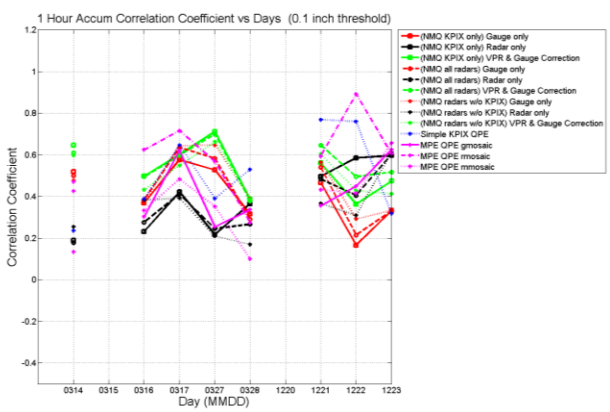

Figure 6. Daily 1 hour accumulation correlation coefficient for each day using a 0.1 inch threshold.

the magenta shows the MPE QPE's. The missing data for 0315 and 1220 stem from the application of the 6 hour rainfall threshold.

The Figure 9 shows the normalized mean bias over 1,3,6,12, and 24 hour rainfall accumulation for all the data over the 10 days considered and meet the minimum threshold. Figure 10 is a plot of the normalized standard error over 1,3,6,12, and 24 hour rainfall accumulation for the same days. The correlation coefficient for the same accumulation periods and days is given in Figure 11.

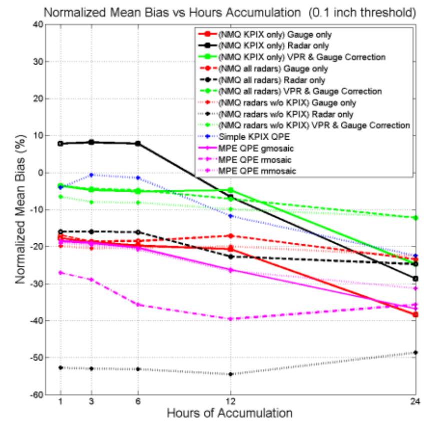

Figure 7. Normalized Mean Bias versus hours of accumulation considering 10days of data using 0.1 inch threshold.

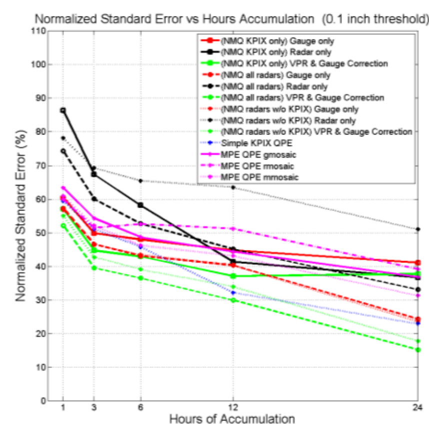

Figure 8. Normalized Standard Error versus hours of accumulation considering 10days of data using 0.1 inch threshold.

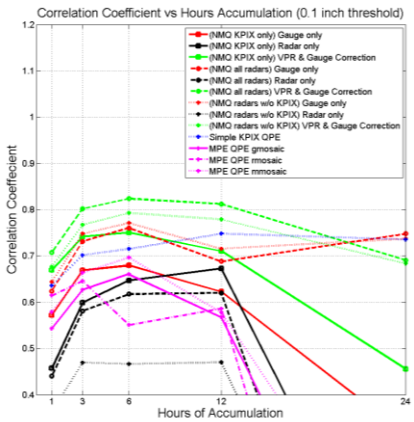

Figure 9. Correlation Coefficient versus hours of accumulation considering 10days of data using 0.1 inch threshold.

3. RESULTS

To illustrate the impact of the KPIX radar on the NMQ QPE products, several scenarios were evaluated by varying the NMQ radar input parameters. The first was to use KPIX as the only NMQ radar input. Then use all radars which include the four local NEXRAD radars along with KPIX. The final scenario was to only use the four NEXRAD radars into the mosaic. With each radar input, the NMQ QPE products of interest were gauge only, radar only, and radar with VPR and gauge correction. Along with the NMQ QPE, a simple KPIX QPE was calculated directly from the raw reflectivity using the Martner Z-R relationship. These QPE results were also compared to the independent gauge QPE.

Results in looking at all 10 days of rainfall events indicate that regardless of NMQ radar input the NMQ QPE product that implements VPR and gauge correction show the closest comparison to the independent gauge set. The simple KPIX also compares well, which is somewhat surprising given the simplicity of the QPE algorithm compared to NMQ and MPE. It is of interest to note how much better the simple KPIX QPE compares to the NMQ radar only QPE especially when the NMQ uses only KPIX as input. The daily statistics in Figs. 6-8 show the large day-to-day variability in relative performance of the QPEs and it is therefore difficult to draw a solid conclusion.

Additional data will help to further clarify the effects of KPIX radar data on QPE performance. The cumulative 10 days of data (Figs. 9-11) indicate good performance for NMQ QPE with VPR and gauge correction for all radar input scenarios, however, given the large day-to-day variability noted above, it is difficult to draw a definitive conclusion regarding which radar input (KPIX-only, all NEXRAD without KPIX, or all radar) provides the best overall QPE.

4. ACKNOWLEDGEMENTS

This work is supported by the Sonoma County Water Agency and the HMT program.

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