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Comparison of Mean Areal Precipitation Estimates Derived from NEXRAD Radar vs. Rain Gage Networks

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ABSTRACT

Historically, hydrologic forecasts and calibration of the National Weather Service (NWS) hydrologic models are typically prepared using inputs of 6-hour mean areal precipitation (MAP) estimates derived from rain gage networks. However, operational hydrologic forecasts can now be prepared using 1- or 6-hour MAPs derived from high resolution gridded precipitation estimates from the NWS Next Generation Radar system, NEXRAD. An initial analysis of 7 months (May 93 - December 93) of 1- and 6-hour operational MAP time series for nine basins revealed differences between the gage and radar MAPs in the long term accumulations, individual storm totals, and timing of events. The 7-month radar MAP accumulations were 10-25 percent less than the gage MAP accumulations. The 6-hour radar and gage MAPs had similar estimates of the timing of events, but the 1-hour radar and gage MAPs showed more discrepancies in the timing of events. The radar MAPs captured more of the variability in the precipitation fields than the gage MAPS at the 1-hour time step. However, the variability of the radar and gage MAPs was nearly equal at the 6-hour time step.

INTRODUCTION

New challenges in operational hydrologic forecasting have materialized because of the installation of an advanced national system of radars called Weather Surveillance Radar 1988-Doppler (WSR88-D), or NEXRAD (Hudlow, 1988). NEXRAD produces high resolution gridded precipitation estimates at a 4x4 km2 spatial scale and a 1-hour time scale. These NEXRAD data provide spatial and temporal estimates of highly variable precipitation fields that are not possible from point measurements of precipitation from rain gage networks.

Hydrologic forecasting at the NWS generally uses a lumped modeling approach in which hydrologic model parameters are averaged over a river basin. The Sacramento Soil Moisture Accounting (SAC-SMA) model (Burnash et al.,1973), which is the most commonly used hydrologic model in the NWS, uses a mean areal precipitation (MAP) input and outputs discharge. The SAC-SMA model parameters are calibrated using 6-hour model input MAPs derived from historical point gage precipitation measurements. These parameters are then used operationally with 6-hour gage MAPs to produce river forecasts with a 6-hour time step. River forecasters now have the option of using 1- or 6-hour radar-derived mean areal precipitation

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(referred to as MAPXs) for operational forecasting. However, the model parameters have not been recalibrated to the MAPX data because only a short 7-month period exists where historical gage and discharge data overlap with the NWS archive of radar data. Therefore, a detailed analysis of model input MAPs is required to understand how these model inputs will impact model performance. The objective of this paper is to analyze the differences in operational methods of estimating 1- and 6-hour MAPs derived from radar and gage networks.

ANALYSIS

The study area is nine basins in the region near the Oklahoma-Arkansas-Missouri state boundaries. This region was analyzed because of its dense gage network, six overlapping radar umbrellas, and one of the longest available periods of archived NEXRAD radar products in the United States to date. MAP and MAPX time series were derived for the period from May 7, 1993 through December 31, 1993. This is the period in which the historical gage and discharge data overlap with archived radar products.

The radar data used for the study are the 4x4 km2 resolution Stage III data. Stage III is a merged radar-gage precipitation field design to provide the spatial resolution of radar data while preserving the precipitation accumulations measured by gages. It assumes the gage data as "ground truth" and scales the radar accumulation estimates to match the gages (Shedd and Smith, 1991). The influence of the gages on the Stage III data diminish with distance from the gage. The gage MAPs were calculated using both the hourly and daily gage accumulations obtained from the National Climatic Data Center's 3200 precipitation data.

Summary statistics were generated for the 1- and 6-hour case, for all nine basins, and for the entire 7-month duration of the MAP and MAPX time series.

Statistics include the mean, standard deviation, and coefficient of variation, all of which are conditioned upon the occurrence of precipitation. The conditional statistics provide information about the ability of radar and gage networks to detect precipitation, as well as their ability to estimate precipitation rates. Cumulative sums for each basin and the percent bias of accumulations from radar vs. gage networks were also tabulated.

RESULTS

Tables 1 and 2 show that for the 7-month period, the Stage III MAPX cumulative totals have a negative bias ranging from -10 to -25 percent as compared to gage MAPs. This under catch of the MAPXs exists for both the 1- and 6-hour cases. The fact that the 6-hour conditional mean of the MAPX is larger than MAP for some basins is attributed to the spatial and temporal averaging of point gage measurements to time increments and areas where it is not raining. This produces rain for time intervals where no rain was occurring, reduces the conditional mean, and hides the actual cumulative bias that exist at the 6-hour case. MAPX is approximately 25 percent greater at detecting the variability in the precipitation at the 1-hour time step than the gage MAPS. However, the normalized mean (coefficient of variation) shows that the variability of the MAPs and MAPXs is nearly equal at the 6-hour time step. This indicates that the radar's ability to capture the variability in precipitation at a 1-hour time step is largely lost when averaging to a

6-hour time step.

Figure 1 illustrates how the cumulative sum of both the MAP and MAPX time series behaves over the 7-month duration for the TIFM7 basin. Only this basin is shown because all nine basins exhibited similar behavior. The figure shows how the gages and radar have different estimates of the volume and timing of individual precipitation events. Figure 1 also shows a plot of the cumulative differences in the MAP and MAPX time series, which highlights the timing and storm-by-storm catch of the two rainfall measurements. Both methods appear to be similar in their estimation of event timing, but a spike appears in the cumulative difference plot when their timing is off. MAPXs have a lower accumulation even in the summer, which may be due to averaging point gage measurements over areas where it is not raining, which overestimates precipitation. Or, the radar may simply be underestimating precipitation rates. Radar generally performs better than gage networks during high intensity convective storms because of the radar's high resolution spatial coverage (Seo and Smith, 1996; Smith et al., 1996).

Basin ID	SUM (mm)		HOURLY MEAN (mm)		HOURLY STD. DV. (mm)		COEF. of VARIATION		% BIAS of SUMS
	MAP3	MAPX	MAP3	MAPX	MAP3	MAPX	MAP3	MAPX	
JOPM7	1207	1040	2.07	1.51	3.26	3.26	1.575	2.160	-13.0
TIFM7	1104	996	1.48	1.32	2.69	2.66	1.820	2.020	-9.8
WTTO2	977	798	1.27	1.04	2.68	2.20	2.107	2.111	-18.3
KNSO2	948	837	1.50	1.41	2.67	2.83	1.782	2.000	-11.7
ELDO2	1056	930	1.51	1.34	2.55	2.90	1.680	2.176	-11.9
TALO2	933	839	1.47	1.33	2.77	3.28	1.880	2.460	-10.1
TENO2	979	784	1.62	1.18	2.85	2.90	1.755	2.460	-19.9
VLBA4	1055	798	1.73	1.07	2.99	2.29	1.730	2.128	-24.4
MLBA4	864	726	1.523	1.11	2.37	2.48	1.547	2.240	-15.9

Basin ID	SUM (mm)		HOURLY MEAN (mm)		HOURLY STD. DV. (mm)		COEF. of VARIATION		% BIAS of SUMS
	MAP3	MAPX	MAP3	MAPX	MAP3	MAPX	MAP3	MAPX	
JOPM7	1207	1040	5.51	5.10	9.29	9.52	1.69	1.87	-13.9
TIFM7	1104	996	4.30	4.70	7.90	8.55	1.84	1.82	-9.8
WTTO2	977	798	3.60	3.82	6.94	6.89	1.93	1.80	-18.3
KNSO2	948	837	4.35	4.65	7.75	8.32	1.78	1.79	-11.7
ELDO2	1056	930	4.19	4.72	7.68	8.79	1.83	1.86	-11.9
TALO2	933	839	4.15	4.49	8.34	9.34	2.01	2.08	-10.1
TENO2	979	784	4.45	4.15	8.64	9.02	1.94	2.17	-19.9
VLBA4	1055	798	4.67	3.80	7.69	6.20	1.65	1.63	-24.4
MLBA4	864	726	4.23	3.65	6.58	6.77	1.56	1.85	-15.9

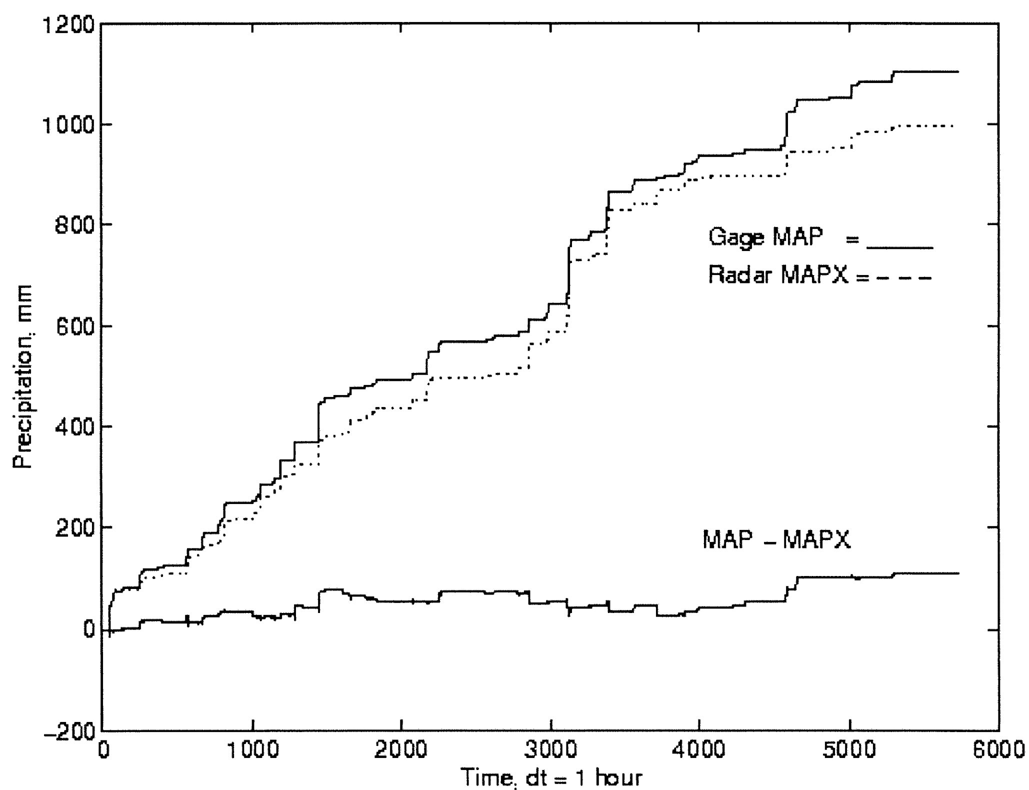

Figure 1. 7-month cumulative sum of 1-hour MAP and MAPX time series for the TIFM7 basin. Time=0 is May 7, 1993, and time=5736 is December 31, 1993. The radar MAPX has a lower cumulative sum of precipitation for the period analyzed. The bottom of the figure shows a plot of the difference between gage and radar mean areal precipitation estimates (MAP - MAPX).

CONCLUSIONS

The most significant result of this preliminary study is that MAPX has a negative bias in the 7-month accumulations for all nine basins analyzed. Any bias in the hydrologic model inputs may impact operational flood forecasts, soil moisture accounting, and long-term water supply forecasts. The 1-hour MAPX detected more precipitation variability than the gage MAPs, but this effect was minimized when averaging to a 6-hour time step. There were clear differences in each method's ability to estimate the timing and volume of the same particular event; however, no clear trend existed for all events. This indicated that hydrologic forecasting can benefit from having both measurement systems available to the forecasters, from which they can choose. Further analysis is required to evaluate what impact these differences between MAP and MAPX model inputs may have on operational hydrologic forecasting.

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