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A COMPARISON OF NATIONAL WEATHER SERVICE RIVER FORECAST CENTER OPERATIONAL PRECIPITATION PROCESSING METHODOLOGIES

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1. Introduction

The Arkansas-Red Basin River Forecast Center (ABRFC) is tasked with monitoring the hydrometeorological state of the Arkansas and Red Rivers from their headwaters in the Colorado and New Mexico Rocky Mountains to Pine Bluff, AR and Fulton, AR, respectively. These 200,000 plus square miles of drainage range from the 14,000-foot peaks of the Continental Divide in Colorado through the Southern Plains toward the Mississippi River Valley. Since July 1994, the ABRFC has utilized Weather Surveillance Radar 1988 Doppler (WSR-88D) and observed precipitation amounts to create gridded precipitation estimates for its area of responsibility. The addition of WSR-88D precipitation estimates to the precipitation processing procedure gives a spatial resolution to rainfall distribution that is not available when using gauge-only estimates. These processed precipitation estimates are meticulously quality-controlled by the Hydrometeorological Analysis and Support (HAS) forecasters at the ABRFC to create the most accurate estimate of precipitation available. How this is done is described in the following sections.

Precipitation estimates are the primary input to the Sacramento Soil Moisture Accounting Model (SAC-SMA), ABRFC's operational hydrologic forecast model. Therefore, it is vital to determine which methodology of precipitation processing results in the most accurate and most useful estimate to ensure the most accurate hydrologic forecasts. Additionally, as semi-distributed and distributed hydrologic models are developed and implemented in an operational environment, the most accurate estimates of the spatial distribution and amount of rainfall will be vital to optimizing the performance of the models.

2. Precipitation Processing

Currently, there are two methods for *estimating* precipitation spatially in an operational environment. The first and older method is the use of observed precipitation measurements. Such actual observations are accepted as the most accurate, however, they are point measurements and must be distributed spatially to be used in hydrologic forecasting. The distribution is accomplished using some sort of weighting technique, either Thiessen polygon, predetermined weights or isohyetal analysis (Larson, 1996). The second method is by means of remote sensing of precipitation amounts using the WSR-88D. This method gives a spatial distribution of precipitation that cannot be matched by a gauge network, however a number of factors affect the accuracy of precipitation estimates which are derived from radar observations. The goal of the HAS function at the ABRFC is to optimize the benefits of each methodology to obtain the most accurate estimation of precipitation possible.

At this time, there are at least three methods of precipitation *processing* used operationally in the National Weather Service (NWS) River Forecast Centers (RFCs). Gauge-only mean areal precipitation (MAP) estimates are used by some RFCs as their operational precipitation input to their hydrologic model. Two other methods strive to integrate WSR-88D estimates of precipitation and observed site-specific measurements of precipitation. A procedure known as Stage III was developed in the late 1980s by the NWS Office of Hydrology (OH). It computes an average bias across a radar's area of coverage by comparing some observed gauge reports to the corresponding WSR-88D precipitation estimates at corresponding locations. The average bias of these sites is then applied to every grid cell within that radar's area of coverage. Data from individual radars are then mosaicked together. Areas covered by more than one radar are resolved by either accepting the largest precipitation value, or assuming the average value of all multisensor precipitation estimates, depending on the user's preference (Briendenbach, et al, 1998). This is a rather simplistic overview of Stage III, but it captures the key assumption that the ABRFC believes accounts for the underestimation of rainfall by Stage III, *the use of a single average bias per radar*.

In 1996, ABRFC developed and implemented a different precipitation-processing algorithm, known as Process 1 (P1), which places more emphasis on the observed gauge network. The roots of P1 are in the program RAIN, developed by Brian McCormick at the US Army Corps of Engineers, Tulsa District. First, each radar's hourly precipitation estimate is mosaicked together by using the average value where coverages overlap. P1 then calculates a unique bias for each HRAP grid cell, rather than Stage III's single bias per radar. This is done by using a double interpolation technique. If an observed rainfall amount is available for a grid cell, that grid cell's precipitation estimate is set to that value and the difference between the WSR-88D rainfall estimate and the observation is calculated. Along a line between two such grid cells an adjusted radar estimate is calculated using a weighted interpolation scheme. This weighting is determined based on how far the grid cell is from each of the two endpoints of the line. This results in a unique bias for each cell. For grid cells that lie between these "bias lines" a bias is calculated by interpolating from the surrounding "bias lines."

3. Methodology

There have been several recent studies on this topic, each with its own methodology and study area. Both Stellman, et al. (1999) and Wang, et al. (2000) have shown that Stage III-derived mean areal precipitation (MAPX) estimates have a significant negative bias when compared to traditional gauge-only MAP estimates for many individual basins in the Southeast River Forecast Center, Lower Mississippi Forecast Center and ABRFC region. However, it is important to note that NWS MAPX estimates can be subdivided into two groups, Stage III-derived and P1-derived.

The present study compared spatially distributed National Climatic Data Center (NCDC) observations of precipitation to the ABRFC P1-derived values on a monthly, grid-by-grid basis from January 1997 to September 1999. NCDC gauge data were used because they are delivered in a tabular format and monthly duration. The gauge-only fields were created using 1000+ gauges in and around the ABRFC with 544 of these gauges falling within the ABRFC boundary (Fig. 1). These numbers are comparable with the number of gauges used operationally at the ABRFC. Over the past three years, the number of daily precipitation observations inside the ABRFC have ranged from 27 to 686 with an average of 412 on any given day. These monthly gauge values were distributed spatially using a second-power inverse distance-weighting (IDW) scheme available in ArcView. Figure 2 provides an example of the May 1998 gauge-only IDW precipitation distribution.

Figure 1. Distribution of NCDC monthly cooperative stations across the ABRFC region (solid boundary).

Monthly P1 fields were reprojected from the original Hydrologic Rainfall Analysis Project (HRAP) projection into a geographic projection using an ArcView Avenue extension provided by the NWS Hydrologic Research Laboratory (HRL). The HRAP projection and the resultant geographic projection have an approximate resolution of 4x4 km. Figure 3 represents a one-month accumulation of P1 precipitation estimates for May 1998. Both of these fields were then exported as delimited text files from ArcView in HRAP projection. Two simple C program language routines were then run on these delimited files to mask out only those HRAP grid bins that lie within the ABRFC boundary and then sum those values. The final product was a monthly volume of rainfall across the entire ABRFC basin for both gauge-only and P1 precipitation estimates.

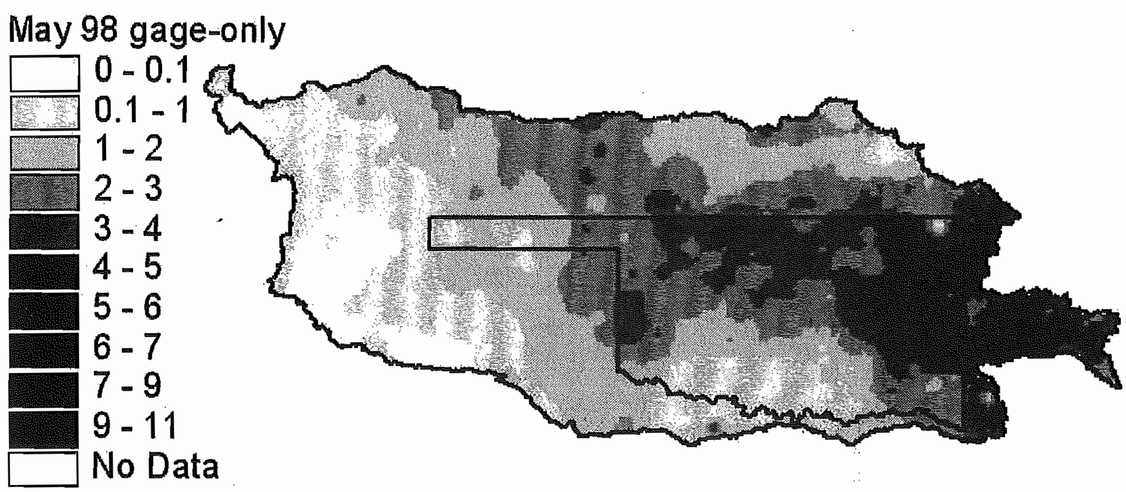

Figure 2. IDW interpolation across the ABRFC area of NCDC gauge-only precipitation data (inches) for May 1998.

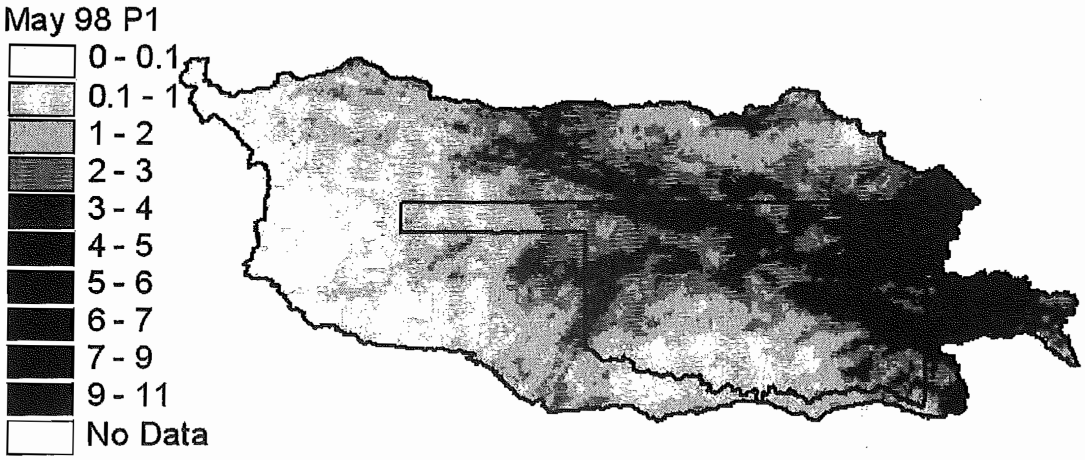

Figure 3. P1 precipitation estimate (inches) for May 1998 across the ABRFC area.

4. Results

A comparison of the monthly volume of precipitation across the entire ABRFC basin using gauge-only and P1 is displayed in Figure 4. Over the entire 33-month period, the ratio of P1-based

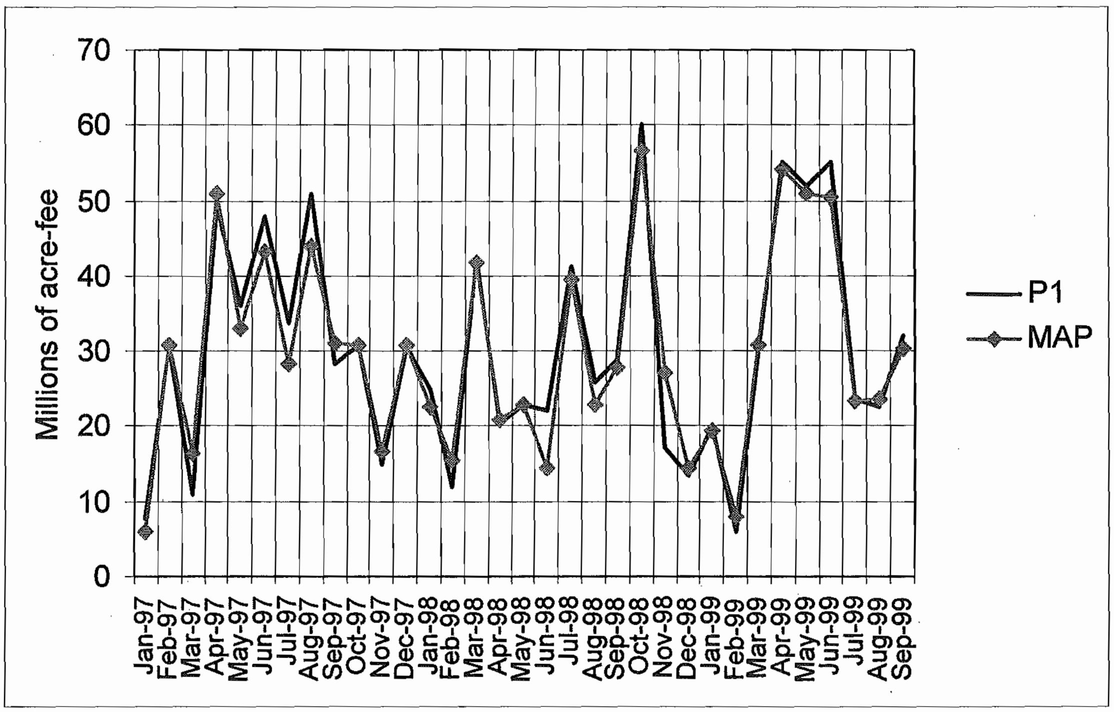

Figure 4. Monthly volume of precipitation across ABRFC area.

volumes of precipitation to gauge-only volumes is 1.019. P1 resulted in 1.9% ***more*** precipitation than gauge-only. This volumetric similarity between gauge-only observed precipitation and P1 estimated precipitation can also be seen in Fig. 5. It is important to note these values are computed on an ABRFC-wide scale; this tempers biases that may exist for specific basins due to individual radar biases and variability of gauge densities.

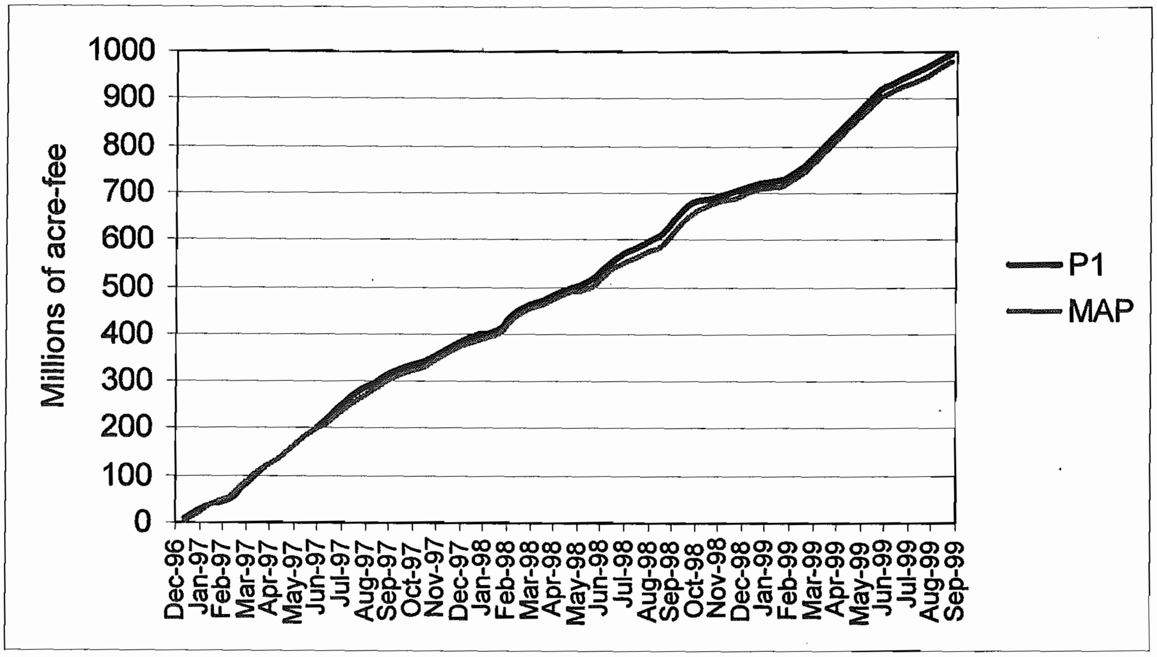

Figure 5. Cumulative volume of monthly precipitation across ABRFC area.

5. Conclusions

Generally, manual observations of precipitation are reliable and accurate, for a single observation site. However, networks of gauges are most often not dense enough to provide an accurate estimate of the spatial distribution of precipitation. While WSR-88D (radar) precipitation estimates leave much to be desired quantitatively, they are generally accurate in their depiction of the spatial distribution of precipitation. P1 incorporates the accuracy of physical measurements of precipitation with the spatial resolution offered by WSR-88D estimates. Currently, P1 is the most accurate method of estimating precipitation available in a NWS RFC operational setting. Examination of Figs. 4 and 5 does not show the long-term negative bias that Stellman, et al. (1999), Wang, et al. (2000), and ABRFC observed in Stage III. Therefore, P1-generated MAPX data *ARE* quantitatively suitable for hydrologic modeling and forecasting.

A comparison of Figs. 2 and 3 illustrates the improved depiction of spatial variability of precipitation across the ABRFC. This is only a qualitative benefit so long as NWS operational forecast models are lumped parameter. To realize the full potential of these gridded precipitation estimates, distributed or semi-distributed hydrologic models must be developed, tested and fielded. Calculations for distributed and semi-distributed models are performed on a gridded basis or use very small basins, respectively. As the state-of-the-art in operational hydrologic forecasting moves toward semi-distributed or distributed models, the most accurate gridded precipitation estimates must also be used to determine their effectiveness. The strength of these models is in their ability to capture the timing and magnitude of hydrologic events based on the physical distribution of rainfall, both spatially and temporally. Applying any sort of mean areal precipitation estimate to these distributed models is not a fair test of the hydrologic models, nor is the use of a biased precipitation estimate.

Further analyses are currently in progress at the ABRFC to study short-term, small-scale differences between Stage I, P1 and gauge-only precipitation estimates. These studies should shed some light on event-scale differences in the spatial distribution and amount of precipitation estimated when using radar-only, gauge-adjusted radar or gauge-only data in estimating precipitation.

6. Acknowledgments

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7. References

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