A First Look at QPF Verification in the Missoula Forecast Area using BOIVerify

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1. Introduction

With the release of BOIVerify version 2.0 in the Fall of 2007, it is now possible to create high resolution verification statistics for Quantitative Precipitation and Probability of Precipitation Forecasts issued using the Graphical Forecaster Editor (GFE) at the local office level. There are still challenges in obtaining an accurate verifying analysis field of precipitation, but the current Quantitative Precipitation Estimate (QPE) grid produced by the Northwest River Forecast Center (NWRFC) in Portland, OR, appears to provide sufficient accuracy to yield valid QPF verification statistics in portions of the Missoula Forecast Area. Initial verification results clearly indicate significant QPF biases exist in portions of the Missoula Forecast Area in forecasts issued by our forecasters and numerical model guidance. This information allows our forecasters to make changes to the forecast process to improve the QPF forecasts.

2. Verification Period

This winter season was quite active with numerous moist weather systems impacting the western half of the Missoula Forecast Area. One of the most active periods during the winter was January 23rd to February 12th, 2008 and thus was chosen for the verification study. Several moist frontal systems moved across the Northern Rockies and were associated with strong westerly wind flow aloft with southerly low level flow, which produced significant orographically induced variations in precipitation amounts. The western half of the Missoula Forecast Area over North Central Idaho and far Northwest Montana experienced several significant snow events, while areas in West Central and Southwest Montana were influenced by downslope drying. These areas still experienced frequent precipitation events, but much less total precipitation per event. During this verification period, any day that at least 75% of our forecast area received measurable precipitation was used in the study. This included 13 days out of the 20 day period.

3. Quality of the Analysis Grid

Initial QPF verification results from the early winter indicated there were significant deficiencies in the QPE grid being used for the verification in the Missoula Forecast Area. Quick efforts by the NWRFC corrected most of the problems providing more representative QPE grids by the middle of January. To ensure the reliability of the QPE grids during the verification period, several comparisons were made at a number of

locations in our forecast area between the QPE 6 and 24 hour values with reliable point precipitation observations. Results were combined for specific regions and are shown in Table 1.

Region	QPE Percent of Actual Precip	Percent in Correct Category (Precip / No Precip)
Glacier Park / Continental Divide	96%	95%
NW MT Low Elevations	79%	79%
NW MT High Elevations	103%	93%
West Cent MT Low Elevations	67%	67%
West Cent MT High Elevations	94%	93%
SW MT Low Elevations	91%	68%
SW MT High Elevations	108%	89%
Clearwater Mountains	107%	97%
Idaho Canyons / Kamas Prairie	94%	88%
Lemhi County	76%	56%

Table 1. Combined results for comparison of QPE grid value vs. point observation precipitation grouped into regions. "QPE Percent of Actual Precipitation" is a measure of QPE divided by measured precipitation. "Percent in Correct Category" is a measure of how often the QPE grid indicated precipitation fell at a given point when precipitation was measured, or when precipitation was not indicated by the QPE grid and precipitation did not occur.

There still appears to be deficiencies in the QPE analysis grids in some areas, specifically the lower elevations where the QPE seems to miss precipitation events and totals. The QPE grids seem more reliable in the higher terrain. It appears the primary reasons for less accuracy of the QPE grids in the lower elevations is the lack of real gauge data being included in the analysis due to timeliness factors and gauge inaccuracies in snowfall situations, and the more scattered/convective nature of the low elevation precipitation "missing" the gauge network being used in the QPE analysis. A number of localized, but intense snow events with significant public impact were not captured by the analysis.

Despite these valley issues, there are a few good valley data points being used for the analysis, such as METAR sites, which improves the reliability of the QPE grids in the vicinity of those sites. The QPE Percent of Actual Precipitation at Missoula Airport, for example, is 98% and the Percent in Correct Category is 96%.

Even though there are reliability issues in some areas in the QPE grids, it appears QPF verification results can provide meaningful general statistics in areas such as the higher terrain of Idaho and Northwest Montana, and near valley locations where observed precipitation is included in the analysis.

4. Verification Results

All of the verification results shown are average or composite biases for the 13 event days during the 20 day verification period. For the first two figures, 6 hour QPF forecasts and 6 hour QPE verifying analysis periods were totaled to produce 12 hour biases. In the remaining figures, the 6 hour periods were combined to produce 24 hour biases for the period ending at 12 UTC. A 24 hour period was used as it emphasizes the

biases in the results. In addition, several of the gauge data used in the analysis by the NWRFC are 24 hour precipitation reports for that period ending at 12 UTC. The NWRFC breaks down these 24 hour totals into 6 hour estimated QPE based on reports from nearby continuously reporting stations. To avoid introducing additional complexities into this general verification study, it was decided to use the simple 24 hour totals ending at 12 UTC.

The first set of results in Figure 1 is a value histogram showing the distribution of point forecasts compared with the QPE verifying analysis. The point forecasts shown are the Official Missoula GFE forecast, and the GFS and NAM raw model QPF forecasts. The results indicate that all 3 forecasts have a wet QPF bias for 12 hour precipitation events less then 0.75". At the few higher values recorded, the GFE and GFS forecasts have a dry bias, while the NAM12 follows the QPE analysis pretty closely. This is an indication that the forecasts for lighter precipitation events are overdone, while the largest precipitation events are often under forecasted. The very high QPE values over 2.00" are likely not correct, as no gauge data support these values during any 12 hour period.

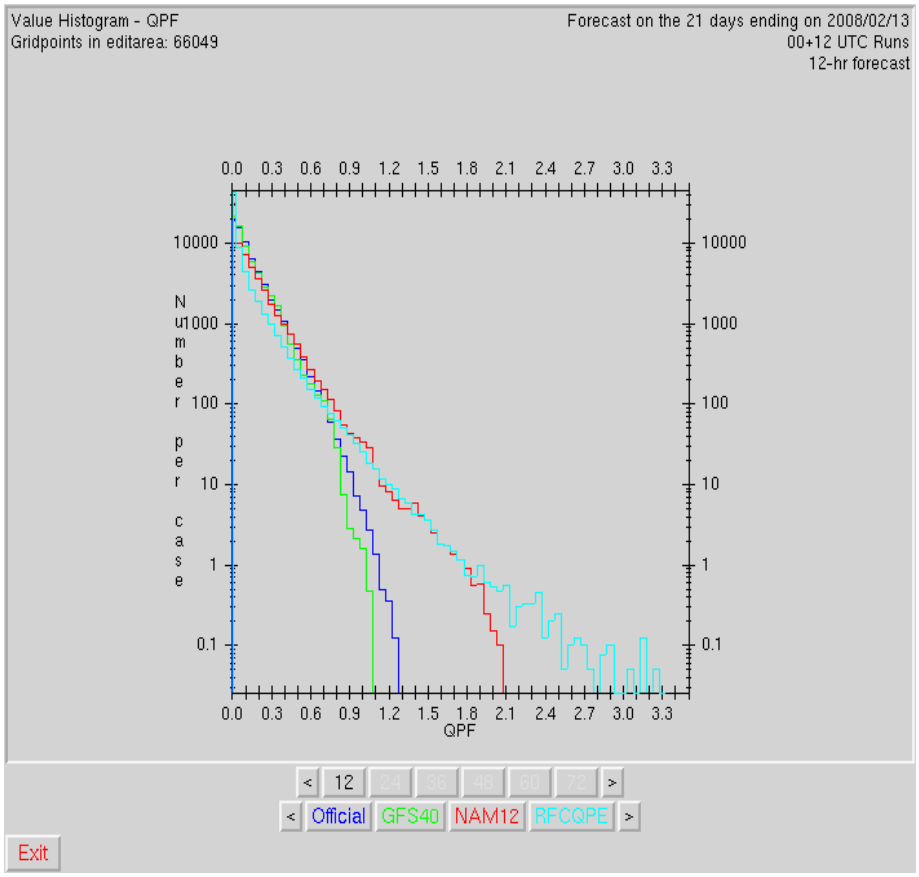

Figure 1. Value Histogram of 12 hour QPF forecasts from the Missoula Official GFE grids compared with the NAM, GFS, and QPE analysis grid for a 12 hour period.

Figure 2 shows similar results for 48 hour forecasts. However the switch from a wet bias to a dry bias for the GFE and GFS forecasts occurs at a lower threshold of about 0.50".

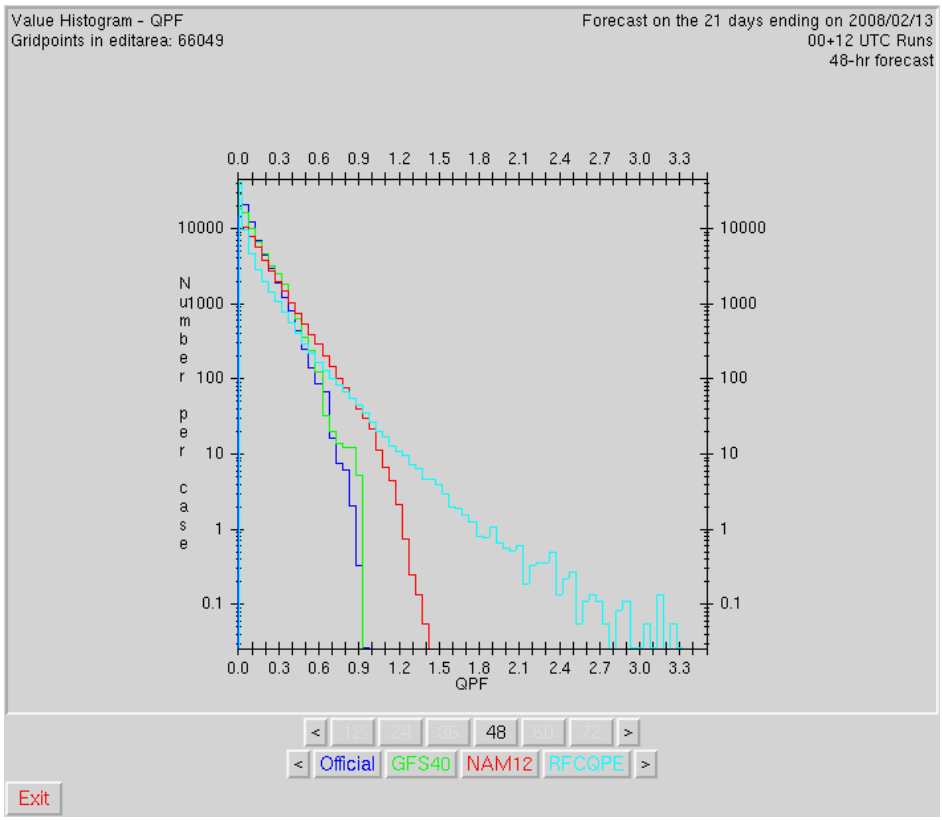

Figure 2. Value Histogram of 48 hour QPF forecasts from the Missoula Official GFE grids compared with the NAM, GFS, and QPE analysis grid for a 12 hour period.

Figure 3 is the 24 hour gridded QPF bias for the Official GFE forecast by the Missoula office for the 13 days noted as event days during the verification period. There are a few problems in the QPE analysis, which show up in this bias grid. The most notable problem area is the extreme dry bias in the southern Bitterroot Mountains. The QPE analysis frequently shows a region of heavy precipitation in this area, which cannot be verified with any gauge data. This feature will be evident in all of the following figures. Otherwise, this bias grid indicates a widespread wet bias in the Official forecast from Northwest Montana down to Southwest Montana and over the central Clearwater Mountain region of Idaho, with notable dry biases along the Continental Divide, in the Northwest Clearwater Mountains, and over the southern portion of the lower Salmon and Hells River Canyons. Due to the under-reporting of the QPE analysis grid of valley precipitation events, the valley dry bias in Western Montana may be somewhat overdone, but the dry bias is likely a real feature as seen in point data verification.

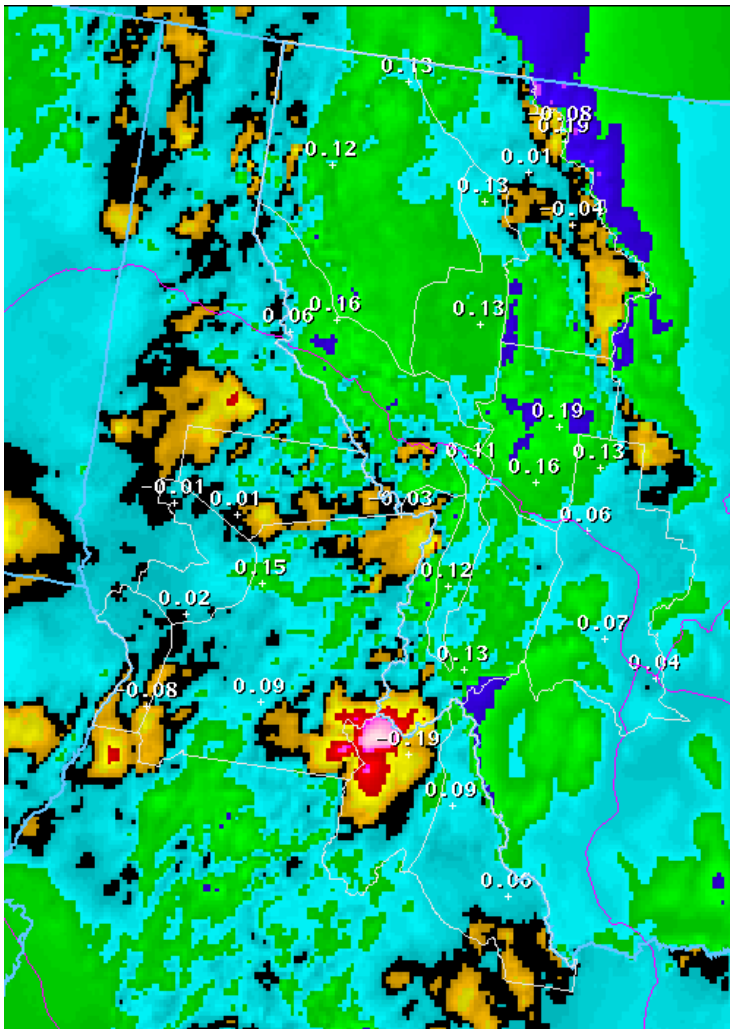

Figure 3. 24 hour Official GFE forecast bias for a 24 hour period

With increasing forecast lead-time, Official QPF forecast values seem to decrease, as seen in the biases, shown in Figure 4. This is for the forecast period starting 48 hours after forecast issuance. The wet bias from Northwest Montana to Southwest Montana is not as large, while a widespread dry bias is indicated over most of North Central Idaho. The dry bias along the Continental Divide becomes more extreme. This apparent decrease in forecasted precipitation values is probably due to decreasing forecaster confidence at the 48 hour period. This is similar to the dry bias often seen in extended period POP forecasts. It is also possible that forecasters may not want to forecast high amounts of precipitation at that lead-time, as it may push snowfall forecast values into winter weather watch/warning criteria. If the forecaster does not have high enough confidence to issue a winter weather highlight for this time frame, they may reduce the precipitation forecasts to values below highlight criteria.

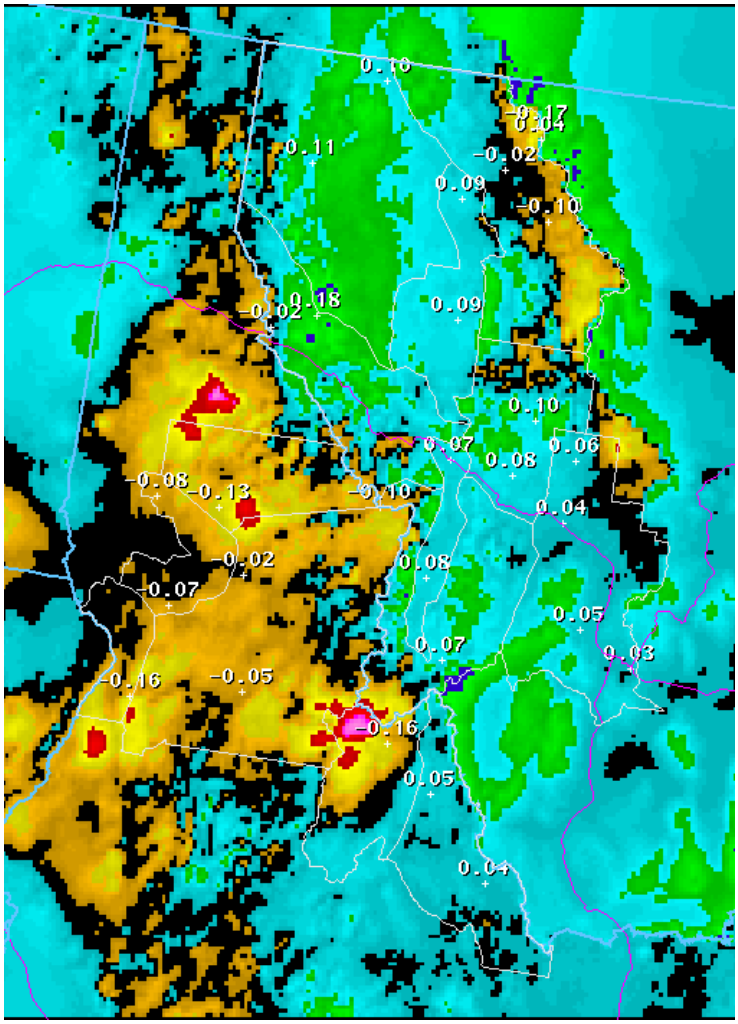

Figure 4. 48 hour Official GFE forecast bias for a 24 hour period

The 24 hour NAM model forecast QPF bias for a 24 hour period is shown in Figure 5. The NAM model bias follows a more complex pattern for the 13 event days then the Official GFE forecast error. In general, the NAM also exhibits a wet QPF bias from Northwest Montana to Southwest Montana, as well as a significant wet bias in the Central Clearwater Mountains of Idaho. The NAM exhibits a dry bias from near Lolo Pass in the Bitterroot Range northward to the southern Mission Valley, the lower elevations of North Central Idaho near the Oregon border, and over the higher terrain of Glacier Park. The NAM QPF fields appear to wash out some valley features in Western Montana resulting in a significant wet bias in some valleys, while there is much less of a wet bias, or even a dry bias, in other valleys. Since the NAM model terrain is a smoothed version of the actual terrain, the orographically favored regions for precipitation in westerly flow are shifted upstream, or westward, from their real locations in both the Clearwater Mountains, and in Glacier Park.

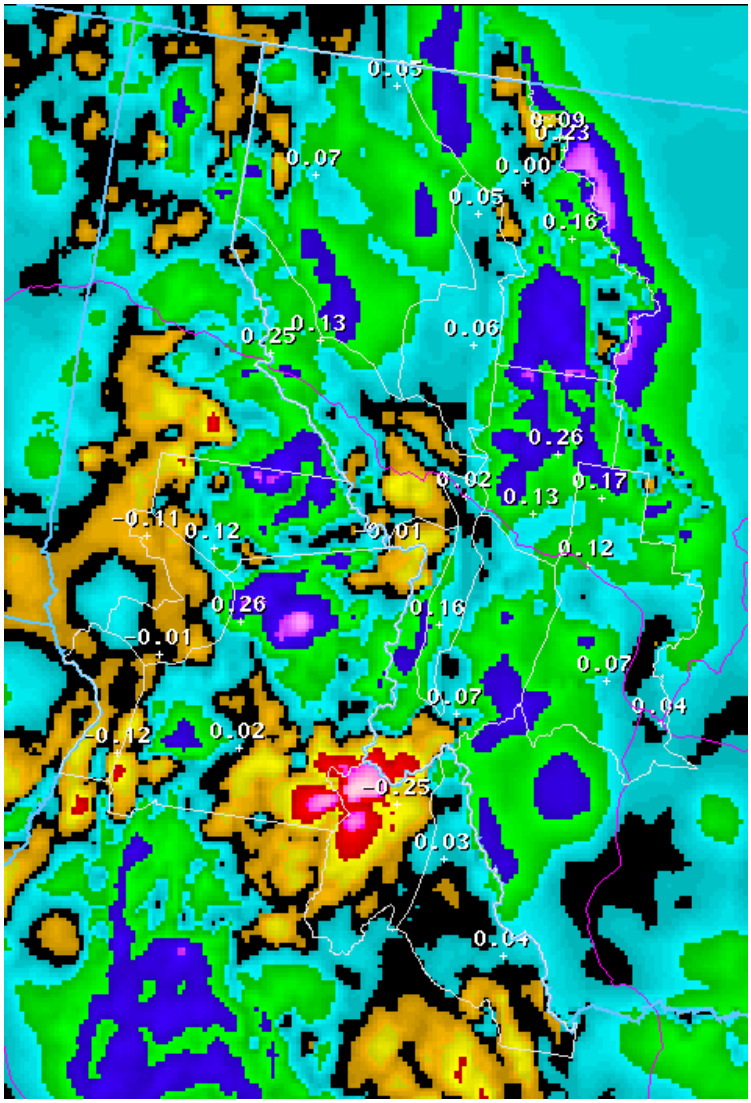

Figure 5. 24 hour NAM forecast bias for a 24 hour period

The 24 hour GFS model forecast QPF bias for a 24 hour period is shown in Figure 6. The GFS forecast model terrain is a significantly smoother version of the actual terrain. The effects of this can be seen in the QPF bias with a widespread and significant wet bias over a large portion of Western Montana. Very large wet biases are indicated in the larger valleys, which often experience significant downslope drying in westerly flow. At the same time, the model has a significant dry bias along the Continental Divide and the Bitterroot Mountains. This is also an indication the model does not properly capture precipitation in the most favored regions for orographic upslope in westerly flow.

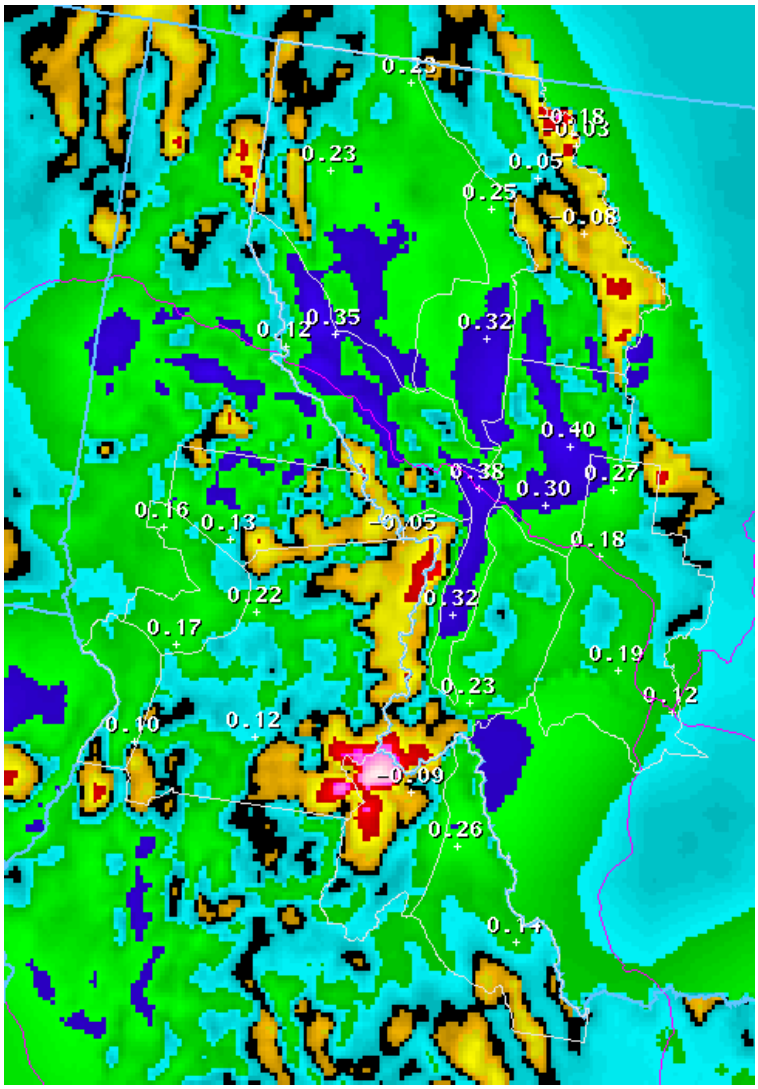

Figure 6. 24 hour GFS forecast bias for a 24 hour period

5. Conclusions

BOIVerify appears to be a viable tool for investigating general high resolution QPF verification in the Missoula Forecast Area. There continues to be deficiencies in the QPE analysis grid the verification is based upon. However, several point data comparisons indicate that the QPE grid is largely valid in the higher terrain. The QPE grid also appears to be reliable in the vicinity of valley METAR observations and a few other valley point observations.

General results of this project indicate significant biases do exist in the Missoula Official, NAM, and GFS QPF forecasts. The NAM and GFS forecasts appear to exhibit biases strongly related to the models inadequate resolution of terrain features, especially the GFS. In fact, it appears the Official Missoula forecast biases are less dominated by terrain features then the numerical models, which might be an indication the forecasters are correcting for the model biases to a degree.

In many of the drier populated valleys in Western Montana, the Official GFE Forecasts are too wet, even after adjusting for the dry bias of the QPE analysis. This result corresponds with the subjective thoughts of the Missoula Office staff. This over forecasting problem might in part be a result of forecasting QPF in 6 hour periods. A GFE tool has been developed to allow the forecasters to combine the 6 hour periods into 12 or 24 hours to evaluate the total precipitation for the period, and adjust accordingly.

Another area of interest in the QPF bias results is the region along the Continental Divide to Glacier Park. All of our forecast guidance, numerical models, and RFC QPF, seem to consistently under forecast QPF in this region. With this knowledge the forecasters can adjust the QPF forecasts upward in the region.