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EVALUATION OF NWS MULTI-SENSOR PRECIPITATION ESTIMATES FOR THE SOUTHEAST UNITED STATES

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1. INTRODUCTION

The national mosaics of radar precipitation estimates calibrated with surface gage observations are created by the National Centers for Environmental Prediction. These products provide estimates of precipitation on a 4.765km grid using Multi-Sensor Precipitation Estimates (MPE) algorithms produced by the NWS River Forecast Centers. MPE provides estimates of observed precipitation in areas where no gages are present. As a result, MPE is used in place of gage observations for a variety of purposes. Considering the wide usage of MPE data it is important to evaluate the accuracy of the precipitation estimates produced by MPE. The goal of this project was to evaluate the accuracy of MPE precipitation across the southeast U.S. against the NWS Cooperative Observer (COOP) gages. The MPE data evaluated in this study is the Stage IV data, which has human quality control applied to it, where the Stage II data does not.

2. APPROACH

NWS COOP stations from six states across the southeast U.S. were used to evaluate the MPE data in two ways. First, the daily COOP precipitation data was compared with the MPE data from the nearest grid point. The second version of the analysis compared the daily COOP precipitation data with the MPE data interpolated from the nearest grid point using bi-linear interpolation. The time span for the daily data was from 1200Z (0700 EST) to 1200Z (0700 EST). We will refer to the former as Nearest Neighbor MPE and the latter as Interpolated MPE.

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For each version of the analysis the daily MPE data were paired with the corresponding daily precipitation observation at each COOP station. For each station multiple statistics were used to evaluate the MPE data, including the root mean square error (RMSE), bias, correlation and the variance of the bias. In this case the bias refers to the MPE estimation minus the observed precipitation. These statistics were evaluated annually as well as seasonally for each station, and then spatially averaged across the domain.

A third analysis was also performed to evaluate the accuracy of MPE data at different thresholds of observed precipitation. This analysis considered the Interpolated MPE against the COOP gage observations. Four intensities levels of observed precipitation were considered; less than 0.25 inches, between 0.25 inches and 0.5 inches, between 0.5 inches and 1 inch and values greater than or equal to 1 inch. For each intensity level the same statistics were considered for each station and averaged over the domain seasonally and annually.

3. RESULTS

3.1 General Trends Between Bi-linear Interpolated MPE and Nearest Neighbor MPE

There was very little difference between the bi-linear interpolated MPE (INT MPE) and the nearest neighbor MPE (NN MPE). Across the entire domain the annual average RMSE for the INT MPE and NN MPE was 0.384 and 0.403 inches respectively. This indicates that the INT MPE has slightly less error then the NN MPE. This pattern was consistent across all the statistics used and for each state and seasonal average. Therefore, the INT MPE will be what is considered from this point forward in this paper.

3.2 Annual Trends

In this section the annual trends for each of the statistics mentioned discussed across the entire

State	RMSE (in)	Bias (in)	Variance of the Bias (in^2)	Correlation
AL	0.496	-0.036	0.106	0.727
FL	0.468	-0.026	0.104	0.750
GA	0.382	-0.023	0.062	0.811
NC	0.327	-0.039	0.048	0.849
SC	0.393	-0.039	0.065	0.780
VA	0.270	-0.007	0.034	0.866

Table 1. Annual Average Statistics for Each State in the Study

domain and for each state in the domain. As mentioned previously the annual average RMSE for the INT MPE was 0.384 inches. The average bias, average variance of the bias and the average correlation were -0.028 inches, 0.068 square inches, and 0.80 respectively. These statistics also show some trends between the states (Table 1). The average RMSE decreases from 0.496 inches in Alabama to 0.270 inches in Virginia. The decreasing error the north matches with the decreasing bias, variance of the bias and the increasing correlation moving northward through the southeast. In Florida, Alabama and Georgia there is the most convective precipitation of the six states in this study. Convective precipitation are typically isolated rainfall events occurring at spatial scales smaller then 4 km. MPE has a hard time reproducing the isolated convection, and is likely to have higher error in states where more convection occurs. This may explain why the MPE has a higher average annual error in the southern most states of the southeast U.S and why the average variance of this bias is much larger in the same states. We will delve more into problems with isolated convection in the discussion of seasonal trends.

3.3 Seasonal Trends

Along with the annually averaged MPE statistics across the southeast U.S. the seasonal averages were calculated for each statistic used in this study. The average RMSE across the southeast was 0.327 inches, 0.363 inches, 0.435 inches and 0.358 inches for winter, spring, summer and fall respectively. It is evident that the RMSE of MPE is highest in the summer and lowest in winter across the southeast. The same pattern was also evident in the variance of the bias (0.045 in^2, 0.064 in^2, 0.112 in^2 and 0.51 in^2 respectively). A similar pattern was also evident in the correlation. The lowest correlation occurred in summer (0.78) while the highest correlation occurred in the fall (0.83). Most of the statistics involved in this study mirrored the summer/winter pattern shown in the average RMSE. However, in the case of the average bias did not show the same pattern compared to the average RMSE. The average bias for winter, spring, summer and fall was -0.039 inches, -0.017 inches, -0.016 inches and -0.053 inches respectively. This suggests the MPE data show a higher error in the spring and summer but are less biased then in the fall and winter. This pattern in the seasonal statistics was also evident for each state across the southeast. The seasonally averaged RMSE error for each state is displayed in Figure 1.

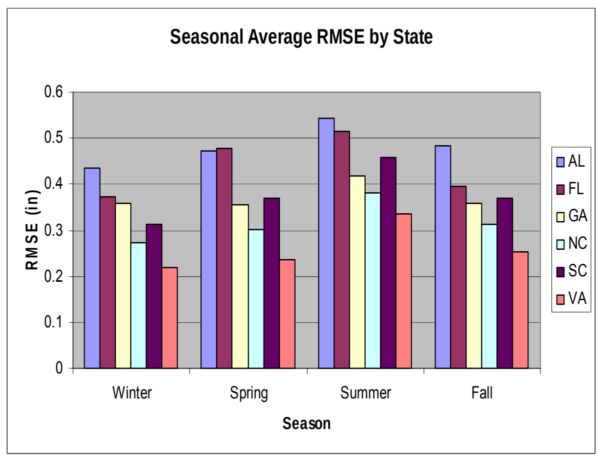
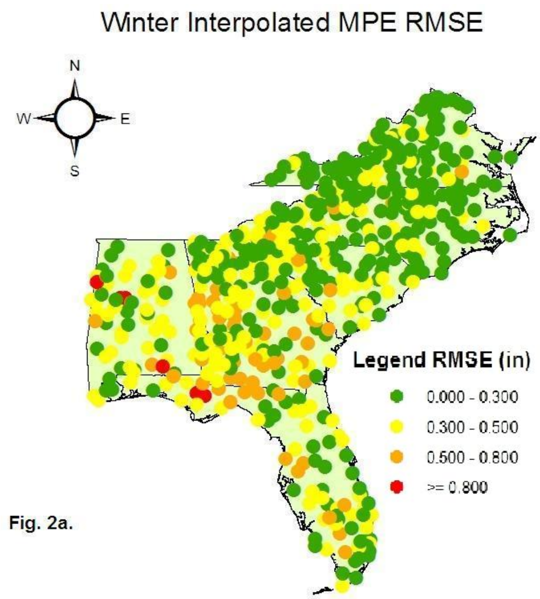


Figure 1. Seasonal Average RMSE by State

It is apparent from the figure that each state has the highest error in the summer and the lowest error in the winter. It is also apparent that Florida and Alabama have the highest error in each season. This is likely because both Florida and Alabama have a large amount of convective precipitation occur throughout the year. In the summer the entire southeast experiences mostly convective precipitation, this coincides with the highest error in the summer. In winter the stratiform precipitation is dominant throughout most of the southeast, but convective precipitation still persists in Florida and Alabama. In general there is less convective precipitation going north through the southeast U.S. This matches with the decreasing average RMSE from Alabama and Florida to Virginia. The increase in error is also evident for many of the stations across the domain.



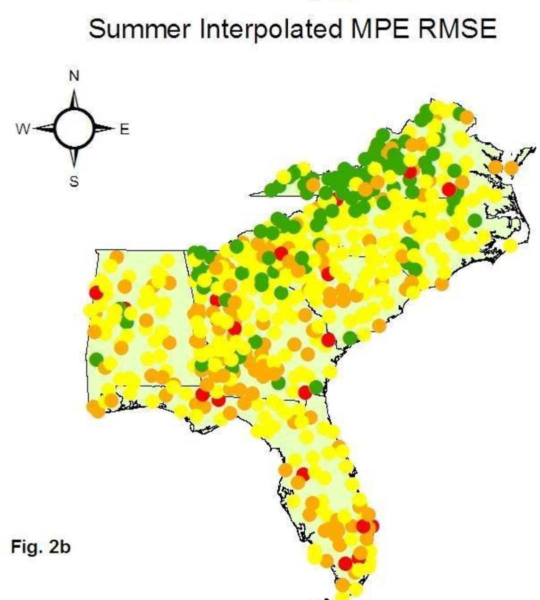


Figure 2. Maps of Seasonally Averaged RMSE by station for (a) winter and (b) summer

Many of the stations in Florida and Alabama in winter have an average RMSE of greater than 0.3 inches (Fig. 2a). In the summer, the number of stations with an average RMSE greater than 0.3 inches increases to include most of the stations across the southeast (Fig. 2b). It follows that the highest error across the southeast occurs at the same time as the largest amount of convective precipitation that MPE may have the highest error in the largest intensities of observed precipitation. This will be the focus of the next section.

3.4 Intensity Trends

Summer in southeast has the most convective precipitation and also the highest average RMSE for the MPE data. Since convective precipitation can be intense, an additional evaluation of MPE in varying intensities of observed precipitation was also performed. The daily observed precipitation for each COOP station was broken into the following intervals; 0-0.25 inches, 0.25-0.5 inches, 0.5-1 inch and greater than 1 inch. Those days falling in each interval were matched with their corresponding MPE estimates of precipitation and evaluated using the same statistics mentioned previously. It is important to note that we only considered times where precipitation actually occurred. Therefore the lowest interval does not include any days where no precipitation was observed at the COOP station. The average RMSE increased with increasing intensity from 0.185 inches to 0.879 inches (Table 2).

Intensity	**RMSE (in)**	**Bias (in)**	**Variance of the Bias (in^2)**	**Correlation**
0-0.25 inches	0.185	0.029	0.041	0.340
0.25-0.5 inches	0.275	-0.027	0.084	0.212
0.5 - 1 inch	0.393	-0.133	0.141	0.293
≥ 1 inch	0.879	-0.460	0.590	0.629

Table 2. Annual Average Statistics for Different Intensities of Observed Precipitation

However the RMSE is dependent on the number of pairs of MPE and observations in each intensity interval, and an observed intensity of greater than 1 inch of precipitation in rare in comparison to observed precipitation less than 0.25 inches. However, the average bias and the average variance of the bias show the same pattern of increase with increasing intensity, suggesting that the MPE does experience higher error for more intense precipitation events. However, the average correlation between the observed precipitation and MPE also increased with increasing intensity. This suggests that there were more extreme values in the data which would have a large impact on the RMSE, but that MPE estimates matched observed precipitation at the largest intensity more often then for lower intensities. In contrast, the lower intensities may have had less extreme values in the error, but also may have had more instances where the estimates were mis-matched with the observed precipitation. To consider the differences between MPE estimates and observed precipitation at each intensity interval, we plotted the density curves of the observed and estimated precipitation. Figure 3 shows the density curve for the 0.25-0.5 inch interval. The observed precipitation is contained in the interval of 0.25-0.5 inches, but the MPE estimates for the same intensity interval includes several values larger then 1 inch and several values of 0. There are more estimates of zero then of larger then one inch which is why the average RMSE in this interval is low.

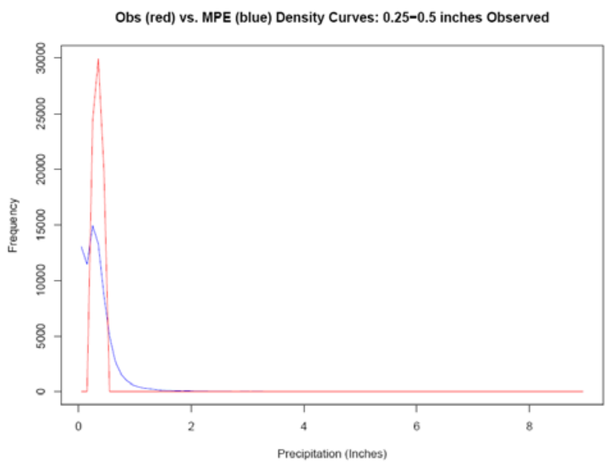


Figure 3. Density Curves for Observed (red) and MPE Estimated (blue) Precipitation – Observed Precipitation of 0.25 – 0.5 inches.

Figure 4 shows the density curves for observed precipitation greater then or equal to 1 inch. The observed precipitation is all larger then 1 inch, but the MPE distribution is still estimating no precipitation or precipitation less than 0.5 inches. The large number of low estimates from MPE was matched by the average bias at this intensity interval from Table 2. The average bias for almost all the intensity intervals was negative, indicating that MPE generally under-estimates for most observed precipitation. However, the absolute value of the bias increased with increasing intensity. This suggests that MPE has a larger under-estimation of precipitation with increasing intensity. In contrast, the average bias of MPE was positive for observed precipitation between 0 and 0.25 inches, suggesting that MPE over-estimates precipitation for this intensity interval. The same patterns for the RMSE, bias and variance of the bias were also present for each individual state. The error for each intensity interval also decreased from south to north across the southeast. The error for each intensity interval also followed the same seasonal pattern discussed previously, both across the entire domain and for each state.

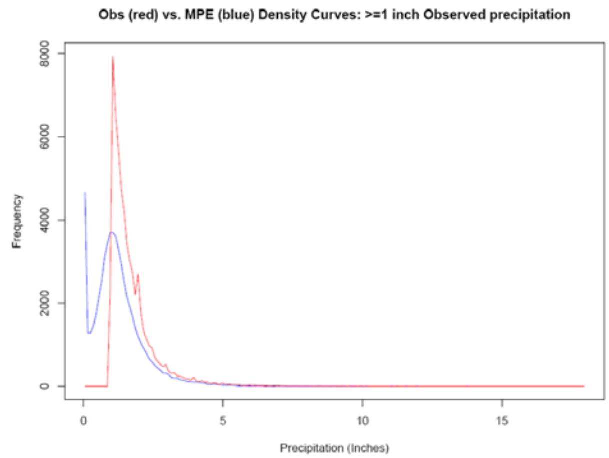


Figure 4. Density Curves for Observed (red) and MPE Estimated (blue) Precipitation – Observed Precipitation ≥ 1 inch.

4. CONCLUSIONS AND FUTURE WORK

The evaluation of the MPE estimates of precipitation showed many trends throughout the southeast U.S. The bi-linear interpolated MPE has lower error across all the analyses than the nearest neighbor MPE. The MPE exhibited an average annual error of 0.384 inches, with the highest seasonal average error in summer (0.435 inches) and the lowest seasonal average error mostly in the winter (0.327 inches). These results were contrary to the results of Boyles (2006). This pattern of error was present in the RMSE, bias and variance of the bias for each state and across the southeast. The error of MPE in summer is likely impacted by the isolated convective precipitation which is dominant in the summer season. Across all seasons the error of MPE was highest in Alabama and Florida. The high error in these states was also likely the result of isolated convective precipitation, which is a dominant form of precipitation in these states even in the fall and winter. However, these conclusions are the result of one study and do not include tests for statistical significance. Future evaluation work to be done on the MPE data includes statistical testing and an expansion of evaluation to include the entire eastern U.S.

5. REFERENCES

Boyles, R. P., 2006: Investigation of Mesoscale Precipitation Processes in the Carolinas Using a Radar-Based Climatology. *Ph.D Dissertation submitted to North Carolina State University.*