2.8 Objective Integration of Satellite, Rain Gauge, and Radar Precipitation Estimates in the Multisensor Precipitation Estimator Algorithm

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1. INTRODUCTION

The Office of Hydrologic Development (OHD) of the National Weather Service (NWS) has developed a precipitation estimation application called the Multisensor Precipitation Estimator (MPE) and deployed at the Weather Forecast Offices and River Forecast Centers throughout the nation. The MPE combines radar rainfall estimates with rain gauge measurements and produces a suite of multisensor rainfall estimates. However, because of the limited effective radar coverage due to beam blockage and radar beam overshooting at far ranges of the radar, the radar-gauge multisensor estimates are of limited utility in the mountainous regions, especially in the western United States. Satellite based rainfall estimates, on the other hand, offer complete spatial coverage and provide often the only real-time precipitation estimates in many pockets of the country. Therefore, Satellite Precipitation Estimates (SPE) produced by the National Environmental Satellite, Data and Information Service (NESDIS) have been made available for hydrological applications to the NWS Advanced Weather Interactive Processing System (AWIPS), of which MPE is a component.

Currently, the MPE has the capability to display the SPE as a separate field for qualitative comparison. Also, if needed, this SPE field can be cut and pasted into any other MPE products through the Graphical User Interface known as HMAP_MPE (Lawrence et al, 2003). Such an operation, however, is subjective and time consuming, and does not amount to quantitative integration of SPE into MPE.

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In a previous study, Kondragunta and Seo (2004) showed the incremental value of local bias correcting the satellite estimates; and also merging the local bias corrected satellite estimates with the rain gauge data, when compared to original satellite estimates. The current study is an extension of the previous study, where we made an attempt to objectively integrate the satellite precipitation estimates with radar and rain gauge data for quantitative multi-sensor precipitation estimation.

2. DATA

Data used in this study are rainfall measurements from the operational rain gauges, rain gauge measurements from the Co-operative rain gauge network, radar rainfall estimates from the WSR-88D network and satellite precipitation estimates from HydroEstimator (formerly known as the Auto-Estimator) algorithm produced by the NESDIS (Vicente et al, 1998). This SPE product is based on infrared cloud top temperature measured by the Geostationary Operational Environmental Satellite (GOES), precipitable water and relative humidity, cloud top growth rate and temperature gradients. This product is also corrected for parallax dislocation and orographic effects (Vicente et al, 2002). The HydroEstimator product is made available to AWIPS at hourly time scale and approximately 4x4 km^2 Hydrologic Rainfall Analysis Project (HRAP) spatial scale.
For this study, California Nevada River Forecast Center (CNRFC) region was chosen because it contains some gaps in radar coverage. The rain

gauge network density is also low in the Nevada area. Hourly operational rain gauge data, hourly Digital Precipitation Array (DPA) from WSR-88D, and hourly HydroEstimator products for the period October 2002 to June 2003 were used in this analysis. Daily co-operative rain gauge measurements were used in validating the results. In order to make the validation totally independent, operational gauges which were part of the co-operative gauge network were removed.

3. METHODOLOGY

The basic methodology followed in this work is similar to that of the MPE (Seo and Breidenbach, 2002) which combines radar and rain gauge data. In order for radar or satellite rainfall estimates to be merged with gauge data in the optimal estimation framework (Seo, 1996), however, they need to be unbiased. Hence, the first step toward quantitative integration is to correct for biases in the radar and HydroEstimator product. A local bias correction algorithm, similar to the one used in the operational MPE is used to correct for biases in the radar and HydroEstimator. For the details of the local bias correction algorithm, the reader is referred to Seo and Breidenbach (2002). The technique collects collocated pairs of radar-rain gauge and satellite-rain gauge values, and calculates the respective biases as the ratio between the sum of rain gauge values and the radar or satellite values within a circular window, the radius of which is an adaptable parameter. The local bias values are then interpolated to entire analysis domain (i.e. the RFC service area) to get the local bias fields for radar and satellite estimates. To obtain the local bias-corrected estimates, the radar and satellite rainfall estimates are multiplied, at each HRAP bin, by their local bias values. In the second step, the local bias corrected radar and local bias corrected satellite rainfall fields are mosaicked by filling the gaps in the radar field with satellite field thereby creating a local bias corrected remotely sensed rainfall field. The third step consists of merging the local bias corrected fields with the rain gauge data using optimal interpolation technique (Seo 1996).

A sample set of analyses illustrating single- and multisensor analyses appears in Fig. 1. Note that the satellite-estimated field fills in much of the analysis in the eastern portion of the area.

In order to determine the incremental value of satellite, radar and rain gauge merging compared to other analysis, four types of fields were generated viz. rain gauge only analysis, local bias corrected radar and satellite mosaicked field merged with rain gauge analysis, local bias corrected radar field merged with rain gauge analysis and local bias corrected satellite field merged with rain gauge analysis. These four analysis fields were validated against independent daily co-operative rain gauge network data. The validation statistics calculated are bias ratio (validation gauge / analysis field), Root Mean Square Error (RMSE) and correlation coefficient. Since the validation data are daily accumulations, we have selected the days for which we have results for all 24 hours. In this paper, we present validation results for the cool season month, December 2002. After accounting for missing and incomplete days, there were six 24-h periods with extensive precipitation during the month, and a total of 570 gauge observations.

The present analysis is focused on the western portion of the CNRFC area of responsibility, because of a scarcity of any rain gauge data and generally dry conditions during this month in the eastern portion. A thorough analysis based on a full year’s worth of data, and the entire CNRFC area, will be presented at the conference.

4. RESULTS AND DISCUSSION

Presented in Fig. 2 (a-d) are scatter plots between the daily validation gauges and gauge only analysis field (GAGE ONLY), local bias corrected radar and satellite mosaicked field merged with gauge data (MERGED (G+R+S)), local bias corrected satellite merged with gauge data (MERGED (G+S)) and local bias corrected radar merged with gauge data (MERGED (G+R)), respectively, for western part of the RFC, for all six cases in December 2002. The better analyses feature biases closer to unity, smaller RMS errors, and higher correlation coefficients. The validation statistics for the three-sensor merged analyses (Fig. 2b) indicate some improvement over the other three in terms of bias ratio (bias ratio of 1.09 vs. 1.19 for the gauge-radar analysis) and marginal improvement in terms of RMS error (12.36 mm vs.12.46 mm for the gauge-radar analysis). In terms of correlation, the radar-gauge-satellite analyses and gauge-radar are similar.

Thus the introduction of satellite information appears to lead to some improvement in the overall analyses, but more importantly, provide a source of remotely sensed precipitation information in radar coverage gaps. This result is consistent with those of Gourley et al. (2002), who applied a similar multisensor merging approach (QPE-SUMS) to precipitation estimation in Arizona. However, our approach utilizes an operational satellite precipitation product, rather than a locally-generated satellite product as is used in QPE-SUMS.

5. CONCLUSIONS AND FUTURE PLANS

The local bias correction improves the original satellite estimates (intermediate step, not shown in this paper). When these local bias corrected satellite estimates are mosaicked with local bias corrected radar estimates to fill gaps in the radar field, and merged with rain gauge data, the final merged analysis shows some improvement over other analysis fields when validated against independent rain gauges. This improvement will likely be most apparent in areas with at least some minimal coverage by rain gauges but significant gaps in radar coverage. In regions where there are not enough gauges to bias correct satellite estimates, the incremental value to the multisensor analysis is dependent on the quality of the satellite estimates themselves. An important conclusion of this study is that it presents a methodology for objectively integrating satellite estimates into the operational MPE algorithm. This significantly saves time in generating operational QPE over current manual technique of inserting SPE to fill in radar coverage gaps.

We plan to expand the study to include other RFC's and to confirm out initial conclusion that satellite precipitation estimates consistently add value to the current operational multisensor precipitation estimation procedure.

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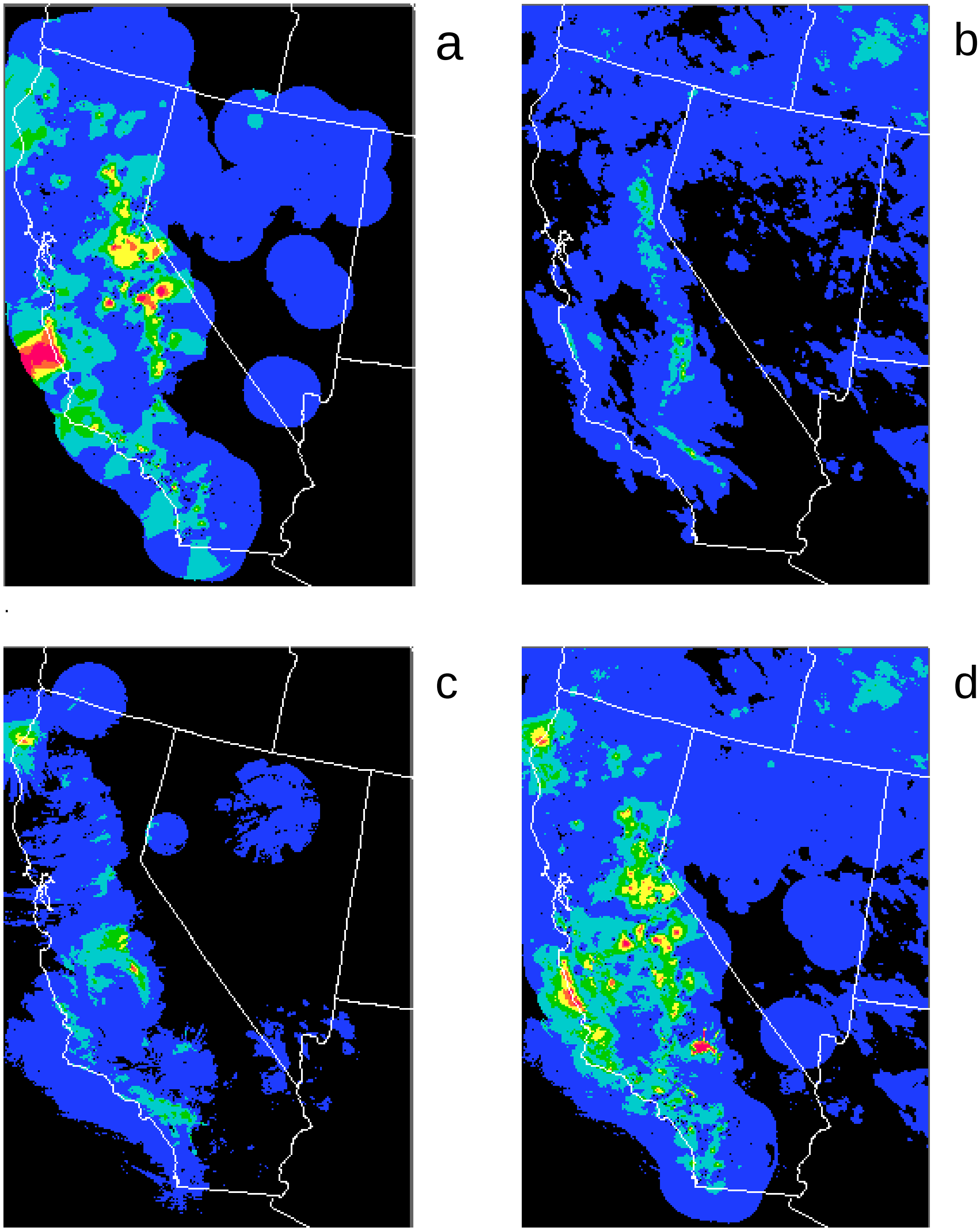

Figure 1. Precipitation analyses for the 24-h period ending 1200 UTC 17 December 2002. Analyses are from (a) rain gauges, (b) bias-corrected satellite Hydroestimator, (c) bias-corrected radar, and (d) gage-radar-satellite merged. Color coding is dark blue (> 0 mm), cyan (> 2.5 mm), green (> 12.5 mm), yellow (> 25 mm), red (> 50 mm).

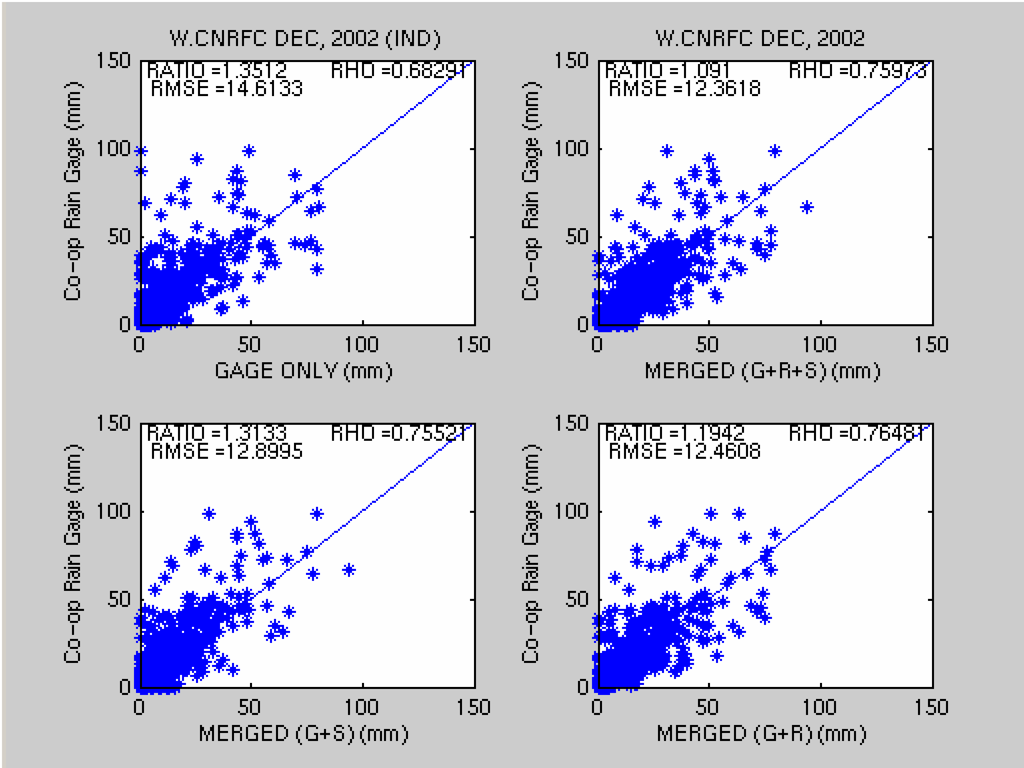

Figure 2. Scatter plots between (a) Co-op gauge data and gauge only analysis (top left), (b) Co-op gauge data and; local bias corrected radar and satellite merged with gauge analysis, (top right) (c) Co-op gauge data and; local bias corrected satellite merged with gauge analysis (bottom left) and (d) Co-op gauge data and; local bias corrected radar merged with gauge analysis (bottom right) for the western part of CNRFC region.