VALIDATION OF SATELLITE-DERIVED RAINFALL ESTIMATES AND NUMERICAL MODEL FORECASTS OF PRECIPITATION OVER THE UNITED STATES

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ABSTRACT

Various satellite-derived and radar-derived estimates of precipitation and numerical model forecasts of precipitation are validated over the U.S. using the Climate Prediction Center rain gauge analysis as the reference standard. The spatial scale of the estimated and reference data sets is 0.25^{o} of latitude and longitude, and daily accumulations (1200-1200 U.T.C.) are used. This validation activity began in April, 2003 and continues to the present time. New results are posted each day at http://www.cpc.ncep.noaa.gov/products/janowiak/us_web.shtml

1. THE VALIDATION REFERENCE DATA SET

The standard of comparison for all validation results that are discussed in this paper is the Climate Prediction Center (CPC) daily (1200 – 1200 U.T.C.) rain gauge analysis (Higgins et al. 2000) which contains rain gauge information from over 7000 stations across the U.S. each day. The gauge data are quality controlled by removing duplicates, ensuring that clouds were present for observations of non-zero precipitation amounts, and “buddy checks” are performed. The data are then objectively analyzed to a 0.25^{o} latitude/longitude grid (Cressman 1959). A typical geographic distribution of the rain gauge locations is shown in Figure 1.

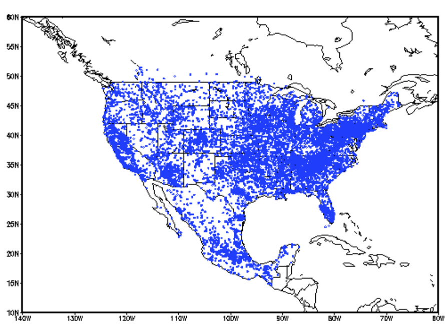

Figure 1. Typical distribution of rain gauge data in the CPC daily rain gauge analysis

Because the data have been objectively analyzed, the spatial coverage of very light intensity observations is inflated and the intensity of intense rainfall events is damped. This is an artifact of all objective analysis techniques but is particularly inherent in the Cressman scheme and the effect is depicted in Figure 2. Note the large coverage of precipitation of < 1 mm day^{-1} (lightest shading) in Figure 2 which is caused by the interpolation procedure. It is for this reason that the spatial coverage statistics that are described in the following section use a threshold of 1 mm day^{-1} instead of zero.

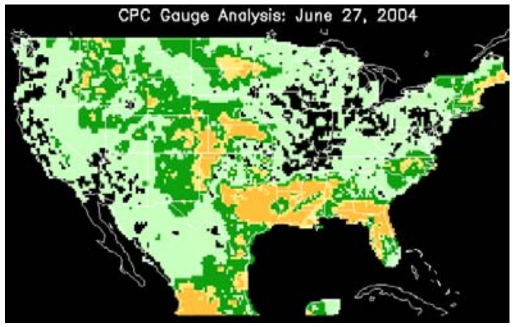

Figure 2. Daily rainfall accumulation from the CPC daily rain gauge analysis for June 27, 2004.

2. THE VALIDATION PROCEDURE

At the present time, eighteen different satellite estimates and model precipitation forecasts are validated. These estimates are grouped into five categories on the validation web page so that the techniques with similar characteristics appear together. For example, estimates from techniques that use only infrared (IR) imagery appear in category "IR". The five categories are:

- Blended passive microwave (PMW) and Infrared (IR)
- Merged PMW only
- IR
- IR and Visible
- Numerical Weather Prediction (NWP) model

A brief description of how the estimates are derived and the originating institution that provides them can be found at the validation web site (see Abstract for the web address).

To ensure a matched sample, each time the validation process is initiated, it first checks each algorithm for the presence of missing data. At each grid location where missing data are encountered in *any* algorithm estimate the values are set to a missing value in *all* the estimates for that day. A standard suite of statistics are then computed and displayed, along with graphical maps of the daily accumulated precipitation from the rain gauge analysis, the radar-derived estimates, the estimates from the algorithm of choice, and the difference from the gauge analysis. An example graphic for a single precipitation estimation technique and day is shown in Figure 3. A contingency table is also displayed that shows the "hits" and "misses" for the occurrence of precipitation, using 1 mm day^{-1} as the threshold for rain v.s. no rain. Note that radar estimates are used both as an estimate to be evaluated and (separately) as the validation reference standard. This was done because of the differences between the radar and rain gauge analyses, i.e. the rain gauge data provides the most accurate reference standard but the gauge network is not spatially complete. Conversely, the radar data are not as accurate as the gauge data but they provide a spatially complete field, except for regions in the West where mountain beam blockage is prevalent.

A standard suite of statistics is computed each day for each technique that is evaluated to assess the accuracy of the estimation algorithm in terms of spatial coverage and intensity of the precipitation.

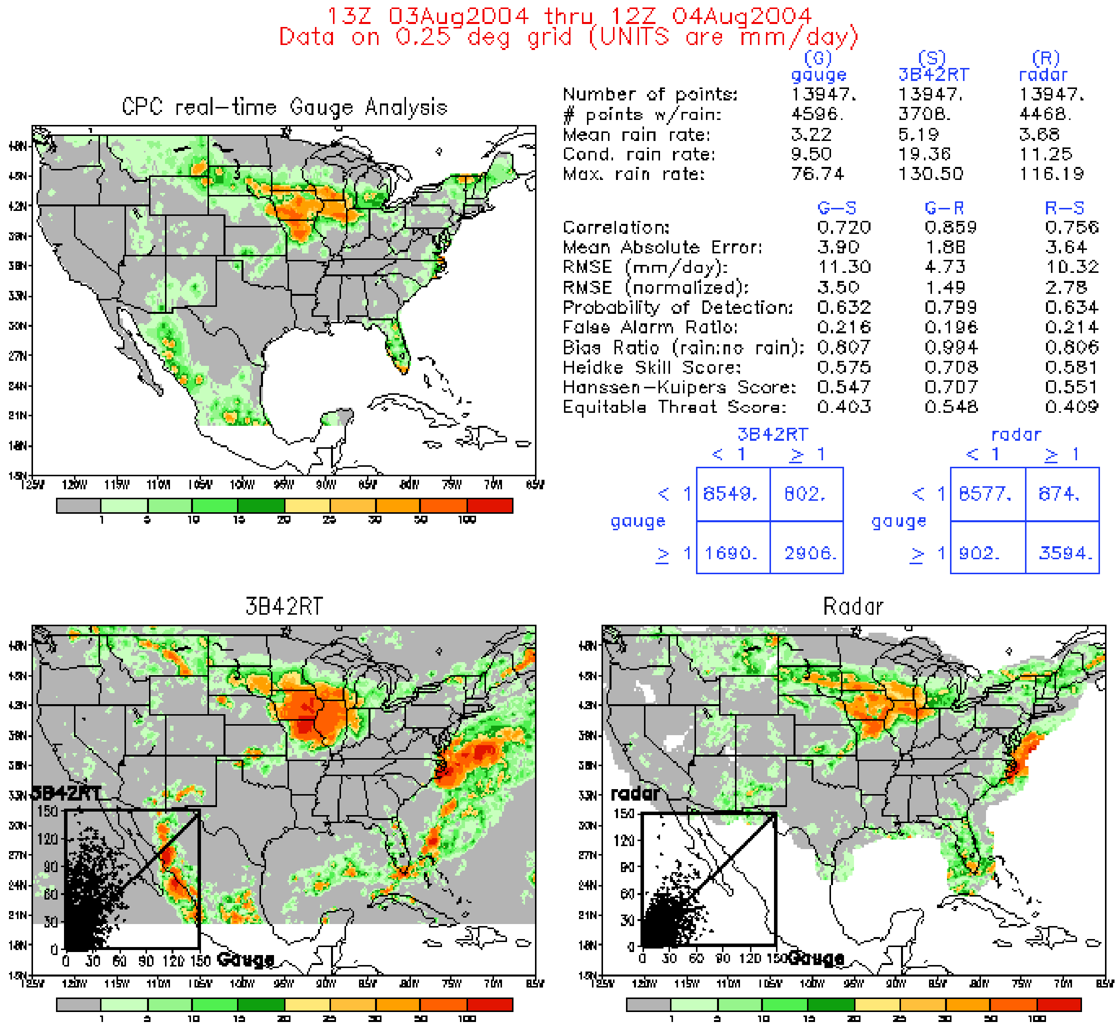

Figure 3. Example of daily validation graphics and statistics for the U.S. validation web page. The headings above the columns in the upper right corner depict “G” for gauge, “S” for satellite, and “R” for radar.

3. VALIDATION RESULTS

Results are presented for both the warm season, when precipitation is primarily convective in nature, and for one cool season when stratiform precipitation dominates. The warm season results, which are displayed in Figure 4, show time series of spatial correlation and Heidke skill score for radar (thick solid line), the NWS/NCEP global forecast model (GFS) 12-36 hour precipitation forecast (dotted line), and the best score by *any* of the satellite estimates for a given day (thin solid line). For almost every day during June-August 2003, the radar performs best and the model forecasts worst compared to the rain gauge analyses. Note that the satellite estimates are very close to the radar values in both statistics over the entire 92 day period. In contrast, the GFS model predictions perform better during the cool season (Figure 4) and the performance measures are much closer among the radar, satellite and model. In fact, the model forecasts often outperform the radar and satellite estimates both in terms of spatial correlation and skill during the cool season.

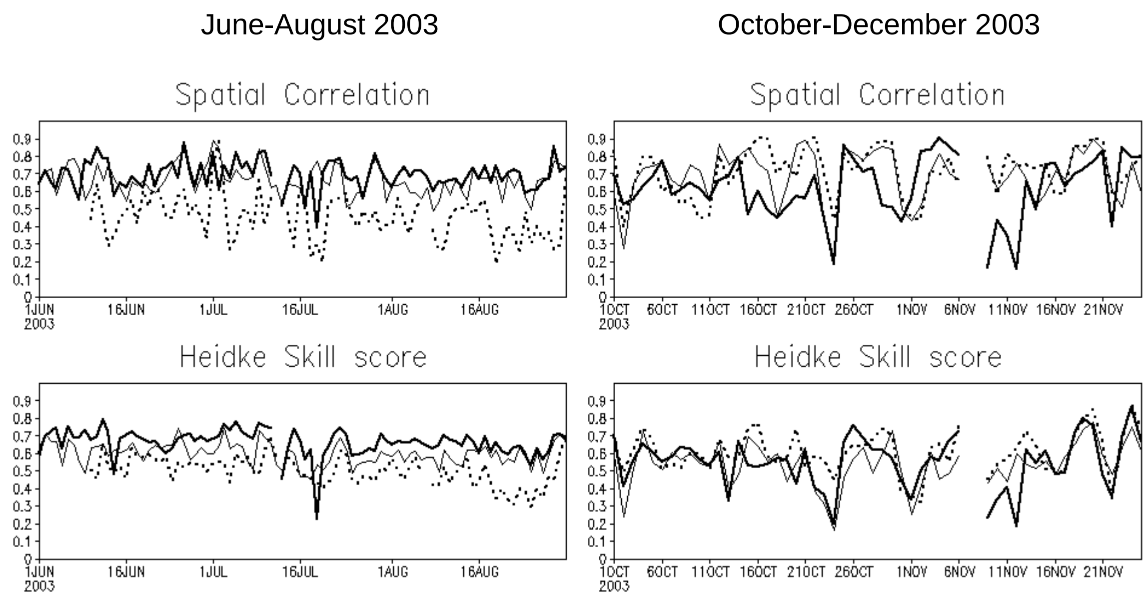

Figure 4. Time series of statistics of a comparison with validating rain gauge analyses over the U.S during June-August, 2003 (left) and October-December, 2003 (right). Thick solid line is radar, dotted line is the GFS model forecasts, thin solid line is the satellite estimate with the best statistic for each day.

An analysis of the validation results during the U.S. summer season reveals a consistent positive bias in the satellite estimates. This observation is depicted in Figure 5, which depicts areas of eastern Montana with rainfall amounts in excess of 40 mm day^{-1} from the satellite estimates but amounts of less than 5 mm day^{-1} from the rain gauge data. Note that radar also overestimates considerably although the amounts are somewhat lighter than the satellite estimates. The “rediscovery” of this positive bias is consistent with the earlier studies of Scofield (1987), Rosenfeld and Mintz (1988) and more recently McCollum et al. (2001) who found that significant evaporation occurs in semi-arid regions between the cloud base and surface. In fact, Rosenfeld and Mintz estimate conservatively that 30% of the rainfall evaporates in the first 1.6 km below the cloud base in semi-arid regions at rainfall intensities as high as 80 mm h^{-1}. One way to account for this overestimation is to use relative humidity data to modulate the rainfall estimates. Scofield (1987) adopted this approach by using the mean humidity from the surface to 500 hPa from numerical forecast model analyses.

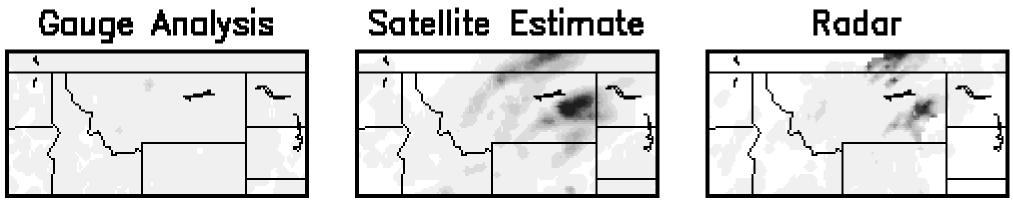

Figure 5. Estimated rainfall over the 24-hour period 1200 UTC 12 August 2003 to 1200 UTC 13August 2003.

To ensure that the gauge analysis was not in error, the gauge results were verified by contacting the Glasgow, Montana NWS forecast office, who in turn verified the precipitation measurements of cooperative observers in the region.

5. SUMMARY

The validation effort over the U.S. is but one of several continental-scale validation efforts that have been endorsed by the International Precipitation Working Group to provide helpful feedback to algorithm developers who can then modify and improve their estimation techniques. A similar continental-scale validation effort is underway over Australia and Europe and in the planning stages over Japan. Certainly, several such efforts over different climatological regions have the potential to provide substantial useful feedback that will help the precipitation estimation algorithm community.

The main results of this validation effort over the United States are:

1. Satellite estimates of precipitation are nearly as accurate as radar estimates during the warm season.

2. Numerical model forecasts of precipitation generally outperform the satellite estimates during the cool season.

3. Remotely sensed precipitation estimates (including radar) exhibit a substantial positive bias over semi-arid regions during the warm season due to evaporation of rain before it reaches the surface.

References

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