Improving Daily Satellite Rainfall Estimated over Africa by Merging With National Raingauge Observations

Tufa Dinku

International Research Institute for Climate and Society (IRI),

The Earth Institute at Columbia University

tufa@iri.columbia.edu

ABSTRACT

Climate data are needed in a number of applications including climate risk management and adaptation to climate change. However, the availability of climate data, particularly throughout rural Africa, is very limited. The available weather stations are unevenly distributed, with most of the stations located in cities and towns along the main roads. This imposes severe limitations to the availability of climate information and services for the rural community where, arguably, these services are needed most. Data available in the cities and towns also suffer from shortness of time series and severe data gaps. Satellite proxies have been used as alternatives because of their availability even over remote parts of the world. However, satellite rainfall estimates also suffer from a number of critical shortcomings that include heterogeneous time series, short time period, and poor accuracy particularly at higher temporal and spatial resolutions. An attempt is made here to alleviate these problems by combining point station measurements with the continuous spatial coverage of the satellite rainfall estimates. Raingauge measurements and satellite rainfall estimates are used to produce a 30-year rainfall time series at spatial resolution of 10 km and daily time scale. This involves quality control of raingauge data, and merging the satellite estimates with the raingauge measurements. Different merging approaches have been explored.

Study Region and Data

The data used in this study comes from two regions of Africa. The first is Ethiopia in the eastern part of Africa (Fig.1), while the second is eight countries in West Africa (Fig.2). Daily station data from 1991 to 2005 is used over Ethiopia. The merging is done using about 450 stations for each day while 25 validation stations are used for the evaluation. Data from about 100 station of Jun-Sep 2001 is used over West Africa. A cross validation scheme was implemented for validation. The Africa Rainfall Climatology (ARC) satellite rainfall estimate from NOAA-CPC has been used for this study.

Methodology

Interpolation of daily rainfall data is a challenging one. There are a number of problems that include:

1.Overestimation of rainfall occurrence or the spatial extent of rainfall; and

2. Underestimation of high rainfall values.

Satellite rainfall estimates, with appropriate techniques, could help to alleviate these problems. Though the accuracy is not very reliable at daily time scale, satellite rainfall estimates can provide information about the spatial structure of rainfall, including where rainfall did or did not occur. These characteristics are used for interpolation of station measurements.

A simpler methodology has been used in the Ethiopian case. A simpler approach is selected because the more sophisticated methods did not work well over the country's complex topography. The method involves the following steps:

i. Use gauge observations to remove bias from satellite estimates for each day;
ii. Interpolate station rainfall occurrence and combine it with satellite rainfall occurrence;
iii. Combine (i) and (ii).

Regression Kiriging was used for merging daily station data with corresponding satellite estimates over West Africa. The flat landscape and associated climatology allows the use of more sophisticated approach. The following steps are used:

i. Perform regression between gauge and satellite values extracted at gauge locations using data from plus-minus seven days from the current day;
ii. Compute residuals;
iii. Interpolate residuals;
iv. Apply regression to the satellite field;
v. Add (iii) and (iv);
vi. Convert satellite image to rainfall occurrence map (0 and 1)
vii. Multiply (v) and (vi).

Outputs

Figures 1 and 2 present sample outputs. Figure 1 compares raingauge data (A), satellite estimate (B), interpolated gauge-only data(C), and interpolated gauge with satellite estimate used as a secondary variable (D) over Ethiopia for 7 July 2003. The satellite product seems to overestimate rainfall over some parts of the country, but does capture the spatial extent and stricture of the rainfall. The gauge-only product(C) looks reasonable over data-rich parts of the country, but gives rainfall over the dry, and dada-sparse, part of the country. As mentioned earlier, this is a typical problem with interpolation of daily rainfall. The combined product (D) is better than both the satellite estimates and the gauge-only product. The false rainfall over southern and southeastern low lands is no more there, and there are higher rainfall values compared to the gauge-only product.

Figure 2 presents an example from West Africa. In this case, even the satellite estimate itself is better than the gauge-only product(C). The combined product (D) brings the satellite estimate closer to the gauge values. Figures 1 and 2 underscore the value of the satellite estimate. The satellite estimate contributes more over data-sparse regions. Note that the satellite estimate used here is not the best in terms of accuracy; it has been selected only because of its consistency. The project aims to produce better IR-only estimates.

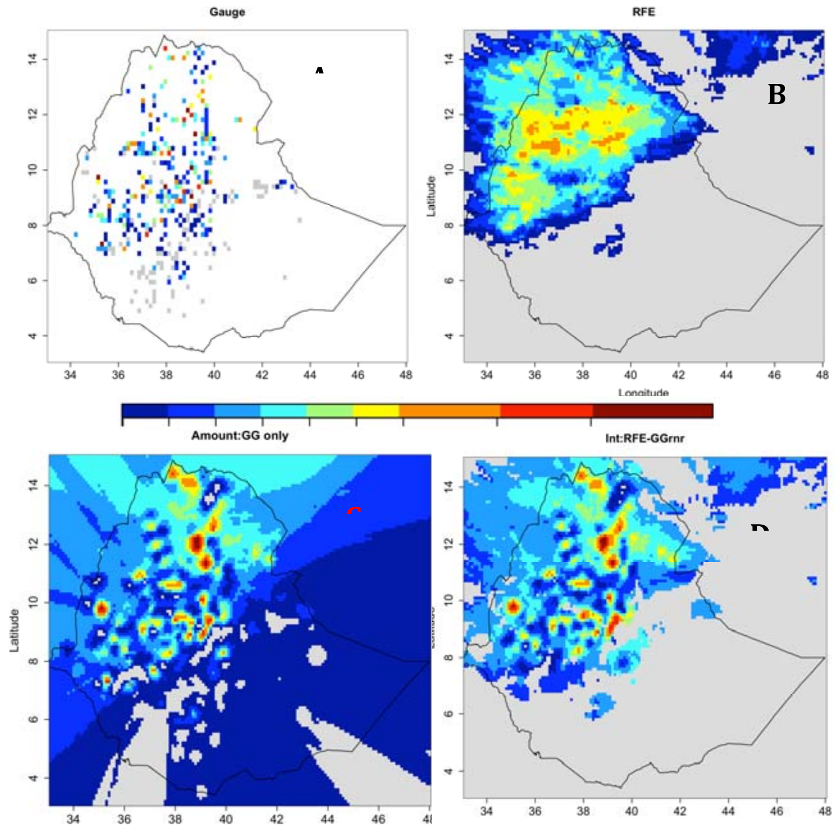

Figure 1: Comparison of raingauge data (A), satellite estimate (B), gauge-only gridded products(C), and combined gauge-satellite product (D), over Ethiopia for 7 July 2003. All products have spatial resolution of 0.1^{o} lat/long.

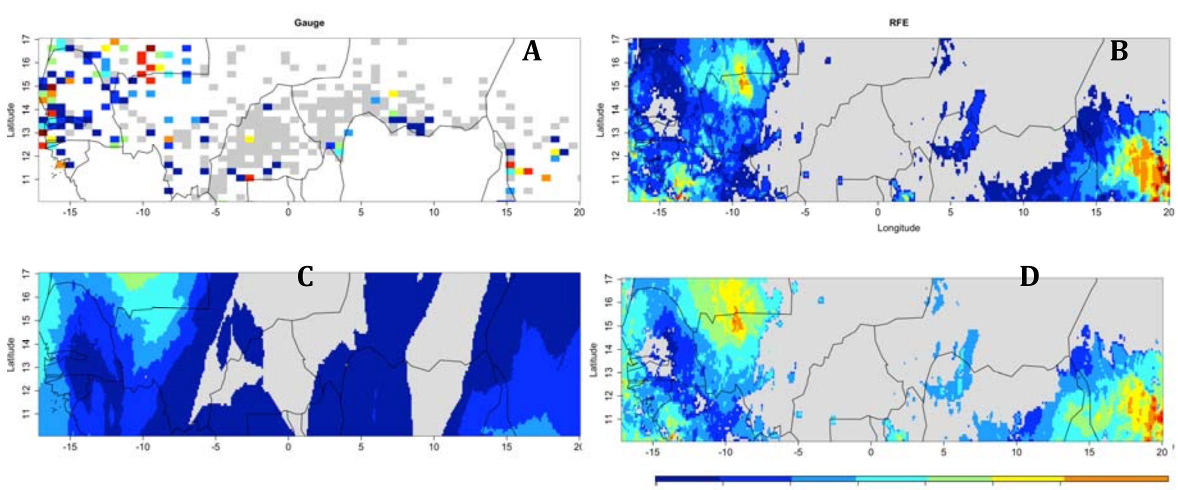

Figure 2: Same as Figure 1, but over West Africa for 10 AUG 2001.

Evaluation

<u>Ethiopia</u>

Frequency bias (FBS), probability of detection (POD) and false alarm ratio are used to assess the skill of the products in detecting the occurrence of rainfall. When appropriate, correlation coefficient, efficiency (Eff) and multiplicative bias are used to evaluate the performance of the different products in estimating rainfall amounts.. Figures 3a and 3b compare the satellite estimate and the merged product with respect of rainfall detection and estimating rainfall amounts, respectively. Both figures show that the merged product is slightly better the satellite estimate. Both products are not good in estimating rainfall amounts (low correlations).

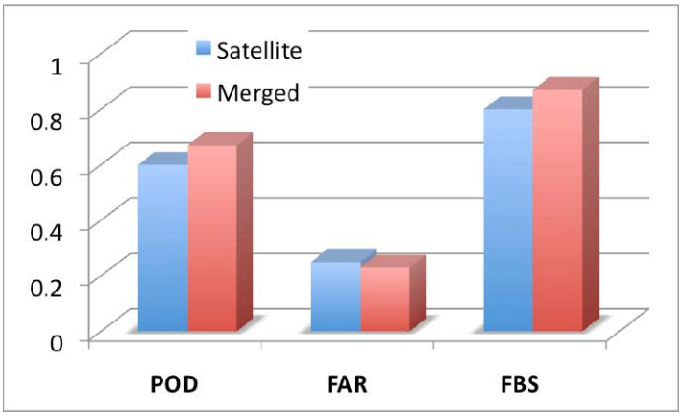

Figure 3a: Evaluating the skill of the products in rainfall detection.

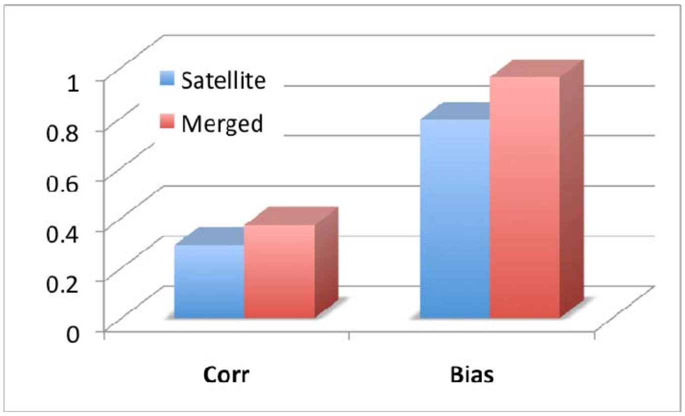

Figure 3b: Evaluating the skill of the products in estimating rainfall amounts

<u>CILSS</u>

Figures 4a and 4b compare the satellite estimate and the merged product with respect of rainfall detection and estimating rainfall amount. The satellite estimate and the merged product have similar performance except that the merged bias has less frequency bias. The satellite estimate and the merged product are similar in terms of detection because the merged product uses satellite rainfall occurrence directly. This is because satellite estimates over West Africa has good detection skill (86% in this case). The merged product has higher correlation and skill (Fig. 4b)

The above evaluations may not really show the value of the merged product. Quantitative evaluation could only be done where there are stations while the value of the merged product is actually over areas where there are no many stations. In this case qualitative comparisons of Fig 1 and Fig 2 may offer a better insight.

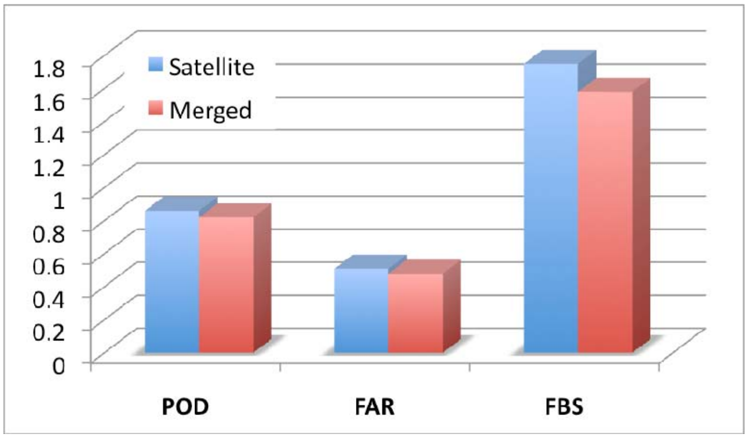

Figure 4a: Evaluating the skill of the products in rainfall detection.

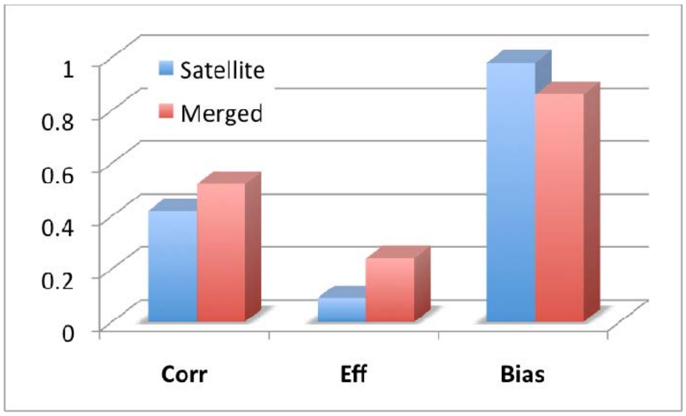

Figure 4b: Evaluating the skill of the products in estimating rainfall amounts.

Summary

Effort is being made to improve the availability daily rainfall time series over Africa by combining station observation with satellite rainfall estimates. Some merging approaches have been tested over Ethiopia in East Africa and some countries in West Africa. The qualitative evaluation of the merged product shows improvements over gauge-only or satellite-only products. Quantitative evaluations also show some improvements, but not as significant. Further investigation would be needed.