P2.2

VERIFICATION OF RAINFALL ESTIMATES OVER AFRICA USING RFE, NASA MPA-RT, AND CMORPH

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1. INTRODUCTION

In response to humanitarian needs in Africa, the US Agency for International Development (USAID) and the Famine Early Warning Systems Network (FEWS-NET) relies on NOAA/CPC to provide operational products such as rainfall estimates/anomalies, regional climate information, and forecast model data. Since its inception in 1995, the CPC/FEWS-NET group has continually worked to develop and improve its products including the Rainfall Estimation algorithm to now be called RFE version 2.0, which was originally based on methodology as described in Xie and Arkin (1996) and has been enhanced, as noted in Herman et al. (1997). The RFE is used in conjunction with several rain gauge-based climatology products to resolve regions of drought and floods over the African continent and surrounding regions.

2. DATA SETS

To determine the validity of the RFE product, this paper and associate poster will attempt to provide a preliminary comparison of the algorithm. Two other global precipitation methods; the NASA TRMM MPA-RT (Huffman et al. 2003) and CPC CMORPH (Joyce et al. *in review*), which are of similar spatial and temporal resolution scales, will be used in the validation assessments. Both of these rainfall products along with the daily RFE estimation are compared to Global Telecommunication System (GTS) ground stations over Africa.

2.1 CPC RFE v. 2.0

In January 2001, the Africa RFE 2.0 was transferred into operations at the NOAA/CPC. The RFE is created using several precipitation estimates and direct measurements. The algorithm inputs contain satellite observations from passive microwave instruments, which include the Advanced Microwave Sounding Unit (AMSU), and the Special Sensor Microwave/Sensor (SSM/I), infrared cloud top temperature measurements from the Meteorological Satellite (Meteosat 5 & 7), and daily rainfall gauge data from up to 1000 Global Telecommunications System stations from across the region. The 3-hour polar-orbiting microwave measurements and half-hour geostationary infrared satellite precipitation estimates are combined using linear interpolation and merged with gridded rainfall gauge measurements using predetermined weighting functions to create the RFE product (Xie 2001).

The RFE algorithm provides 24-hour rainfall accumulations on a horizontal scale of 0.1˚ x 0.1˚. The spatial extent of the product extends from

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40˚S to 40˚N and from 20˚W to 55˚E, which covers the African continent and surrounding regions. Daily rainfall accumulations are combined to provide data sets of weekly, 10-day (dekadal), monthly, and seasonal products. An example of the RFE product is shown in Figure 1a over the Sahel and Greater Horn Regions of Africa.

2.2 NASA TRMM MPA-RT

The NASA Tropical Rainfall Measuring Mission (TRMM) Multi-satellite Precipitation Analysis – Real Time (MPA-RT, 3B-42RT) is composed entirely of satellite measurements. The input satellite data is similar to that of the RFE consisting of microwave estimates from polar-orbiting satellite platforms, namely the TRMM Microwave Imager (TMI), SSM/I, AMSU, and the Advanced Microwave Scanning Radiometer (AMSR), as well as infrared data from the global constellation of geosynchronous platforms: GOES, Meteosat, and GMS.

As described in Huffman et al. (2003), the microwave data sets are merged together and used to calibrate the infrared estimates. Then, the estimates are combined with the resulting infrared measurements such that it fills in gaps in the microwave coverage. The MPA-RT is a global (60˚N – 60˚S) product, which is produced on a 3-hour basis with a spatial resolution of 0.25˚ x 0.25˚. For comparison purposes the MPA-RT estimates are summed into daily files. An example of a daily rainfall estimate over central portions of Africa is shown in Figure 1b.

2.3 CPC CMORPH

The CPC Morphing (CMORPH) algorithm is a new global rainfall product introduced in November 2002 that also depends on passive remote sensing estimates. Similar satellite platforms to the RFE and MPA-RT techniques are used in this product, but the algorithm takes a different approach by taking advantage of the superior precipitation estimates of the microwave data and the higher temporal resolution of the infrared data, while compensating for the sparse time-sampling of the microwave and weak instantaneous connection between infrared data and precipitation rate. The CMOPRH algorithm begins by determining the time sequence of feature motions maps from the infrared brightness temperature data, and then these maps are used to provide the displacement vectors for “morphing” from one instantaneous microwave estimate to the next, whenever such images are locally available.

The CMORPH product is produced globally from 60˚N – 60˚S on a latitude/longitude grid that provides an 8km scale at the equator. The finer temporal resolution of the geostationary infrared data allows the rainfall estimates to be disseminated every half-hour, which the CPC/FEWS-NET group converts into daily precipitation files. Figure 1c shows a similar example, as the RFE and MPA-RT, of the daily CMORPH rainfall estimate over Africa.

3. RESULTS

The CPC generates daily global precipitation and temperature files for over 7000 world-wide locations using METAR and synoptic data. METAR (hourly data) and synoptic (6-hourly data with 3-hourly data used to fill gaps) observations are collected both manually and through automated observing systems, then transmitted via the Global Telecommunications System (GTS) to NCEP in Camp Springs, MD.

To quantify the performance of the three algorithms, 1259 GTS stations over the African continent were selected for validation purposes. However, many of these stations are unreliable and incorrectly label missing values as zero rainfall, so it is necessary to only use stations that report daily rainfall. To resolve this quality control issue for this research, only stations that reported greater than 0 mm will be used in the comparisons.

After each station was selected as having reported non-zero rainfall for the previous 24-hour period, the site is co-located by latitude and longitude to the nearest grid box of each rainfall estimate. In this point-to-grid box comparison, the stations are assumed to be “ground truth” for the rainfall product validation. Each of the three products were compared to the station data and daily biases are calculated. This type of comparison is necessary because unfortunately, it is nearly impossible to construct a precipitation analysis due to the unreliability and coarse spatial resolution of the gauge data (1 gauge per 23000 sq. km) and lack of other useful remote sensors such as ground-based radar.

As the GTS station data are utilized as input data into the RFE algorithm, a slightly different approach is adopted to make the comparisons. The method used in this research drops a random 10% of the station data, while re-implementing the

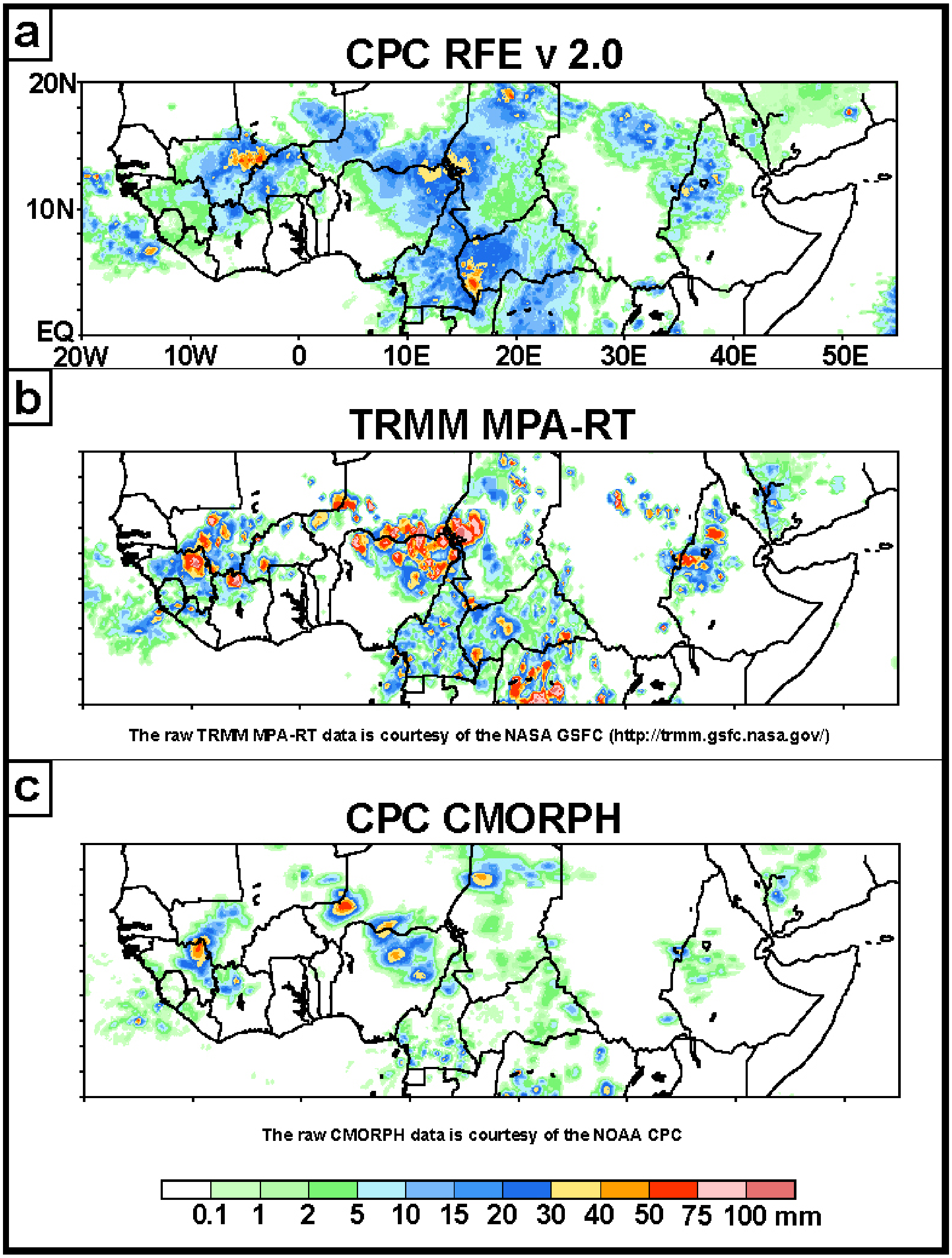

Figure 1. Sample rainfall estimations from the Sahel to the Greater Horn regions in Africa from 4 August 2003 for a) RFE v 2.0, b) TRMM MPA-RT, and c) CPC CMORPH

RFE algorithm. The station data thus removed are then used as an "independent" comparison to the product. This technique is repeated 10 times for each day, removing a unique 10% of the GTS data, to ensure that the entire African continent is represented in the comparisons.

Figures 2 and 3 show the mean bias (GTS station data minus rainfall product estimations) and standard deviation of the mean difference, respectively. Both the RFE and MPA-RT products are compared from January through August 2003, while CMORPH product is included from April 2003 onward since it is relatively new and experienced several major upgrades prior to that time. The x-axis of both figures represents successive intervals in the amount of estimated rainfall by each product. This was done to better determine the performance of the algorithms across the range of estimated precipitation amounts.

The mean bias of the RFE is represented by the blue (solid) line in Figure 2. The bias is around +10 mm (product underestimation) when the RFE algorithm estimates 0 mm of rainfall. A slight underestimate is shown for the two other products in this same category (MPA-RT, red short-dash; CMORPH, green long-dash), which is expected considering that for quality control purposes, all stations that contained a 0 mm report is removed from the GTS data set. As the product estimates increase (1-10 mm) all three products continue to slightly underestimate (+5 to +6 mm) when compared to reported rainfall. This trend continues as the estimated rainfall amount increases. The RFE, MPA-RT, and CMORPH show a mean bias of about 0 mm when the products estimate rainfall amounts between 11 and 20 mm. However, when the estimated amounts increase to between 21 and 50 mm, each product begins to overestimate. In this category the RFE does slightly better, overestimating by 4 mm, while the MPA-RT and CMORPH products produce slightly higher totals of 11-12 mm when compared to gauge data. When the products estimate precipitation at amounts greater than 50 mm, all three products, again, show a negative bias in rainfall. The CMORPH (overestimation - 25 mm) shows the best performance when compared to the RFE (-39 mm) and MPA-RT (-48 mm). However, for this category the number of data points is significantly lower than for lighter categories (the number of data points is in parenthesis below each category on Figure 2). It is also interesting to note that in the >50 mm bin the three products show progressively greater average difference for progressively larger intrinsic grid sizes. It is possible that the relatively rare high rain rates are progressively suppressed by the additional averaging implicit in moving to larger grid boxes.

Figure 3 represents the standard deviation of the mean bias. This was calculated to show the fluctuations of the differences between each product and the GTS station data. All three products show similar trends as the estimated rainfall amounts increase. Deviation amounts are not meaningful for the 0 mm because of the station quality control used. The standard deviation for the RFE is slightly better (14 mm) than the MPA-RT and CMORPH (both 16 mm) when the products estimate rainfall amounts from 1-10 mm, however, from 11-20 mm the CMORPH shows slightly less deviation (14 mm), while the RFE and MPA-RT show a deviation of 16 mm. When the rainfall categories are higher than 21 mm, all three products begin to show larger deviations. The trends increase to around 21-25 mm deviation for the 21-50 mm category and an even higher deviation (39-44 mm) for rainfall that is estimated by the products to be above 50 mm. The increase with increasing rain rate is both a result of the smaller number of samples and the intrinsic increase in the variability of rain rates.

4. SUMMARY

The preliminary results above show similar findings and trends of the mean bias and standard deviation for the RFE, TRMM MPA-RT, and CPC CMORPH rainfall products over Africa. Since the RFE product is used as the primary rainfall estimate at CPC/FEWS-NET, the results have greater implications as the group expands and begins to focus on weather extremes on an international scale. Future work will include comparisons with independent data sets from individual African countries that are represented under the FEWS-NET program. Other work will be comprised of fine scale evaluations to verify the performance of these products over mountainous, tropical, and semi-arid regions of the continent. Additional products and work can be found at: http://www.cpc.ncep.noaa.gov/products/fews.html

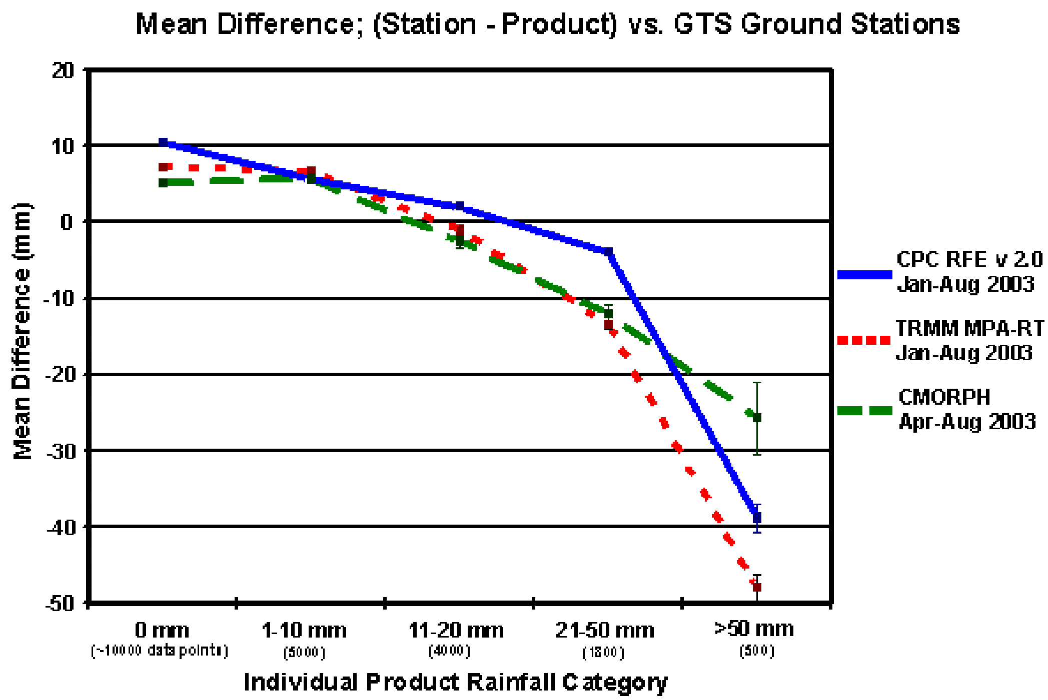

Figure 2. Mean difference of three daily rainfall estimates over Africa. The rain amounts (x-axis) represent the categorical amount of precipitation estimated by each product.

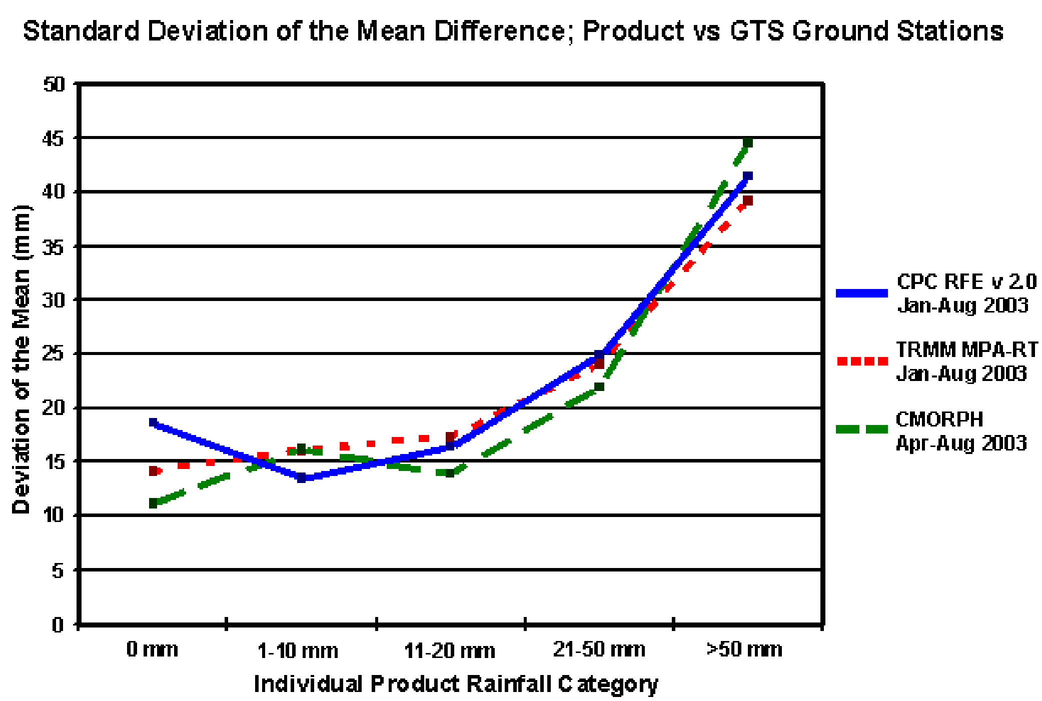

Figure 3. Similar to Figure 2, but showing the standard deviation of the mean difference.

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