



The Use of Gridded Climate Data sets for Improved Climate Services and Climate Change Assessment in the Greater Horn of Africa

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Abstract

The IGAD Climate Prediction and Applications Centre (ICPAC) in collaboration with the National Meteorological and Hydrological Services (NMHSs) of countries in the Greater Horn of Africa region, FEWSNET, PREPARED project and the University of California, Santa Barbara, has produced improved regional and national gridded rainfall data sets that can be used for various applications. A satellite-derived background rainfall data set known as CHIRPS (Climate Hazards Group InfraRed Precipitation with Station data) was blended with station observed monthly and dekadal rainfall data provided by National Meteorological Services in the GHA region to generate a new and improved data set. The tool used for blending was the GeoCLIM (Geo-spatial CLIMatological) analysis tool. These high resolution (5X5 km grid space) blended monthly and dekadal rainfall data sets produced using the GeoCLIM tool can be employed to develop several products, including baseline climate maps, trends, drought indices and the length of growing periods. The data sets can also be used to identify climate hotspots and conduct vulnerability assessments. The initiative, which includes capacity-building through training of staff from member countries on climate data gridding, has been financially supported by USAID-East Africa, the IGAD-UNDP project and the African Development Bank (AfDB). This paper discusses the approach used to generate the data sets, products developed and limitations in using the data sets.

1. Introduction

The demand for credible climate information that is timely, trusted, usable and tailored to user-specific needs is growing from time to time. Such data sets are vital for rational decision making in various socio-economic sectors, including agriculture, water, health and disaster risk management as well as in addressing the challenges of climate change.

The most common sources of data for generating weather and climate information are station observations. Currently there are tens of thousands of meteorological stations around the world that are being used for routine monitoring of weather and climate. The spatial coverage of meteorological stations in Africa in general and in the Horn of Africa in particular is poor for various reasons. This has posed a serious challenge to providing improved climate services.

Another key source of data on weather and climate are meteorological satellites. There are currently several meteorological satellites which have gathered a huge volume of data in various forms. Satellite based data which have the advantage of good spatial coverage and availability in near real time need to be exploited to improve the quality of climate information.

In order to address the challenge of inadequate station coverage and poor climate services, several organizations have recently made efforts to produce blended and gridded climate data sets by combining ground observations with satellite observations and reanalyzed model data. Such data sets include Climate Hazards group Infrared Precipitation with Stations (CHIRPS), Tropical Rainfall Measuring Mission (TRMM), Global Precipitation Measurement (GPM), Enhancing National Climate Services (ENACTS), Nonhydrostatic Mesoscale Model (NMM) and Coupled Model Intercomparison Project Phase 5 (CMIP5), among others.

ICPAC, in collaboration with FEWSNET, the University of California Santa Barbara and PREPARED project, has been making efforts to generate improved regional and national data sets by blending more station data with CHIRPS and by training staff from member countries in climate data gridding. The National Meteorological and Hydrological Services (NHMSs) of countries of the GHA were fully involved in the development of the new data set. Staff of the data management teams of the member countries were trained in gridding techniques and eventually gridded their own data sets. Experts from user sectors, like agriculture, disaster management and water resources, were also incorporated in the trainings.

2. Methodology and Data

The background Climate Hazard Infrared Precipitation (CHIRP) data are derived from NOAA CPC satellite rainfall estimates and infrared precipitation estimates derived from Cold Cloud Duration data. CHIRP data are blended with in-situ station observed data (obtained from the World Meteorological Organization's Global Telecommunication System) to give CHIRPS. CHIRPS data, which start from 1981 and incorporate 0.05° resolution satellite imagery with in-situ station data is a gridded rainfall data set which is also a function of elevation, latitude and longitude (Funk and others, 2014). This data set was prepared and provided by the Climate Hazard Group of the University of California, Santa Barbara. For each grid location in the CHIRP domain, the five nearest station observations are used to calculate an adjustment ratio for the CHIRP value. Each station is assigned a weight proportional to the square of their expected correlation. Closer stations receive higher weights. These five weights are then scaled to sum to 1 and used to blend the station data into a single modifier (ratio) that can be used to adjust the CHIRP estimates. This ratio was capped at 3.0 to limit the possible impact of bad station data (Funk and others, 2014). More information about CHIRPS is available at the University of Santa Barbara website (<http://chg.geog.ucsb.edu/data/chirps/>).

Monthly and dekadal observed data for a total of 102 stations were provided by the national meteorological services of the member countries covering the 1981-2014 period.

GeoCLIM is a user-driven geospatial climate data-management and analysis software tool, which supports provision of climate information services at regional to sub-national level. It addresses the issue of climate “data-gaps” in time and space, leverages on available observational field and satellite observations, and is an easy to use freeware with GIS compatibility.

The two data sets, namely the CHIRPS and the station observations provided by the national meteorological departments, are further blended to produce a new gridded data set as illustrated in Figure 1.

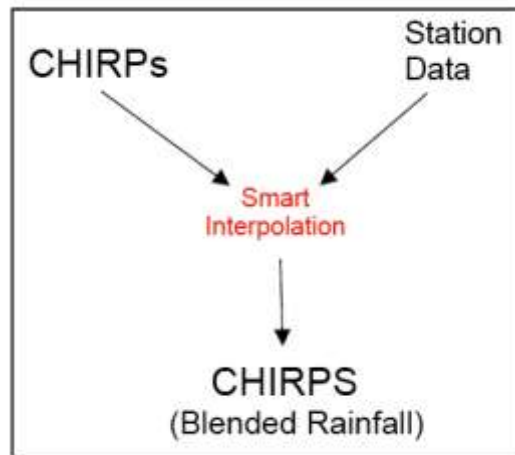


Figure 1: Diagrammatic representation of the gridding process. Here CHIRPs represents the satellite-derived background rainfall data set provided by Climate Hazard Group of the University of California and CHIRPS represents the new data set generated by blending CHIRPs with rainfall data from station observations provided by meteorological departments). Source: ICPAC, 2014.

3. Validation of the data set

Funk and others (2015) have discussed extensively the CHIRPS methodology and validation exercise made on the data set in different parts of the world.

We also have made an examination of the precision of the blended data by comparing CHIRPS vs. blended vs. station data for selected months and years (Figure 2). Four different years and four months from each of the four seasons in the region are purposively selected. The reference years used for the validation/comparison are 1981, 1990, 2000 and 2014. From the months January (representing the dry season), May (representing the wet season for the areas south of the equator), August (representing the wet season for the areas north of the equator) and October (representing short rains) are selected. Meteorological data for 102 stations are used to compare and validate the results of the satellite data and the blended grid data. Simple correlation and Pearson's correlation coefficients (r^2) are used to examine the strength of relationships between the three products (Table 1).

The result of the correlation between the station data versus the CHIRPS data shows a weaker correlation as compared with the blended data versus the station data. This indicates that the blended data are closely related to the station data, indicating in turn its enhanced accuracy compared with the raw satellite image or the globally blended data product. The coefficient of determination also reveals that the blended data product can better predict the values of the meteorological stations data, again confirming the superiority of the regionally blended product over the unblended CHIRPS data. In general, this exercise provides very good insights into climate data verification and validation using station records of over three decades.

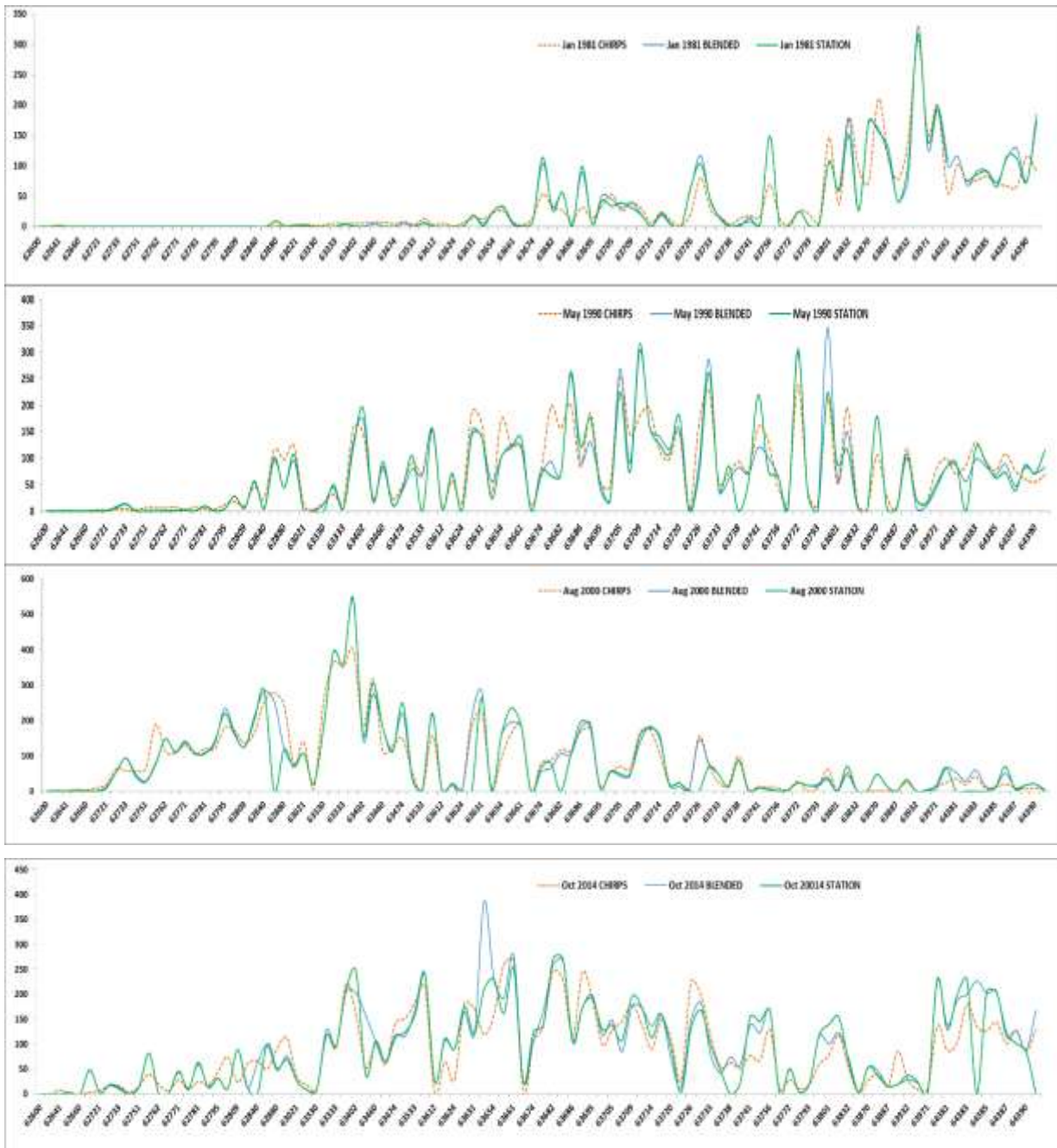


Figure 2: Visual Comparison of the CHIRPS, blended and met-station rainfall data for selected years and months.

In order to see the statistical strength of the relationship between the data types, the following results on simple correlation and regression model are generated.

Table 1: Correlation and Pearson's correlation coefficient (r²)

Reference Month & Year	Correlation (r)			Pearson's Correlation Coefficient (r ²)		
	CHIRPS vs. BLENDED	CHIRPS vs. STATION	BLENDED vs. STATION	CHIRPS vs. BLENDED	CHIRPS vs. STATION	BLENDED vs. STATION
January 1981	0.91	0.90	0.99	0.82	0.82	0.99
May 1990	0.90	0.87	0.95	0.81	0.77	0.91
August 2000	0.95	0.86	0.93	0.89	0.75	0.86
October 2014	0.82	0.84	0.89	0.71	0.70	0.79

4. Application of the data sets

4.1 Generation of mean (baseline) climates

According to the World Meteorological Organization (WMO), mean (baseline) climatology is produced by computing statistical averages of climate observations made over a period of 30 years. The current WMO reference period is 1981-2010. In the analysis and assessment of climate data it is usual practice to generate mean, reference or baseline maps to make comparisons with current conditions and compute anomalies. Improved monthly, seasonal and annual climatological maps for the GHA region have been produced easily using the new data set and the GeoCLIM tool (Figure 3 and 4). Such maps provide a snapshot of the distribution of mean rainfall over time and space. The maps also show the strong seasonality of rainfall across the region.

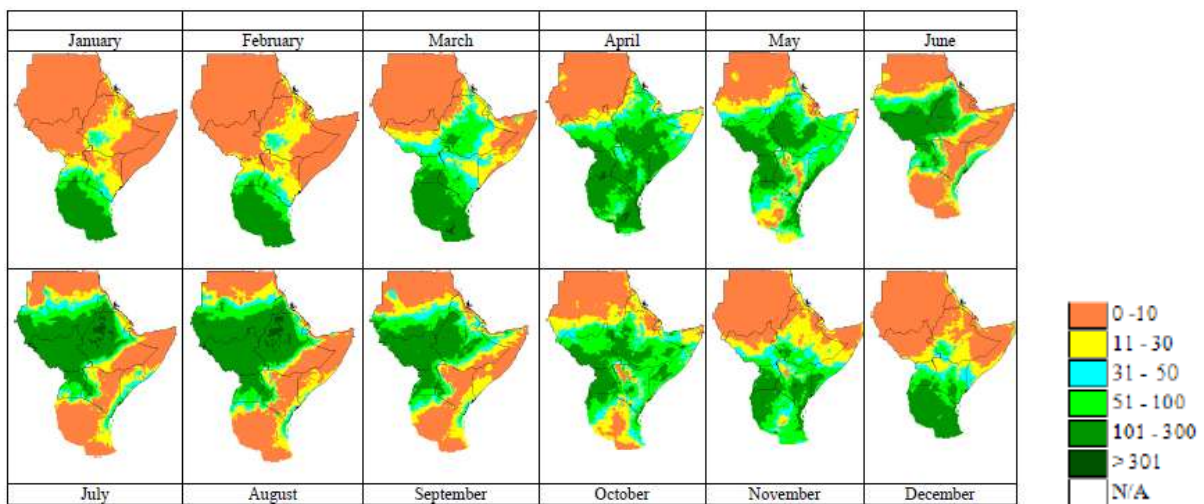


Figure 3: Monthly mean (baseline) rainfall distribution maps for the 1981-2010

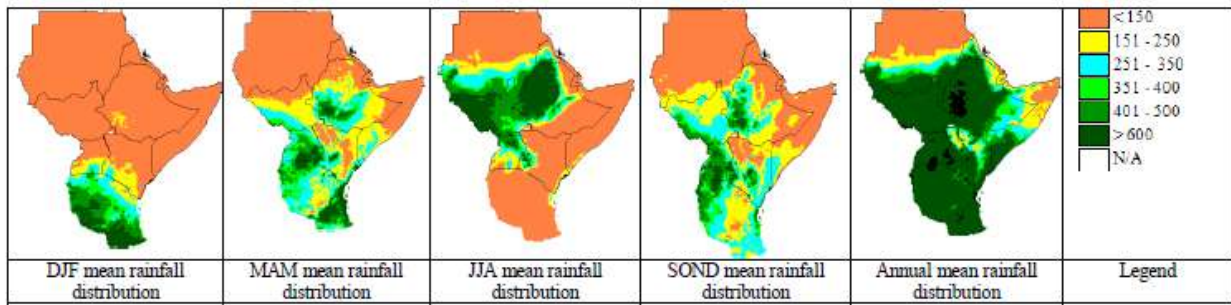


Figure 4: Seasonal and annual mean (baseline) rainfall maps for the 1981-2010 period

4.2 Coefficient of Rainfall Variability

The coefficient of variability (CV) is used to indicate stability and reliability of climate parameters, and higher values of CVs (≥ 30) generally indicate high variability and less stability (reliability) of a parameter over an area. Figure 5 shows maps of the CV of seasonal and annual rainfall over the GHA region. The maps clearly show that rainfall is highly variable in most parts of the region. This poses significant climate risk for socio-economic activities such as agriculture in those areas. Areas that have reliable rainfall are found in many parts of Tanzania, Burundi, Rwanda, Uganda, western Kenya, southern Sudan and the western half of Ethiopia.

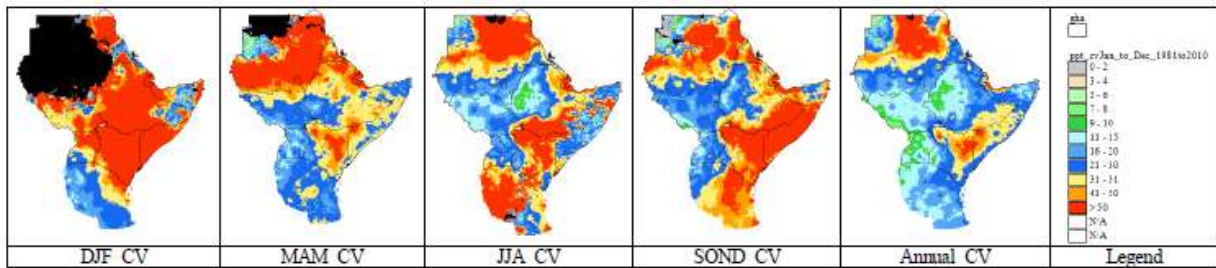


Figure 5: Coefficient of Variability (CV) of seasonal and annual rainfall in the GHA

4.3 Rainfall trend

Documenting observed variability and trends based on historically recorded climate data is the starting point in any climate change related studies. Figure 6 shows maps of observed seasonal and annual rainfall trends computed from the data sets. The maps show drying trends of MAM (March, April, May) rainfall in eastern Ethiopia and Kenya while a wetting trend has been observed in Sudan, Ethiopia and the western half of Kenya. An increasing trend in rainfall can be noted over Uganda, Kenya and Southern Ethiopia for the SOND (September, October, November and December) season. The JJA (June, July, and August) rainfall has shown an increasing trend over Southern half of Sudan and many parts of Ethiopia.

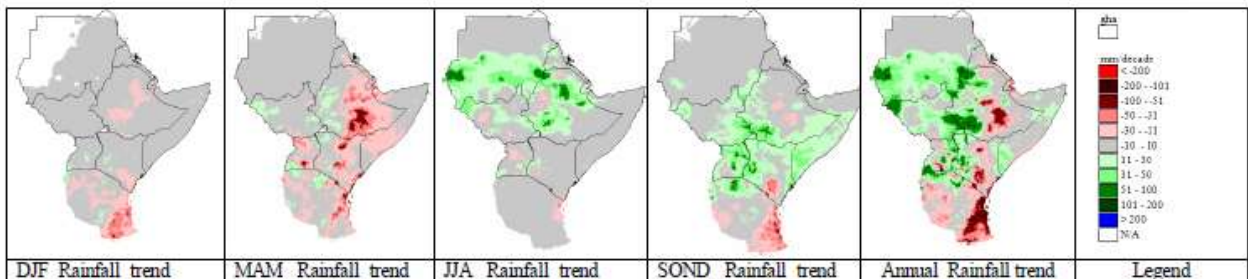


Figure 6: Seasonal and annual rainfall trends in the GHA

4.4 Drought monitoring

Drought is a recurrent feature of climate, which occurs in almost all climatic zones of the Earth. It has occurred in the past and will occur in the future, imposing its social, economic and environmental impacts on society. The Horn of Africa is one of the most vulnerable regions to drought in the world. Past drought events have inflicted enormous losses of human life and economic damage in the region, itself evidence of its vulnerability to drought.

Drought monitoring is an essential component of effective drought early warning systems and contributes significantly to drought disaster risk reduction. Drought is monitored using indices and one of the most widely used indices is the standardized precipitation index (SPI). The SPI shows precipitation shortfall and excess over a variety of time scales. Other indices used to monitor drought include the crop moisture index (CMI), the water requirement satisfaction index (WRSI), the soil moisture index (SMI) and the Palmer drought index.

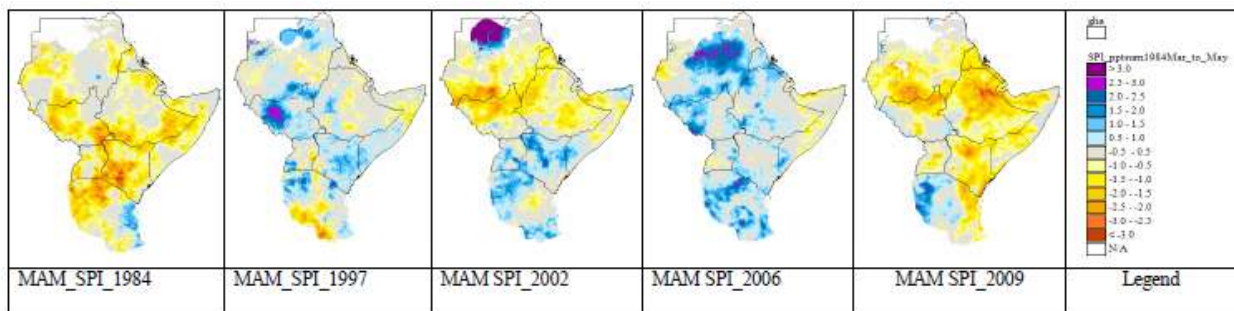


Figure 7: Distribution of the SPI for MAM in 1984, 1997, 2002, 2006 and 2009

Figure 7 provides maps of SPI generated using the data sets. The maps clearly show the drought and wet years, and the spatial extent and intensity of drought and wet events. MAM was dry for the years 1984, 2002 and 2009 while it was wet in 1997 and 2006 in most parts of the region.

5. Conclusions and recommendations

The existing meteorological station network in the GHA region is generally poor in terms of spatial distribution and it may remain so in the near future. This situation requires complementing ground observation with satellite data to fill the gap of data scarcity. This paper has presented the products that can be generated using an improved data set and the GeoCLIM tool. It shows the importance of making improved data sets and tools available to provide improved climate services. The validation exercise reveals that the regionally blended data are closely related to the station data, indicating its enhanced accuracy compared with the raw satellite image or globally blended data product.

The need to integrate climate information in investment decisions will continue to grow. This is because addressing the challenge of climate variability and change requires the integration of climate variables in the design of policies and plans and infrastructure investments. The IGAD Climate Prediction and Application Centre (ICPAC), which has a mandate to provide user tailored, accurate and timely climate information, should make further efforts to come up with more improved data sets by working closely with national meteorological departments and other relevant organizations. Ultimately improved data sets will benefit society in general as they are critical inputs to make better decisions at various levels.

6. References

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