Analysis of satellite monthly precipitation time series over East Africa

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Precipitation variability over East Africa (1/3)



Annual precipitation from GPCC Climatology at 0.5°

East Africa (EA) is characterized by complex topography and highly varying climatic conditions, which reflect into a marked geographic variability of precipitation...



Precipitation variability over East Africa (2/3)

... clustering...



Eight areas (clusters) were identified by applying a non-hierarchical k-mean cluster analysis to the GPCC_CLIM data on the basis of the characteristics of the precipitation annual cycle.

Clusters

1, 3, 6 & 8 Southeastern Ethiopia, Somalia, Kenya, Southern Uganda and Tanzania

2 Central Ethiopia (Rift Valley, W & E Highlands escarpments), part of Uganda, Kenya

4 Mountainous coastal Somalia (Gulf of Aden), Central Uganda, Congo

5 Sudan, Western Ethiopian Highlands

7 Northern Sudan, coastal Eritrea

Meyer-Christoffer, A. *et al.* GPCC Climatology Version 2011 at 0.25°: Monthly Land-Surface Precipitation Climatology for Every Month and the Total Year from Rain-Gauges built on GTS-based and Historic Data. doi: 10.5676/DWD_GPCC/CLIM_M_V2011_025 (2011).

Precipitation variability over East Africa (3/3)

... and different precipitation seasonality.



Meyer-Christoffer, A. et al. GPCC Climatology Version 2011 at 0.25°: Monthly Land-Surface Precipitation Climatology for Every Month and the Total Year from Rain-Gauges built on GTS-based and Historic Data. doi: 10.5676/DWD_GPCC/CLIM_M_V2011_025 (2011).

Drought events and precipitation measurements



Produced by EUMETSAT in collaboration with the COMET® Program

The frequency and impacts of these extreme events require a continuous monitoring of precipitation as a key variable for the inclusion of these phenomena in regional climatological studies and their timely forecast.

Satellite precipitation products are particularly necessary in EA to enhance the observational capabilities of sparse rain-gauge networks.

GPCC Full Data Product Version 6 Gauge-Based Analysis 0.5 degree number of stations per grid for year (Jan - Dec) 2001



Precipitation measurements from satellite

Algorithm	Spatial resolution	Time resolution	Input data	Producer/reference
3B42_daily v7	0.25°	daily	MW, GEO-IR, gauges	NASA/GSFC Huffman et al., 2007
CMORPH v1 bias corrected	0.25°	daily	MW, GEO-IR motion vectors, daily gauges	NOAA/CPC Joyce et al., 2004
GSMaP_MVK v5.222.1	0.1°	hourly	MW, GEO-IR, GEO-IR motion vectors	EORC/JAXA Aonashi et al., 2009 Kubota et al., 2007 Ushio et al., 2009
TAMSAT – TARCAT v2	0.0375°	monthly	GEO-IR, climatological calibration with rain gauges	University of Reading Grimes et al., 1999 Maidment et al., 2014
PERSIANN	0.25°	6-hourly	GEO-IR, PMW rainfall estimates to update model parameters	UC Irvine Hsu et al., 1997
3B31 v7	0.5°	monthly	TRMM TMI and PR	NASA/GSFC, JAXA Haddad et al., 1997
RFE v2	0.1°	daily	PMW, GEO-IR with GPI, GTS rain gauges	NOAA/CPC Xie and Arkin, 1996

Monthly accumulated precipitation was calculated for each satellite product and for the time period 2001-2009. All data sets were re-projected on a common grid at 0.5°.

Mean precipitation annual cycles (2001-2009) from satellite products at 0.5°





Satellite products reproduce the characteristics of the precipitation cycle of each cluster: wet season duration, identification of peak intensity months, and presence of a prevailing wet season in case of bi-modal cycles.



Precipitation intensity distribution of satellite products at 0.5°



- Consistency among the intensity precipitation distributions of the various satellite products.
- All bi-modal clusters exhibit precipitation distributions with 2 peaks at 25-50 and 100-150 mm; the mono-modal cluster 5 has a occurrence peak in the range 100-300 mm, whereas in cluster 7 (arid region with very scarce precipitation) most of the occurrences concentrate in the first 4 bins (< 50 mm).
- Satellite products generally overestimate the occurrences with monthly precipitation < 10 mm with respect to GPCC_FD.

Schneider, U. *et al.* GPCC Full Data Reanalysis Version 6.0 at 0.5°: Monthly Land-Surface Precipitation from Rain-Gauges built on GTS-based and Historic Data. doi:10.5676/DWD_GPCC/FD_M_V6_050 (2011)

Satellite precipitation estimate variability (1/2)



Seasonal six-member ensemble means (2001-2009)

A first assessment of the differences among the satellite products was obtained by analysing the standard deviations from the ensemble of the six monthly satellite products (Tian and Peters-Lidard, 2010).

This method is instrumental to identify situations that reveal particularly problematic for the precipitation retrieval from satellite.

Satellite precipitation estimate variability (2/2)



Seasonal average standard deviations from the six-member ensemble (2001-2009)

- 10°N

Ensemble standard deviation is linked to:

- precipitation intensity
- precipitation seasonality

orography

Standard deviation even greater than 80 mm over West Ethiopian Highlands in summer.

Comparisons between satellite products and GPCC_FD v6 at 0.5° (1/2)

Key points to be considered:

- GPCC_FD is the most accurate in situ precipitation data set of GPCC, nevertheless the local poor density (Somalia, Eritrea, and Djibouti) of rain stations has to be considered.
- This affects the quality of the GPCC_FD and of the satellite products that make use of rain gauge measurements.
- Satellite products exploiting rain gauge measurements (3B42 in particular) are expected to better agree with GPCC_FD data set. For these products comparisons with GPCC can not be interpreted as a completely independent validation.

Statistical parameters:

$$BIAS = \frac{\sum_{i} sat_precip_{i}}{\sum_{i} gpcc_fd_{i}}$$

$$RMSE = \sqrt{\frac{1}{N}\sum_{i} (sat_precip_{i} - gpcc_fd_{i})^{2}}$$

$$MAE = \frac{1}{N}\sum_{i} |sat_precip_{i} - gpcc_fd_{i}|$$

$$EFF = 1 - \frac{\sum_{i} (sat_precip_{i} - gpcc_fd_{i})^{2}}{\sum_{i} (gpcc_fd_{i} - \overline{gpcc_fd})^{2}}$$

$$EFF \text{ skill score of satellite estimates accuracy vs GPCC_FD}$$

$$\bullet \quad 1 \text{ best score}$$

- O satellite estimates are as accurate as the rain gauge mean value
- <0 rain gauge mean value is a better estimate than satellite estimates

Comparisons between satellite products and GPCC_FD v6 at 0.5° (2/2)

BIAS Root-mean-square error CMORPH CMORPH 3831 3831 1.8 180 RFE Root-mean-square error(mm) RFE PERSIANN PERSIANN 3542 3b42 1.5 150 GSMaP GSMaP TAMSAT TAMSAT 1.2 120 BIAS 0.9 90 0.6 60 0.3 30 0.0 CI.1 Ci.2 Ci.3 Ci.4 CI.5 CI.6 Cİ.7 ci.5 Cİ.6 CI.7 CI.8 CI.1 CI.2 CI.3 CI.4 CI.8 Efficiency score Mean absolute error 120 CMORPH CMORPH 3831 1.5 RFE RFE PERSIANN 100 Mean absolute error(mm) PERSIANN 3b42 3542 GSMaP 1.0 GSMaP TAMSAT Efficiency score 80 TAMSAT 0.5 60 0.0 -0.5 20 -1.0 0 ci.6 Cİ.5 CI.1 CI.2 CI.3 CI.4 CI.7 CI.8 CI.1 CI.2 ci.3 Ci.4 CI.5 CI.6 CI.7

- 1. TRMM-3B42 best performance satellite product in all clusters with MAE values in the range 5-25 mm/month and best Efficiency Score (EFF≈0.7 for all clusters) values.
- 2. RFE and TAMSAT exhibit similar performances in terms of MAE, RMSE, and EFF (>≈0.5), with lower BIAS values for TAMSAT.
- **3. GSMaP** results similar to those of **CMORPH** (MAE, RMSE, and EFF) with differences for cluster 5. GSMaP's BIAS values are more variable.
- 4. PERSIANN and 3B31 show very low EFF, even negative.

Comparisons between satellite products and GPCC_FD v6: the terrain elevation (1/3)

The complex orography can be an issue for the precipitation retrieval from satellite:

- IR-based retrievals can have problems to identify warm orographic rainfall
- MW-based retrievals rely on ice scattering over land, which can be moderate in case of warm orographic rain
- The presence of snow or ice on the ground is a further difficulty for the MW-based retrieval

Monthly mean precipitation as a function of elevation.

- Generally precipitation intensity increases with elevation (H > 250-500 m) with a trend which depends on clusters.
- Satellite products give similar results over grid cells with H < 250-500 m.
- Larger differences among satellite products are detected for H > 250-500 m.



Comparisons between satellite products and GPCC_FD v6: the terrain elevation (2/3)



Monthly mean precipitation as a function of elevation.

- For H > 1000-1500 m the precipitation increase with elevation becomes weaker (clusters 1, 2, 3, 4, 5, 8).
- Over high-elevated grid cells 3B31, 3B42, and CMORPH exhibit the highest precipitation intensity values.
- Cluster 7: scarce dependence between precipitation and elevation, but only 16 grid cells out of 96 have H > 500 m.

Comparisons between satellite products and GPCC_FD v6: the terrain elevation (3/3)



RMSE as a function of the elevation

Generally there is an increase in the RMSE with the elevation.

3B42 has the lowest dependence between the RMSE and the elevation and the lowest RMSE values.



2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011





Conclusions

- The different precipitation annual cycles characteristics of the region are identified by using the climatological data set GPCC_CLIM.
- The satellite data sets correctly reproduce the annual cycle identified by means of climatological data in terms of wet season duration, prevailing wet season (for bi-modal cycles), and intensity peak months.
- Insights on the satellite precipitation estimate variability can be obtained from the analysis of the standard deviation of the six satellite product ensemble. The greater standard deviation values are associated with mountainous areas and more intense precipitation.
- Performances of satellite products were quantified by comparisons with GPCC_FD data set. As expected and due to the use of GPCC data, 3B42 is the best performance satellite product with MAE in the range 5-25 mm/month and best EFF ≅ 0.7 for all clusters.
- CMORPH and RFE make also use of rain gauge estimates for precipitation bias correction, but their agreement with GPCC_FD data is not as good as that of 3B42. Nevertheless both products have positive EFF.

- RFE and TAMSAT give similar results in terms of MAE, RMSE, and EFF (≥ 0.5) and lower BIAS for TAMSAT. The TAMSAT dry BIAS is recognized in Maidment et al. (2014) and attributed to the approach used in algorithm calibration, more oriented to drought monitoring and low intensity precipitation retrieval.
- TAMSAT is based on IR T_B from Meteosat with a calibration methodology exploiting historic rain gauge data across large climatically homogeneous regions. This calibration methodology represents a valid alternative to the use of local satellitecontemporaneous rain gauges, especially in EA with sparse gauge network.
- GSMaP statistical scores are similar to those of CMORPH with BIAS values more variable for GSMaP and better EFF score for CMORPH (cluster 5, 6, and 7). GSMaP exploits a morphing approach of PMW rainfall similarly to CMORPH, but unlike CMORPH it does not include the bias correction by means of rain gauge data.
- Orography represents an issue for the precipitation estimate from satellite, this is evident from the analysis of the six member ensemble standard deviation and the increase of the RMSE as a function of the terrain elevation.