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Highlights:	23
• Twenty-three satellite-based precipitation products were selected for this study from	24
the Frequent Rainfall Observations on GridS (FROGS) daily precipitation database.	25

- We propose the use of a hydrological model to evaluate the performance of satellite based precipitation products.
 27
- Precipitation over the Congo River Basin has large spatial and temporal variabilities 28 that also have a significant contribution depending on the characteristics of the 29 precipitation product under choice.
 30
- Precipitation performances, in reproducing the annual cycle distributions, influence the 31 model's abilities in simulating the water flow and water balance components. 32
- The gauge-calibrated satellite performed better than satellite source for simulated 33 streamflow taking the 3B42 v7.0 as reference.
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Abstract: Hydrological models have become practical tools to understand impacts in water 36 resources and to support the development of management policies. Precipitation is a major 37 driving force of hydrological processes and is one of the main input datasets for hydrological 38 39 models. However, gauge measurements have several issues, such as incomplete areal coverage and deficiencies over most tropical regions. The precipitation data obtained by remote sensing 40 is an alternative in areas where data is scarce or not available, like in the tropics. However, the 41 feasibility of using satellite-based precipitation products for simulating streamflow needs to be 42 verified, for different hydrological models and basins. Congo River Basin is one of the least 43 studied major river basins in the world and suffers from the scarcity and difficulty in accessing 44 rain gauge data, which makes satellite precipitation estimates necessary for hydrological 45 studies. In this study, we analyzed twenty-three satellite-based precipitation products, acquired 46 from Frequent Rainfall Observations on GridS (FROGS) daily precipitation database. We 47 evaluated these precipitation products over the Congo River Basin using the hydrological 48 model SWAT (Solid & Water Assessment Tool) for streamflow and water balance components 49 50 at basin scale. Our findings showed that the products based on satellite-only source tend to

overestimate the rainy season peaks in comparison with the 3B42_V7 product. On the other 51 hand, the satellite products that consider gauge calibration presented better agreements between 52 each other. The hydrological model was able to reproduce the general precipitation products 53 characteristics, while the gauge-adjusted satellite products performed better than those without 54 gauge adjustments. Thus, the overall precipitation patterns have a crucial effect on model's 55 performance and leads to different streamflow and water balance components values. The 56 choice of rainfall product has a significant importance in the interpretation of the simulated 57 hydrological cycle. 58

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Keywords: precipitation, satellite observations, FROGS, SWAT model, Congo River Basin. 60

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1. Introduction

Hydrological models are frequently used as practical tools to assess and to predict the impacts63of anthropogenic activities on water resources and also assist in their management or create a64basis for decision-making on sustainable development alternatives and conservation practices65(Abbaspour et al., 2015, Loucks and Beek, 2017). However, these models require distributed66meteorological information (precipitation, temperature, wind speed, etc.), which is a great67challenge in large and poorly gauged areas such as tropical regions.68

Precipitation is one of the main parameters for hydrological models, but its estimation is still 69 very difficult, because of its strong spatio-temporal heterogeneity (Beck et al., 2016). There are 70 three ways of measuring precipitation over a basin: (i) conventional instrumentation, using 71 networks of rain (or snow) meters; (ii) ground based weather radar; and (iii) satellite 72 measurement. Nevertheless, despite the accuracy of estimates from conventional 73 instrumentation and weather radar, the distribution and density of these methods are highly 74 variable. Another issue with these methods is the completeness and consistency of the historical 75 data series as well as the availability for near real-time analysis (Kidd and Levizzani, 2011, 76 Sun et al., 2018). The precipitation data obtained by satellite is an alternative in regions where 77 data is scarce, with a large number of free products available with high spatial and temporal 78 resolution that can fill historical gaps and complement or replace in situ stations (Kidd et al., 79 2017). With the advent of the satellite Tropical Rainfall Measuring Mission (TRMM, Huffman 80 et al., 2007), from later 1997 to 2014, transitioning with the launch of the Global 81 PrecipitationMeasurement (GPM, Hou et al., 2014; Skofronick-Jackson et al., 2017) Mission 82 that is actually operating in conjunction with other passive microwave platforms, the 83 performance of satellite precipitation estimates has significantly evolved along the years and 84 numerous satellite-based precipitation products, with different characteristics (i.e., spatial, 85 temporal, among others), have been developed and improved for distinct application purposes, 86 such as for climatological, hydrological, agricultural and monitoring studies. Numerous 87 observational daily precipitation products, including satellite estimates, are now available in a 88 common 1°x1° grid format through the Frequent Rainfall Observations on GridS (FROGS) 89 database (Roca et al., 2019). FROGS database enables easier intercomparisons and 90 applications, based on the selection of a single to multiple products considering their category 91 (i.e., satellite-only, gauge-adjusted satellite estimates, among others). Nonetheless, the 92 estimation of satellite precipitation data is not wholly reliable due to the uncertainties arising 93 from measurement errors associated with observations, sampling, recovery algorithms and bias 94 correction processes that leads to systematic and random errors (Roca et al., 2010, Oliveira et 95 al., 2016, Beck et al., 2016, Beck et al., 2017, Sun et al., 2017). 96

Tropical forests, including the Congo River Basin (CRB), strongly influence both the regional 97 and global climate, storing large carbon stocks and regulating energy and water cycles. In this 98 sense, any changes in the structure of these ecosystems, such as those caused by deforestation, 99 can create positive feedbacks and increase climate change trends (Kruijt et al. 2016). The CRB 100 in central Africa is the second-largest river basin in the world and supports one of Earth's three 101 major humid tropical forest regions (Alsdorf et al., 2016); it contains about 70 percent of 102 Africa's forest cover: Of the Congo Basin's 530 million hectares of land, 300 million are 103 covered by forest. Almost 99 % of the forested area is primary or naturally regenerated forest 104 as opposed to plantations, and 46 % is lowland dense forest. The average annual precipitation 105 is around 1500 - 2000 mm of precipitation per year and is the most convectively active region 106 of the world (Dezfuli, 2017). Almost 60% of precipitation occurs during the wet seasons and 107 the basin-wide average seasonal cycle has two precipitation peaks, one in March and the other 108 in November (Hua et al. 2019, Crowhurst et al., 2020). This basin is currently an object of 109 concern because of evidence of a significant multidecadal drying trend, one of the most 110 significant worldwide (Zhou et al., 2014, Harris et al., 2017). Despite the important role in the 111 tropical climate system, the CRB is plagued by a scarcity of precipitation ground-data 112 especially after the early 1990s. Since the meteorological services of both Angola and the 113 Democratic Republic of the Congo; countries that include most of the Congo rain forest, 114 essentially ceased to function for decades and have been slow to rebuild their services (Alsdorf 115 et al., 2016). The lack of in situ data leads most hydrological studies in the Congo basin to 116 depend on satellite precipitation estimates. 117

It is essential to verify the quality and the applicability of precipitation data derived from multi-118 satellites through statistical evaluation strategies. The variability of precipitation plays a key 119 role in determining the hydrological response of river basins. We assume that the river 120 streamflow follows the variability of rainfall and we propose to use a hydrological model to 121 evaluate the performance of multiple and distinct precipitation products. This study aims to 122 contribute to the debate on the performance of satellite precipitation estimates that are based 123 on different techniques. To achieve that, specifically this study aims to (i) analyze and 124 intercompare the precipitation distribution characteristics from 23 satellite-based precipitation 125

products over the CRB during the period from 2001 to 2012 from FROGS database; (ii) 126 evaluate the selected satellite precipitation products' skills in simulating the streamflow and 127 water balance components through a hydrological model, SWAT (Soil & Water Assessment 128 Tool, Arnold et al. 1998) at monthly time scale. Thus, this article is organized as follows. In 129 Section 2 we describe the study area, the precipitation database and the methodology. Section 130 3 provides an assessment and discussion of the selected precipitation products, which are 131 subsequently applied through the SWAT model, and which are exploited in the same section. 132 Finally, the conclusions are presented in Section 4. 133

2. Materials and Methods

2.1. Study Area and data

The intracratonic depression in Central Africa called the CRB (Figure 1) is situated between 137 latitudes 9°N and 14°S and longitudes 11°E and 34°E. It covers an area of approximately 3.7 138 million km² including most of the Democratic Republic of Congo, (DRC, formerly Zaire), the 139 People's Republic of Congo (ROC) and the Central African Republic (CAR). Elevations within 140 the basin are above 3000 meters above sea level (m asl) in the Eastern highlands and less than 141 300 m asl in the center of the basin (Runge et al., 2007). The physiography of the CRB varies 142 and consists of the northern peneplains of bushy/wooded savanna with tropical humid climate 143 (Bultot, 1971). The middle basin includes the dense and heavily forested swamp forest of the 144 Cuvette Centrale, and the sandy sandstone formations of the Batékés Plateaux of between 350 145 - 930 meters altitude covered by bushy savanna (Laraque et al., 2001). 146

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Figure 1.

Mean annual rainfall is 2000 mm/y⁻¹ in the central basin decreasing northward to southward to 150 1100 mm/y⁻¹ (Alsdorf et al., 2016). The basic rainfall pattern across the basin is thought to be 151 due to the bi-annual passage of the inter-tropical convergence zone (ITCZ) across the basin. 152 The ITCZ over Africa is acknowledged as the location where the dry northeasterly harmattan 153 meets the moist southerly flow of the monsoon and a major control on tropical rainfall. Recent 154 evidence concerning the latitudinal progression of the equatorial rainy season however suggests 155 that this view of the ITCZ may be challenged (Jackson et al., 2009; Nicholson et al., 2019). 156 Rainfall across the basin occurs with a seasonal peak in Precipitation from December to March 157 in areas of the southern hemisphere with northern hemisphere basins having theirs within July 158 159 to October (Moukandi et al., 2021). Annual extremes of precipitation in the equatorial regions are in April and October while sharp precipitation gradients, which may result in spurious 160 trends, are noticed in the south-Eastern parts of the basin (Yin and G, 2010; Tshimanga et al., 161 2012). 162

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2.2. Satellite-Based Precipitation Datasets

Twenty-three precipitation products, with a common period from 2001 to 2012 (except 3B42 165 v7.0, period from 1998 to 2012), were selected for this study (Table 1). These datasets were 166 acquired from The Frequent Rainfall Observations on GridS (FROGS) database (Roca et al., 167 2019). FROGS is composed of several quasi-global and regional daily precipitation products 168 with a common spatial resolution of $1^{\circ} \times 1^{\circ}$. Although FROGS database includes satellites, 169 ground-based and reanalysis products, only the satellite-based category was considered for this 170 study. The satellite-based precipitation products, which differ from each other in multiple 171 aspects (e.g., satellite source, with or without gauge adjustments, among others), are here sub-172 divided into two main groups: i) the satellite-only and ii) the gauge-calibrated satellite. These 173 products are retrieved utilizing infrared (IR) observations from geostationary satellites and/or 174

passive microwave observations from multiple or single low elevation orbiting (LEO)	175
satellites. The gauge-based calibration step is distinctly applied to those satellite precipitation	176
products. These adjustments are climatological on a monthly or daily time step and take into	177
consideration in-situ observations from the Global Telecommunication System (GTS) or other	178
gauged-based precipitation products (e.g., GPCC). Table 1 shows the satellite-based	179
precipitation products selected for this study and their main characteristics. FROGS database	180
is freely available from ftp://ftp.climserv.ipsl.polytechnique.fr/FROGs/. See Roca et al. (2019)	181
for a detailed description of each product.	182

Table 1.

- 184 185
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- 2.3. SWAT Model 187

The soil & Water Assessment Tool is a continuous-time, spatially distributed hydrological 188 basin scale model that simulates water, sediment, nutrient, chemical, and bacterial transport in 189 a basin resulting from the interactions among weather condition, soil properties, stream channel 190 characteristics, vegetation and crop growth, as well as land-management practices. The model 191 calculates pollutant loads from various non-point and point sources (Arnold et al., 1998). 192 Fundamentally, the model is hydrologically driven, based upon the water balance of an 193 individual landscape unit: 194

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$$SW_t = SW_0 + \sum_{i=1}^t (R_{dayi} - Q_{surfi} - E_{ai} - w_{seepi} - Q_{gwi})$$
(1) 196

197

where SW_t is the final soil water content (mm H_2O); SW₀ is the initial soil water content (mm 198 H_2O); t is time (days); R_{dayi} is precipitation on day i (mm H_2O); Q_{surfi} is surface runoff on day 199

i (mm H₂O); E_{ai} is evapotranspiration on day i (mm H₂O); w_{seepi} is the amount of water from 200 the soil profile inflowing to the vadose zone on day i (mm H₂O); and Q_{gwi} is the base flow on 201 day i (mm H₂O). 202

2.3.1. Model Setup

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SWAT2012 version (Winchell et al., 2013) was set up for the CRB using the datasets listed in 205 Table 2. The basin was delineated based on the dominant land use, soil and slope classes taking 206 into cognizance the size and spatial heterogeneity of the basin allocating one Hydrologic 207 Response Unit (HRU) per subbasin resulting in 272 subbasins and HRUs. The period of 208 simulation was from 1998 to 2012, comprising calibration (2000-2006), validation (2006-2012), and a two-year warm-up period (1998-2000). 210

In the SWAT model, the evapotranspiration is calculated using the Penman-Monteith method. 211 The Penman-Monteith method also gave better estimates of evapotranspiration when used with 212 the plant growth modification of Strauch and Volk (2013). The plant growth module was used 213 since the SWAT model simulates plant growth based on dormancy during the winter season 214 for the reinitiation of the growing season for perennial plants and this process is not a valid 215 growing pattern in the tropics. The surface runoff was calculated using the Soil Conservation 216 Service's Curve Number method (USDA Soil Conservation Service, 1972) and the variable 217 storage method (Williams, 1969) was used for channel routing. 218

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2.3.2 Model calibration

Model calibration was based on the optimization of the parameter values by adjusting the 223 simulated streamflow (Q_{sim}) at observed streamflow (Q_{obs}). The monthly Q_{obs} data from the 224

Table 2.

five gauging stations (Figure 1) were available for the period 2000-2012 (Table 2). In the model 225 set-up used in this study, the simulated streamflow was adjusted to the observed streamflow by 226 manual calibration (trial and error). Further details of the calibration and validation procedures 227 can be found in Datok et al. (2021). 228

For the evaluation of model performance, we used the Nash and Sutcliffe (1970) efficiency 229 (NSE) that measures the magnitude of residual variance, compared to observed variance 230 (Moriasi et al., 2007); the coefficient of determination (\mathbb{R}^2) that describes the degree of linear 231 relationship between observed and simulated streamflow and percent bias (PBIAS) which 232 evaluates the average tendency of the magnitude of simulated values in relation to the observed 233 ones. Kling–Gupta efficiency (KGE) by Gupta et al., (2009), which provides decomposition 234 of NSE and mean squared error; KGE facilitates the analysis of relative importance of 235 correlation, bias, and variability in hydrologic modeling (KGE-hydroGOF, 2017). For 236 streamflow, Moriasi et al. (2015) proposed NSE values > 0.50, $R^2 > 0.60$ and PBIAS $< \pm 25$ to 237 be a satisfactory level for monthly scales. A KGE value > 0.50 is also considered satisfactory 238 (Gupta et al., 2009). 239

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2.4. Evaluation of the performance of precipitation datasets using SWAT model 241 The SWAT model was run for twenty-three scenarios based on the precipitation products 242 described in Table 1. The base scenario is based on the 3B42_v7.0 product and it was calibrated 243 with observed streamflow (see above). The others precipitation scenarios were run using 244 identical datasets (see Table 1) so that variations in streamflow and other hydrological 245 components were uniquely attributable to precipitation. For the evaluation of the performance 246 of precipitation datasets, we used KGE and PBIAS objective functions calculated using the 247 streamflow of base scenario (3B42_v7.0) as reference. 248

3. Results and Discussion

Precipitation regimes over the CRB are firstly assessed through the 23 satellite-based 251 precipitation products during the period from 2001 to 2012. Secondly, the model calibration 252 and validation are performed for the period from 1998 to 2012 (two-years of warm-up for the 253 model). Afterwards, hydrological evolution (streamflow and water balance components) 254 through the 23 precipitation products during 2003 to 2012 (two-years of warn-up) are assessed. 255 Finally, we discuss the influence of the precipitation input on model performance when the 256 model has been pre-calibrated with one of the products (here 3B42). 257

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3.1. Comparison of the different precipitation datasets

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Satellite precipitation estimates, through different gridded products, has been constantly 260 evaluated and assessed across West Africa, considering gauged-precipitation observations as a 261 reference (e.g., Gosset et al., 2018, Nicholson et al., 2019, Satgé et al., 2020). The reliability 262 of satellite precipitation estimates depends on several factors (e.g., seasonality, the gauge 263 network densities) and can vary in space and time. The precipitation regime (i.e., seasonality) 264 over the CRB varies regionally (e.g., Munzimi et al., 2015). Spatially, there are remarkable 265 characteristics on the precipitation distribution over CRB, which are demonstrated through the 266 unconditional annual mean and the 99th percentile (Figure 2). The central region of the CRB 267 and the northern portion of the Luabala sub-basin experience the largest amounts of 268 precipitation with about 7 and 10 mm day-1, respectively. Nevertheless, the Luabala also 269 showed the largest regional contrast of precipitation amounts, with most of the watershed area 270 presenting precipitation mean lower than 3 mm day⁻¹. These spatial characteristics were 271 directly linked to the extreme precipitation occurrences, represented by the 99th percentile, 272 strongly influenced by the surface type (i.e., orographic) conditions, where the highest values 273 (>50 mm day⁻¹) were found mainly across the wetland zones and over the northwest part of 274 Luabala. Figure 3 depicts the annual cycle of precipitation, through the monthly accumulated 275 mean distributions, from all the selected satellite-based precipitation products over the five 276 CRB sub-basins, during the period from 2001 to 2012. The contrasts between the satellite-only 277 and satellite gauged-adjusted precipitation are assessed considering the 3B42 v7.0 product as 278 baseline. Overall, three different precipitation regimes, which were associated with the 279 geographic characteristics, were observed across the five Congo's sub-basins, which is in 280 agreement with previous findings based on both the satellite and rain gauge data (e.g., Munzimi 281 et al., 2015): i) Kasai and Luabala, located in the southernmost portion, presenting a well-282 defined dry/wet period, with the maximum (minimum) from November to March (between 283 June and August); ii) Sangha and Ubangi, in the northern portions, present a prolonged rainy 284 period (peak of maximums around August/September) and a short-term dry season (December 285 and January); and iii) the central part, which is characterized by a less well-defined monsoonal 286 regime, with a dry period less pronounced and two rainy peaks (the first around March and the 287 second during October/November). 288

Although all the satellite precipitation products were able to successfully represent the annual 289 cycle of rainfall over each watershed under study, notable differences along the year on the 290 magnitudes of the precipitation amounts were observed. Overall, two remarkable performance 291 characteristics were noted. The group of satellite-only products mostly overestimates the rainy 292 seasons' peaks compared to the rest of the products. In particular, the CMORPH v1.0 RAW, 293 3B42RT_UNCAL_v7.0, followed by IMERG_V06_EU and IMERG_V06_LU products stand 294 295 out for presenting the highest peaks, especially during the rainy seasons, systematically for all the five sub-basins. For instance, CMORPH_v1.0_RAW overestimates about 100 mm/month, 296 in comparison to the rest of the products, at most of the sub-basins. On the other hand, the 297 group of gauge-adjusted satellite products presented better agreements between each other and 298 compared to 3B42_v7.0, except for GSMAP-gauges-RNLv6.0 and CMORPH_v1.0_CRT, 299

which exhibited opposite performances to its satellite-only versions, underestimating the 300 monthly totals during a greater part of the year for all the five sub-basins. In addition, 301 TAMSAT_v2 stands out due to its difficulties in following the annual cycle properly (e.g., 302 Central), underestimating the rainiest months at all sub-basins and also overestimating drier 303 periods, especially over the northern portions (i.e., at Sangha and Ubangi). 304

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- Figure 2.
- Figure 3.

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Other particular basin characteristics and the performance diversities of both the satellite-only 310 and gauge-adjusted products are clear considering the relative differences (%) of each product 311 compared to 3B42_v7.0 as reference (in Supplementary Material, Figure S1). The 312 overestimations found by satellite-only products were relatively larger during the dry and dry-313 to-wet periods over Kasai and Luabala sub-basins. In this case, during these periods at Luabala, 314 the 3B42_IR_v7.0, 3B42RT_UNCAL_v7.0 and CMORPH_v1.0_RAW products stand out for 315 presenting the largest relative differences among all the sub-basins, with more than 300 %, 316 200 % and about 290 %, respectively. An opposite behavior, with negative relative differences 317 (in about -100%) during the dry period at Kasai and Luabala sub-basins, was observed for the 318 gauge-adjusted satellite group, with slight exception 3B42RT_v7.0 and CMORPH_v1.0_CRT 319 (at Luabala). The regional TAMSAT v2.0, TAMSAT v3.0 and ARC2 products, in 320 comparison to 3B42 v7.0 product, tend to overestimate January's amounts of precipitation (the 321 dry period) at Sangha and Ubangi, which are consistent with the findings of Ayehu et al., (2018) 322 323 for another African region.

It is worth mentioning that the performance and/or agreement of certain satellite precipitation 324 products, in particular the native versions (satellite-only) and those ones adjusted/calibrated by 325 rain gauges, in representing the local and/or regional precipitation regimes, are extremely 326 linked to the region of interest. This is because the precipitation regimes are driven by multiple 327 factors, including the frequency and intensity of rainy/non-rainy days to its monthly totals, as 328 well as the contribution of a certain class of precipitation occurrences and the corroboration of 329 moderate-extreme and extreme events over tropical land regions (Roca, 2019). These factors 330 can be represented differently by satellite estimates and the differences are related to distinct 331 aspects (e.g., the product technique itself, platform sources, gauge-adjustments, systematic 332 333 uncertainties, among others).

Figure 4 shows the cumulative density functions (CDF) of occurrence and volume (amount) of 334 daily precipitation during the period from 2001 to 2012 over the five Congo sub-basins 335 computed for each satellite precipitation product (satellite-only and satellite gauge-adjusted) 336 acquired from FROGs database. Through the overall CDF analyses, it becomes more evident, 337 the differences between the two groups of satellite precipitation compared to the 3B42 v7.0 338 reference database. It is also possible to note that, even though the monthly totals are impacted 339 differently, these two distinct CDF distributions are preserved for all the five watersheds. Better 340 agreements between all the satellite-only products compared to the 3B42_v7.0, in both the 341 occurrences and amounts of precipitation distributions, were observed. Slight overestimations 342 (underestimations) on the amounts (occurrences) frequencies of rainfalls lower (greater) than 343 \sim 5 mm day⁻¹ were observed from most of the satellite-only products compared to 3B42 v7.0. 344 However, the ARC2 and CHIRP_V2 products presented opposite features, especially at the 345 Luabala and the Central basins respectively. In contrast, the group of gauge-adjusted satellite 346 precipitation products showed larger differences (heterogeneities) across all precipitation 347 distribution ranges, especially in the volume of precipitation frequencies (e.g., up to 45 % of 348

frequency differences at precipitation intensities from 1 to 5 mm day⁻¹). In parallel to the 349 scattered frequency distributions on the rainfall occurrences, an overestimation, most 350 prominent at rainfall intensities greater than 10 mm day 1, were observed from almost all the 351 satellite+gauge products in comparison to 3B42 v7.0, except for CMORPH v1.0 CRT (at 352 Luabala) and TAMSAT_v2 (at Sangha and Ubangi). Such characteristics suggest that the 353 gauge inclusion and/or adjustment techniques could directly impact quantitatively and 354 qualitatively the daily precipitation distributions, from low to larger intensities, modifying its 355 amount and occurrence frequencies. 356

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Figure 4.

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3.2. Model Calibration and Efficiency

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The statistical results and graphical comparisons of the simulated SWAT calibration and 361 validation aggregated monthly streamflow (Qsim) versus corresponding measured streamflow 362 (Q_{obs}) are listed in table 3 and shown in figure 5 for all gauge sites (Figure 1). The NSE, R² and 363 KGE values for the calibration and validation periods for Ubangi/Bangui and Sangha/Ouesso 364 gauges suggest good model performance. For Kasai/Kutu-Moke and Brazzaville/Kinshasa 365 (outlet) gauges, these values suggest acceptable model performance, but for Lualaba/Kisangani 366 the model, performance is less acceptable. The Ubangui and Sangha basins, mostly draining 367 the northern hemisphere, present few hydrological and hydraulic singularities, thus it is not 368 surprising that the conversion of rainfall into discharge is well performed by the model. The 369 Lualaba sub-basin presents many lakes and swamps, including the Tanganyika lake which 370 behavior was complicated to model due to the lack hydraulic / hydrological data (e.g. volume 371 of water stored, surface area) for these lakes. PBIAS suggest good fit between simulated and 372 observed streamflow for all gauge sites. However, the PBIAS indicated an underestimation for 373

the calibration period, except for Kasai/Kutu-Moke gauge; and overestimation for the 374 validation period, with the exception of the Brazzaville/Kinshasa (outlet) gauge. 375

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Table 3.

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379 Figure 6 shows the relative error between Q_{obs} and Q_{sim} (positive values indicate overestimated Qsim and negative values indicate underestimated Qsim). For Ubangi/Bangui, Sangha/Ouesso, 380 381 and Kasai/Kutu-Moke, the model in general overestimated low flows in Q_{obs} in the calibration and validation periods. Conversely, for Lualaba/Kisangani and Brazzaville/Kinshasa (outlet) 382 the model underestimated low flows periods. The peak flow at Brazzaville/Kinshasa (outlet) 383 was underestimated, while for other gauges the peak flow was slightly underestimated. The 384 overestimation of minimum values of Qobs is linked to the lower baseflow and faster recession 385 during the dry season. This overestimation could not be corrected by an increase of baseflow 386 recession constant, because it would lead to overestimating streamflow during the beginning 387 of the rainy season. Further details about the drainage sub-basins and calibration and validation 388 389 can be found in Datok et al. (2021).

Figure 5.

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Figure 6.

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3.3. Hydrological evaluation3953.3.1. Streamflow396The hydrographs (Figure 7) indicate that the SWAT model follows the key features of the397

satellite precipitation products as the dry and wet season at the five-gauge sites studied, and 398

thus, it is possible to evaluate the performance of those products without recalibration. It is 399 expected however that the twenty-two precipitation products inputs lead to different 400 streamflow prediction than the 3B42_v7.0 (base scenario) at all five-gauges. In general, and as 401 expected, the products without precipitation adjustments (satellite-only) predicts higher 402 streamflow. However, according to the results some satellite products behave differently, for 403 example CMORPH_v1.0_CRT predicts higher streamflow at the gauge Lualaba/Kisangani, 404 but in other gauges, this product underestimated the streamflow. 405

Statistical analysis (Figure 8) and the Δ % (Supplementary Material—Table S2) demonstrated 406 that the hydrological model driven by the precipitation products with precipitation adjustments 407 (satellite+gauge) performed better than those without precipitation adjustments; as expected, 408 but trends between the products and differences between the regions are evident. The KGE and 409 PBIAS indexes indicates some products can provide satisfactory performance at 410 Ubangi/Bangui, Lualaba/Kisangani and Brazzaville/Kinshasa (outlet) without model 411 recalibration. Figure 8 also highlights that GPCP_CDR_v1.3_not_enforced, which it is a 412 satellite only product, demonstrates a good performance (KGE 0.71) at Ubangi/Bangui gauge. 413 When looking at the entire CRB, the worst scores were obtained by 3B42RT_UNCAL_v7.0 414 and CMORPH_v1.0_RAW satellite-only products. It is evidenced by Figure 8 that while some 415 satellite-only products tend to lead to higher streamflow predictions (such as 416 CMORPH_v1.0_RAW and 3B42RT_UNCAL_v7.0), others as 3B42_IR_v7.0 417 and 3B42_MW_v7.0 tend to lead to lower streamflows in particularly at Sangha/Ouesso and 418 Ubangi/Bangui dry regions of CRB. The regional products (TAMSAT v2.0, v3.0 and ARC2) 419 did not perform well in estimating streamflow, when compared to quasi-global products such 420 as the IMERG_v6.0_FC or land-only products like the CHIRPS_v2.0. Although ARC2 421 performed better than the other regional products, it still did consequently underestimate the 422 streamflow at four-gauge stations. 423

The near-real-time (NRT) precipitation products (important for now-casting and forecasting 424 streamflow in applications such as early warning systems) such as IMERG_v6.0_EU and 425 IMERG_v6.0_LU did not provide a good prediction of streamflow, showing a consequent 426 overestimation at all gauges. Among the NRT products, only 3B42RT_v7.0 had a good 427 performance at the Ubangi/Bangui stations, and Brazzaville/Kinshasa (outlet) and Kasai/Kutu-428 Moke. The PBIAS indicates a good performance when compared to the base scenario, maybe 429 due to the similarities with the product used in our base scenario. 430

In general, the monthly streamflow simulation results and the statistical scores from 431 IMERG_v6.0_FC and CHIRPS_v2.0 presented consistent streamflow simulations, except for 432 433 Kasai/Kutu-Moke and Sangha/Ouesso gauges. Studies as Tan et al. (2018) and Amorim et al. (2020) have shown the better performance of IMERG products to estimate streamflow all 434 around the world in comparison to TMPA products, due to its improvement in precipitation 435 estimation. In our case, the recalibration of model parameters for IMERG products could 436 improve streamflow simulations, specifically at the gauge stations where 3B42_v7.0 did not 437 perform well. 438

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- Figure 7.
- Figure 8.

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3.3.2. Water balance components

To better understand the influence of the different precipitation products in in predicting the 445 water balance components (WBC) utilizing the SWAT model, we analyzed the monthly cycle 446 of evapotranspiration (ET), surface runoff (SURQ), lateral flow (LATQ), percolation (PERC), 447 soil water content (SW), groundwater contribution to streamflow (GWQ) and water yield 448

(WYLD) simulated at the sub-basin scale. The results show that the satellite-only products tend 449 to overestimate the WBC, especially in the rainy season. However, the level of overestimation 450 and underestimation depends on the type of WBC and the region in the CRB. 451 For ET predictions (Figure 9), the precipitation products have the tendency to overestimate in 452 both dry and wet seasons when compared to 3B42_v7.0, although some track ET much more 453 closely than others. The CMORPH_v1.0_RAW and GSMAP_gauges_RNL_v6.0 have the 454 tendency to underestimated this component. Peak basin-wide ET during March is 455 overestimated for almost all products, while the basin's low at June, July and August is 456 underestimated at Lualaba and overestimated at other regions. At Ubangi, most of the 457 precipitation products capture the same tendency of 3B42_v7.0 between June to February. 458 Overall, the global ET prediction is overestimated at all sub-basins (in Supplementary Material, 459 Table S3). 460

461

Figure 9.

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The SURQ (Figure 10), LATQ and PERC (Supplementary Material - Figures S4 and S5) 464 predictions, -which are intrinsically linked to the amount and dynamics of precipitation- are 465 similar for the dry season at Kasai, Ubangi and Sangha sub-basins. However, none of the 466 products capture the full amplitude of fluctuations across seasons at the Central and Lualaba 467 sub-basins. The predictions are overestimated even in the dry season. For the wet season, the 468 satellite precipitation products have the tendency to overestimate these components in regards 469 to 3B42_v7.0 at five regions. Kasai and Lualaba sub-basins presenting one large peak of 470 SURQ, LAT and PERC between November to March. Sangha and Ubangi have one peak 471 around August/September while the Central region has two peaks, the first around March/April 472 and the second during October/November. These peaks are overestimated and some products 473

+	groundwater	flow	+ tile	flow -	- transmission	loss)	are	also	overestimated	compared	to

490 The seasonal cycle of GWQ does not present a large fluctuation across seasons, but the tracks 491 are scattered at all regions studied. This behaviour could be linked to the SWAT model, because 492 the model simulates groundwater using the two-way groundwater-surface water exchange 493 494 which limits the ability to predict groundwater storage (Malaku and Wang, 2019, Shao et al., 2019). Also, the surface water-groundwater interaction mechanisms are less studied than other 495 WBC in the Congo Basin (Alsdorf et al., 2016). 496

The WYLD (Supplementary Material—Figures - S6) predictions (consisting of: surface runoff

refers to water stored in soil - demonstrate a wide range of simulated values, particularly for 481 GWQ, hence overestimates of these components for both satellite-only and satellite+gauge 482 with respect to 3B42 v7.0. SW the precipitation products generally follow the seasonal shape, 483 except some products as CMORPH_v1.0_RAW and GSMAP_gauges_RNL_v6.0 although 484 none of them capture the full amplitude of fluctuations across seasons. The tracks are closer 485 than others for SW in the dry season at Lualaba and Ubangi, but for Central, Kasai and Sangha, 486

the tracks are scattered.

The SW (Figure 11) and GWQ (Supplementary Material - Figure S6) predictions, - which

as TAMSAT_v3.0 and ARC2 do not follow the same seasonal shape of 3B42_v7.0. In general, 474 the global SURQ, LATQ and PERC (in Supplementary Material, Table S3) are overestimated, 475 although some track much more closely than others, especially in the dry season. 476

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Figure 10.

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Figure 11.

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3B42_v7.0. The peak flows have the same characteristic of SURQ at all regions, with two 499 peaks at the Central, Kasai and Lualaba. However, peak shapes of some precipitation products 500 are wider than the peak of 3B42_v7.0. Similar to the GWQ, the WYLD tracks are scattered at 501 all sub-basins. 502

Overall, the trends between the precipitation products and differences between the regions 503 affects the WBC. The Δ % (Supplementary Material—Table S3) showed that even a small 504 increase or decrease of amounts of precipitation would cause increase or decrease in the WBC, 505 especially the components that are dependent on the dynamics of precipitation as surface runoff 506 and percolation. However, some precipitation products behave differently, for example, in most 507 508 of the analyzed products, an increase in amount of precipitation leads to an increase in the values of the WBC, but CMORPH_v1.0_CRT shows a decrease of amount of precipitation 509 then an increase in surface runoff values at the Central, Kasai and Sangha, that leads to a 510 decrease of percolation. Several possible causes could lead to these results, the hydrological 511 response of the WBC is linked to precipitation and design and assumptions of the model to 512 type of vegetation, topography and soil. It is expected that in forest areas there will be less 513 surface runoff than in pasture areas for example. Soil degradation will also lead to an increase 514 of runoff. 515

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The SWAT model was originally based on the climate and environmental conditions in the 518 United States, and it proved to be an effective tool to evaluate land management practices in 519 floodplains and agricultural chemicals and water resources over other regions around the world 520 (e.g.: Wei et al., 2019, Cakir et al., 2020, Sok et al., 2020). However, SWAT requires certain 521 improvements before it can be applied in tropical regions; such as improvements to crop and 522 soil parameters. Nonetheless, several studies in tropical regions reported good performance of 523

3.4 Influence of the precipitation input on model performance

this model, especially at monthly time step (e.g.: Dos Santos et al., 2018, Galavi and Mirzaei, 524
2020, Tan and Yang 2020, Mandal et al., 2021).
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To compare the hydrological performance of the satellite-based precipitation products using 526 the SWAT model, we summarized some recent hydrological evaluation studies around the 527 world in Table 4 (Tuo et al., 2016, Tan et al., 2018, Amorim et al., 2020, Sharannya et al., 528 2020, Peng et al., 2021, Wang et al., 2021). Four main conclusions can be drawn from the 529 comparisons: i) in many cases, the IMERG_v6.0_FC outperforms 3B42_v7.0 in hydrological 530 simulations due to its improvement in precipitation estimation; ii) the performance of the 531 satellite-based precipitation products depends on the basin localization and simulations scale 532 (daily or monthly); iii) hydrological model choice will affect the accuracy assessment of 533 precipitation products for detecting streamflow extremes; and iv) the recalibration of the model 534 parameters for each satellite-based precipitation product effectively improved the precision of 535 streamflow simulations. 536

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Table 4

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As shown in the hydrological evaluation section, the IMERG_v6.0_FC and CHIRPS v2.0 540 products demonstrates good performance without recalibration and could be used to study the 541 hydrological cycle in the CRB, especially for streamflow and evapotranspiration. These results 542 agree with the findings reported in Table 4, and a recalibration of the model parameters could 543 effectively improve the precision of satellite-based precipitation product simulations, 544 especially for WBC that are connected to the amount and dynamics of precipitation as SURQ, 545 LATQ and PERC. 546

Nevertheless, the bias in satellite-based precipitation products was recognized as a major issue 547 across several basins around the world (Maggioni and Massari, 2018), and the inaccuracy of 548

satellite data may lead to unrealistic parameter values when recalibrating the model (Peng et 549 al., 2021). Maggioni and Massari (2018) have shown that model recalibration was also raised 550 as a viable option to improve streamflow simulations from satellite-based precipitation 551 products, but caution is necessary when recalibrating models. Another option is the bias 552 correction of the satellite products with ground-based measurements of precipitation to obtain 553 more realistic flow simulations (Wang et al., 2021). 554

However, satellites estimate appear to not perform well over the CRB (McCollum et al., 2000; 555 Awange et al., 2016) and there are large discrepancies between gauge-based products from 556 GPCC (Global Precipitation Climatology Centre), CMAP (CPC Merged Analysis of 557 Precipitation), GPCP (Global Precipitation Climatology Project), and CPC (Climate Prediction 558 Center) in the interannual and decadal variations in precipitation over the basin (Negron Juarez 559 et al., 2009). The lack of a dense and reliable network of rain gauges makes it impossible to 560 assess quantitatively the rainfall products against a proper ground validation reference. In 561 addition, for the long-term mean, GPCP and CMAP display the major precipitation patterns, 562 although substantial discrepancies occur in areas with low gauge densities, such as equatorial 563 West Africa (Yin et al., 2004). However, independent of these discrepancies, our findings show 564 that the IMERG_v6.0_FC and CHIRPS v2.0 are potential alternative sources of data for 565 hydrological modeling using SWAT in the CRB. 566

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Table 4.

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4. Conclusions

The present work investigated the performances of 23 satellite-based precipitation products 571 (Table 1) in simulating streamflow and water balance components at the Congo River Basin 572 through the SWAT model. The key findings are as follows: 573

The precipitation products were able to represent with consistency the annual cycle of rainfall 574 and the frequencies of rain intensities/occurrences over each sub-basin studied. However, the 575 precipitation amount magnitudes along the year are different, especially due to high 576 precipitation intensities. In the absence of a reliable dense ground validation network, the gauge 577 adjusted version of 3B42_v7.0, which has been shown to provide good simulations of the 578 discharge through the SWAT model, was taken as a benchmark to analyze the skills of other 579 precipitation products. Overall, the group of satellite-only precipitation products mostly 580 overestimates the rainy season peaks; and the gauge-adjusted satellite products presented better 581 agreements between each other and compared to 3B42_v7.0, except for GSMAP-gauges-582 RNLv6.0 and CMORPH v1.0 CRT. 583

Streamflow and water balance components simulation replicate precipitation products patterns, 584 and gauge-adjusted satellite performed better than satellite-only for streamflow. In addition, 585 during the rainy season, the precipitation products have the tendency to overestimate the 586 SURQ, LATQ and PERC in regards to 3B42_v7.0 over the Congo Basin. For others 587 components (ET, SW, GWQ and WYLD) and streamflow predictions, there is an 588 overestimation at all sub-basins. However, IMERG_v6.0_FC and CHIRPS v2.0 products 589 demonstrate good performance with our model, and could be used to predict the hydrological 590 cycle. 591

In general, the selection of precipitation products has a crucial effect on model performance 592 and has to be taken into consideration since it is one of the sources of uncertainties. 593 Unfortunately, the Congo River Basin is deprived of a quality and dense rain gauge network 594 for assessing these uncertainties more quantitatively. Using the hydrological model with an 595 ensemble of available products provides a good illustration of the impact of the uncertainties 596 and can be used to filter out the products which behave like outliers and/or to indicate the 597 confidence in the simulated hydrological variables. The combination of bias correction of the 598

satellite products with ground-based measurements and recalibration of the model parameters 599

could effectively improve prediction of the hydrological cycle.

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References

- Abbaspour, K.C., Rouholahnejad, E., Vaghefi, S., Srinivasan, R., Yang, H., and Kløve, B. A., 2015. continental-scale hydrology and water quality model for Europe: Calibration and uncertainty of a high-resolution large-scale SWAT model. J. Hydrol., 524, 733–752. 610 https://doi.org/10.1016/j.jhydrol.2015.03.027 611
- Alsdorf, D., Beighley, E., Laraque, A., Lee, H., Tshimanga, R., O'Loughlin, F., Mahé, G., 612 Dinga, B., Moukandi, G., and Spencer, R. G. M., 2016. Opportunities for hydrologic 613 Congo Geophys., research in the Basin. Rev. of 54(2), 378-409. 614 https://doi.org/10.1002/2016RG000517 615
- Amorim, J.d.S., Viola, M.R., Junqueira, R., Oliveira, V.A.d., and Mello, C.R.d., 2020.
 Evaluation of satellite precipitation products for hydrological modeling in the Brazilian Cerrado biome. Water, 12(9), 2571. https://doi.org/10.3390/w12092571
- Arnold, J.G., Srinivasan, R., Muttiah, R.S., and Williams, J.R., 1998. Large area hydrologic
 modeling and assessment part I: Model development. JAWRA Journal of the American
 Water Resour. Assoc., 34(1), 73–89. https://doi.org/10.1111/j.1752-1688.1998.tb05961.x
- Ashouri, H., Hsu, K.-L., Sorooshian, S., Braithwaite, D.K., Knapp, K.R., Cecil, L.D., Nelson, 622
 B.R., and Prat, O.P., 2015. PERSIANN-CDR: daily precipitation climate data record 623
 frommultisatellite observations for hydrological and climate studies. Bull. Am. 624
 Meteorol.Soc., 96(1), 69–83. https://doi.org/10.1175/BAMS-D-13-00068.1
- Awange, J., Ferreira, V., Forootan, E., Khandu, Andam-Akorful, S., Agutu, N., He, F., 626
 2016.Uncertainties in remotely sensed precipitation data over Africa. Int. J. Climatol., 36, 627
 303–323.https://doi.org/10.1002/joc.4346.
- Ayehu, G. T., Tadesse, T., Gessesse, B., and Dinku, T., 2018. Validation of new satellite 629 rainfall products over the Upper Blue Nile Basin, Ethiopia, Atmos. Meas. Tech., 11, 630 1921–1936. https://doi.org/10.5194/amt-11-1921-2018 631
- Beck, H.E., van Dijk, A.I., De Roo, A., Miralles, D.G., McVicar, T.R., Schellekens, J., and
 Bruijnzeel, L.A., 2016. Global-scale regionalization of hydrologic model parameters.
 Water Resour. Res., 52 (5), 3599–3622. https://doi.org/10.1002/2015WR018247
 634
- Beck, H.E., Van Dijk, A.I., Levizzani, V., Schellekens, J., Gonzalez Miralles, D., Martens, B., 635 and De Roo, A., 2017. MSWEP: 3-hourly 0.25 global gridded precipitation (1979–2015) 636 by merging gauge, satellite, and reanalysis data. Hydrol. Earth Syst. Sci., 21(1), 589–615. 637 https://doi.org/10.5194/hess-21-589-2017 638

Bultot, F., 1971. Atlas Climatique du Bassin Congolais : Deuxième partie, les composantes du 639

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600

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606

bilan d'eau. Publications de L'Institut National pour L'Etude Agronomique du Congo 640 (I.N.E.A.C.). 641

- Cakir, R., Sauvage, S., Gerino, M., Volk, M., and Sanchez-Perez, J.M., 2020. Assessment of ecological function indicators related to nitrate under multiple human stressors in a large watershed. Ecol. Indicat., 111, 106016. https://doi.org/10.1016/j. 644 ecolind.2019.106016. 645
- Crowhurst, D., Dadson, S., Peng, J., and Washington R., 2021. Contrasting controls on Congo 646 Basin evaporation at the two rainfall peaks. Clim Dyn., 56, 1609–1624. 647 https://doi.org/10.1007/s00382-020-05547-1 648
- Datok, P., Fabre, C., Sauvage, S., N'kaya, G.M., Paris, A., Dos Santos, V., Laraque, A., and
 Sánchez Pérez, J.-M. 2021. Investigating the role of the Cuvette Centrale in the hydrology
 of the Congo River Basin. In: Congo Basin Hydrology, Climate, and Biogeochemistry: A
 Foundation for the Future. Geophysical Monograph Series. Alsdorf, D., Moukandi, G.,
 Tshimanga, R., Eds. John Wiley & Sons Inc. Hoboken, NJ, USA.
- Dos Santos, V., Laurent, F., Abe, C., and Messner, F., 2018. Hydrologic Response 654 to Land Use Change in a Large Basin in Eastern Amazon. Water, 10, 655 1–19. https://doi.org/10.3390/w10040429 656
- Développement BRLi. (2016). l'outil mise place de de 657 et en modélisation d'allocation des du et ressources en eau Bassin 658 Congo: Rapport technique de de calage du construction et du 659 modèle, CICOS, Kinshasa, RDC. https://www.cicos.int 660
- Dile, Y. T., and Srinivasan, R., 2014. Evaluation of CFSR climate data for hydrologic 661 prediction in data- scarce watersheds: An application in the Blue Nile River Basin. Journal 662 of the American Water Resour. Assoc., 50(5), 1226–1241. 663 https://doi.org/10.1111/jawr.12182 664
- Funk, C., Peterson, P., Landsfeld, M., Pedreros, D., Verdin, J., Shukla, S., Husak, G., Rowland,
 J., Harrison, L., Hoell, A., and Michaelsen J., 2015. The climate hazards infrared
 precipitation with stations A new environmental record for monitoring extremes. Sci.
 Data, 2, 1–21. https://doi.org/10.1038/sdata.2015.66
- Galavi, H., and Mirzaei, M., 2020. Analyzing Uncertainty Drivers of Climate Change Impact
 Studies in Tropical and Arid Climates. Water Resour Manage, 34, 2097–2109.
 https://doi.org/10.1007/s11269-020-02553-0
 671
- Gosset, M., Alcoba, M., Roca, R., Urbani, G., and Cloché, S., 2018. Evaluation of TAPEER daily estimates and other GPM era products against dense gauge networks in West Africa, analyzing ground reference uncertainty Q. J. R. Meteorol. Soc., 144, 255–69. 674 https://doi.org/10.1002/qj.3335
- Gupta, H.V., Kling, H., Yilmaz, K.K., and Martinez, G.F., 2009. Decomposition of the mean squared error and NSE performance criteria: Implications for improving hydrological 677 modelling. J. Hydrol., 377 (1–2), 80–91.https://doi.org/10.1016/j.jhydrol.2009.08.003 678
- Harris, N. L., Goldman, E., Gabris, C., Nordling, J., Minnemeyer, S., Ansari, S., Lippmann, 679
 M., Bennett, L., Raad, M., Hansen, M., and Potapov, P., 2017. Using spatial statistics to 680
 identify emerging hot spots of forest loss. Environ. Res. Lett., 12, L024012. 681
 https://doi.org/10.1088/1748-9326/aa5a2f
- Hou, A. Y., Kakar, R. K., Neeck, S., Azarbarzin, A. A., Kummerow, C. D., Kojima, M., Oki, 683
 R., Nakamura, K., & Iguchi, T. (2014). The Global Precipitation Measurement Mission, 684
 Bulletin of the American Meteorological Society, 95(5), 701-722, 685
 https://doi.org/10.1175/BAMS-D-13-00164.1
- Hua, W., Zhou, L., Nicholson, S.E. Chen, H., and Qin, M., 2019. Assessing reanalysis data for understanding rainfall climatology and variability over Central Equatorial Africa. Clim Dyn., 53, 651–669. https://doi.org/10.1007/s00382-018-04604-0

- Huffman, G.J., Adler, R.F., Morrissey, M.M., Bolvin, D.T., Curtis, S., Joyce, R., McGavock, 690
 B., and Susskind, J., 2001. Global precipitation at one-degree daily resolution 691
 frommultisatellite observations. J. Hydrometeorol., 2 (1), 36–50. 692
 https://doi.org/10.1175/1525-7541(2001)002<0036:GPAODD>2.0.CO;2 693
- Huffman, G.J., Bolvin, D.T., Nelkin, E.J., Wolff, D.B., Adler, R.F., Gu, G., Hong, Y., 694
 Bowman,K.P., and Stocker, E.F., 2007. The TRMM multisatellite precipitation analysis (TMPA):quasi-global, multiyear, combined-sensor precipitation estimates atfine scales.J. 696
 Hydrometeorol., 8 (1), 38–55. https://doi.org/10.1175/JHM560.1 697
- Huffman, G.J., Bolvin, D.T., Braithwaite, D., Hsu, K.L., Joyce, R., Kidd, C., Nelkin, E.J.,
 Sorooshian, S., Tan, J., and Xie, P. 2019. Algorithm Theoretical Basis Document (ATBD)
 Version 06 NASA Global Precipitation Measurement (GPM) Integrated Multi-satellitE
 Retrievals for GPM (IMERG) ; National Aeronautics and Space Administration
 (NASA):Washington, DC, USA, pp. 1–34.
- Jackson, Nicholson, S. E., and Klotter, D., 2009. Mesoscale convective systems over western 703 equatorial Africa and their relationship to large-scale circulation. Mon. Weather Rev., 704 137, 1272–1294. https://doi.org/10.1175/2008MWR2525.1 705
- KGE-hydroGOF, 2017. "Kling–Gupta Efficiency." 706 https://www.rforge.net/doc/packages/hydroGOF/KGE.html 707
- Kidd, C., and Levizzani, V., 2011. Status of satellite precipitation retrievals, Hydrol. Earth 708
 Syst. Sci., 15, 1109–1116, https://doi.org/10.5194/hess-15-1109-2011 709
- Kidd, C., Becker, A., Huffman, G. J., Muller, C. L., Joe, P., Skofronick-Jackson, G., & 710 Kirschbaum, D. B. (2017). So, How Much of the Earth's Surface Is Covered by Rain 711 Gauges?, Bulletin of the American Meteorological Society, 98(1), 69-78, 712 https://doi.org/10.1175/BAMS-D-14-00283.1
- Kubota, T., Shige, S., Hashizume, H., Aonashi, K., Takahashi, N., Seto, S., Hirose, M., 714
 Takayabu, Y. N., Ushio, T., Nakagawa, K., Iwanami, K., Kachi, M. and Okamoto, K., 715
 2007. Global Precipitation Map Using Satellite-Borne Microwave Radiometers by the 716
 GSMaP Project: Production and Validation, IEEE 5 Trans. Geosci. Remote Sens., 45(7), 717
 2259–2275, https://doi.org/10.1109/tgrs.2007.895337. 718
- Laraque, A., Mahé, G., Orange, D. and Marieu, B., 2001. Spatiotemporal variations in 719 hydrological regimes within Central Africa during the XXth century. J. Hydrol., 245(1-4), 104–117. https://doi.org/10.1016/S0022-1694(01)00340-7 721
- Loucks, D. P. and Van Beek, E., 2017. An Introduction to Probability, Statistics, and 722 Uncertainty, in: Water Resource Systems Planning and Management, 51 -72, Springer, 723 Cham, 2017. https://doi.org/10.1007/978-3-319-44234-1 724
- Maggioni, V., Massari, C., 2018. On the performance of satellite precipitation products in 725 riverine flood modeling: a review. J. Hydrol., 558, 214–224. 726 https://doi.org/10.1016/j.jhydrol.2018.01.039 727
- Maidment, R. I., Grimes, D., Black, E., Tarnavsky, E., Young, M., Greatrex, H., Allan, R. P., 728
 Stein, T., Nkonde, E., Senkunda, S. and Alcántara, E. M. U., 2017. A new, long-term 729
 daily satellite-based rainfall dataset for operational monitoring in Africa. Sci. Data., 4, 1– 730
 19. https://doi.org/10.1038/sdata.2017.63 731
- Mandal, U., Sena, D.R., Dhar, A., Panda, S.N., Adhikary, P.P., Mishra, P.K., 2021. Assessment 732 of climate change and its impact on hydrological regimes and biomass yield of a tropical river basin. Ecol. Ind., 126, 107646. https://doi.org/10.1016/j. ecolind.2021.107646 734
- McCollum, J. R., Gruber A., and Ba M. B., 2000. Discrepancy between gauges and satellite 735 estimates of rainfall in equatorial Africa. J. Appl. Meteor., 39, 666–679. 736 https://doi.org/10.1175/1520-0450-39.5.666 737
- Melaku, N. D., and Wang, J., 2019. A modified SWAT module for estimating groundwater 738 table at Lethbridge and Barons, Alberta, Canada. J. Hydrol., 575, 420–431. 739

 Moriasi, D.N., Arnold, J.G., van Liew, M.W., Bingner, R.L., Harmel, R.D., Veith, T.L., 2007. Yal Model evaluation guidelines for systematic quantification of accuracy in watershed 742 simulations, Trans, ASABE 50, 885 900. https://doi.org/10.1031/2013.23153 Yat Moriasi, D.N., Gitau, M.W., Pai, N., Daggupati, P., 2015. Hydrologic and water quality Patter and Control and Patter and Pathematical Trans, ASABE 58, 1763–1785. Yat Moriasi, D.N., Gitau, M.W., Pai, N., Daggupati, P., 2015. Hydrologic and water quality Yat models: performance measures and evaluation criteria. Trans. ASABE 58, 1763–1785. Yat Muti- decadal chronicles. In: Alsdorf, D., Tshinanaga Muamba, R., and Moukandi 749 N'kaya, G. D. (Eds.), Congo Basin Hydrology, Climate, and Biogeochemistry: A 750 Foundation for the Future, AGU Geophysical Monograph Series. Hoboken, NJ: John 751 Wiley & Sons, Inc. Wiley & Sons, Inc. Muzimi, Y.A., Hansen, M.C., Adusei, B. and Senay, G.B., 2015. Characterizing Congo basin 753 rainfall and climate using Tropical Rainfall Measuring Mission (TRMM) satellite data 754 and limited rain gauge ground observations. J. Appl. Meteorol. Climatol., 54, 541–555. https://doi.org/10.1175/JAMC-D-14-0052.1 Nash, J.E. and Sutcliffe, J.V., 1970. River Flow Forecasting through Conceptual Model. Part 757 I-A Discussion of Principles. J. Hydrol., 10, 282-290. http://dx.doi.org/10.1016/0022-758 1694(70)90255-6 Negron Juarez, R. I. N., Li, W. H., Fu, R., Fernandes, K., and Cardoso, A. D., 2009. Comparison of precipitation datasets over the tropical South American and African 761 continents. J. Hydrometeor., 10, 289–299. https://doi.org/10.1175/J008/HM1023.1. Nicholson, S. E., Kloter, D., Zhou, L., and Hua, W., 2019. Validation of Satellite Precipitation 763	 Moriasi, D.N., Arnold, J.G., van Liew, M.W., Bingner, R.L., Harmel, R.D., Veith, T.L., 2007. Model evaluation guidelines for systematic quantification of accuracy in watershed simulations. Trans. ASABE 50, 885–900. https://doi.org/10.1303/12013.23153 Moriasi, D.N., Gitau, M.W., Pai, N., Daggupati, P., 2015. Hydrologic and water quality models: performance measures and evaluation criteria. Trans. ASABE 58, 1763–1785. Hutps://doi.org/10.13031/trans.58.10715 Moukandi N'kaya, G. D., Laraque, A., Paturel, J. M, Gulemvuga, G., Mahé, G., and Tshimanga Muamba, R. (2021). A new look at hydrology in the Congo Basin, based on the study of multi-decadal chronicles. In: Alsdorf, D., Tshimanga Muamba, R., and Moukandi N'kaya, G. D. (Eds.), Congo Basin Hydrology, Climate, and Biogeochemistry: A Foundation for the Future, AGU Geophysical Monograph Series. Hoboken, NJ: John wiley & Sons, Inc. Munzimi, Y.A., Hansen, M.C., Adusei, B. and Senay, G.B., 2015. Characterizing Congo basin rainfall and climate using Tropical Rainfall Measuring Mission (TRMM) satellite data and limited rain gauge ground observations. J. Appl. Meteorol. Climatol., 54, 541–555. https://doi.org/10.1175/JAMC-D-14-0052.1 Nash, J.E. and Sutcliffe, J.V., 1970. River Flow Forecasting through Conceptual Model. Part I-A Discussion of Principles. J. Hydrol., 10, 282-290. http://dx.doi.org/10.1016/0022- f694(70)90255-6 Negron Juarez, R. I. N., Li, W. H., Fu, R., Fernandes, K., and Cardoso, A. D., 2009. Comparison of precipitation datasets over the tropical South American and African continents. J. Hydrometor, 10, 289–299. https://doi.org/10.1175/2008JHM1023.1. Nicholson, S. E., Klotter, D., Zhou, L., and Hua, W., 2019. Validation of Statellite Precipitation fa	https://doi.org/10.1016/j.jhydrol.2019.05.052	740
 Model evaluation guidelines for systematic quantification of accuracy in watershed yits simulations. Trans. ASABE 50, 885–900. https://doi.org/10.13031/2013.23153 Moriasi, D.N., Gitau, M.W., Pai, N., Dagupati, P., 2015. Hydrologic and water quality 744 models: performance measures and evaluation criteria. Trans. ASABE 58, 1763–1785. Motkandi N'kaya, G. D., Laraque, A., Paturel, J.M., Gulemvuga, G., Mahé, G., and Tshimanga 747 Muamba, R. (2021). A new look at hydrology in the Congo Basin, based on the study of 748 multi- decadal chronicles. In: Alsdorf, D., Tshimanga Muamba, R., and Moukandi 749 N'kaya, G. D. (Eds.), Congo Basin Hydrology, Climate, and Biogeochemistry: A 750 Foundation for the Future, AGU Geophysical Monograph Series. Hoboken, NJ: John 712 Wiley & Sons, Inc. Munzimi, Y.A., Hansen, M.C., Adusei, B. and Senay, G.B., 2015. Characterizing Congo basin rainfall and climate using Tropical Rainfall Measuring Mission (TRMM) satellite data 744 and limited rain gauge ground observations. J. Appl. Meteorol. Climatol., 54, 541–555. https://doi.org/10.1175/JAMC-D-14-0052.1 Nash, J.E. and Sutcliffe, J.V., 1970. River Flow Forecasting through Conceptual Model. Part 751 r-A Discussion of Principles. J. Hydrol., 10, 282-290. http://dx.doi.org/10.1016/022-758 1694(70)90255-6 Negron Juarez, R. I. N., Li, W. H., Fu, R., Fernandes, K., and Cardoso, A. D., 2009. 760 Comparison of precipitation dtasets over the tropical South American and African continents. J. Hydrometeor., 10, 289–299. https://doi.org/10.1175/2008JHM1023.1 Nicholson, S. E., Klotter, D., Zhou, L., and Hua, W., 2019. Validation of Satellite Precipitation 761 Early Warning Systems. J. Appl. Meteorol. Climatol., 52, 588-606. Novella, N.S. and Thiaw, W.M., 2013. African Rainfall Climatology Version 2 for Famine 764 Rainfall. Estimates over the Congo Basin. J. Hydrometeorol., 20(4), 631-656, 764 https://doi.org/10.1350/rs8070544 Peng, J., Li	 Model evaluation guidelines for systematic quantification of accuracy in watershed 7: simulations. Trans. ASABE 50, 885–900. https://doi.org/10.13031/2013.23153 Moriasi, D.N., Gitau, M.W., Pai, N., Dagguapti, P., 2015. Hydrologic and water quality 7: models: performance measures and evaluation criteria. Trans. ASABE 58, 1763–1785. Mutsadi, N.Kaya, G. D., Laraque, A., Paturel, J. M. Gulemvuga, G., Mahé, G., and Tshimanga 7. Muamba, R. (2021). A new look at hydrology in the Congo Basin, based on the study of 7. multi- decadal chronicles. In: Alsdorf, D., Tshimanga Muamba, R., and Moukandi 7. N'kaya, G. D. (Eds.), Congo Basin Hydrology, Climate, and Biogeochemistry: A 7. Foundation for the Future, AGU Geophysical Monograph Series. Hoboken, NJ: John 7. Wiley & Sons, Inc. Munzimi, Y.A., Hansen, M.C., Adusei, B. and Senay, G.B., 2015. Characterizing Congo basin rainfall and climate using Tropical Rainfall Measuring Mission (TRMM) satellite data 7. and limited rain gauge ground observations. J. Appl. Meteorol. Climatol., 54, 541–555. Mtps://doi.org/10.1175/JAMC-D-14-0052.1 Nash, J.E. and Sutcliffe, J.V., 1970. River Flow Forecasting through Conceptual Model. Part 1-A Discussion of Principles. J. Hydrol., 10, 282-290. http://dx.doi.org/10.1016/0022-1694(70)9025-6 Negron Juarez, R. I. N., Li, W. H., Fu, R., Fernandes, K., and Cardoso, A. D., 2009. Comparison of precipitation datasets over the tropical South American and African 70 continents. J. Hydrometeor, 10, 289–299. https://doi.org/10.1175/JOMS1-018-0118.1 Novella, N.S. and Thiaw, W.M., 2013. African Rainfall Climatology Version 2 for Famine 74. Patigati, Maggioni, V.; Vila, D.; Morales, C. Characteristics and Diurnal Cycle of GPM 74. Novella, N.S. and Thiaw, W.M., 2013. African Rainfall Climatology Version 2 for Famine 74. Pony J. Liau, T., Huang, Y., Liz, Z. Bao, A., Chen, X., Kurban, A., and De Maeyer, 74.<td>Ioriasi, D.N., Arnold, J.G., van Liew, M.W., Bingner, R.L., Harmel, R.D., Veith, T.L., 2007.</td><td>741</td>	Ioriasi, D.N., Arnold, J.G., van Liew, M.W., Bingner, R.L., Harmel, R.D., Veith, T.L., 2007.	741
 simulations. Trans. ÄSABE 50, 885–900. https://doi.org/10.13031/2013.23153 Yata Moriasi, D.N., Gitau, M.W., Pai, N., Dagupati, P., 2015. Hydrologic and water quality rdtps://doi.org/10.13031/trans.58.10715 Motakadi N'kaya, G. D., Laraque, A., Paturel, J. M, Gulemvuga, G., Mahé, G., and Tshimanga Muamba, R. (2021). A new look at hydrology in the Congo Basin, based on the study of rdtp. Anamol. A. (2021). A new look at hydrology, Climate, and Biogeochemistry: A Oroundation for the Future, AGU Geophysical Monograph Series. Hoboken, NJ: John Wiley & Sons, Inc. Munzimi, Y.A., Hansen, M.C., Adusei, B. and Senay, G.B., 2015. Characterizing Congo basin rainfall and climate using Tropical Rainfall Measuring Mission (TRMM) satellite data rainfall and climate using Tropical Rainfall Measuring Mission (TRMM) satellite data rainfall and climate using Tropical Rainfall Measuring Mission (TRMM) satellite data rada and Sutcliffe, J.V., 1970. River Flow Forecasting through Conceptual Model. Part rada Sutcliffe, J.V., 1970. River Flow Forecasting through Conceptual Model. Part rada Sutcliffe, J.V., 1970. River Flow Forecasting through Conceptual Model. Part respons Juarez, R. I. N., Li, W. H., Fu, R., Fernandes, K., and Cardoso, A. D., 2009. Comparison of precipitation datasets over the tropical South American and African rotinents. J. Hydrometeor., 10, 289–299. https://doi.org/10.1175/2008JHM1023.1. Novella, N.S. and Thiaw, W.M., 2013. African Rainfall Climatology Version 2 for Famine respons. J. Appl. Meteorol. Climatol., 52, 588-600. respons, J. Appl. Meteorol. Climatol., 52, 588-600. respons, J. Appl. Meteorol. Climatol., 52, 588-600. respons, J. Jup, Y., Lin, Z., Bao, A., Chen, X., Kurban, A., and De Maeyer, P., 2021.	 simulations. Trans. ASABE 50, 885–900. https://doi.org/10.13031/2013.23153 Moriasi, D.N., Gitau, M.W., Pai, N., Daggupati, P., 2015. Hydrologic and water quality 7-models: performance measures and evaluation criteria. Trans. ASABE 58, 1763–1785. Mutasati, P.Y., Karague, A., Paturel, J. M, Gulemvuga, G., Mahé, G., and Tshimanga 7-Muamba, R. (2021). A new look at hydrology in the Congo Basin, based on the study of 7-multi- decadal chronicles. In: Alsdorf, D., Tshimanga Muamba, R., and Moukandi 7. N'kaya, G. D. (Eds.), Congo Basin Hydrology, Climate, and Biogeochemistry: A 7. Foundation for the Future, AGU Geophysical Monograph Series. Hoboken, NJ: John 7. Wiley & Sons, Inc. Munzimi, Y.A., Hansen, M.C., Adusei, B. and Senay, G.B., 2015. Characterizing Congo basin 7: rainfall and climate using Tropical Rainfall Measuring Mission (TRMM) satellite data 7: and limited rain gauge ground observations. J. Appl. Meteorol. Climatol., 54, 541–555. Natsh, J.E. and Sutcliffe, J.V., 1970. River Flow Forecasting through Conceptual Model. Part 7: 1-694(70)90255-6 Negron Juarez, R. I. N., Li, W. H., Fu, R., Fernandes, K., and Cardoso, A. D., 2009. 70 comparison of principles. J. Hydrol., 10, 282-290. http://dx.doi.org/10.1175/JAMC-D-18-0118.1 Nicholson, S. E., Klotter, D., Zhou, L., and Hua, W., 2019. Validation of Satellite Precipitation 74 Estimates over the Congo Basin. J. Hydrometeorol., 20(4), 631-656, 74 https://doi.org/10.1175/JAMC-D-11-0238.1 Oliveira, R.; Maggioni, V.; Vila, D.; Morales, C. Characteristics and Diurnal Cycle of GPM 74 Rainfall Estimates over the Central Amazon Region. Remote Sens. 2016, 8, 544. Mttps://doi.org/10.3390/rs8070544 Peng, J., Liu, T., Huang, Y., Li, Z., Bao, A., Chen, X., Kurban, A., and De Maeyer, 74, 2019. Statellite-Based Precipitation Datasets Evaluation Using Gauge Observation and 74 Hydrological Modeling in a Typical Ard Land Watershed of Central Asia. Remote	Model evaluation guidelines for systematic quantification of accuracy in watershed	742
 Moriasi, D.N., Gitau, M.W., Pai, N., Daggupati, P., 2015. Hydrologic and water quality 744 models: performance measures and evaluation criteria. Trans. ASABE 58, 1763–1785. 745 https://doi.org/10.13031/trans.58.10715 Moukandi N'kaya, G. D., Laraque, A., Paturel, J. M, Gulemvuga, G., Mahé, G., and Tshimanga 747 Muamba, R. (2021). A new look at hydrology in the Congo Basin, based on the study of 748 multi- decadal chronicles. In: Alsdorf, D., Tshimanga Muamba, R., and Moukandi 749 N'kaya, G. D. (Eds.), Congo Basin Hydrology, Climate, and Biogeochemistry: A 750 Foundation for the Future, AGU Geophysical Monograph Series. Hoboken, NJ: John 751 wiley & Sons, Inc. Munzimi, Y.A., Hansen, M.C., Adusei, B. and Senay, G.B., 2015. Characterizing Congo basin 753 rainfall and climate using Tropical Rainfall Measuring Mission (TRMM) satellite data 744 and limited rain gauge ground observations. J. Appl. Meteorol. Climatol., 54, 541–555. 755 https://doi.org/10.1175/JAMC-D-14-0052.1 Nash, J.E. and Sutcliffe, J.V., 1970. River Flow Forecasting through Conceptual Model. Part 757 1-A Discussion of Principles. J. Hydrol., 10, 282-290. http://dx.doi.org/10.1016/0022-759 Negron Juarez, R. I. N., Li, W. H., Fu, R., Fernandes, K., and Cardoso, A. D., 2009. Comparison of precipitation datasets over the tropical South American and African 761 continents. J. Hydrometeor, 10, 289 -299. https://doi.org/10.1175/JUMD-23.1 Nicholson, S. E., Klotter, D., Zhou, L., and Hua, W., 2019. Validation of Satellite Precipitation 763 Estimates over the Congo Basin. J. Hydrometeorol., 20(4), 631-656, 764 https://doi.org/10.1375/JAMC-D-11-0238.1 Novella, N.S. and Thiaw, W.M., 2013. African Rainfall Climatology Version 2 for Famine 766 Early Warning Systems. J. Appl. Meteorol. Climatol., 52, 588-606. 767 https://doi.org/10.390/rs807544 Peng, J., Liu, T., Huang, Y., Ling, Y., Lia, Z., Bao, A., Chen, X., Kurban, A., and De Maeyer, 772 P., 2021. Satellite-B	 Moriasi, D.N., Gitau, M.W., Pai, N., Daggupati, P., 2015. Hydrologic and water quality 7-models: performance measures and evaluation criteria. Trans. ASABE 58, 1763–1785. Moukandi N'kaya, G. D., Laraque, A., Paturel, J. M, Gulemvuga, G., Mahé, G., and Tshimanga Muamba, R. (2021). A new look at hydrology in the Congo Basin, based on the study of 7-multi-decadal chronicles. In: Alsdorf, D., Tshimanga Muamba, R., and Moukandi 7. N'kaya, G. D. (Eds.), Congo Basin Hydrology. Climate, and Biogeochemistry: A 7. Foundation for the Future, AGU Geophysical Monograph Series. Hoboken, NJ: John 7: Wiley & Sons, Inc. Munzimi, Y.A., Hansen, M.C., Adusei, B. and Senay, G.B., 2015. Characterizing Congo basin rainfall and climate using Tropical Rainfall Measuring Mission (TRMM) satellite data 7: and limited rain gauge ground observations. J. Appl. Meteorol. Climatol., 54, 541–555. Nttps://doi.org/10.1175/JAMC-D-14-0052.1 Nash, J.E. and Sutcliffe, J.V., 1970. River Flow Forecasting through Conceptual Model. Part 7: 1-A Discussion of Principles. J. Hydrol., 10, 282-290. http://dx.doi.org/10.1016/0022-1694(70)90255-6 Negron Juarez, R. I. N., Li, W. H., Fu, R., Fernandes, K., and Cardoso, A. D., 2009. Comparison of precipitation datasets over the tropical South American and African 7: continents. J. Hydrometeor., 10, 289–299. https://doi.org/10.1175/2008JHM1023.1. Nicholson, S. E., Klotter, D., Zhou, L., and Hua, W., 2019. Validation of Satellite Precipitation 7: Estimates over the Congo Basin. J. Hydrometeorol., 20(4), 631-656, 7: https://doi.org/10.1175/JAMC-D-11-0238.1 Novella, N.S. and Thiaw, W.M., 2013. African Rainfall Climatology Version 2 for Famine 7. Early Warning Systems. J. Appl. Meteorol. Climatol., 52, 588-606. 70 https://doi.org/10.3390/rs8070544 Peng, J., Liu, T., Huang, Y., Lig, Y., Li, Z., Bao, A., Chen, X., Kurban, A., and De Maeyer, 7. P., 2021. Satellite-Based Precipitation Datasets Evaluation Usi	simulations. Trans. ASABE 50, 885–900. https://doi.org/10.13031/2013.23153	743
 models: performance measures and evaluation criteria. Trans. ASABE 58, 1763–1785. 745 https://doi.org/10.13031/trans.58.10715 Moukandi N'kaya, G. D., Laraque, A., Paturel, J. M, Gulemvuga, G., Mahé, G., and Tshimanga Muamba, R. (2021). A new look at hydrology in the Congo Basin, based on the study of 748 multi- decadal chronicles. In: Alsdorf, D., Tshimanga Muamba, R., and Moukandi Yaya, G. D. (Eds.), Congo Basin Hydrology, Climate, and Biogeochemistry: A 750 Foundation for the Future, AGU Geophysical Monograph Series. Hoboken, NJ: John Yiley & Sons, Inc. Munzimi, Y. A., Hansen, M.C., Adusei, B. and Senay, G.B., 2015. Characterizing Congo basin rainfall and climate using Tropical Rainfall Measuring Mission (TRMM) satellite data rainfall and climate using Tropical Rainfall Measuring Mission (TRMM) satellite data rainfall and climate using Tropical Rainfall Measuring Mission (TRMM) satellite data rainfall and climate using Tropical Rainfall Measuring Mission (TRMM) satellite data rainfall and Sutcliffe, J.V., 1970. River Flow Forecasting through Conceptual Model. Part r.A. Discussion of Principles. J. Hydrol., 10, 282-290. http://dx.doi.org/10.1016/0022- 759 Negron Juarez, R. I. N., Li, W. H., Fu, R., Fernandes, K., and Cardoso, A. D., 2009. Comparison of precipitation datasets over the tropical South American and African rofic continents. J. Hydrometeor, 10, 289-299. https://doi.org/10.1175/2008JHM1023.1. rofic Barly Warning Systems. J. Appl. Meteorol. Climatol., 52, 588-606. Korbal, N.S. and Thiaw, W.M., 2013. African Rainfall Climatology Version 2 for Famine rearly Warning Systems. J. Appl. Meteorol. Climatol., 52, 588-606. Rainfall Estimates over the Central Amazon Region. Remote Sens. 2016, 8, 544.<td> models: performance measures and evaluation criteria. Trans. ASABE 58, 1763–1785. https://doi.org/10.13031/trans.58.10715 Moukandi N'kaya, G. D., Laraque, A., Paturel, J. M, Gulemvuga, G., Mahé, G., and Tshimanga Muamba, R. (2021). A new look at hydrology in the Congo Basin, based on the study of multi-decadal chronicles. In: Alsdorf, D., Tshimanga Muamba, R., and Moukandi N'kaya, G. D. (Eds.), Congo Basin Hydrology, Climate, and Biogeochemistry: A Foundation for the Future, AGU Geophysical Monograph Series. Hoboken, NJ: John Wiley & Sons, Inc. Munzimi, Y.A., Hansen, M.C., Adusei, B. and Senay, G.B., 2015. Characterizing Congo basin rainfall and climate using Tropical Rainfall Measuring Mission (TRMM) satellite data rainfall and climate using Tropical Rainfall Measuring Mission (CIImatol., 54, 541–555. https://doi.org/10.1175/JAMC-D-14-0052.1 Nash, J.E. and Sutcliffe, J.V., 1970. River Flow Forecasting through Conceptual Model. Part 1-A Discussion of Principles. J. Hydrol. 10, 282-290. http://dx.doi.org/10.1016/0022- 1694(70)90255-6 Negron Juarez, R. I. N., Li, W. H., Fu, R., Fernandes, K., and Cardoso, A. D., 2009. Comparison of preipitation datasets over the tropical South American and African continents. J. Hydrometeor., 10, 289–299. https://doi.org/10.1175/2008JHM1023.1. Nicholson, S. E., Klotter, D., Zhou, L., and Hua, W., 2019. Validation of Satellite Precipitation Estimates over the Congo Basin. J. Hydrometeorol., 20(4), 631-656, 70 https://doi.org/10.1175/JAMC-D-14-018.1 Novella, N.S. and Thiaw, W.M., 2013. African Rainfall Climatology Version 2 for Famine Farly Warning Systems. J. Appl. Meteorol. Climatol., 52, 588-606. Hydrological Modeling in a Typical Arid Land Watershed of Central Asia. Remot</td><td>Ioriasi, D.N., Gitau, M.W., Pai, N., Daggupati, P., 2015. Hydrologic and water quality</td><td>744</td>	 models: performance measures and evaluation criteria. Trans. ASABE 58, 1763–1785. https://doi.org/10.13031/trans.58.10715 Moukandi N'kaya, G. D., Laraque, A., Paturel, J. M, Gulemvuga, G., Mahé, G., and Tshimanga Muamba, R. (2021). A new look at hydrology in the Congo Basin, based on the study of multi-decadal chronicles. In: Alsdorf, D., Tshimanga Muamba, R., and Moukandi N'kaya, G. D. (Eds.), Congo Basin Hydrology, Climate, and Biogeochemistry: A Foundation for the Future, AGU Geophysical Monograph Series. Hoboken, NJ: John Wiley & Sons, Inc. Munzimi, Y.A., Hansen, M.C., Adusei, B. and Senay, G.B., 2015. Characterizing Congo basin rainfall and climate using Tropical Rainfall Measuring Mission (TRMM) satellite data rainfall and climate using Tropical Rainfall Measuring Mission (CIImatol., 54, 541–555. https://doi.org/10.1175/JAMC-D-14-0052.1 Nash, J.E. and Sutcliffe, J.V., 1970. River Flow Forecasting through Conceptual Model. Part 1-A Discussion of Principles. J. Hydrol. 10, 282-290. http://dx.doi.org/10.1016/0022- 1694(70)90255-6 Negron Juarez, R. I. N., Li, W. H., Fu, R., Fernandes, K., and Cardoso, A. D., 2009. Comparison of preipitation datasets over the tropical South American and African continents. J. Hydrometeor., 10, 289–299. https://doi.org/10.1175/2008JHM1023.1. Nicholson, S. E., Klotter, D., Zhou, L., and Hua, W., 2019. Validation of Satellite Precipitation Estimates over the Congo Basin. J. Hydrometeorol., 20(4), 631-656, 70 https://doi.org/10.1175/JAMC-D-14-018.1 Novella, N.S. and Thiaw, W.M., 2013. African Rainfall Climatology Version 2 for Famine Farly Warning Systems. J. Appl. Meteorol. Climatol., 52, 588-606. Hydrological Modeling in a Typical Arid Land Watershed of Central Asia. Remot	Ioriasi, D.N., Gitau, M.W., Pai, N., Daggupati, P., 2015. Hydrologic and water quality	744
 https://doi.org/10.13031/trans.58.10715 Moukandi N'kaya, G. D., Laraque, A., Paturel, J. M, Gulenvuga, G., Mahé, G., and Tshimanga Muamba, R. (2021). A new look at hydrology in the Congo Basin, based on the study of Pranka, R. (2021). A new look at hydrology, Climate, and Biogeochemistry: A N'kaya, G. D. (Eds.), Congo Basin Hydrology, Climate, and Biogeochemistry: A Foundation for the Future, AGU Geophysical Monograph Series. Hoboken, NJ: John Wiley & Sons, Inc. Munzimi, Y.A., Hansen, M.C., Adusei, B. and Senay, G.B., 2015. Characterizing Congo basin rainfall and climate using Tropical Rainfall Measuring Mission (TRMM) satellite data and limited rain gauge ground observations. J. Appl. Meteorol. Climatol., 54, 541–555. https://doi.org/10.1175/JAMC-D-14-0052.1 Nash, J.E. and Suculiffe, J.V., 1970. River Flow Forecasting through Conceptual Model. Part 1-A Discussion of Principles. J. Hydrol., 10, 282-290. http://dx.doi.org/10.1016/0022- Patorison of principles. J. Hydrol., 10, 282-290. http://dx.doi.org/10.1016/0022- Nicholson, S. E., Klotter, D., Zhou, L., and Hua, W., 2019. Validation of Satellite Precipitation restimates over the Congo Basin. J. Hydrometeorol., 20(4), 631-656, 764 https://doi.org/10.1175/JHMC-D-11-0238.1 Oliveira, R.; Maggioni, V.; Vila, D.; Morales, C. Characteristics and Diurnal Cycle of GPM regn, J., Liu, T., Huang, Y., Ling, Y., Li, Z., Bao, A., Chen, X., Kurban, A., and De Maeyer, P., 2021. Satellite-Based Precipitation Datasets Evaluation Using Gauge Observation and Hydrological Modeling in a Typical Arid Land Watershed of Central Asia. Remote Sens., regn, J., Liu, T., Huang, Y., Ling, Y., Li, Z., Bao, A., Chen, X., Kurban, A., and De Maeyer, P., 2021. Satellite-Based Precipitation Datasets Eva	 https://doi.org/10.13031/trans.58.10715 Moukandi N'kaya, G. D., Laraque, A., Paturel, J. M, Gulemvuga, G., Mahé, G., and Tshimanga Muamba, R. (2021). A new look at hydrology in the Congo Basin, based on the study of multi- decadal chronicles. In: Alsdorf, D., Tshimanga Muamba, R., and Moukandi N'kaya, G. D. (Eds.), Congo Basin Hydrology, Climate, and Biogeochemistry: A Foundation for the Future, AGU Geophysical Monograph Series. Hoboken, NJ: John Wiley & Sons, Inc. Munzimi, Y.A., Hansen, M.C., Adusei, B. and Senay, G.B., 2015. Characterizing Congo basin rainfall and climate using Tropical Rainfall Measuring Mission (TRMM) satellite data and limited rain gauge ground observations. J. Appl. Meteorol. Climatol., 54, 541–555. https://doi.org/10.1175/JAMC-D-14-0052.1 Nash, J.E. and Sutcliffe, J.V., 1970. River Flow Forecasting through Conceptual Model. Part 1-A Discussion of Principles. J. Hydrol., 10, 282-290. http://dx.doi.org/10.1016/0022- Regron Juarez, R. I. N., Li, W. H., Fu, R., Fernandes, K., and Cardoso, A. D., 2009. Comparison of precipitation datasets over the tropical South American and African continents. J. Hydrometeor., 10, 289–299. https://doi.org/10.1175/2081HM1023.1. Nicholson, S. E., Klotter, D., Zhou, L., and Hua, W., 2019. Validation of Satellite Precipitation Eatly Warning Systems. J. Appl. Meteorol. Climatol., 52, 588-606. https://doi.org/10.1175/JHM-D-18-0118.1 Novella, N.S. and Thiaw, W.M., 2013. African Rainfall Climatology Version 2 for Famine Peng, J., Liu, T., Huang, Y., Ling, Y., Li, Z., Bao, A., Chen, X., Kurban, A., and De Maeyer, P., 2021. Satellite-Based Precipitation Datasets Evaluation Using Gauge Observation and Hydrologr/10.1175/J0.590/7544 Peng, J., Liu, T., Huang, Y., Ling, Y., Li, Z	models: performance measures and evaluation criteria. Trans. ASABE 58, 1763–1785.	745
 Moukandi N'kaya, G. D., Laraque, A., Paturel, J. M, Gulemvuga, G., Mahé, G., and Tshimanga 747 Muamba, R. (2021). A new look at hydrology in the Congo Basin, based on the study of 748 multi-decadal chronicles. In: Alsdorf, D., Tshimanga Muamba, R., and Moukandi 749 N'kaya, G. D. (Eds.), Congo Basin Hydrology, Climate, and Biogeochemistry: A 750 Foundation for the Future, AGU Geophysical Monograph Series. Hoboken, NJ: John 751 Wiley & Sons, Inc. 752 Munzimi, Y.A., Hansen, M.C., Adusei, B. and Senay, G.B., 2015. Characterizing Congo basin 753 rainfall and climate using Tropical Rainfall Measuring Mission (TRMM) satellite data 754 and limited rain gauge ground observations. J. Appl. Meteorol. Climatol., 54, 541–555. https://doi.org/10.1175/JAMC-D-14-0052.1 Nash, J.E. and Sutcliffe, J.V., 1970. River Flow Forecasting through Conceptual Model. Part 1-A Discussion of Principles. J. Hydrol., 10, 282-290. http://dx.doi.org/10.1016/0022-758 Negron Juarez, R. I. N., Li, W. H., Fu, R., Fernandes, K., and Cardoso, A. D., 2009. Micholson, S. E., Klotter, D., Zhou, L., and Hua, W., 2019. Validation of Satellite Precipitation 761 continents. J. Hydrometeor., 10, 289–299. https://doi.org/10.1175/JMMI023.1. Novella, N.S. and Thiaw, W.M., 2013. African Rainfall Climatology Version 2 for Famine 766 https://doi.org/10.1175/JAMC-D-11-0238.1 Oliveira, R.; Maggioni, V.; Vila, D.; Morales, C. Characteristics and Diurnal Cycle of GPM 769 Rainfall Estimates over the Congo Jasain. J. Hydronelocol. 2016, 8, 544. Oliveira, R.; Maggioni, V.; Vila, D.; Morales, C. Characteristics and Diurnal Cycle of GPM 769 Rainfall Estimates over the Central Amazon Region. Remote Sens. 2016, 8, 544. 770 Paj, J., Liu, T., Huang, Y., Li, Z., Bao, A., Chen, X., Kurban, A., and De Maeyer, 772	 Moukandi N'kaya, G. D., Laraque, A., Paturel, J. M, Gulemvuga, G., Mahé, G., and Tshimanga Muamba, R. (2021). A new look at hydrology in the Congo Basin, based on the study of multi- decadal chronicles. In: Alsdorf, D., Tshimanga Muamba, R., and Moukandi N'kaya, G. D. (Eds.), Congo Basin Hydrology, Climate, and Biogeochemistry: A Foundation for the Future, AGU Geophysical Monograph Series. Hoboken, NJ: John Wiley & Sons, Inc. Munzimi, Y.A., Hansen, M.C., Adusei, B. and Senay, G.B., 2015. Characterizing Congo basin rainfall and climate using Tropical Rainfall Measuring Mission (TRMM) satellite data rainfall and climate using Tropical Rainfall Measuring Mission (TRMM) satellite data rainfall and climate using Tropical Rainfall Measuring Mission (TRMM) satellite data rainfall and climate using Tropical Rainfall Measuring Mission (TRMM) satellite data rainfall and Climate using Tropical Rainfall Measuring Mission (TRMM) satellite data rainfall and Climate using Tropical Rainfall Measuring Mission (TRMM) satellite data rainfall and climate using Tropical Rainfall Measuring Mission (TRMM) satellite data rainfall and climate using Tropical Rainfall Measuring Mission (TRMM) satellite data rainfall trainfall Measuring Mission (TRMM) satellite data rainfall trainfall Measuring Mission (TRMM) satellite data rainfall trainfall Measuring Mission (TRMM) satellite data rainfall measuring Mission (TRMM) satellite data rainfall trainfall Measuring Mission (TRMM) satellite data rainfall treasuring Mission (Principles. J. Hydrol., 10, 282-290. https:	https://doi.org/10.13031/trans.58.10715	746
 Muamba, R. (2021). A new look at hydrology in the Congo Basin, based on the study of 748 multi- decadal chronicles. In: Alsdorf, D., Tshimanga Muamba, R., and Moukandi 749 N'kaya, G. D. (Eds.), Congo Basin Hydrology, Climate, and Biogeochemistry: A 750 Foundation for the Future, AGU Geophysical Monograph Series. Hoboken, NJ: John 751 Wiley & Sons, Inc. 752 Munzimi, Y.A., Hansen, M.C., Adusei, B. and Senay, G.B., 2015. Characterizing Congo basin 733 rainfall and climate using Tropical Rainfall Measuring Mission (TRMM) satellite data 754 and limited rain gauge ground observations. J. Appl. Meteorol. Climatol., 54, 541–555. 755 https://doi.org/10.1175/JAMC-D-14-0052.1 Nash, J.E. and Sutcliffe, J.V., 1970. River Flow Forecasting through Conceptual Model. Part 1-A Discussion of Principles. J. Hydrol., 10, 282-290. http://dx.doi.org/10.1016/0022-758 1694(70)90255-6 Negron Juarez, R. I. N., Li, W. H., Fu, R., Fernandes, K., and Cardoso, A. D., 2009. Comparison of precipitation datasets over the tropical South American and African 761 continents. J. Hydrometeor, 10, 289–299. https://doi.org/10.1175/2008JHM1023.1. Nicholson, S. E., Klotter, D., Zhou, L., and Hua, W., 2019. Validation of Satellite Precipitation Early Warning Systems. J. Appl. Meteorol. Climatol, 52, 588-606. Novella, N.S. and Thiaw, W.M., 2013. African Rainfall Climatology Version 2 for Famine Early Warning Systems. J. Appl. Meteorol. Climatol., 52, 588-606. Oliveira, R.; Maggioni, V.; Vila, D.; Morales, C. Characteristics and Diurnal Cycle of GPM 748 antiful Bistimates over the Central Amazon Region. Remote Sens. 2016, 8, 544. Oliveira, R.; Maggioni, V.; Vila, D.; Morales, C. Characteristics and Diurnal Cycle of GPM 740 https://doi.org/10.13390/rs8070544 Peng, J., Liu, T., Huang, Y., Ling, Y., Li, Z., Bao, A., Chen, X., Kurban, A., and De Maeyer, 72 P., 2021. Satellite-Based Precipitation Datasets Evaluation Using Gauge Observation and Hy	 Muamba, R. (2021). A new look at hydrology in the Congo Basin, based on the study of multi- decadal chronicles. In: Alsdorf, D., Tshimanga Muamba, R., and Moukandi N'kaya, G. D. (Eds.), Congo Basin Hydrology, Climate, and Biogeochemistry: A Foundation for the Future, AGU Geophysical Monograph Series. Hoboken, NJ: John Zhing Wasser, M.C., Adusei, B. and Senay, G.B., 2015. Characterizing Congo basin rainfall and climate using Tropical Rainfall Measuring Mission (TRMM) satellite data and limited rain gauge ground observations. J. Appl. Meteorol. Climatol., 54, 541–555. https://doi.org/10.1175/JAMC-D-14-0052.1 Nash, J.E. and Sutcliffe, J.V., 1970. River Flow Forecasting through Conceptual Model. Part 1-A Discussion of Principles. J. Hydrol., 10, 282-290. http://dx.doi.org/10.1016/0022- 71694(70)90255-6 Negron Juarez, R. I. N., Li, W. H., Fu, R., Fernandes, K., and Cardoso, A. D., 2009. Comparison of precipitation datasets over the tropical South American and African 70 continents. J. Hydrometeor., 10, 289–299. https://doi.org/10.1175/2008JHM1023.1. Nicholson, S. E., Klotter, D., Zhou, L., and Hua, W., 2019. Validation of Satellite Precipitation 74 Estimates over the Congo Basin. J. Hydrometeorol., 20(4), 631-656, 74 https://doi.org/10.1175/JAMC-D-11-0238.1 Novella, N.S. and Thiaw, W.M., 2013. African Rainfall Climatology Version 2 for Famine 74 Early Warning Systems. J. Appl. Meteorol. Climatol., 52, 588-606. Mittps://doi.org/10.3390/rs8070544 Peng, J., Liu, T., Huang, Y., Ling, Y., Li, Z., Bao, A., Chen, X., Kurban, A., and De Maeyer, 74 P., 2021. Satellite-Based Precipitation Datasets Evaluation Using Gauge Observation and 74 Hydrological Modeling in a Typical Arid Land Watershed of Central Asia. Remote Sens., 71 41 Hys://doi.org/10.3390/rs13020221 Roca, R. Estimation of extreme daily precipitation thermodynamic scaling using gridded 73 astellite precipitation products over tropical la	Ioukandi N'kaya, G. D., Laraque, A., Paturel, J. M, Gulemvuga, G., Mahé, G., and Tshimanga	747
 multi- decadal chronicles. In: Alsdorf, D., Tshimanga Muamba, R., and Moukandi Ykaya, G. D. (Eds.), Congo Basin Hydrology, Climate, and Biogeochemistry: A Foundation for the Future, AGU Geophysical Monograph Series. Hoboken, NJ: John Wiley & Sons, Inc. Munzimi, Y.A., Hansen, M.C., Adusei, B. and Senay, G.B., 2015. Characterizing Congo basin rainfall and climate using Tropical Rainfall Measuring Mission (TRMM) satellite data and limited rain gauge ground observations. J. Appl. Meteorol. Climatol., 54, 541–555. https://doi.org/10.1175/JAMC-D-14-0052.1 Nash, J.E. and Sutcliffe, J.V., 1970. River Flow Forecasting through Conceptual Model. Part 1694(70)90255-6 Negron Juarez, R. I. N., Li, W. H., Fu, R., Fernandes, K., and Cardoso, A. D., 2009. Comparison of principlation datasets over the tropical South American and African rotinents. J. Hydrometeor., 10, 289–299. https://doi.org/10.1175/2008JHM1023.1. Nicholson, S. E., Klotter, D., Zhou, L., and Hua, W., 2019. Validation of Satellite Precipitation Estimates over the Congo Basin. J. Hydrometeorol., 20(4), 631-656, https://doi.org/10.1175/JHM-D-18-0118.1 Novella, N.S. and Thiaw, W.M., 2013. African Rainfall Climatology Version 2 for Famine Early Warning Systems. J. Appl. Meteorol. Climatol., 52, 588-606. https://doi.org/10.1175/JAMC-D-11-0238.1 Oliveira, R.; Maggioni, V.; Vila, D.; Morales, C. Characteristics and Diurnal Cycle of GPM Ryadille Estimates over the Central Amazon Region. Remote Sens. 2016, 8, 544. 921. Satellite-Based Precipitation Datasets Evaluation Using Gauge Observation and Hydrological Modeling in a Typical Arid Land Watershed of Central Asia. Remote Sens., 174 3, 221. https://doi.org/10.3390/rs13020221 Roca, R. Estimation of ext	 multi- decadal chronicles. In: Alsdorf, D., Tshimanga Muamba, R., and Moukandi 7. N'kaya, G. D. (Eds.), Congo Basin Hydrology, Climate, and Biogeochemistry: A 7. Foundation for the Future, AGU Geophysical Monograph Series. Hoboken, NJ: John 7. Wiley & Sons, Inc. Munzimi, Y.A., Hansen, M.C., Adusei, B. and Senay, G.B., 2015. Characterizing Congo basin 7. rainfall and climate using Tropical Rainfall Measuring Mission (TRMM) satellite data 7. and limited rain gauge ground observations. J. Appl. Meteorol. Climatol., 54, 541–555. https://doi.org/10.1175/JAMC-D-14-0052.1 Nash, J.E. and Sutcliffe, J.V., 1970. River Flow Forecasting through Conceptual Model. Part 7. 1-A Discussion of Principles. J. Hydrol., 10, 282-290. http://dx.doi.org/10.1016/0022-7.1694(70)90255-6 Negron Juarez, R. I. N., Li, W. H., Fu, R., Fernandes, K., and Cardoso, A. D., 2009. 70 Comparison of precipitation datasets over the tropical South American and African 70 continents. J. Hydrometeor., 10, 289–299. https://doi.org/10.1175/2008JHM1023.1. Nicholson, S. E., Klötter, D., Zhou, L., and Hua, W., 2019. Validation of Satellite Precipitation 70 Estimates over the Congo Basin. J. Hydrometeorol., 20(4), 631-656, 70 https://doi.org/10.1175/JIM-D-18-0118.1 Novella, N.S. and Thiaw, W.M., 2013. African Rainfall Climatology Version 2 for Famine 70 Early Warning Systems. J. Appl. Meteorol. Climatol., 52, 588-606. 71 https://doi.org/10.1175/JAMC-D-11-0238.1 Oliveira, R.; Maggioni, V.; Vila, D.; Morales, C. Characteristics and Diurnal Cycle of GPM 74 reg. J. Liu, T., Huang, Y., Ling, Y., Li, Z., Bao, A., Chen, X., Kurban, A., and De Maeyer, 77 P., 2021. Satellite-Based Precipitation Datasets Evaluation Using Gauge Observation and 74 rydrological Modeling in a Typical Arid Land Watershed of Central Asia. Remote Sens. 71 13, 221. https://doi.org/10.3390/rs13020221 Roca, R. Estimation of extreme daily precipitation thermodynamic scaling using gridded 7 satel	Muamba, R. (2021). A new look at hydrology in the Congo Basin, based on the study of	748
 N'kaya, G. D. (Eds.), Congo Basin Hydrology, Climate, and Biogeochemistry: A 750 Foundation for the Future, AGU Geophysical Monograph Series. Hoboken, NJ: John 751 Wunzimi, Y.A., Hansen, M.C., Adusei, B. and Senay, G.B., 2015. Characterizing Congo basin rainfall and climate using Tropical Rainfall Measuring Mission (TRMM) satellite data 754 and limited rain gauge ground observations. J. Appl. Meteorol. Climatol., 54, 541–555. 755 Nash, J.E. and Sutcliffe, J.V., 1970. River Flow Forecasting through Conceptual Model. Part 1-A Discussion of Principles. J. Hydrol., 10, 282-290. http://dx.doi.org/10.106/0022-758 Negron Juarez, R. I. N., Li, W. H., Fu, R., Fernandes, K., and Cardoso, A. D., 2009. Comparison of precipitation datasets over the tropical South American and African continents. J. Hydrometeor., 10, 289–299. https://doi.org/10.1175/2008JHM1023.1. Nicholson, S. E., Klotter, D., Zhou, L., and Hua, W., 2019. Validation of Satellite Precipitation 761 Estimates over the Congo Basin. J. Hydrometeorol., 20(4), 631-656, 764 https://doi.org/10.1175/JHM-D-18-0118.1 Novella, N.S. and Thiaw, W.M., 2013. African Rainfall Climatology Version 2 for Famine Early Warning Systems. J. Appl. Meteorol. Climatol., 52, 588-606, 767 Oliveira, R.; Maggioni, V.; Vila, D.; Morales, C. Characteristics and Diurnal Cycle of GPM 769 Rainfall Estimates over the Central Amazon Region. Remote Sens. 2016, 8, 544. 770 https://doi.org/10.3390/rs13020221 Roca, R., Estimation of exterme daily precipitation thermodynamic scaling using gridded 766 astellite precipitation products over tropical land. Environ. Res. Lett., IOP Publishing, 72019, 14. https://doi.org/10.1088/1748-9326/ab35c6 778 Roca, R., Alexander, L. V., Potter, G., Bador, M., Jucá, R., Contractor, S., Bosilovich, M. G., 779 and Cloché, S., 2019. FROGS: a daily 1°×1°	 N'kaya, G. D. (Eds.), Congo Basin Hydrology, Climate, and Biogeochemistry: A 7: Foundation for the Future, AGU Geophysical Monograph Series. Hoboken, NJ: John 7: Wiley & Sons, Inc. Munzimi, Y.A., Hansen, M.C., Adusei, B. and Senay, G.B., 2015. Characterizing Congo basin 7: rainfall and climate using Tropical Rainfall Measuring Mission (TRMM) satellite data 7: and limited rain gauge ground observations. J. Appl. Meteorol. Climatol., 54, 541–555. 7: https://doi.org/10.1175/JAMC-D-14-0052.1 Nash, J.E. and Sutcliffe, J.V., 1970. River Flow Forecasting through Conceptual Model. Part 7: 1-A Discussion of Principles. J. Hydrol., 10, 282-290. http://dx.doi.org/10.1016/0022-7.1694(70)90255-6 Negron Juarez, R. I. N., Li, W. H., Fu, R., Fernandes, K., and Cardoso, A. D., 2009. 7(Comparison of precipitation datasets over the tropical South American and African 7(continents. J. Hydrometeor., 10, 289–299. https://doi.org/10.1175/2008JHM1023.1. Nicholson, S. E., Klotter, D., Zhou, L., and Hua, W., 2019. Validation of Satellite Precipitation 74 Estimates over the Congo Basin. J. Hydrometeorol., 20(4), 631-656, 70(https://doi.org/10.1175/JHM-D-18-0118.1 Novella, N.S. and Thiaw, W.M., 2013. African Rainfall Climatology Version 2 for Famine 74 Early Warning Systems. J. Appl. Meteorol. Climatol., 52, 588-606. 70 Mainfall Estimates over the Central Amazon Region. Remote Sens. 2016, 8, 544. 7 https://doi.org/10.1390/rs8070544 Peng, J., Liu, T., Huang, Y., Ling, Y., Li, Z., Bao, A., Chen, X., Kurban, A., and De Maeyer, 7 P., 2021. Satellite-Based Precipitation Datasets Evaluation Using Gauge Observation and 74 Hydrological Modeling in a Typical Arid Land Watershed of Central Asia. Remote Sens., 71 3, 221. https://doi.org/10.1390/rs13020221 Roca, R. Estimation of exterme daily precipitation thermodynamic scaling using gridded 73 atellite precipitation products over tropical land. Environ. Res.	multi- decadal chronicles. In: Alsdorf, D., Tshimanga Muamba, R., and Moukandi	749
 Foundation for the Future, AGU Geophysical Monograph Series. Hoboken, NJ: John 751 Wiley & Sons, Inc. 752 Munzimi, Y.A., Hansen, M.C., Adusei, B. and Senay, G.B., 2015. Characterizing Congo basin 753 rainfall and climate using Tropical Rainfall Measuring Mission (TRMM) satellite data 754 and limited rain gauge ground observations. J. Appl. Meteorol. Climatol., 54, 541–555. 755 https://doi.org/10.1175/JAMC-D-14-0052.1 Nash, J.E. and Sutcliffe, J.V., 1970. River Flow Forecasting through Conceptual Model. Part 1-A Discussion of Principles. J. Hydrol., 10, 282-290. http://dx.doi.org/10.1016/0022-758 1694(70)90255-6 Negron Juarez, R. I. N., Li, W. H., Fu, R., Fernandes, K., and Cardoso, A. D., 2009. 760 Comparison of precipitation datasets over the tropical South American and African continents. J. Hydrometeor., 10, 289–299. https://doi.org/10.1175/2008JHM1023.1. Nicholson, S. E., Klotter, D., Zhou, L., and Hua, W., 2019. Validation of Satellite Precipitation 763 Estimates over the Congo Basin. J. Hydrometeorl., 20(4), 631-656, 764 https://doi.org/10.1175/JHMC-D-18-0118.1 Novella, N.S. and Thiaw, W.M., 2013. African Rainfall Climatology Version 2 for Famine Early Warning Systems. J. Appl. Meteorol. Climatol., 52, 588-606. 767 https://doi.org/10.1175/JIAMC-D-11-0238.1 Oliveira, R.; Maggioni, V.; Vila, D.; Morales, C. Characteristics and Diurnal Cycle of GPM 769 Rainfall Estimates over the Central Amazon Region. Remote Sens. 2016, 8, 544. 770 https://doi.org/10.3390/rs130200544 Peng, J., Liu, T., Huang, Y., Ling, Y., Li, Z., Bao, A., Chen, X., Kurban, A., and De Maeyer, P., 2021. Satellite-Based Precipitation Datasets Evaluation Using Gauge Observation and 773 Hydrological Modeling in a Typical Arid Land Watershed of Central Asia. Remote Sens. 774 13, 221. https://doi.org/10.1380/rs13020221 Roca, R., Alexander, L. V., Potter, G., Bador, M., Jucá, R., Contractor, S., Bosilovich, M. G., 779 and Cloché, S.	 Foundation for the Future, AGU Geophysical Monograph Series. Hoboken, NJ: John 7: Wiley & Sons, Inc. Munzimi, Y.A., Hansen, M.C., Adusei, B. and Senay, G.B., 2015. Characterizing Congo basin 7: arinfall and climate using Tropical Rainfall Measuring Mission (TRMM) satellite data 7: and limited rain gauge ground observations. J. Appl. Meteorol. Climatol., 54, 541–555. 7: https://doi.org/10.1175/JAMC-D-14-0052.1 Nash, J.E. and Sutcliffe, J.V., 1970. River Flow Forecasting through Conceptual Model. Part 7: 1-A Discussion of Principles. J. Hydrol., 10, 282-290. http://dx.doi.org/10.1016/0022-7: 1694(70)90255-6 Negron Juarez, R. I. N., Li, W. H., Fu, R., Fernandes, K., and Cardoso, A. D., 2009. 70 Comparison of precipitation datasets over the tropical South American and African 7 continents. J. Hydrometeor., 10, 289–299. https://doi.org/10.1175/2008JHM1023.1. Nicholson, S. E., Klotter, D., Zhou, L., and Hua, W., 2019. Validation of Satellite Precipitation 74 Estimates over the Congo Basin. J. Hydrometeorol., 20(4), 631-656, 74 https://doi.org/10.1175/JHM-D-18-0118.1 Novella, N.S. and Thiaw, W.M., 2013. African Rainfall Climatology Version 2 for Famine 74 Early Warning Systems. J. Appl. Meteorol. Climatol., 52, 588-606. 70 https://doi.org/10.1375/JAMC-D-11-0238.1 Oliveira, R.; Maggioni, V.; Vila, D.; Morales, C. Characteristics and Diurnal Cycle of GPM 74 Rainfall Estimates over the Central Amazon Region. Remote Sens. 2016, 8, 544. 77 https://doi.org/10.3390/rs13020221 Roca, R. Estimation of extreme daily precipitation thermodynamic scaling using gridded 75 astellite precipitation products over tropical land. Environ. Res. Lett., IOP Publishing, 72 2019. 14. https://doi.org/10.1088/1748-9326/ab35c6 Roca, R., Alexander, L. V., Potter, G., Bador, M., Jucá, R., Contractor, S., Bosilovich, M. G., 77 and Cloché, S., 2019. FROGS: a daily 1° × 1° gridded precipitation database of rain 74 gauge, satellite and reanalysis products, Earth Syst. Sci.	N'kaya, G. D. (Eds.), Congo Basin Hydrology, Climate, and Biogeochemistry: A	750
 Wiley & Sons, Inc. 752 Munzimi, Y.A., Hansen, M.C., Adusei, B. and Senay, G.B., 2015. Characterizing Congo basin 753 rainfall and climate using Tropical Rainfall Measuring Mission (TRMM) satellite data and limited rain gauge ground observations. J. Appl. Meteorol. Climatol., 54, 541–555. 755 https://doi.org/10.1175/JAMC-D-14-0052.1 766 767 1-A Discussion of Principles. J. Hydrol., 10, 282-290. http://dx.doi.org/10.1016/0022- 758 1694(70)90255-6 759 Negron Juarez, R. I. N., Li, W. H., Fu, R., Fernandes, K., and Cardoso, A. D., 2009. 760 760 comparison of precipitation datasets over the tropical South American and African 761 continents. J. Hydrometeor., 10, 289–299. https://doi.org/10.1175/2008JHM1023.1. 762 Nicholson, S. E., Klotter, D., Zhou, L., and Hua, W., 2019. Validation of Satellite Precipitation 763 764 https://doi.org/10.1175/JHM-D-18-0118.1 765 766 767 767 768 769 769 760 761 762 764 765 764 765 764 766 767 767 766 767 767 768 768 769 769 760 760 761 762 762 764 765 764 765 764 766 767 767 766 767 767 768 768 769 769 760 760 760 761 762 762 764 765 765 766 767 766 767 766 767 767 766 768 768 769 769 769 760 760 761 761 761 762 766 767 	 Wiley & Sons, Inc. Munzimi, Y.A., Hansen, M.C., Adusei, B. and Senay, G.B., 2015. Characterizing Congo basin rainfall and climate using Tropical Rainfall Measuring Mission (TRMM) satellite data and limited rain gauge ground observations. J. Appl. Meteorol. Climatol., 54, 541–555. Thtps://doi.org/10.1175/JAMC-D-14-0052.1 Nash, J.E. and Sutcliffe, J.V., 1970. River Flow Forecasting through Conceptual Model. Part 1-A Discussion of Principles. J. Hydrol., 10, 282-290. http://dx.doi.org/10.1016/0022- 1694(70)90255-6 Negron Juarez, R. I. N., Li, W. H., Fu, R., Fernandes, K., and Cardoso, A. D., 2009. Comparison of precipitation datasets over the tropical South American and African ro continents. J. Hydrometeor., 10, 289–299. https://doi.org/10.1175/2008JHM1023.1. Nicholson, S. E., Klotter, D., Zhou, L., and Hua, W., 2019. Validation of Satellite Precipitation Estimates over the Congo Basin. J. Hydrometeorol., 20(4), 631-656, https://doi.org/10.1175/JHMC-D-11-0138.1 Novella, N.S. and Thiaw, W.M., 2013. African Rainfall Climatology Version 2 for Famine Early Warning Systems. J. Appl. Meteorol. Climatol., 52, 588-606. Oliveira, R.; Maggioni, V.; Vila, D.; Morales, C. Characteristics and Diurnal Cycle of GPM Rainfall Estimates over the Central Amazon Region. Remote Sens. 2016, 8, 544. Peng, J., Liu, T., Huang, Y., Ling, Y., Li, Z., Bao, A., Chen, X., Kurban, A., and De Maeyer, P., 2021. Satellite-Based Precipitation Datasets Evaluation Using Gauge Observation and Hydrological Modeling in a Typical Arid Land Watershed of Central Asia. Remote Sens., 721. https://doi.org/10.1390/rs13020221 Roca, R. Estimation of extreme daily precipitation thermodynamic scaling using gridded 7321. https://doi.org/10.1088/1748-9326/ab35c6 Roca, R., Alexander, L. V., Potter, G., Bador, M., Jucá, R., Contractor, S., Bosilo	Foundation for the Future, AGU Geophysical Monograph Series. Hoboken, NJ: John	751
 Munzimi, Y.A., Hansen, M.C., Adusei, B. and Senay, G.B., 2015. Characterizing Congo basin 753 rainfall and climate using Tropical Rainfall Measuring Mission (TRMM) satellite data 754 and limited rain gauge ground observations. J. Appl. Meteorol. Climatol., 54, 541–555. Natsh, J.E. and Sutcliffe, J.V., 1970. River Flow Forecasting through Conceptual Model. Part 1-A Discussion of Principles. J. Hydrol., 10, 282-290. http://dx.doi.org/10.1016/0022-758 Negron Juarez, R. I. N., Li, W. H., Fu, R., Fernandes, K., and Cardoso, A. D., 2009. 760 Comparison of precipitation datasets over the tropical South American and African continents. J. Hydrometeor., 10, 289–299. https://doi.org/10.1175/2008JHM1023.1. Nicholson, S. E., Klotter, D., Zhou, L., and Hua, W., 2019. Validation of Satellite Precipitation 763 Estimates over the Congo Basin. J. Hydrometeorol., 20(4), 631-656, 764 https://doi.org/10.1175/JHM-D-18-0118.1 Novella, N.S. and Thiaw, W.M., 2013. African Rainfall Climatology Version 2 for Famine 766 Early Warning Systems. J. Appl. Meteorol. Climatol., 52, 588-606. 767 https://doi.org/10.1175/JAMC-D-11-0238.1 Oliveira, R.; Maggioni, V.; Vila, D.; Morales, C. Characteristics and Diurnal Cycle of GPM 769 Rainfall Estimates over the Central Amazon Region. Remote Sens. 2016, 8, 544. 770 https://doi.org/10.390/rs8070544 Preg, J., Liu, T., Huang, Y., Ling, Y., Li, Z., Bao, A., Chen, X., Kurban, A., and De Maeyer, P., 2021. Satellite-Based Precipitation Datasets Evaluation Using Gauge Observation and Hydrological Modeling in a Typical Arid Land Watershed of Central Asia. Remote Sens., 714 3, 221. https://doi.org/10.1088/1748-9326/ab35c6 Roca, R., Alexander, L. V., Potter, G., Bador, M., Jucá, R., Contractor, S., Bosilovich, M. G., 719 and Cloché, S., 2019. FROGS: a daily 1° × 1° gridded precipitation database of rain gauge, satellite and reanalysis products, Earth Syst. Sci. Data, 11, 1017–1035. 781 mttps://doi.org/10.519	 Munzimi, Y.A., Hansen, M.C., Adusei, B. and Senay, G.B., 2015. Characterizing Congo basin 7: rainfall and climate using Tropical Rainfall Measuring Mission (TRMM) satellite data 7: and limited rain gauge ground observations. J. Appl. Meteorol. Climatol., 54, 541–555. Nash, J.E. and Sutcliffe, J.V., 1970. River Flow Forecasting through Conceptual Model. Part 1: A Discussion of Principles. J. Hydrol., 10, 282-290. http://dx.doi.org/10.1016/0022-7: 1694(70)90255-6 Negron Juarez, R. I. N., Li, W. H., Fu, R., Fernandes, K., and Cardoso, A. D., 2009. 70. Comparison of precipitation datasets over the tropical South American and African continents. J. Hydrometeor., 10, 289–299. https://doi.org/10.1175/2008JHM1023.1. Nicholson, S. E., Klotter, D., Zhou, L., and Hua, W., 2019. Validation of Satellite Precipitation 76. Estimates over the Congo Basin. J. Hydrometeorol., 20(4), 631-656, 77. https://doi.org/10.1175/JHM-D-18-0118.1 Novella, N.S. and Thiaw, W.M., 2013. African Rainfall Climatology Version 2 for Famine Early Warning Systems. J. Appl. Meteorol. Climatol., 52, 588-606. 70. https://doi.org/10.1175/JAMC-D-11-0238.1 Oliveira, R.; Maggioni, V.; Vila, D.; Morales, C. Characteristics and Diurnal Cycle of GPM 74. https://doi.org/10.3390/rs8070544 Peng, J., Liu, T., Huang, Y., Ling, Y., Li, Z., Bao, A., Chen, X., Kurban, A., and De Maeyer, 77. P., 2021. Satellite-Based Precipitation Datasets Evaluation Using Gauge Observation and 74. https://doi.org/10.3390/rs13020221 Roca, R. Estimation of extreme daily precipitation thermodynamic scaling using gridded 75. satellite precipitation products over tropical land. Environ. Res. Lett., IOP Publishing, 72. 2019. 4. https://doi.org/10.1088/1748-9326/ab35c6 Roca, R., Alexander, L. V., Potter, G., Bador, M., Jucá, R., Contractor, S., Bosilovich, M. G., 74. and Cloché, S., 2019. FROGS: a daily 1° × 1° gridded precipitation database of rain 74. gauge, satellite and reanalysis products, Earth Syst. Sci.	Wiley & Sons, Inc.	752
 rainfall and climate using Tropical Rainfall Measuring Mission (TRMM) satellite data 754 and limited rain gauge ground observations. J. Appl. Meteorol. Climatol., 54, 541–555. https://doi.org/10.1175/JAMC-D-14-0052.1 Nash, J.E. and Sutcliffe, J.V., 1970. River Flow Forecasting through Conceptual Model. Part 757 1-A Discussion of Principles. J. Hydrol., 10, 282-290. http://dx.doi.org/10.1016/0022-758 1694(70)90255-6 Negron Juarez, R. I. N., Li, W. H., Fu, R., Fernandes, K., and Cardoso, A. D., 2009. Comparison of precipitation datasets over the tropical South American and African 761 continents. J. Hydrometeor, 10, 289–299. https://doi.org/10.1175/2008JHM1023.1 Nicholson, S. E., Klotter, D., Zhou, L., and Hua, W., 2019. Validation of Satellite Precipitation 763 Estimates over the Congo Basin. J. Hydrometeorol., 20(4), 631-656, 764 https://doi.org/10.1175/JHM-D-18-0118.1 Novella, N.S. and Thiaw, W.M., 2013. African Rainfall Climatology Version 2 for Famine 766 Oliveira, R.; Maggioni, V.; Vila, D.; Morales, C. Characteristics and Diurnal Cycle of GPM 769 Rainfall Estimates over the Central Amazon Region. Remote Sens. 2016, 8, 544. 770 https://doi.org/10.3390/rs8070544 Peng, J., Liu, T., Huang, Y., Ling, Y., Li, Z., Bao, A., Chen, X., Kurban, A., and De Maeyer, 772 P., 2021. Satellite-Based Precipitation Datasets Evaluation Using Gauge Observation an 773 Hydrological Modeling in a Typical Arid Land Watershed of Central Asia. Remote Sens., 714 13, 221. https://doi.org/10.3390/rs13020221 Roca, R., Estimation of extreme daily precipitation thermodynamic scaling using gridded satellite precipitation products over tropical land. Environ. Res. Lett., IOP Publishing, 2019, 14. https://doi.org/10.1088/1748-9326/ab35c6 Roca, R., Chambon, P., Jobard, I., Kirstetter, P., Gosset, M., & Bergès, J. C. (2010). Comparing 708 gauge, satellite and reanalysis products, Earth Syst. Sci. Data, 11, 1017–1035. 781 https://	 rainfall and climate using Tropical Rainfall Measuring Mission (TRMM) satellite data 7: and limited rain gauge ground observations. J. Appl. Meteorol. Climatol., 54, 541–555. 7: https://doi.org/10.1175/JAMC-D-14-0052.1 Nash, J.E. and Sutcliffe, J.V., 1970. River Flow Forecasting through Conceptual Model. Part 1-A Discussion of Principles. J. Hydrol., 10, 282-290. http://dx.doi.org/10.1016/0022-7.1694(70)90255-6 Negron Juarez, R. I. N., Li, W. H., Fu, R., Fernandes, K., and Cardoso, A. D., 2009. 7: comparison of precipitation datasets over the tropical South American and African 7: continents. J. Hydrometeor., 10, 289–299. https://doi.org/10.1175/2008JHM1023.1. Nicholson, S. E., Klotter, D., Zhou, L., and Hua, W., 2019. Validation of Satellite Precipitation 4: for extra over the Congo Basin. J. Hydrometeorol., 20(4), 631-656, 7: https://doi.org/10.1175/JHM-D-18-0118.1 Novella, N.S. and Thiaw, W.M., 2013. African Rainfall Climatology Version 2 for Famine Early Warning Systems. J. Appl. Meteorol. Climatol., 52, 588-606. 7: https://doi.org/10.1175/JAMC-D-11-0238.1 Oliveira, R.; Magioni, V.; Vila, D.; Morales, C. Characteristics and Diurnal Cycle of GPM 74. https://doi.org/10.3390/rs8070544 Peng, J., Liu, T., Huang, Y., Ling, Y., Li, Z., Bao, A., Chen, X., Kurban, A., and De Maeyer, 7: P., 2021. Satellite-Based Precipitation Datasets Evaluation Using Gauge Observation and 7: Hydrological Modeling in a Typical Arid Land Watershed of Central Asia. Remote Sens., 77 13, 221. https://doi.org/10.3390/rs8070544 Peng, R., Estimation of extreme daily precipitation thermodynamic scaling using gridded 7: satellite precipitation products over tropical land. Environ. Res. Lett., IOP Publishing, 70 2019, 14. https://doi.org/10.1088/1748-9326/ab35c6 Roca, R., Alexander, L. V., Potter, G., Bador, M., Jucá, R., Contractor, S., Bosilovich, M. G., 7 and Cloché, S., 2019. FROGS: a daily 1° × 1° gridded precipitation database of rain 74 gauge, satellite and	Iunzimi, Y.A., Hansen, M.C., Adusei, B. and Senay, G.B., 2015. Characterizing Congo basin	753
 and limited rain gauge ground observations. J. Appl. Meteorol. Climatol., 54, 541–555. 755 https://doi.org/10.1175/JAMC-D-14-0052.1 Nash, J.E. and Sutcliffe, J.V., 1970. River Flow Forecasting through Conceptual Model. Part 1-A Discussion of Principles. J. Hydrol., 10, 282-290. http://dx.doi.org/10.1016/0022-758 Negron Juarez, R. I. N., Li, W. H., Fu, R., Fernandes, K., and Cardoso, A. D., 2009. Comparison of precipitation datasets over the tropical South American and African 761 continents. J. Hydrometeor., 10, 289–299. https://doi.org/10.1175/2008JHM1023.1. Nicholson, S. E., Klotter, D., Zhou, L., and Hua, W., 2019. Validation of Satellite Precipitation 763 Estimates over the Congo Basin. J. Hydrometeorol., 20(4), 631-656, 764 https://doi.org/10.1175/JHM-D-18-0118.1 Novella, N.S. and Thiaw, W.M., 2013. African Rainfall Climatology Version 2 for Famine 766 Early Warning Systems. J. Appl. Meteorol. Climatol., 52, 588-606. Oliveira, R.; Maggioni, V.; Vila, D.; Morales, C. Characteristics and Diurnal Cycle of GPM 769 Rainfall Estimates over the Central Amazon Region. Remote Sens. 2016, 8, 544. Prog. J., Liu, T., Huang, Y., Ling, Y., Li, Z., Bao, A., Chen, X., Kurban, A., and De Maeyer, 712 P., 2021. Satellite-Based Precipitation Datasets Evaluation Using Gauge Observation and Hydrological Modeling in a Typical Arid Land Watershed of Central Asia. Remote Sens., 774 Noca, R. Estimation of extreme daily precipitation thermodynamic scaling using gridded satellite precipitation products over tropical land. Environ. Res. Lett., IOP Publishing, 2019. 14. https://doi.org/10.1088/1748-9326/ab35c6 Roca, R., Alexander, L. V., Potter, G., Bador, M., Jucá, R., Contractor, S., Bosilovich, M. G., 779 and Cloché, S., 2019. FROGS: a daily 1° × 1° gridded precipitation database of rain 780 gauge, satellite and reanalysis produ	 and limited rain gauge ground observations. J. Appl. Meteorol. Climatol., 54, 541–555. https://doi.org/10.1175/JAMC-D-14-0052.1 Nash, J.E. and Sutcliffe, J.V., 1970. River Flow Forecasting through Conceptual Model. Part 1-A Discussion of Principles. J. Hydrol., 10, 282-290. http://dx.doi.org/10.1016/0022- 1694(70)90255-6 Negron Juarez, R. I. N., Li, W. H., Fu, R., Fernandes, K., and Cardoso, A. D., 2009. 70 Comparison of precipitation datasets over the tropical South American and African 71 continents. J. Hydrometeor., 10, 289–299. https://doi.org/10.1175/2008JHM1023.1. 72 Nicholson, S. E., Klotter, D., Zhou, L., and Hua, W., 2019. Validation of Satellite Precipitation 74 Estimates over the Congo Basin. J. Hydrometeorol., 20(4), 631-656, 75 https://doi.org/10.1175/JHM-D-18-0118.1 76 Novella, N.S. and Thiaw, W.M., 2013. African Rainfall Climatology Version 2 for Famine 76 Early Warning Systems. J. Appl. Meteorol. Climatol., 52, 588-606. 77 Rainfall Estimates over the Central Amazon Region. Remote Sens. 2016, 8, 544. 77 P., 2021. Satellite-Based Precipitation Datasets Evaluation Using Gauge Observation and 77 Hydrological Modeling in a Typical Arid Land Watershed of Central Asia. Remote Sens., 71 79 A., 212. https://doi.org/10.1390/rs13020221 70 Roca, R., Estimation of extreme daily precipitation thermodynamic scaling using gridded 77 and Clocké, S., 2019. FROGS: a daily 1° × 1° gridded precipitation database of rain 79 gauge, satellite and reanalysis products, Earth Syst. Sci. Data, 11, 1017–1035. 70 Tropical Science Adaily 10 × 10° gridded precipitation database of rain 79 gauge, satellite and reanalysis products, Earth Syst. Sci. Data, 11, 1017–1035. 	rainfall and climate using Tropical Rainfall Measuring Mission (TRMM) satellite data	754
 https://doi.org/10.1175/JAMC-D-14-0052.1 Nash, J.E. and Sutcliffe, J.V., 1970. River Flow Forecasting through Conceptual Model. Part 1-A Discussion of Principles. J. Hydrol., 10, 282-290. http://dx.doi.org/10.1016/0022- 1694(70)90255-6 Negron Juarez, R. I. N., Li, W. H., Fu, R., Fernandes, K., and Cardoso, A. D., 2009. Comparison of precipitation datasets over the tropical South American and African continents. J. Hydrometeor., 10, 289–299. https://doi.org/10.1175/2008JHM1023.1. Nicholson, S. E., Klotter, D., Zhou, L., and Hua, W., 2019. Validation of Satellite Precipitation Estimates over the Congo Basin. J. Hydrometeorol., 20(4), 631-656, Novella, N.S. and Thiaw, W.M., 2013. African Rainfall Climatology Version 2 for Famine Early Warning Systems. J. Appl. Meteorol. Climatol., 52, 588-606. Nitps://doi.org/10.390/rs8070544 Peng, J., Liu, T., Huang, Y., Ling, Y., Li, Z., Bao, A., Chen, X., Kurban, A., and De Maeyer, Priz P., 2021. Satellite-Based Precipitation Datasets Evaluation Using Gauge Observation and Hydrological Modeling in a Typical Arid Land Watershed of Central Asia. Remote Sens., 774 Poca, R. Estimation of extreme daily precipitation thermodynamic scaling using gridded 776 777 778 770 771 772 774 775 775 775 775 775 776 776 776 777 778 779 770 770 771 772 774 774 775 775 775 775 775 776 776 776 776 776 776 776 7	 https://doi.org/10.1175/JAMC-D-14-0052.1 Nash, J.E. and Sutcliffe, J.V., 1970. River Flow Forecasting through Conceptual Model. Part 1-A Discussion of Principles. J. Hydrol., 10, 282-290. http://dx.doi.org/10.1016/0022- 1694(70)90255-6 Negron Juarez, R. I. N., Li, W. H., Fu, R., Fernandes, K., and Cardoso, A. D., 2009. Comparison of precipitation datasets over the tropical South American and African 7/ Comparison of precipitation datasets over the tropical South American and African 7/ Nicholson, S. E., Klotter, D., Zhou, L., and Hua, W., 2019. Validation of Satellite Precipitation Estimates over the Congo Basin. J. Hydrometeorol., 20(4), 631-656, 7/ https://doi.org/10.1175/JHM-D-18-0118.1 Novella, N.S. and Thiaw, W.M., 2013. African Rainfall Climatology Version 2 for Famine Early Warning Systems. J. Appl. Meteorol. Climatol., 52, 588-606. 70 https://doi.org/10.1175/JAMC-D-11-0238.1 Oliveira, R.; Maggioni, V.; Vila, D.; Morales, C. Characteristics and Diurnal Cycle of GPM 70 Rainfall Estimates over the Central Amazon Region. Remote Sens. 2016, 8, 544. 71 Peng, J., Liu, T., Huang, Y., Ling, Y., Li, Z., Bao, A., Chen, X., Kurban, A., and De Maeyer, 72 P., 2021. Satellite-Based Precipitation Datasets Evaluation Using Gauge Observation and 74 Pydcological Modeling in a Typical Arid Land Watershed of Central Asia. Remote Sens., 72019, 14. https://doi.org/10.1088/1748-9326/ab35c6 76 Roca, R., Alexander, L. V., Potter, G., Bador, M., Jucá, R., Contractor, S., Bosilovich, M. G., 77 and Cloché, S., 2019. FROGS: a daily 1° × 1° gridded precipitation database of rain 77 gauge, satellite and reanalysis products, Earth Syst. Sci. Data, 11, 1017–1035. 77 	and limited rain gauge ground observations. J. Appl. Meteorol. Climatol., 54, 541–555.	755
 Nash, J.E. and Sutcliffe, J.V., 1970. River Flow Forecasting through Conceptual Model. Part 757 1-A Discussion of Principles. J. Hydrol., 10, 282-290. http://dx.doi.org/10.1016/0022-758 1694(70)90255-6 Negron Juarez, R. I. N., Li, W. H., Fu, R., Fernandes, K., and Cardoso, A. D., 2009. 760 Comparison of precipitation datasets over the tropical South American and African 761 continents. J. Hydrometeor., 10, 289–299. https://doi.org/10.1175/2008JHM1023.1. Nicholson, S. E., Klotter, D., Zhou, L., and Hua, W., 2019. Validation of Satellite Precipitation 763 Estimates over the Congo Basin. J. Hydrometeorol., 20(4), 631-656, 764 https://doi.org/10.1175/JHM-D-18-0118.1 Novella, N.S. and Thiaw, W.M., 2013. African Rainfall Climatology Version 2 for Famine 766 Early Warning Systems. J. Appl. Meteorol. Climatol., 52, 588-606. Nitps://doi.org/10.1175/JAMC-D-11-0238.1 Oliveira, R.; Maggioni, V.; Vila, D.; Morales, C. Characteristics and Diurnal Cycle of GPM 769 Rainfall Estimates over the Central Amazon Region. Remote Sens. 2016, 8, 544. Peng, J., Liu, T., Huang, Y., Ling, Y., Li, Z., Bao, A., Chen, X., Kurban, A., and De Maeyer, 72 P., 2021. Satellite-Based Precipitation Datasets Evaluation Using Gauge Observation and Hydrological Modeling in a Typical Arid Land Watershed of Central Asia. Remote Sens., 714 13, 221. https://doi.org/10.3390/rs13020221 Roca, R. Estimation of extreme daily precipitation thermodynamic scaling using gridded satellite precipitation products over tropical land. Environ. Res. Lett., IOP Publishing, 777 and Cloché, S., 2019. FROGS: a daily 1° × 1° gridded precipitation database of rain 780 gauge, satellite and reanalysis products, Earth Syst. Sci. Data, 11, 1017–1035. Roca, R., Chambon, P., Jobard, I., Kirstetter, P., Gosset, M., & Bergès, J. C. (2010). Comparing 83 Eatellite and Surface Rainfall Products over West Africa at Meteorologically Relevant 784 Scales during the AMMA Campai	 Nash, J.E. and Sutcliffe, J.V., 1970. River Flow Forecasting through Conceptual Model. Part 1-A Discussion of Principles. J. Hydrol., 10, 282-290. http://dx.doi.org/10.1016/0022- 1694(70)90255-6 Negron Juarez, R. I. N., Li, W. H., Fu, R., Fernandes, K., and Cardoso, A. D., 2009. Comparison of precipitation datasets over the tropical South American and African continents. J. Hydrometeor., 10, 289–299. https://doi.org/10.1175/2008JHM1023.1. Nicholson, S. E., Klotter, D., Zhou, L., and Hua, W., 2019. Validation of Satellite Precipitation Estimates over the Congo Basin. J. Hydrometeorol., 20(4), 631-656, Novella, N.S. and Thiaw, W.M., 2013. African Rainfall Climatology Version 2 for Famine Early Warning Systems. J. Appl. Meteorol. Climatol., 52, 588-606. Nittps://doi.org/10.1175/JAMC-D-11-0238.1 Oliveira, R.; Maggioni, V.; Vila, D.; Morales, C. Characteristics and Diurnal Cycle of GPM Rainfall Estimates over the Central Amazon Region. Remote Sens. 2016, 8, 544. Peng, J., Liu, T., Huang, Y., Ling, Y., Li, Z., Bao, A., Chen, X., Kurban, A., and De Maeyer, P., 2021. Satellite-Based Precipitation Datasets Evaluation Using Gauge Observation and Hydrological Modeling in a Typical Arid Land Watershed of Central Asia. Remote Sens., 13, 221. https://doi.org/10.3390/rs13020221 Roca, R. Estimation of extreme daily precipitation thermodynamic scaling using gridded satellite precipitation products over tropical land. Environ. Res. Lett., IOP Publishing, 2019, 14. https://doi.org/10.1088/1748-9326/ab35c6 Roca, R., Alexander, L. V., Potter, G., Bador, M., Jucá, R., Contractor, S., Bosilovich, M. G., 71 and Cloché, S., 2019. FROGS: a daily 1° × 1° gridded precipitation database of rain 73 gauge, satellite and reanalysis products, Earth Syst. Sci. Data, 11, 1017–1035. 	https://doi.org/10.1175/JAMC-D-14-0052.1	756
 1-A Discussion of Principles. J. Hydrol., 10, 282-290. http://dx.doi.org/10.1016/0022-758 1694(70)90255-6 Negron Juarez, R. I. N., Li, W. H., Fu, R., Fernandes, K., and Cardoso, A. D., 2009. Comparison of precipitation datasets over the tropical South American and African 761 continents. J. Hydrometeor., 10, 289–299. https://doi.org/10.1175/2008JHM1023.1. Nicholson, S. E., Klotter, D., Zhou, L., and Hua, W., 2019. Validation of Satellite Precipitation 763 Estimates over the Congo Basin. J. Hydrometeorol., 20(4), 631-656, 764 https://doi.org/10.1175/JHM-D-18-0118.1 Novella, N.S. and Thiaw, W.M., 2013. African Rainfall Climatology Version 2 for Famine 766 Early Warning Systems. J. Appl. Meteorol. Climatol., 52, 588-606. Oliveira, R.; Maggioni, V.; Vila, D.; Morales, C. Characteristics and Diurnal Cycle of GPM 769 Rainfall Estimates over the Central Amazon Region. Remote Sens. 2016, 8, 544. Peng, J., Liu, T., Huang, Y., Ling, Y., Li, Z., Bao, A., Chen, X., Kurban, A., and De Maeyer, 772 P., 2021. Satellite-Based Precipitation Datasets Evaluation Using Gauge Observation and 773 Hydrological Modeling in a Typical Arid Land Watershed of Central Asia. Remote Sens., 774 13, 221. https://doi.org/10.1390/rs13020221 Roca, R. Estimation of extreme daily precipitation thermodynamic scaling using gridded 776 satellite precipitation products over tropical land. Environ. Res. Lett., IOP Publishing, 777 and Cloché, S., 2019. FROGS: a daily 1° × 1° gridded precipitation database of rain 780 gauge, satellite and reanalysis products, Earth Syst. Sci. Data, 11, 1017–1035. Roca, R., Chambon, P., Jobard, I., Kirstetter, P., Gosset, M., & Bergès, J. C. (2010). Comparing 783 Satellite and Strafeer Rainfall Products over West Africa at Meteorologically Relevant 784 Scales during the AMMA Campaign Using Error Estimates, Journal of Applied 785 	 1-A Discussion of Principles. J. Hydrol., 10, 282-290. http://dx.doi.org/10.1016/0022- 1694(70)90255-6 Negron Juarez, R. I. N., Li, W. H., Fu, R., Fernandes, K., and Cardoso, A. D., 2009. 74. Comparison of precipitation datasets over the tropical South American and African continents. J. Hydrometeor., 10, 289–299. https://doi.org/10.1175/2008JHM1023.1. 74. Nicholson, S. E., Klotter, D., Zhou, L., and Hua, W., 2019. Validation of Satellite Precipitation Estimates over the Congo Basin. J. Hydrometeorol., 20(4), 631-656, 75. Novella, N.S. and Thiaw, W.M., 2013. African Rainfall Climatology Version 2 for Famine Early Warning Systems. J. Appl. Meteorol. Climatol., 52, 588-606. 76. https://doi.org/10.1175/JAMC-D-11-0238.1 77. Oliveira, R.; Maggioni, V.; Vila, D.; Morales, C. Characteristics and Diurnal Cycle of GPM 77. Rainfall Estimates over the Central Amazon Region. Remote Sens. 2016, 8, 544. 77. Peng, J., Liu, T., Huang, Y., Ling, Y., Li, Z., Bao, A., Chen, X., Kurban, A., and De Maeyer, 77. P., 2021. Satellite-Based Precipitation Datasets Evaluation Using Gauge Observation and Hydrological Modeling in a Typical Arid Land Watershed of Central Asia. Remote Sens., 77. Roca, R. Estimation of extreme daily precipitation thermodynamic scaling using gridded satellite precipitation products over tropical land. Environ. Res. Lett., IOP Publishing, 77. 2019, 14. https://doi.org/10.1088/1748-9326/ab35c6 76. Roca, R., Alexander, L. V., Potter, G., Bador, M., Jucá, R., Contractor, S., Bosilovich, M. G., 77. and Cloché, S., 2019. FROGS: a daily 1° × 1° gridded precipitation database of rain 73. gauge, satellite and reanalysis products, Earth Syst. Sci. Data, 11, 1017–1035. 	lash, J.E. and Sutcliffe, J.V., 1970. River Flow Forecasting through Conceptual Model. Part	757
 1694(70)90255-6 Negron Juarez, R. I. N., Li, W. H., Fu, R., Fernandes, K., and Cardoso, A. D., 2009. Negron Juarez, R. I. N., Li, W. H., Fu, R., Fernandes, K., and Cardoso, A. D., 2009. Comparison of precipitation datasets over the tropical South American and African 761 continents. J. Hydrometeor., 10, 289–299. https://doi.org/10.1175/2008JHM1023.1. Nicholson, S. E., Klotter, D., Zhou, L., and Hua, W., 2019. Validation of Satellite Precipitation 763 Estimates over the Congo Basin. J. Hydrometeorol., 20(4), 631-656, 764 https://doi.org/10.1175/JHM-D-18-0118.1 Novella, N.S. and Thiaw, W.M., 2013. African Rainfall Climatology Version 2 for Famine 766 Early Warning Systems. J. Appl. Meteorol. Climatol., 52, 588-606. Oliveira, R.; Maggioni, V.; Vila, D.; Morales, C. Characteristics and Diurnal Cycle of GPM 769 Rainfall Estimates over the Central Amazon Region. Remote Sens. 2016, 8, 544. Peng, J., Liu, T., Huang, Y., Ling, Y., Li, Z., Bao, A., Chen, X., Kurban, A., and De Maeyer, 712 P., 2021. Satellite-Based Precipitation Datasets Evaluation Using Gauge Observation and Hydrological Modeling in a Typical Arid Land Watershed of Central Asia. Remote Sens., 774 13, 221. https://doi.org/10.390/rs13020221 Roca, R., Estimation of extreme daily precipitation thermodynamic scaling using gridded satellite precipitation products over tropical land. Environ. Res. Lett., IOP Publishing, 777 2019, 14. https://doi.org/10.1088/1748-9326/ab35c6 Roca, R., Alexander, L. V., Potter, G., Bador, M., Jucá, R., Contractor, S., Bosilovich, M. G., 719 and Cloché, S., 2019. FROGS: a daily 1° × 1° gridded precipitation database of rain 780 gauge, satellite and reanalysis products, Earth Syst. Sci. Data, 11, 1017–1035. Roca, R., Chambon, P., Jobard, I., Kirstetter, P., Gosset, M., & Bergès, J. C. (2010). Comparing 783 Satellite and Surface Rainfall	 1694(70)90255-6 Negron Juarez, R. I. N., Li, W. H., Fu, R., Fernandes, K., and Cardoso, A. D., 2009. 74 Comparison of precipitation datasets over the tropical South American and African 75 Comparison of precipitation datasets over the tropical South American and African 76 Comparison of precipitation datasets over the tropical South American and African 77 Comparison of precipitation datasets over the tropical South American and African 78 Comparison of precipitation datasets over the tropical South American and African 79 Comparison of precipitation datasets over the tropical South American and African 70 Comparison of precipitation datasets over the tropical South American and African 71 Notella, N.S. E., Klotter, D., Zhou, L., and Hua, W., 2019. Validation of Satellite Precipitation 70 Estimates over the Congo Basin. J. Hydrometeorol., 20(4), 631-656, 70 https://doi.org/10.1175/JHM-D-18-0118.1 71 Novella, N.S. and Thiaw, W.M., 2013. African Rainfall Climatology Version 2 for Famine 72 Early Warning Systems. J. Appl. Meteorol. Climatol., 52, 588-606. 74 Rainfall Estimates over the Central Amazon Region. Remote Sens. 2016, 8, 544. 74 Preng, J., Liu, T., Huang, Y., Ling, Y., Li, Z., Bao, A., Chen, X., Kurban, A., and De Maeyer, 7 74 P., 2021. Satellite-Based Precipitation Datasets Evaluation Using Gauge Observation and 71 Hydrological Modeling in a Typical Arid Land Watershed of Central Asia. Remote Sens., 71 13, 221. https://doi.org/10.1088/1748-9326/ab35c6 77 Roca, R. Estimation of extreme daily precipitation thermodynamic scaling using gridded 72 satellite precipitation products over tropical land. Environ. Res. Lett., IOP Publishing, 72 2019, 14. https://doi.org/10.1088/1748-9326/ab35c6 78 Roca, R., Alexander, L. V., Potter, G., Bador, M., Jucá, R., Contractor, S., Bosilovich, M. G., 73 and Cloché, S., 2019. FROGS: a daily 1° × 1° gridded precipita	1-A Discussion of Principles. J. Hydrol., 10, 282-290. http://dx.doi.org/10.1016/0022-	758
 Negron Juarez, R. I. N., Li, W. H., Fu, R., Fernandes, K., and Cardoso, A. D., 2009. 760 Comparison of precipitation datasets over the tropical South American and African 761 continents. J. Hydrometeor., 10, 289–299. https://doi.org/10.1175/2008JHM1023.1. 762 Nicholson, S. E., Klotter, D., Zhou, L., and Hua, W., 2019. Validation of Satellite Precipitation 763 Estimates over the Congo Basin. J. Hydrometeorol., 20(4), 631-656, 764 https://doi.org/10.1175/JHM-D-18-0118.1 765 Novella, N.S. and Thiaw, W.M., 2013. African Rainfall Climatology Version 2 for Famine 766 Early Warning Systems. J. Appl. Meteorol. Climatol., 52, 588-606. 767 https://doi.org/10.1175/JAMC-D-11-0238.1 768 Oliveira, R.; Maggioni, V.; Vila, D.; Morales, C. Characteristics and Diurnal Cycle of GPM 769 Rainfall Estimates over the Central Amazon Region. Remote Sens. 2016, 8, 544. 770 https://doi.org/10.3390/rs8070544 771 Peng, J., Liu, T., Huang, Y., Ling, Y., Li, Z., Bao, A., Chen, X., Kurban, A., and De Maeyer, 772 P., 2021. Satellite-Based Precipitation Datasets Evaluation Using Gauge Observation and Hydrological Modeling in a Typical Arid Land Watershed of Central Asia. Remote Sens. 774 13, 221. https://doi.org/10.1088/1748-9326/ab35c6 778 Roca, R., Alexander, L. V., Potter, G., Bador, M., Jucá, R., Contractor, S., Bosilovich, M. G., 779 and Cloché, S., 2019. FROGS: a daily 1° × 1° gridded precipitation database of rain gauge, satellite and reanalysis products, Earth Syst. Sci. Data, 11, 1017–1035. 781 https://doi.org/10.5194/essd-11-1017-2019 782 Roca, R., Chambon, P., Jobard, I., Kirstetter, P., Gosset, M., & Bergès, J. C. (2010). Comparing 782 Satellite and Surface Rainfall Products over West Africa at Meteorologically Relevant 8 Scales during the AMMA Campaign Using Error Estimates, Journal of Applied 785 	 Negron Juarez, R. I. N., Li, W. H., Fu, R., Fernandes, K., and Cardoso, A. D., 2009. 76 Comparison of precipitation datasets over the tropical South American and African 77 continents. J. Hydrometeor., 10, 289–299. https://doi.org/10.1175/2008JHM1023.1. 76 Nicholson, S. E., Klotter, D., Zhou, L., and Hua, W., 2019. Validation of Satellite Precipitation 76 Estimates over the Congo Basin. J. Hydrometeorol., 20(4), 631-656, 76 https://doi.org/10.1175/JHM-D-18-0118.1 76 Novella, N.S. and Thiaw, W.M., 2013. African Rainfall Climatology Version 2 for Famine 76 Early Warning Systems. J. Appl. Meteorol. Climatol., 52, 588-606. 76 https://doi.org/10.1175/JAMC-D-11-0238.1 76 Oliveira, R.; Maggioni, V.; Vila, D.; Morales, C. Characteristics and Diurnal Cycle of GPM 78 Rainfall Estimates over the Central Amazon Region. Remote Sens. 2016, 8, 544. 77 https://doi.org/10.3390/rs8070544 77 Peng, J., Liu, T., Huang, Y., Ling, Y., Li, Z., Bao, A., Chen, X., Kurban, A., and De Maeyer, 77 P., 2021. Satellite-Based Precipitation Datasets Evaluation Using Gauge Observation and 71 Hydrological Modeling in a Typical Arid Land Watershed of Central Asia. Remote Sens., 71 3, 221. https://doi.org/10.3390/rs13020221 77 Roca, R. Estimation of extreme daily precipitation thermodynamic scaling using gridded 74 satellite precipitation products over tropical land. Environ. Res. Lett., IOP Publishing, 72 019, 14. https://doi.org/10.1088/1748-9326/ab35c6 77 Roca, R., Alexander, L. V., Potter, G., Bador, M., Jucá, R., Contractor, S., Bosilovich, M. G., 74 and Cloché, S., 2019. FROGS: a daily 1° × 1° gridded precipitation database of rain 78 gauge, satellite and reanalysis products, Earth Syst. Sci. Data, 11, 1017–1035. 78 	1694(70)90255-6	759
 Comparison of precipitation datasets over the tropical South American and African 761 continents. J. Hydrometeor., 10, 289–299. https://doi.org/10.1175/2008JHM1023.1. 762 Nicholson, S. E., Klotter, D., Zhou, L., and Hua, W., 2019. Validation of Satellite Precipitation 763 Estimates over the Congo Basin. J. Hydrometeorol., 20(4), 631-656, 764 https://doi.org/10.1175/JHM-D-18-0118.1 765 Novella, N.S. and Thiaw, W.M., 2013. African Rainfall Climatology Version 2 for Famine 766 Early Warning Systems. J. Appl. Meteorol. Climatol., 52, 588-606. 767 https://doi.org/10.1175/JAMC-D-11-0238.1 768 Oliveira, R.; Maggioni, V.; Vila, D.; Morales, C. Characteristics and Diurnal Cycle of GPM 769 Rainfall Estimates over the Central Amazon Region. Remote Sens. 2016, 8, 544. 770 https://doi.org/10.3390/rs8070544 771 Peng, J., Liu, T., Huang, Y., Ling, Y., Li, Z., Bao, A., Chen, X., Kurban, A., and De Maeyer, 772 P., 2021. Satellite-Based Precipitation Datasets Evaluation Using Gauge Observation and Hydrological Modeling in a Typical Arid Land Watershed of Central Asia. Remote Sens. 774 13, 221. https://doi.org/10.3390/rs13020221 775 Roca, R. Estimation of extreme daily precipitation thermodynamic scaling using gridded satellite precipitation products over tropical land. Environ. Res. Lett., IOP Publishing, 2019, 14. https://doi.org/10.1088/1748-9326/ab35c6 778 Roca, R., Alexander, L. V., Potter, G., Bador, M., Jucá, R., Contractor, S., Bosilovich, M. G., 779 and Cloché, S., 2019. FROGS: a daily 1° × 1° gridded precipitation database of rain 780 gauge, satellite and reanalysis products, Earth Syst. Sci. Data, 11, 1017–1035. 781 https://doi.org/10.5194/essd-11-1017-2019 782 Roca, R., Chambon, P., Jobard, I., Kirstetter, P., Gosset, M., & Bergès, J. C. (2010). Comparing 782 Scales during the AMMA Campaign Using Error Estimates, Journal of Applied 785 	 Comparison of precipitation datasets over the tropical South American and African 74 continents. J. Hydrometeor., 10, 289–299. https://doi.org/10.1175/2008JHM1023.1. Nicholson, S. E., Klotter, D., Zhou, L., and Hua, W., 2019. Validation of Satellite Precipitation 74 Estimates over the Congo Basin. J. Hydrometeorol., 20(4), 631-656, 74 https://doi.org/10.1175/JHM-D-18-0118.1 Novella, N.S. and Thiaw, W.M., 2013. African Rainfall Climatology Version 2 for Famine 74 Early Warning Systems. J. Appl. Meteorol. Climatol., 52, 588-606. Oliveira, R.; Maggioni, V.; Vila, D.; Morales, C. Characteristics and Diurnal Cycle of GPM 74 Rainfall Estimates over the Central Amazon Region. Remote Sens. 2016, 8, 544. Peng, J., Liu, T., Huang, Y., Ling, Y., Li, Z., Bao, A., Chen, X., Kurban, A., and De Maeyer, 77 P., 2021. Satellite-Based Precipitation Datasets Evaluation Using Gauge Observation and 74 Hydrological Modeling in a Typical Arid Land Watershed of Central Asia. Remote Sens., 71 13, 221. https://doi.org/10.3390/rs13020221 Roca, R. Estimation of extreme daily precipitation thermodynamic scaling using gridded 77 satellite precipitation products over tropical land. Environ. Res. Lett., IOP Publishing, 72 2019, 14. https://doi.org/10.1088/1748-9326/ab35c6 Roca, R., Alexander, L. V., Potter, G., Bador, M., Jucá, R., Contractor, S., Bosilovich, M. G., 74 and Cloché, S., 2019. FROGS: a daily 1° × 1° gridded precipitation database of rain 78 gauge, satellite and reanalysis products, Earth Syst. Sci. Data, 11, 1017–1035. 	legron Juarez, R. I. N., Li, W. H., Fu, R., Fernandes, K., and Cardoso, A. D., 2009.	760
 continents. J. Hydrometeor., 10, 289–299. https://doi.org/10.1175/2008JHM1023.1. 762 Nicholson, S. E., Klotter, D., Zhou, L., and Hua, W., 2019. Validation of Satellite Precipitation 763 Estimates over the Congo Basin. J. Hydrometeorol., 20(4), 631-656, 764 https://doi.org/10.1175/JHM-D-18-0118.1 765 Novella, N.S. and Thiaw, W.M., 2013. African Rainfall Climatology Version 2 for Famine Early Warning Systems. J. Appl. Meteorol. Climatol., 52, 588-606, 767 https://doi.org/10.1175/JAMC-D-11-0238.1 Oliveira, R.; Maggioni, V.; Vila, D.; Morales, C. Characteristics and Diurnal Cycle of GPM Rainfall Estimates over the Central Amazon Region. Remote Sens. 2016, 8, 544. 770 https://doi.org/10.3390/rs8070544 771 Peng, J., Liu, T., Huang, Y., Ling, Y., Li, Z., Bao, A., Chen, X., Kurban, A., and De Maeyer, 772 P., 2021. Satellite-Based Precipitation Datasets Evaluation Using Gauge Observation and Hydrological Modeling in a Typical Arid Land Watershed of Central Asia. Remote Sens., 774 13, 221. https://doi.org/10.3390/rs13020221 Roca, R. Estimation of extreme daily precipitation thermodynamic scaling using gridded satellite precipitation products over tropical land. Environ. Res. Lett., IOP Publishing, 777 2019, 14. https://doi.org/10.1088/1748-9326/ab35c6 Roca, R., Alexander, L. V., Potter, G., Bador, M., Jucá, R., Contractor, S., Bosilovich, M. G., 788 Roca, R., Chambon, P., Jobard, I., Kirstetter, P., Gosset, M., & Bergès, J. C. (2010). Comparing 782 Rocales during the AMMA Campaign Using Error Estimates, Journal of Applied 	 continents. J. Hydrometeor., 10, 289–299. https://doi.org/10.1175/2008JHM1023.1. Nicholson, S. E., Klotter, D., Zhou, L., and Hua, W., 2019. Validation of Satellite Precipitation Estimates over the Congo Basin. J. Hydrometeorol., 20(4), 631-656, 74 https://doi.org/10.1175/JHM-D-18-0118.1 Novella, N.S. and Thiaw, W.M., 2013. African Rainfall Climatology Version 2 for Famine Early Warning Systems. J. Appl. Meteorol. Climatol., 52, 588-606. https://doi.org/10.1175/JAMC-D-11-0238.1 Oliveira, R.; Maggioni, V.; Vila, D.; Morales, C. Characteristics and Diurnal Cycle of GPM Rainfall Estimates over the Central Amazon Region. Remote Sens. 2016, 8, 544. Peng, J., Liu, T., Huang, Y., Ling, Y., Li, Z., Bao, A., Chen, X., Kurban, A., and De Maeyer, P., 2021. Satellite-Based Precipitation Datasets Evaluation Using Gauge Observation and Hydrological Modeling in a Typical Arid Land Watershed of Central Asia. Remote Sens., 77 Roca, R. Estimation of extreme daily precipitation thermodynamic scaling using gridded 77 Roca, R., Alexander, L. V., Potter, G., Bador, M., Jucá, R., Contractor, S., Bosilovich, M. G., 77 Roca, R., Alexander, L. V., Potter, G., Bador, M., Jucá, R., Contractor, S., Bosilovich, M. G., 77 and Cloché, S., 2019. FROGS: a daily 1° × 1° gridded precipitation database of rain 78 79 70 70 71 71 72 74 75 76 77 78 78 78 79 79 70 70 71 71 71 74 75 76 77 78 78 79 79 70 70 74 75 76 76 77 78 78 79 79 79 70 70 70 71 71 74 <l< td=""><td>Comparison of precipitation datasets over the tropical South American and African</td><td>761</td></l<>	Comparison of precipitation datasets over the tropical South American and African	761
 Nicholson, S. E., Klotter, D., Zhou, L., and Hua, W., 2019. Validation of Satellite Precipitation 763 Estimates over the Congo Basin. J. Hydrometeorol., 20(4), 631-656, 764 https://doi.org/10.1175/JHM-D-18-0118.1 765 Novella, N.S. and Thiaw, W.M., 2013. African Rainfall Climatology Version 2 for Famine 766 Early Warning Systems. J. Appl. Meteorol. Climatol., 52, 588-606. 767 https://doi.org/10.1175/JAMC-D-11-0238.1 768 Oliveira, R.; Maggioni, V.; Vila, D.; Morales, C. Characteristics and Diurnal Cycle of GPM 769 Rainfall Estimates over the Central Amazon Region. Remote Sens. 2016, 8, 544. 770 https://doi.org/10.3390/rs8070544 771 Peng, J., Liu, T., Huang, Y., Ling, Y., Li, Z., Bao, A., Chen, X., Kurban, A., and De Maeyer, 772 P., 2021. Satellite-Based Precipitation Datasets Evaluation Using Gauge Observation and Hydrological Modeling in a Typical Arid Land Watershed of Central Asia. Remote Sens., 774 13, 221. https://doi.org/10.3390/rs13020221 775 Roca, R. Estimation of extreme daily precipitation thermodynamic scaling using gridded 776 satellite precipitation products over tropical land. Environ. Res. Lett., IOP Publishing, 777 2019, 14. https://doi.org/10.1088/1748-9326/ab35c6 778 Roca, R., Alexander, L. V., Potter, G., Bador, M., Jucá, R., Contractor, S., Bosilovich, M. G., and Cloché, S., 2019. FROGS: a daily 1° × 1° gridded precipitation database of rain gauge, satellite and reanalysis products, Earth Syst. Sci. Data, 11, 1017–1035. 781 https://doi.org/10.5194/essd-11-1017-2019 782 Roca, R., Chambon, P., Jobard, I., Kirstetter, P., Gosset, M., & Bergès, J. C. (2010). Comparing Satellite and Surface Rainfall Products over West Africa at Meteorologically Relevant Scales during the AMMA Campaign Using Error Estimates, Journal of Applied 785 	 Nicholson, S. E., Klotter, D., Zhou, L., and Hua, W., 2019. Validation of Satellite Precipitation 76 Estimates over the Congo Basin. J. Hydrometeorol., 20(4), 631-656, 76 https://doi.org/10.1175/JHM-D-18-0118.1 Novella, N.S. and Thiaw, W.M., 2013. African Rainfall Climatology Version 2 for Famine 76 Early Warning Systems. J. Appl. Meteorol. Climatol., 52, 588-606. Nttps://doi.org/10.1175/JAMC-D-11-0238.1 Oliveira, R.; Maggioni, V.; Vila, D.; Morales, C. Characteristics and Diurnal Cycle of GPM 76 Rainfall Estimates over the Central Amazon Region. Remote Sens. 2016, 8, 544. Peng, J., Liu, T., Huang, Y., Ling, Y., Li, Z., Bao, A., Chen, X., Kurban, A., and De Maeyer, 77 P., 2021. Satellite-Based Precipitation Datasets Evaluation Using Gauge Observation and 77 Hydrological Modeling in a Typical Arid Land Watershed of Central Asia. Remote Sens., 71 3, 221. https://doi.org/10.3390/rs13020221 Roca, R. Estimation of extreme daily precipitation thermodynamic scaling using gridded 77 satellite precipitation products over tropical land. Environ. Res. Lett., IOP Publishing, 72 2019, 14. https://doi.org/10.1088/1748-9326/ab35c6 Roca, R., Alexander, L. V., Potter, G., Bador, M., Jucá, R., Contractor, S., Bosilovich, M. G., 74 and Cloché, S., 2019. FROGS: a daily 1° × 1° gridded precipitation database of rain 74 gauge, satellite and reanalysis products, Earth Syst. Sci. Data, 11, 1017-1035. 	continents. J. Hydrometeor., 10, 289–299. https://doi.org/10.1175/2008JHM1023.1.	762
 Estimates over the Congo Basin. J. Hydrometeorol., 20(4), 631-656, 764 https://doi.org/10.1175/JHM-D-18-0118.1 Novella, N.S. and Thiaw, W.M., 2013. African Rainfall Climatology Version 2 for Famine 766 Early Warning Systems. J. Appl. Meteorol. Climatol., 52, 588-606. 767 https://doi.org/10.1175/JAMC-D-11-0238.1 Oliveira, R.; Maggioni, V.; Vila, D.; Morales, C. Characteristics and Diurnal Cycle of GPM 769 Rainfall Estimates over the Central Amazon Region. Remote Sens. 2016, 8, 544. 770 https://doi.org/10.3390/rs8070544 Peng, J., Liu, T., Huang, Y., Ling, Y., Li, Z., Bao, A., Chen, X., Kurban, A., and De Maeyer, 772 P., 2021. Satellite-Based Precipitation Datasets Evaluation Using Gauge Observation and Hydrological Modeling in a Typical Arid Land Watershed of Central Asia. Remote Sens., 13, 221. https://doi.org/10.3390/rs13020221 Roca, R. Estimation of extreme daily precipitation thermodynamic scaling using gridded 776 satellite precipitation products over tropical land. Environ. Res. Lett., IOP Publishing, 777 and Cloché, S., 2019. FROGS: a daily 1° × 1° gridded precipitation database of rain 780 gauge, satellite and reanalysis products, Earth Syst. Sci. Data, 11, 1017–1035. 781 https://doi.org/10.5194/essd-11-1017-2019 Roca, R., Chambon, P., Jobard, I., Kirstetter, P., Gosset, M., & Bergès, J. C. (2010). Comparing 783 Satellite and Surface Rainfall Products over West Africa at Meteorologically Relevant 784 Scales during the AMMA Campaign Using Error Estimates, Journal of Applied 785 	 Estimates over the Congo Basin. J. Hydrometeorol., 20(4), 631-656, 76 https://doi.org/10.1175/JHM-D-18-0118.1 Novella, N.S. and Thiaw, W.M., 2013. African Rainfall Climatology Version 2 for Famine Early Warning Systems. J. Appl. Meteorol. Climatol., 52, 588-606. https://doi.org/10.1175/JAMC-D-11-0238.1 Oliveira, R.; Maggioni, V.; Vila, D.; Morales, C. Characteristics and Diurnal Cycle of GPM 76 Rainfall Estimates over the Central Amazon Region. Remote Sens. 2016, 8, 544. Peng, J., Liu, T., Huang, Y., Ling, Y., Li, Z., Bao, A., Chen, X., Kurban, A., and De Maeyer, 77 P., 2021. Satellite-Based Precipitation Datasets Evaluation Using Gauge Observation and Hydrological Modeling in a Typical Arid Land Watershed of Central Asia. Remote Sens., 77 13, 221. https://doi.org/10.3390/rs13020221 Roca, R. Estimation of extreme daily precipitation thermodynamic scaling using gridded rsatellite precipitation products over tropical land. Environ. Res. Lett., IOP Publishing, 77 2019, 14. https://doi.org/10.1088/1748-9326/ab35c6 Roca, R., Alexander, L. V., Potter, G., Bador, M., Jucá, R., Contractor, S., Bosilovich, M. G., 77 and Cloché, S., 2019. FROGS: a daily 1° × 1° gridded precipitation database of rain 74 gauge, satellite and reanalysis products, Earth Syst. Sci. Data, 11, 1017–1035. 	licholson, S. E., Klotter, D., Zhou, L., and Hua, W., 2019. Validation of Satellite Precipitation	763
 https://doi.org/10.1175/JHM-D-18-0118.1 765 Novella, N.S. and Thiaw, W.M., 2013. African Rainfall Climatology Version 2 for Famine Farly Warning Systems. J. Appl. Meteorol. Climatol., 52, 588-606. 767 https://doi.org/10.1175/JAMC-D-11-0238.1 768 Oliveira, R.; Maggioni, V.; Vila, D.; Morales, C. Characteristics and Diurnal Cycle of GPM 769 Rainfall Estimates over the Central Amazon Region. Remote Sens. 2016, 8, 544. 770 Peng, J., Liu, T., Huang, Y., Ling, Y., Li, Z., Bao, A., Chen, X., Kurban, A., and De Maeyer, 77. P., 2021. Satellite-Based Precipitation Datasets Evaluation Using Gauge Observation and Hydrological Modeling in a Typical Arid Land Watershed of Central Asia. Remote Sens., 774 13, 221. https://doi.org/10.3390/rs13020221 Roca, R. Estimation of extreme daily precipitation thermodynamic scaling using gridded 776 Roca, R., Alexander, L. V., Potter, G., Bador, M., Jucá, R., Contractor, S., Bosilovich, M. G., 779 and Cloché, S., 2019. FROGS: a daily 1° × 1° gridded precipitation database of rain 780 gauge, satellite and reanalysis products, Earth Syst. Sci. Data, 11, 1017–1035. 781 Rttps://doi.org/10.5194/essd-11-1017-2019 782 Roca, R., Chambon, P., Jobard, I., Kirstetter, P., Gosset, M., & Bergès, J. C. (2010). Comparing Satellite and Surface Rainfall Products over West Africa at Meteorologically Relevant Scales during the AMMA Campaign Using Error Estimates, Journal of Applied 	 https://doi.org/10.1175/JHM-D-18-0118.1 Novella, N.S. and Thiaw, W.M., 2013. African Rainfall Climatology Version 2 for Famine Early Warning Systems. J. Appl. Meteorol. Climatol., 52, 588-606. https://doi.org/10.1175/JAMC-D-11-0238.1 Oliveira, R.; Maggioni, V.; Vila, D.; Morales, C. Characteristics and Diurnal Cycle of GPM Rainfall Estimates over the Central Amazon Region. Remote Sens. 2016, 8, 544. Peng, J., Liu, T., Huang, Y., Ling, Y., Li, Z., Bao, A., Chen, X., Kurban, A., and De Maeyer, P., 2021. Satellite-Based Precipitation Datasets Evaluation Using Gauge Observation and Hydrological Modeling in a Typical Arid Land Watershed of Central Asia. Remote Sens., 13, 221. https://doi.org/10.3390/rs13020221 Roca, R. Estimation of extreme daily precipitation thermodynamic scaling using gridded satellite precipitation products over tropical land. Environ. Res. Lett., IOP Publishing, 7/2019, 14. https://doi.org/10.1088/1748-9326/ab35c6 Roca, R., Alexander, L. V., Potter, G., Bador, M., Jucá, R., Contractor, S., Bosilovich, M. G., 7/2019, satellite and reanalysis products, Earth Syst. Sci. Data, 11, 1017–1035. 	Estimates over the Congo Basin. J. Hydrometeorol., 20(4), 631-656,	764
 Novella, N.S. and Thiaw, W.M., 2013. African Rainfall Climatology Version 2 for Famine 766 Early Warning Systems. J. Appl. Meteorol. Climatol., 52, 588-606. 767 https://doi.org/10.1175/JAMC-D-11-0238.1 768 Oliveira, R.; Maggioni, V.; Vila, D.; Morales, C. Characteristics and Diurnal Cycle of GPM 769 Rainfall Estimates over the Central Amazon Region. Remote Sens. 2016, 8, 544. 770 https://doi.org/10.3390/rs8070544 771 Peng, J., Liu, T., Huang, Y., Ling, Y., Li, Z., Bao, A., Chen, X., Kurban, A., and De Maeyer, 72 P., 2021. Satellite-Based Precipitation Datasets Evaluation Using Gauge Observation and 773 Hydrological Modeling in a Typical Arid Land Watershed of Central Asia. Remote Sens., 774 13, 221. https://doi.org/10.3390/rs13020221 775 Roca, R. Estimation of extreme daily precipitation thermodynamic scaling using gridded 776 satellite precipitation products over tropical land. Environ. Res. Lett., IOP Publishing, 777 2019, 14. https://doi.org/10.1088/1748-9326/ab35c6 778 Roca, R., Alexander, L. V., Potter, G., Bador, M., Jucá, R., Contractor, S., Bosilovich, M. G., 779 and Cloché, S., 2019. FROGS: a daily 1° × 1° gridded precipitation database of rain 780 gauge, satellite and reanalysis products, Earth Syst. Sci. Data, 11, 1017–1035. 781 https://doi.org/10.5194/essd-11-1017-2019 782 Roca, R., Chambon, P., Jobard, I., Kirstetter, P., Gosset, M., & Bergès, J. C. (2010). Comparing 783 Satellite and Surface Rainfall Products over West Africa at Meteorologically Relevant 784 	 Novella, N.S. and Thiaw, W.M., 2013. African Rainfall Climatology Version 2 for Famine 76 Early Warning Systems. J. Appl. Meteorol. Climatol., 52, 588-606. https://doi.org/10.1175/JAMC-D-11-0238.1 Oliveira, R.; Maggioni, V.; Vila, D.; Morales, C. Characteristics and Diurnal Cycle of GPM 76 Rainfall Estimates over the Central Amazon Region. Remote Sens. 2016, 8, 544. Peng, J., Liu, T., Huang, Y., Ling, Y., Li, Z., Bao, A., Chen, X., Kurban, A., and De Maeyer, 77 P., 2021. Satellite-Based Precipitation Datasets Evaluation Using Gauge Observation and Hydrological Modeling in a Typical Arid Land Watershed of Central Asia. Remote Sens., 71 3, 221. https://doi.org/10.3390/rs13020221 Roca, R. Estimation of extreme daily precipitation thermodynamic scaling using gridded 71 satellite precipitation products over tropical land. Environ. Res. Lett., IOP Publishing, 72 2019, 14. https://doi.org/10.1088/1748-9326/ab35c6 Roca, R., Alexander, L. V., Potter, G., Bador, M., Jucá, R., Contractor, S., Bosilovich, M. G., 74 and Cloché, S., 2019. FROGS: a daily 1° × 1° gridded precipitation database of rain 74 gauge, satellite and reanalysis products, Earth Syst. Sci. Data, 11, 1017–1035. 	https://doi.org/10.1175/JHM-D-18-0118.1	765
 Early Warning Systems. J. Appl. Meteorol. Climatol., 52, 588-606. 767 https://doi.org/10.1175/JAMC-D-11-0238.1 Oliveira, R.; Maggioni, V.; Vila, D.; Morales, C. Characteristics and Diurnal Cycle of GPM Rainfall Estimates over the Central Amazon Region. Remote Sens. 2016, 8, 544. 770 https://doi.org/10.3390/rs8070544 Peng, J., Liu, T., Huang, Y., Ling, Y., Li, Z., Bao, A., Chen, X., Kurban, A., and De Maeyer, 772 P., 2021. Satellite-Based Precipitation Datasets Evaluation Using Gauge Observation and 773 Hydrological Modeling in a Typical Arid Land Watershed of Central Asia. Remote Sens., 774 13, 221. https://doi.org/10.3390/rs13020221 Roca, R. Estimation of extreme daily precipitation thermodynamic scaling using gridded 776 Roca, R., Alexander, L. V., Potter, G., Bador, M., Jucá, R., Contractor, S., Bosilovich, M. G., 779 and Cloché, S., 2019. FROGS: a daily 1° × 1° gridded precipitation database of rain 780 gauge, satellite and reanalysis products, Earth Syst. Sci. Data, 11, 1017–1035. 781 https://doi.org/10.5194/essd-11-1017-2019 Roca, R., Chambon, P., Jobard, I., Kirstetter, P., Gosset, M., & Bergès, J. C. (2010). Comparing 783 Satellite and Surface Rainfall Products over West Africa at Meteorologically Relevant 784 785 	 Early Warning Systems. J. Appl. Meteorol. Climatol., 52, 588-606. 76 https://doi.org/10.1175/JAMC-D-11-0238.1 Oliveira, R.; Maggioni, V.; Vila, D.; Morales, C. Characteristics and Diurnal Cycle of GPM 76 Rainfall Estimates over the Central Amazon Region. Remote Sens. 2016, 8, 544. 77 https://doi.org/10.3390/rs8070544 Peng, J., Liu, T., Huang, Y., Ling, Y., Li, Z., Bao, A., Chen, X., Kurban, A., and De Maeyer, 77 P., 2021. Satellite-Based Precipitation Datasets Evaluation Using Gauge Observation and 77 Hydrological Modeling in a Typical Arid Land Watershed of Central Asia. Remote Sens., 71 13, 221. https://doi.org/10.3390/rs13020221 Roca, R. Estimation of extreme daily precipitation thermodynamic scaling using gridded 77 satellite precipitation products over tropical land. Environ. Res. Lett., IOP Publishing, 71 2019, 14. https://doi.org/10.1088/1748-9326/ab35c6 Roca, R., Alexander, L. V., Potter, G., Bador, M., Jucá, R., Contractor, S., Bosilovich, M. G., 74 and Cloché, S., 2019. FROGS: a daily 1° × 1° gridded precipitation database of rain 78 gauge, satellite and reanalysis products, Earth Syst. Sci. Data, 11, 1017–1035. 78 https://doi.org/10.5194/sssd.11-1017-2019 	lovella, N.S. and Thiaw, W.M., 2013. African Rainfall Climatology Version 2 for Famine	766
 https://doi.org/10.11/5/JAMC-D-11-0238.1 Oliveira, R.; Maggioni, V.; Vila, D.; Morales, C. Characteristics and Diurnal Cycle of GPM Rainfall Estimates over the Central Amazon Region. Remote Sens. 2016, 8, 544. https://doi.org/10.3390/rs8070544 Peng, J., Liu, T., Huang, Y., Ling, Y., Li, Z., Bao, A., Chen, X., Kurban, A., and De Maeyer, P., 2021. Satellite-Based Precipitation Datasets Evaluation Using Gauge Observation and Hydrological Modeling in a Typical Arid Land Watershed of Central Asia. Remote Sens., 13, 221. https://doi.org/10.3390/rs13020221 Roca, R. Estimation of extreme daily precipitation thermodynamic scaling using gridded satellite precipitation products over tropical land. Environ. Res. Lett., IOP Publishing, 2019, 14. https://doi.org/10.1088/1748-9326/ab35c6 Roca, R., Alexander, L. V., Potter, G., Bador, M., Jucá, R., Contractor, S., Bosilovich, M. G., and Cloché, S., 2019. FROGS: a daily 1° × 1° gridded precipitation database of rain gauge, satellite and reanalysis products, Earth Syst. Sci. Data, 11, 1017–1035. Roca, R., Chambon, P., Jobard, I., Kirstetter, P., Gosset, M., & Bergès, J. C. (2010). Comparing Satellite and Surface Rainfall Products over West Africa at Meteorologically Relevant Scales during the AMMA Campaign Using Error Estimates, Journal of Applied 	 https://doi.org/10.11/5/JAMC-D-11-0238.1 Oliveira, R.; Maggioni, V.; Vila, D.; Morales, C. Characteristics and Diurnal Cycle of GPM Rainfall Estimates over the Central Amazon Region. Remote Sens. 2016, 8, 544. Peng, J., Liu, T., Huang, Y., Ling, Y., Li, Z., Bao, A., Chen, X., Kurban, A., and De Maeyer, P., 2021. Satellite-Based Precipitation Datasets Evaluation Using Gauge Observation and Hydrological Modeling in a Typical Arid Land Watershed of Central Asia. Remote Sens., 13, 221. https://doi.org/10.3390/rs13020221 Roca, R. Estimation of extreme daily precipitation thermodynamic scaling using gridded satellite precipitation products over tropical land. Environ. Res. Lett., IOP Publishing, 2019, 14. https://doi.org/10.1088/1748-9326/ab35c6 Roca, R., Alexander, L. V., Potter, G., Bador, M., Jucá, R., Contractor, S., Bosilovich, M. G., and Cloché, S., 2019. FROGS: a daily 1° × 1° gridded precipitation database of rain gauge, satellite and reanalysis products, Earth Syst. Sci. Data, 11, 1017–1035. 	Early Warning Systems. J. Appl. Meteorol. Climatol., 52, 588-606.	767
 Oliveira, K.; Maggioni, V.; Vila, D.; Morales, C. Characteristics and Diurnal Cycle of GPM Rainfall Estimates over the Central Amazon Region. Remote Sens. 2016, 8, 544. Rota Statellite State S	 Oliveira, R.; Maggioni, V.; Vila, D.; Morales, C. Characteristics and Diurnal Cycle of GPM 76 Rainfall Estimates over the Central Amazon Region. Remote Sens. 2016, 8, 544. 77 https://doi.org/10.3390/rs8070544 77 Peng, J., Liu, T., Huang, Y., Ling, Y., Li, Z., Bao, A., Chen, X., Kurban, A., and De Maeyer, 77 P., 2021. Satellite-Based Precipitation Datasets Evaluation Using Gauge Observation and 77 Hydrological Modeling in a Typical Arid Land Watershed of Central Asia. Remote Sens., 71 13, 221. https://doi.org/10.3390/rs13020221 77 Roca, R. Estimation of extreme daily precipitation thermodynamic scaling using gridded satellite precipitation products over tropical land. Environ. Res. Lett., IOP Publishing, 77 2019, 14. https://doi.org/10.1088/1748-9326/ab35c6 77 Roca, R., Alexander, L. V., Potter, G., Bador, M., Jucá, R., Contractor, S., Bosilovich, M. G., 74 and Cloché, S., 2019. FROGS: a daily 1° × 1° gridded precipitation database of rain 78 gauge, satellite and reanalysis products, Earth Syst. Sci. Data, 11, 1017–1035. 78 https://doi.org/10.5194/essd.11.1017-2019 	https://doi.org/10.11/5/JAMC-D-11-0238.1	/68
 Rainfail Estimates over the Central Amazon Region. Remote Sens. 2016, 8, 544. 770 https://doi.org/10.3390/rs8070544 Peng, J., Liu, T., Huang, Y., Ling, Y., Li, Z., Bao, A., Chen, X., Kurban, A., and De Maeyer, 772 P., 2021. Satellite-Based Precipitation Datasets Evaluation Using Gauge Observation and 773 Hydrological Modeling in a Typical Arid Land Watershed of Central Asia. Remote Sens., 774 13, 221. https://doi.org/10.3390/rs13020221 Roca, R. Estimation of extreme daily precipitation thermodynamic scaling using gridded 776 satellite precipitation products over tropical land. Environ. Res. Lett., IOP Publishing, 777 2019, 14. https://doi.org/10.1088/1748-9326/ab35c6 Roca, R., Alexander, L. V., Potter, G., Bador, M., Jucá, R., Contractor, S., Bosilovich, M. G., 779 and Cloché, S., 2019. FROGS: a daily 1° × 1° gridded precipitation database of rain 780 gauge, satellite and reanalysis products, Earth Syst. Sci. Data, 11, 1017–1035. 781 https://doi.org/10.5194/essd-11-1017-2019 Roca, R., Chambon, P., Jobard, I., Kirstetter, P., Gosset, M., & Bergès, J. C. (2010). Comparing 783 Satellite and Surface Rainfall Products over West Africa at Meteorologically Relevant 784 Scales during the AMMA Campaign Using Error Estimates, Journal of Applied 785 	 Rainfall Estimates over the Central Amazon Region. Remote Sens. 2016, 8, 544. 7 https://doi.org/10.3390/rs8070544 7 Peng, J., Liu, T., Huang, Y., Ling, Y., Li, Z., Bao, A., Chen, X., Kurban, A., and De Maeyer, 7 P., 2021. Satellite-Based Precipitation Datasets Evaluation Using Gauge Observation and 7 Hydrological Modeling in a Typical Arid Land Watershed of Central Asia. Remote Sens., 7 13, 221. https://doi.org/10.3390/rs13020221 7 Roca, R. Estimation of extreme daily precipitation thermodynamic scaling using gridded 7 satellite precipitation products over tropical land. Environ. Res. Lett., IOP Publishing, 7 2019, 14. https://doi.org/10.1088/1748-9326/ab35c6 7 Roca, R., Alexander, L. V., Potter, G., Bador, M., Jucá, R., Contractor, S., Bosilovich, M. G., 7 and Cloché, S., 2019. FROGS: a daily 1° × 1° gridded precipitation database of rain 74 gauge, satellite and reanalysis products, Earth Syst. Sci. Data, 11, 1017–1035. 75 	Diveira, R.; Maggioni, V.; Vila, D.; Morales, C. Characteristics and Diurnal Cycle of GPM	/69
 Peng, J., Liu, T., Huang, Y., Ling, Y., Li, Z., Bao, A., Chen, X., Kurban, A., and De Maeyer, P., 2021. Satellite-Based Precipitation Datasets Evaluation Using Gauge Observation and Hydrological Modeling in a Typical Arid Land Watershed of Central Asia. Remote Sens., 774 13, 221. https://doi.org/10.3390/rs13020221 Roca, R. Estimation of extreme daily precipitation thermodynamic scaling using gridded rotatellite precipitation products over tropical land. Environ. Res. Lett., IOP Publishing, 2019, 14. https://doi.org/10.1088/1748-9326/ab35c6 Roca, R., Alexander, L. V., Potter, G., Bador, M., Jucá, R., Contractor, S., Bosilovich, M. G., and Cloché, S., 2019. FROGS: a daily 1° × 1° gridded precipitation database of rain gauge, satellite and reanalysis products, Earth Syst. Sci. Data, 11, 1017–1035. Roca, R., Chambon, P., Jobard, I., Kirstetter, P., Gosset, M., & Bergès, J. C. (2010). Comparing Satellite and Surface Rainfall Products over West Africa at Meteorologically Relevant 784 Scales during the AMMA Campaign Using Error Estimates, Journal of Applied 	 Peng, J., Liu, T., Huang, Y., Ling, Y., Li, Z., Bao, A., Chen, X., Kurban, A., and De Maeyer, 7' P., 2021. Satellite-Based Precipitation Datasets Evaluation Using Gauge Observation and 7' Hydrological Modeling in a Typical Arid Land Watershed of Central Asia. Remote Sens., 7' 13, 221. https://doi.org/10.3390/rs13020221 Roca, R. Estimation of extreme daily precipitation thermodynamic scaling using gridded satellite precipitation products over tropical land. Environ. Res. Lett., IOP Publishing, 7' 2019, 14. https://doi.org/10.1088/1748-9326/ab35c6 Roca, R., Alexander, L. V., Potter, G., Bador, M., Jucá, R., Contractor, S., Bosilovich, M. G., 7' and Cloché, S., 2019. FROGS: a daily 1° × 1° gridded precipitation database of rain 78 gauge, satellite and reanalysis products, Earth Syst. Sci. Data, 11, 1017–1035. 78 https://doi.org/10.5194/essd.11-1017-2019 	kainian Esumates over the Central Amazon Region. Remote Sens. 2010, 8, 544.	//0
 Peng, J., Elu, T., Huang, T., Elng, T., El, Z., Bao, A., Chen, A., Kutbah, A., and De Maeyel, 772 P., 2021. Satellite-Based Precipitation Datasets Evaluation Using Gauge Observation and 773 Hydrological Modeling in a Typical Arid Land Watershed of Central Asia. Remote Sens., 13, 221. https://doi.org/10.3390/rs13020221 Roca, R. Estimation of extreme daily precipitation thermodynamic scaling using gridded 776 satellite precipitation products over tropical land. Environ. Res. Lett., IOP Publishing, 2019, 14. https://doi.org/10.1088/1748-9326/ab35c6 Roca, R., Alexander, L. V., Potter, G., Bador, M., Jucá, R., Contractor, S., Bosilovich, M. G., 779 and Cloché, S., 2019. FROGS: a daily 1° × 1° gridded precipitation database of rain 780 gauge, satellite and reanalysis products, Earth Syst. Sci. Data, 11, 1017–1035. 781 https://doi.org/10.5194/essd-11-1017-2019 Roca, R., Chambon, P., Jobard, I., Kirstetter, P., Gosset, M., & Bergès, J. C. (2010). Comparing 783 Satellite and Surface Rainfall Products over West Africa at Meteorologically Relevant 784 Scales during the AMMA Campaign Using Error Estimates, Journal of Applied 785 	 Peng, J., Elu, T., Huang, T., Elng, T., El, Z., Bao, A., Chen, A., Kurban, A., and De Maeyer, P., 2021. Satellite-Based Precipitation Datasets Evaluation Using Gauge Observation and Hydrological Modeling in a Typical Arid Land Watershed of Central Asia. Remote Sens., 13, 221. https://doi.org/10.3390/rs13020221 Roca, R. Estimation of extreme daily precipitation thermodynamic scaling using gridded realitie precipitation products over tropical land. Environ. Res. Lett., IOP Publishing, 2019, 14. https://doi.org/10.1088/1748-9326/ab35c6 Roca, R., Alexander, L. V., Potter, G., Bador, M., Jucá, R., Contractor, S., Bosilovich, M. G., and Cloché, S., 2019. FROGS: a daily 1° × 1° gridded precipitation database of rain gauge, satellite and reanalysis products, Earth Syst. Sci. Data, 11, 1017–1035. 78 https://doi.org/10.5194/essd-11-1017-2019 	nups://doi.org/10.3390/IS80/0544	//1 772
 Hydrological Modeling in a Typical Arid Land Watershed of Central Asia. Remote Sens., 13, 221. https://doi.org/10.3390/rs13020221 Roca, R. Estimation of extreme daily precipitation thermodynamic scaling using gridded recipitation products over tropical land. Environ. Res. Lett., IOP Publishing, 2019, 14. https://doi.org/10.1088/1748-9326/ab35c6 Roca, R., Alexander, L. V., Potter, G., Bador, M., Jucá, R., Contractor, S., Bosilovich, M. G., and Cloché, S., 2019. FROGS: a daily 1° × 1° gridded precipitation database of rain gauge, satellite and reanalysis products, Earth Syst. Sci. Data, 11, 1017–1035. Roca, R., Chambon, P., Jobard, I., Kirstetter, P., Gosset, M., & Bergès, J. C. (2010). Comparing Satellite and Surface Rainfall Products over West Africa at Meteorologically Relevant Scales during the AMMA Campaign Using Error Estimates, Journal of Applied 785 	 Hydrological Modeling in a Typical Arid Land Watershed of Central Asia. Remote Sens., 7' 13, 221. https://doi.org/10.3390/rs13020221 Roca, R. Estimation of extreme daily precipitation thermodynamic scaling using gridded 7' satellite precipitation products over tropical land. Environ. Res. Lett., IOP Publishing, 7' 2019, 14. https://doi.org/10.1088/1748-9326/ab35c6 Roca, R., Alexander, L. V., Potter, G., Bador, M., Jucá, R., Contractor, S., Bosilovich, M. G., 7' and Cloché, S., 2019. FROGS: a daily 1° × 1° gridded precipitation database of rain 74 gauge, satellite and reanalysis products, Earth Syst. Sci. Data, 11, 1017–1035. 75 https://doi.org/10.5194/essd.11-1017-2019 	P 2021 Satellite Based Precipitation Datasets Evaluation Using Gauge Observation and	112 272
 Roca, R., Alexander, L. V., Potter, G., Bador, M., Jucá, R., Contractor, S., Bosilovich, M. G., and Cloché, S., 2019. FROGS: a daily 1° × 1° gridded precipitation database of rain 780 gauge, satellite and reanalysis products, Earth Syst. Sci. Data, 11, 1017–1035. Roca, R., Chambon, P., Jobard, I., Kirstetter, P., Gosset, M., & Bergès, J. C. (2010). Comparing 783 Satellite and Surface Rainfall Products over West Africa at Meteorologically Relevant 784 Scales during the AMMA Campaign Using Error Estimates, Journal of Applied 785 	 Roca, R. Estimation of extreme daily precipitation thermodynamic scaling using gridded 7' satellite precipitation products over tropical land. Environ. Res. Lett., IOP Publishing, 7' 2019, 14. https://doi.org/10.1088/1748-9326/ab35c6 7' Roca, R., Alexander, L. V., Potter, G., Bador, M., Jucá, R., Contractor, S., Bosilovich, M. G., 7' and Cloché, S., 2019. FROGS: a daily 1° × 1° gridded precipitation database of rain 73 gauge, satellite and reanalysis products, Earth Syst. Sci. Data, 11, 1017–1035. 78 https://doi.org/10.5194/essd-11-1017-2019 	Hydrological Modeling in a Typical Arid L and Watershed of Central Asia, Permete Sans	115
 Roca, R. Estimation of extreme daily precipitation thermodynamic scaling using gridded 776 satellite precipitation products over tropical land. Environ. Res. Lett., IOP Publishing, 777 2019, 14. https://doi.org/10.1088/1748-9326/ab35c6 778 Roca, R., Alexander, L. V., Potter, G., Bador, M., Jucá, R., Contractor, S., Bosilovich, M. G., 779 and Cloché, S., 2019. FROGS: a daily 1° × 1° gridded precipitation database of rain 780 gauge, satellite and reanalysis products, Earth Syst. Sci. Data, 11, 1017–1035. 781 https://doi.org/10.5194/essd-11-1017-2019 782 Roca, R., Chambon, P., Jobard, I., Kirstetter, P., Gosset, M., & Bergès, J. C. (2010). Comparing 783 Satellite and Surface Rainfall Products over West Africa at Meteorologically Relevant 784 Scales during the AMMA Campaign Using Error Estimates, Journal of Applied 785 	 Roca, R. Estimation of extreme daily precipitation thermodynamic scaling using gridded 7' satellite precipitation products over tropical land. Environ. Res. Lett., IOP Publishing, 7' 2019, 14. https://doi.org/10.1088/1748-9326/ab35c6 7' Roca, R., Alexander, L. V., Potter, G., Bador, M., Jucá, R., Contractor, S., Bosilovich, M. G., 7' and Cloché, S., 2019. FROGS: a daily 1° × 1° gridded precipitation database of rain 78 gauge, satellite and reanalysis products, Earth Syst. Sci. Data, 11, 1017–1035. 78 https://doi.org/10.5194/essd-11-1017-2019 	13 221 https://doi.org/10.3390/rs13020221	775
 Roca, R. Estimation of extreme daily precipitation methodynamic scaling using gridded view of extreme daily precipitation methodynamic scaling using gridded view of satellite precipitation products over tropical land. Environ. Res. Lett., IOP Publishing, 2019, 14. https://doi.org/10.1088/1748-9326/ab35c6 view of satellite scales daily 10.1088/1748-9326/ab35c6 view of satellite and reanalysis products, R., Contractor, S., Bosilovich, M. G., and Cloché, S., 2019. FROGS: a daily 1° × 1° gridded precipitation database of rain view of satellite and reanalysis products, Earth Syst. Sci. Data, 11, 1017–1035. view of view	 koca, K. Estimation of extreme daily precipitation methodynamic scaling using gridded 7 satellite precipitation products over tropical land. Environ. Res. Lett., IOP Publishing, 7' 2019, 14. https://doi.org/10.1088/1748-9326/ab35c6 7' Roca, R., Alexander, L. V., Potter, G., Bador, M., Jucá, R., Contractor, S., Bosilovich, M. G., 7' and Cloché, S., 2019. FROGS: a daily 1° × 1° gridded precipitation database of rain 78 gauge, satellite and reanalysis products, Earth Syst. Sci. Data, 11, 1017–1035. 78 https://doi.org/10.5194/essd.11-1017-2019 	toca R Estimation of extreme daily precipitation thermodynamic scaling using gridded	776
 Satellite precipitation products over tropical faild. Environ. Res. Lett., for Fublishing, 777 2019, 14. https://doi.org/10.1088/1748-9326/ab35c6 Roca, R., Alexander, L. V., Potter, G., Bador, M., Jucá, R., Contractor, S., Bosilovich, M. G., 779 and Cloché, S., 2019. FROGS: a daily 1° × 1° gridded precipitation database of rain 780 gauge, satellite and reanalysis products, Earth Syst. Sci. Data, 11, 1017–1035. 781 https://doi.org/10.5194/essd-11-1017-2019 Roca, R., Chambon, P., Jobard, I., Kirstetter, P., Gosset, M., & Bergès, J. C. (2010). Comparing 783 Satellite and Surface Rainfall Products over West Africa at Meteorologically Relevant 784 Scales during the AMMA Campaign Using Error Estimates, Journal of Applied 785 	 2019, 14. https://doi.org/10.1088/1748-9326/ab35c6 Roca, R., Alexander, L. V., Potter, G., Bador, M., Jucá, R., Contractor, S., Bosilovich, M. G., 7' and Cloché, S., 2019. FROGS: a daily 1° × 1° gridded precipitation database of rain 78 gauge, satellite and reanalysis products, Earth Syst. Sci. Data, 11, 1017–1035. 78 https://doi.org/10.5194/essd-11-1017-2019 	satellite precipitation products over tropical land Environ Res Lett IOP Publishing	770
 Roca, R., Alexander, L. V., Potter, G., Bador, M., Jucá, R., Contractor, S., Bosilovich, M. G., 779 and Cloché, S., 2019. FROGS: a daily 1° × 1° gridded precipitation database of rain 780 gauge, satellite and reanalysis products, Earth Syst. Sci. Data, 11, 1017–1035. 781 https://doi.org/10.5194/essd-11-1017-2019 782 Roca, R., Chambon, P., Jobard, I., Kirstetter, P., Gosset, M., & Bergès, J. C. (2010). Comparing 783 Satellite and Surface Rainfall Products over West Africa at Meteorologically Relevant 784 Scales during the AMMA Campaign Using Error Estimates, Journal of Applied 785 	 Roca, R., Alexander, L. V., Potter, G., Bador, M., Jucá, R., Contractor, S., Bosilovich, M. G., 7' and Cloché, S., 2019. FROGS: a daily 1° × 1° gridded precipitation database of rain 78 gauge, satellite and reanalysis products, Earth Syst. Sci. Data, 11, 1017–1035. 78 https://doi.org/10.5194/essd-11-1017-2019 	2019 14 https://doi.org/10.1088/1748-9326/ab35c6	778
 and Cloché, S., 2019. FROGS: a daily 1° × 1° gridded precipitation database of rain 780 gauge, satellite and reanalysis products, Earth Syst. Sci. Data, 11, 1017–1035. 781 https://doi.org/10.5194/essd-11-1017-2019 782 Roca, R., Chambon, P., Jobard, I., Kirstetter, P., Gosset, M., & Bergès, J. C. (2010). Comparing 783 Satellite and Surface Rainfall Products over West Africa at Meteorologically Relevant 784 Scales during the AMMA Campaign Using Error Estimates, Journal of Applied 785 	and Cloché, S., 2019. FROGS: a daily 1° × 1° gridded precipitation database of rain 78 gauge, satellite and reanalysis products, Earth Syst. Sci. Data, 11, 1017–1035. 78 https://doi.org/10.5194/essd-11-1017-2019	coca R Alexander I. V Potter G Bador M Jucá R Contractor S Bosilovich M G	779
 gauge, satellite and reanalysis products, Earth Syst. Sci. Data, 11, 1017–1035. Roca, R., Chambon, P., Jobard, I., Kirstetter, P., Gosset, M., & Bergès, J. C. (2010). Comparing 783 Satellite and Surface Rainfall Products over West Africa at Meteorologically Relevant 784 Scales during the AMMA Campaign Using Error Estimates, Journal of Applied 785 	gauge, satellite and reanalysis products, Earth Syst. Sci. Data, 11, 1017–1035. 78 https://doi.org/10.5194/essd-11-1017-2019	and Cloché S 2019 FROGS: a daily $1^{\circ} \times 1^{\circ}$ gridded precipitation database of rain	780
 https://doi.org/10.5194/essd-11-1017-2019 Roca, R., Chambon, P., Jobard, I., Kirstetter, P., Gosset, M., & Bergès, J. C. (2010). Comparing Satellite and Surface Rainfall Products over West Africa at Meteorologically Relevant Scales during the AMMA Campaign Using Error Estimates, Journal of Applied 785 	https://doi.org/10.519//essd-11-1017-2019	gauge satellite and reanalysis products Earth Syst. Sci. Data 11, 1017–1035	781
 Roca, R., Chambon, P., Jobard, I., Kirstetter, P., Gosset, M., & Bergès, J. C. (2010). Comparing Satellite and Surface Rainfall Products over West Africa at Meteorologically Relevant Scales during the AMMA Campaign Using Error Estimates, Journal of Applied 785 		https://doi.org/10.5194/essd-11-1017-2019	782
Satellite and Surface Rainfall Products over West Africa at Meteorologically Relevant 784 Scales during the AMMA Campaign Using Error Estimates, Journal of Applied 785	Roca, R., Chambon, P., Jobard, I., Kirstetter, P., Gosset, M., & Bergès, J. C. (2010). Comparing 78	Coca, R., Chambon, P., Jobard, I., Kirstetter, P., Gosset, M., & Bergès, J. C. (2010). Comparing	783
Scales during the AMMA Campaign Using Error Estimates, Journal of Applied 785	Satellite and Surface Rainfall Products over West Africa at Meteorologically Relevant 78	Satellite and Surface Rainfall Products over West Africa at Meteorologically Relevant	784
	Scales during the AMMA Campaign Using Error Estimates, Journal of Applied 78	Scales during the AMMA Campaign Using Error Estimates, Journal of Applied	785
Meteorology and Climatology, 49(4), 715-731. 786	Meteorology and Climatology, 49(4), 715-731. 78	Meteorology and Climatology, 49(4), 715-731.	786
https://doi.org/10.1175/2009JAMC2318.1 787	https://doi.org/10.1175/2009JAMC2318.1	https://doi.org/10.1175/2009JAMC2318.1	787
Runge, J., 2007. The Congo River, Central Africa, in Large Rivers: Geomorphology and 788	Runge, J., 2007. The Congo River, Central Africa, in Large Rivers: Geomorphology and 78	Lunge, J., 2007. The Congo River, Central Africa, in Large Rivers: Geomorphology and	788
Management In Large Director A El 202 200 Will U.V. 700	Management. In: Large Rivers. Gupta, A., Ed. 293-309, Wiley, U.K. 78	Management. In: Large Rivers. Gupta, A., Ed. 293-309, Wiley, U.K.	789

https://doi.org/10.1002/9780470723722.ch14	790
Satgé, F. D., Defrance, B. S., Bonnet, M.P., Seyler, F., Rouché, N., Pierron, F., and Paturel,	791
J.E., 2020. Evaluation of 23 gridded precipitation datasets across West Africa. J. Hydrol.,	792
581, 124412. https://doi.org/10.1016/j.jhydrol.2019.124412	793
Shao, G., Guan, Y., Zhang, D., Yu, B., and Zhu, J., 2018. The Impacts of Climate Variability	794
and Land Use Change on Streamflow in the Hailiutu River Basin. Water, 10, 814.	795
https://doi.org/10.3390/w10060814	796
Sharannya, T.M., Al-Ansari, N., Deb Barma, S., and Mahesha, A., 2020. Evaluation of Satellite	797
Precipitation Products in Simulating Streamflow in a Humid Tropical Catchment of India	798
Using a Semi-Distributed Hydrological Model. Water, 12, 2400.	799
https://doi.org/10.3390/w12092400	800
Skofronick-Jackson, G., Petersen, W.A., Berg, W., Kidd, C., Stocker, E.F., Kirschbaum, D.B.,	801
Kakar R. Braun S.A. Huffman G.J. Jouchi T. Kirstetter, P.E. Kummerow C.	802
Meneghini R Oki R Olson W S Takayabu Y N Kurukawa K and Wilheit T	803
(2017) The Global Precipitation Measurement (GPM) mission for science and society	804
Bulletin of the American Meteorological Society 08 1670 1605	805
https://doi.org/10.1175/BAMS.D.15.00306.1	805
Solv T. Oourng C. Joh J. Souwage S. and Sánahaz Páraz, J. M. 2020. Assessment of	800
Judralagy and Sadimant Vield in the Makana Divar Dasin Haing SWAT Model Water	007
12, 2502, https://doi.org/10.2200/w12122502	000
12, 5505. $\text{nups://doi.org/10.5590/w12125505}$	809
Strauch, M., and Volk, M., 2013. SWA1 plant growth modification for improved modeling of	810
perennial vegetation in the tropics. Ecol. Model., 269, 98–112.	811
https://doi.org/10.1016/j.ecolmodel.2013.08.013	812
Sun, Q., Miao, C., Duan, Q., Ashouri, H., Sorooshian, S., and Hsu, K. L. 2018. A review of	813
global precipitation datasets: data sources, estimation, and intercomparisons. Rev.	814
Geophys., 56, 79–10. https://doi.org/10.1002/2017RG000574	815
Tan, M.L., and Yang, X., 2020. Effect of rainfall station density, distribution and missing	816
values on SWAT outputs in tropical region. J. Hydrol., 584 (2020), 124660.	817
https://doi.org/10.1016/j.jhydrol.2020.124660	818
Tan, M.L., Samat, N., Chan, N.W., and Roy, R., 2018. Hydro-meteorological assessment of	819
three GPM satellite precipitation products in the Kelantan River Basin, Malaysia. Remote	820
Sens., 10, 1011. https://doi.org/10.3390/rs10071011	821
Tshimanga, R.M., and Hughes, D.A., 2012. Climate change and impacts on the hydrology of	822
the Congo Basin: The case of the northern sub-basins of the Oubangui and Sangha Rivers.	823
Phys. Chem. Earth, Parts A/B/C, 50–52, 72–83. https://doi.org/10.1016/j.pce.2012.08.002	824
Tuo, Y., Duan, Z., Disse, M., and Chiogna, G., 2016. Evaluation of precipitation input for	825
SWATmodeling in Alpine catchment: a case study in the Adige river basin (Italy). Sci.	826
TotalEnviron., 573, 66–82. https://doi.org/10.1016/j.scitotenv.2016.08.034	827
USDA Soil Conservation Service. National Engineering Handbook; Section 4, Hydrology,	828
Chapter 21; USDA Soil Conservation Service: Washington, DC, USA, 1972.	829
Wang, O., Xia, J., She, D., Zhang, X. Liu, J., and Zhang, Y., 2021. Assessment of four latest	830
long-term satellite-based precipitation products in capturing the extreme precipitation and	831
streamflow across a humid region of southern China Atmos Res 257 105554	832
101016/i atmosres 2021 105554	833
Wei X Sauvage S Le TPO Quillon S Orange D Vinh VD and Sanchez-Perez IM	834
2019 A Modeling Approach to Diagnose the Impacts of Global Changes on Discharge	835
and Suspended Sediment Concentration within the Red River Basin Water 11 958	836
https://doi.org/10.3390/w11050958	837
Williams I R Flood routing with variable travel time or variable storage coefficients. Trans	838
ASABE 1969. 12, 100-0103, https://doi.org/10.13031/2013.38772	839
	500

Winchell, M.; Srinivasan, R.; Di Luzio, M.; and Arnold, J.G. Arcswat Interface for SWAT2012: User's Guide; Blackland Research Center, Texas AgriLife Research:	840 841
Temple, TX, USA, 2013.	842
Xie, P., Joyce, R., Wu, S., Yoo, S.H., Yarosh, Y., Sun, F., and Lin, R. 2017. Reprocessed, bias-	843
Corrected CMORPH global nign-resolution precipitation estimates from 1998. J. Hydrometeorol 18 1617 1641 https://doi.org/10.1175/JHM.D.16.0168.1	844 845
Vin X and Gruber A 2010 Validation of the abrunt change in GPCP precipitation in the	845 846
Congo River Basin Int I Climatol 30(1) 110–119 https://doi.org/10.1002/ioc.1875	847
Yin X. Gruber A. and Arkin P. 2004. Comparison of the GPCP and CMAP merged gauge-	848
satellite monthly precipitation products for the period 1979–2001. J. Hydrometeorol.	849
5(6), 1207–1222. https://doi.org/10.1175/JHM-392.1	850
Zhou, L., Tian, Y., Myneni, R., Ciais, P., Saatchi, S., Liu, Y. Y., Piao, S., Chen, H. Vermote,	851
E. F., Song, C., and Hwang, T., 2014. Widespread decline of Congo rainforest greenness	852
in the past decade. Nature, 509, 86–90. https://doi.org/10.1038/nature13265.	853
	854
	855
	856
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	857
	858
	850
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	860
	861
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Figure and table captions	874
	875
Figure 1. Congo sub-basins studied. Also, the locations of gauge stations used in this study.	876
	877
Figure 2. The spatial distribution of a) unconditional annual mean and b) 99 th percentile of	878
daily accumulated precipitation (in mm/day) during the period from 2001 to 2012 over Congo	879
by the 3B42_v7.0 product from 1°/daily FROGS database.	880
	881
Figure 3. Annual cycle of precipitation (in mm/month) during the period from 2001 to 2012	882
over the five Congo sub-basins from FROGs database. Dots and lines represent the monthly	883
accumulated medians of each satellite-based precipitation product. Gray shading indicates the	884
30th and 70th percentile ranges. Satellite-only (gauge-calibrated satellite) precipitation	885
products are represented by dashed (solid) lines.	886
	887
Figure 4. Cumulative probability density functions of occurrence (dashed lines) and amount	888
(solid lines) of daily precipitation during the period from 2001 to 2012 over the five Congo	889
sub-basins from FROGs database. Satellite-only (gauge-calibrated satellite) precipitation	890
products are represented at left (right) panels.	891
	892
Figure 5. Monthly observed and simulated streamflow at gauge stations (a)	893
Brazzaville/Kinshasa (outlet), (b) Lualaba/Kisangani, (c) Kasai/Kutu-Moke, (d)	894
Sangha/Ouesso, and (e) Ubangi/Bangui.	895
	896

Figure 6. Relative error between observed and simulated streamflow (Relative error = $(Q_{sim}$ 897 $-Q_{obs})/Q_{obs}$) at gauge stations (a) Brazzaville/Kinshasa (outlet), (b) Lualaba/Kisangani, (c)898Kasai/Kutu-Moke, (d) Sangha/Ouesso, and (e) Ubangi/Bangui.899

900

Figure 7. Simulated streamflow (in m³/s) hydrographs during the period from 2003 to 2012901for gauges stations:Brazzaville/Kinshasa (outlet), Kasai/Kutu-Moke, Lualaba/Kisangani,902Sangha/Ouesso and Ubangi/Bangui.Dots and Lines represent the monthly streamflow of each903satellite-based precipitation product.Satellite-only (gauge-calibrated satellite) precipitation904products are represented by dashed (solid) lines.905

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Figure 8. Heat map statistical analysis (KGE and PBIAS) of the streamflow simulation results907of the selected satellite-based precipitation product. The statistical analysis was calculated908using the streamflow from base scenario (3B42_v7.0) as reference.909

910

Figure 9. Simulated annual cycle of evapotranspiration (in mm/month) during the period from9112003 to 2012. Dots and lines represent the monthly accumulated medians of each satellite-912based precipitation product. Satellite-only (gauge-calibrated satellite) precipitation products913are represented by dashed (solid) lines.914

915

Figure 10. Simulated annual cycle of surface runoff (in mm/month) during the period from9162003 to 2012. Dots and lines represent the monthly accumulated medians of each satellite-917based precipitation product. Satellite-only (gauge-calibrated satellite) precipitation products918are represented by dashed (solid) lines.919

Figure 11. Simulated annual cycle of soil water content (in mm/month) during the period from	921
2003 to 2012. Dots and lines represent the monthly accumulated medians of each satellite-	922
based precipitation product. Satellite-only (gauge-calibrated satellite) precipitation products	923
are represented by dashed (solid) lines.	924
Table 1. Summary of the selected satellite-based precipitation products used in the present	925 926
study. * Multiple platforms and # Single platform.	927
	928
Table 2. Description of the nature and source of datasets employed in the SWAT Model	929
	930
Table 3. SWAT model performance for predicting monthly streamflow	931
	932
Table 4. Summary of various hydrological studies utilizing satellite-based precipitation	933
products run with the SWAT model	934
	935
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Figures

Figure 1.





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Figure 5.



+ Observed streamflow + Simulated Streamflow

Figure	6.
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Figure 8.



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4.76

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89.29 91.88

310.75

128.04

227,41











Tables

Table 1.

Type of data	Satellite source	#	Product short name and version	Temporal coverage	Spatial coverage	Reference
	IR+MW*	1	IMERG v6.0 - Early	2000-2018	60° N-S	Huffman et al. (2019)
	IR+MW*	2	IMERG v6.0 - Late	2000-2018	60° N-S	Huffman et al. (2019)
	IR+MW*	3	IMERG V06 - Final Uncal	2000-2018	60° N-S	Huffman et al. (2019)
	IR+MW*	4	3B42 RT v7.0 uncalibrated	2000–2017	50° N-S	Huffman et al. (2007)
Satellite-only (10)	IR+MW*	5	GSMaP-RNL - no gauge v6.0	2001–2013	50° N-S	Kubota et al. (2007)
	IR+MW*	6	GSMaP-NRT - no gauge v6.0	2001–2017	50° N-S	Kubota et al. (2007)
	IR+MW*	7	CMORPH v1.0 RAW	1998–2017	60° N-S	Xie et al. (2017)
	MW*	8	3B42 v7.0 MW	1998–2018	50° N-S	Huffman et al. (2007)
	IR	9	3B42 v7.0 IR	1998–2018	50° N-S	Huffman et al. (2007)
	IR	10	CHIRP v2.0	1981–2016	50° N-S	Funk et al. (2015)
	IR+MW*	11	IMERG v6.0 - Final Cal	2000-2018	60° N-S	Huffman et al. (2019)
	IR+MW*	12	3B42 v7.0	1998–2018	50° N-S	Huffman et al. (2007)
	IR+MW*	13	3B42 RT v7.0	2000–2017	50° N-S	Huffman et al. (2007)
	IR+MW*	14	GSMaP-RNL - gauge v6.0	2001 -2013	50° N-S	Kubota et al. (2007)
	IR+MW*	15	GSMaP-NRT - gauge v6.0	2001–2017	50° N-S	Kubota et al. (2007)
Causa	IR+MW*	16	CMORPH V1.0 CRT	1998–2017	60° N-S	Xie et al. (2017)
Gauge- calibrated satellite (13)	IR+MW#	17	GPCP 1DD CDR v1.3 (yes_enforced)	1997–2017	90° N-S	Huffman et al. (2001)
	IR+MW#	18	GPCP 1DD CDR v1.3 (not_enforced)	1997–2017	90° N-S	Huffman et al. (2001)
	IR	19	PERSIANN CDR v1 r1	1983–2017	50° N-S	Ashouri et al. (2015)
	IR	20	CHIRPS v2.0	1981–2016	50° N-S	Funk et al. (2015)
	IR	21	TAMSAT v2.0	1983–2017	Africa (Land only)	Maidment et al. (2017)
	IR	22	TAMSAT v3.0	1983–2017	Africa (Land only)	Maidment et al. (2017)
	IR	23	ARC v2	1983–2017	Africa (Land only)	Novella and Thiaw (2013)

Table	2.
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Data Type	Period	Resolution	Source
Digital Elevation Model (DEM)	2008	90 m	Consortium for spatial information (https://cgiarcsi.community/data/srtm-90m-digital- elevation-database)
Soil	2012	1 km	Harmonized World Soil Database v 1.1 (http://webarchive.iiasa.ac.at/Research/LUC/External- World-soil-database/HTML/index.html?sb=1)
Land use	2000	1 km	Global Land Cover 2000 database (http://forobs.jrc.ec.europa.eu/products/glc2000/product s.php)
Meteorological data [daily temperature (min., max.), solar radiation, relative air humidity, wind speed]	1998 – 2012	~38 km	Climate Forecast System Reanalysis (CFSR) Model (http://rda.ucar.edu/pub/cfsr.html & http://globalweather.tamu.edu/) Dile and Srinivasan (2014)
Precipitation data [3B42 v7.0]	1998 - 2015	0.25°	Huffman et al. (2007)
River discharge	2000 - 2012	Daily	SO-HYBAM (http://www.so-hybam.org/); BRLi (2016)

Table 3	3.
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	Calibration				Validation			
	NSE	\mathbb{R}^2	PBIAS	KGE	NSE	\mathbb{R}^2	PBIAS	KGE
Brazzaville/Kinshasa (outlet)	0.16	0.59	14.52	0.71	0.44	0.54	4.10	0.71
Kasai/Kutu-Moke	0.63	0.76	-2.11	0.48	0.59	0.78	-4.66	0.48
Lualaba/Kisangani	0.02	0.49	7.84	0.23	0.08	0.39	-8.19	0.23
Sangha/Ouesso	0.67	0.71	8.37	0.80	0.59	0.65	-1.30	0.80
Ubangi/Bangui	0.81	0.83	4.01	0.90	0.66	0.67	-0.86	0.90

Table 4.

Satellite-based precipitation products	Period	Study area	Latitude	Recalibration of parameters	Highlight	Reference
3B42_v7.0 and CHIRPS_v2.0	1998 - 2010	Adige Basin (Italy)	45°N	yes	Four precipitation datasets were tested, where two were satellite-based. The satellite dataset was compared to data from de precipitation gauge stations. The results indicate the applied precipitation input influenced the estimated model parameters.	Tuo et al., 2016
IMERG_v6.0_EU, IMERG_v6.0_LU and IMERG_v6.0_FC	2014 - 2016	Kelantan Basin (Malaysia)	6°N - 4°N	yes	The satellite dataset was compared to data from de precipitation gauge stations. IMERG_FC outperformed the near real-time products in cumulative streamflow measurement. The results indicate the IMERG products could be an alternative precipitation source for this region.	Tan et al., 2018
3B42_v7.0 and IMERG_v6.0_FC	2000 - 2018	Tocantins- Araguaia basin (Brazil)	14°S - 16°S	yes	Two satellite-based precipitation products were tested. The satellite dataset was compared to data from de precipitation gauge stations. The results demonstrating the satellite dataset were able to simulate the hydrological regime adequately.	Amorim et al., 2020
3B42_v7.0 and CHIRPS_v2.0	2001 - 2012	Gurupura basin (India)	13°N - 12°N	yes	Tree precipitation datasets were tested, where two were satellite-based. CHIRPS has been tested with two different resolutions: 0.05 and 0.25. 3B42_v7.0 performed better than CHIRPS-0.05, and CHIRPS-0.25, but 3B42_v7.0 underestimated the flow for agricultural water availability in 30%.	Sharannya et al., 2020
PERSIANN-CDR_v1_r1, CHIRPS_v2.0, CMORPH_IFIOODS_v1.0, IMERG_v6.0_FC, GSMaP_gauges_v6. and 3B42_v7.0	1998 - 2019	Tarim Basin (China)	41°N	no	Seven satellite-based precipitation products were tested. The satellite dataset was compared to data from de precipitation gauge stations. The IMERG_v6.0_FC and PERSIANN-CDR_v1_r1were the best datasets for the daily and monthly scale precipitation accuracy evaluations. PERSIANN-CDR_v1_r1 and CMORPH_IFIOODS_v1.0 performed better than others in monthly runoff simulations. All datasets have the potential to provide valuable input data in hydrological modeling.	Peng et al., 2021

CHIRPS_v2.0, 3B42_v7.0, CMORPH_CRT and PERSIANN-CDR_v1_r1	1998 - 2014	Ganjiang Basin (China)	28°N - 24°N	no	Four satellite-based precipitation products were tested. The satellite dataset was compared to data from de precipitation gauge stations. The results indicate 3B42_v7.0 provides the most accurate hydrological model simulation results, while simulated streamflow forced by CMORPH_CRT exhibits considerable underestimation of streamflow.	Wang et al., 2021
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