ADHI: The African Database of Hydrometric Indices (1950-2018)

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Abstract

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The African continent is probably the one with the lowest density of hydrometric stations currently measuring river discharge, despite the fact that the number of operating stations was quite important until the 70s. This new African Database of Hydrometric Indices (ADHI) provides a wide range of hydrometric indices and hydrological signatures computed from different sources of data after a quality control. It includes 1466 stations with at least 10 years of daily discharge data over the period 1950-2018. The average record length is 33 years and ~~for over 100~~131 stations have complete records ~~are available~~ over 50 years. With this new dataset spanning most climatic regions of the African continent, several hydrometric indices have been computed, representing mean flow characteristics and extremes (low flows and floods), ~~and~~ that are made accessible to the scientific community. The database will be updated on a regular basis to include more hydrometric stations and longer time series of river discharge. The ADHI database is available for download at: https://doi.org/10.23708/LXGXQ9 (Tramblay and Rouché, 2020).

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1. Introduction

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There is a growing need for large-scale streamflow archives (Addor et al., 2020; Hannah et al., 2011), that are extremely useful to evaluate continental land-surface simulations (Archfield et al., 2015; Newman et al., 2015; Ghiggi et al., 2019; Do et al., 2020), remote sensing data products (Beck et al., 2017; Brocca et al., 2019; Forootan et al., 2019; Satgé et al., 2020), develop operational flood or drought monitoring systems (Alfieri et al., 2020; Harrigan et al., 2020; Lavers et al., 2019; Thiemig et al., 2011), or evaluate aquifer outflows and characteristics (Dewandel et al., 2003, 2004). In Africa, the density of active monitoring networks is lower compared to other continents and there are challenges in the exchange of hydrometric data across countries (Mahé and Olivry, 1999; Viglione et al., 2010; Mahe et al., 2013; Stewart, 2015; Dixon et al., 2020).

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African countries are largely under-represented in large-scale databases such as the Global Runoff Data Center (GRDC) or the recent GSIM initiative (Do et al., 2018; Gudmundsson et al., 2018), and/or the time series are mostly not updated. At the African scale, there is still a lack of coordination for hydrological data collection and dissemination, despite the launch in 1975 of the UNESCO Intergovernmental Hydrological Program (IHP) dedicated to water research, water resources management,

118 as well as education and capacity building. This initiative enhanced the set up and
119 management of international rainfall and runoff databases at the regional scale of the
120 FRIEND programs (Van Lanen et al., 2014), but these are still largely not updated.
121 There is still not enough partnership between the national hydrological services and in
122 many countries licensing issues prevent the distribution of the data collected.
123
124 The density of monitoring networks in Africa has been declining over time; a serious
125 concern for hydrologists since data acquisition and experimental data analysis remain
126 central to understand hydrological processes and their spatio-temporal variability
127 (Hannah et al., 2011; Roudier et al., 2014; Blume et al., 2016; Beven et al., 2020).
128 There are several reasons for this decline: the budgetary austerity measures imposed
129 by the international financial institutions, the lack of permanent funding of national
130 hydrological services, and the typically low number of well-trained technical staff in
131 these departments (Bodian et al., 2016, 2020; Hannah et al., 2011). As a result,
132 hydrological monitoring is now often dependent on research projects that cannot
133 support long term observations. Studies focusing on regional river discharge variability
134 are rare at the scale of Africa due to the lack of data. For instance, Conway et al. (2009)
135 could only present a study on a reduced number of representative regional basins, and
136 Roudier et al. (2014) compared only published anomaly results in their review of climate
137 change impacts on the hydrology of West Africa.
138
139 Since in many cases, there are strict conditions related to the redistribution of un-
140 processed data (Do et al., 2018), it is very often not possible to provide the complete
141 time series of discharge data. To address these challenges, the focus has been shifted
142 to publishing hydrological indices and signatures, which are useful to Nevertheless,
143 hydrological indices or hydrological signatures are useful to characterize the behavior of
144 different components of river discharge, from low flows, annual runoff to floods (Addor
145 et al., 2018; McMillan et al., 2017), and to assess the potential impact of climate change
146 and human activities on river regimes (Mahe et al., 2013). They can be used for various
147 purposes, including basin classifications, aquifer properties characterization,
148 hydrological predictions in ungauged catchments (Westerberg et al., 2016, Gnann et al.,
149 2020) and to investigate long term trends for different hydrological processes (Do et al.,
150 2017; Nka et al., 2015). We introduce here the African Dataset of Hydrometric Indices
151 (ADHI) that aims at giving access to an ensemble of hydrometric indices computed from
152 an unprecedented large ensemble of stations with daily discharge data (Tramblay et al.,
153 2020, Tramblay and Rouché, 2020). Thus, a minimum of useful information regarding
154 the African rivers' variability over the last 68 years can be shared with the international
155 community, while respecting the confidentiality of the original records when these are
156 not allowed to be publicly shared by the national authorities.
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2. Data sources and processing

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2.1 Data collection

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The database used in the present work is based on the collection of stations from the Global Runoff Data Center (GRDC) and the SIEREM database (Boyer et al., 2006; Dieulin et al., 2019). The hydro-climatological data contained in SIEREM is the legacy from the former *Laboratoire d'Hydrologie* of the *Office de la recherche scientifique et technique outre-mer* (ORSTOM, now *Institut de Recherche pour le Développement*, IRD, France). It must be noted that in addition to the daily data, the SIEREM database also contains instantaneous rainfall and discharge for hundreds of experimental small catchments mostly established in the 1950s and 1960s. The criterion to include a station in the ADHI database is to have a minimum of 10 full years, not necessarily consecutive, of daily discharge data between 1950 and 2018. Most of the hydrological stations in French-speaking countries have been set up and managed for decades by the ORSTOM Institute (Mahe and Olivry, 1999). At the time the data were processed, the SIEREM database included a total of 1046 series, with several of them being duplicates of the same monitoring station but for different time periods. There are a total of 101 stations with 2 times series, 42 stations with 3 time series, 24 stations with 4 time series and 7 stations with 5 time series. In most cases, one time series includes the longest record and that one was kept for the analysis in the present paper. For some stations, the different time series were differing substantially during the same period, due to different rating curves. A visual inspection of these series led to the elimination of erroneous or doubtful data. Only for 17 stations the time series were concatenated, after making sure the rating curve(s) applied on the different time periods to compute river discharge were adequate, by comparing daily runoff on a common period. Additionally, to these 1046 series, 933 stations have been retrieved from the GRDC database. For 106 of these stations, there was a duplicate station in the SIEREM database with longer time series and the latter were selected. After this data quality processing step, 672 stations were kept for SIEREM and 794 for the GRDC database for a total of 1466 stations (Figure 1). The stations from SIEREM mostly cover the Western, Central and Northern African regions and stations from the GRDC the Eastern and Southern parts of Africa. Figure 2 depicts the number of stations available per year, showing a sharp decline at the end of the 1980s, and shows the number of stations having from 10 to 69 years of record. It can be seen that, for about 100 stations, complete records are available over 50 years.

195

2.2 Data quality

197
198 Since the data collected are sometimes from manual records, they are subject to
199 possible errors in the reporting of discharge values. For outlier detection, no single
200 method can outperform visual inspection and local expert knowledge (Crochemore et
201 al., 2020). Indeed, in rivers with a strong variability in the annual regime and extremes,
202 the most important flood peaks may be wrongly reported as outliers. Consequently, we
203 carried out a visual inspection of the data when the maximum value was exceeding 5
204 times the median discharge. For only a few data points in the discharge time series,
205 some obvious errors were detected with daily discharge exceeding by several orders of
206 magnitude the median flow. In these cases, the data has been reported as missing data
207 in an absence of an objective criterion to correct the record. In addition, through visual
208 inspection it was possible to identify stations where some gap filling methods have been
209 applied (13 stations) or where the data are suspicious (28 stations). A flag has been
210 added in the metadata to identify these stations. It is worth noting that, for the stations of
211 the SIEREM database, most of the data were analyzed and criticized prior to the
212 inclusion in the database by the former ORSTOM hydrology laboratory, with therefore a
213 reduced level of error in the archived data.
214
215 In addition, to detect possible shifts in the data due to non-natural influences, such as
216 an artificial drift in the monitoring devices, changing instrumentation, recalibration of the
217 rating curve, or river regulation by dams or reservoirs, the Pettitt test (Pettitt, 1979) was
218 applied to mean annual runoff series. We reported the cases when the null hypothesis
219 of homogeneity was rejected, at the 5% significance level. 14 stations are reported with
220 homogeneity breaks in the metadata and this result was consistent with a visual
221 inspection. Since the possible causes of these changes in flow regime could be
222 manyfold and should be investigated with a more detailed case-by-case analysis, we
223 choose to keep these stations in the database, but to flag them accordingly.
224
225 **2.3 Climate characteristics**
226
227 This data collection results in the largest ever built database of daily discharge data in
228 Africa. These stations belong to different climate zones (Figure 1), according to the
229 Köppen-Geiger climate classification (Peel et al., 2007). The main climate zone
230 represented is Savannah (class Aw) for 687 stations corresponding to west and central
231 Africa basins. The second most represented climate zone is Steppe-hot (Bsh) for 207
232 stations located in the Sahel region and southern Africa (Botswana, Namibia). The
233 temperate with dry winter classes (Cwa and Cwb) include 187 and 125 stations,
234 respectively located in southern Africa (Zambia, Angola, Rwanda, Mozambique, South
235 Africa and Zimbabwe). The 98 stations belonging to the Desert-hot class (Bwh) are
236 mostly located in the northern and southern boundaries of the Sahara Desert. 87

237 Stations under a temperate climate with dry hot summer, corresponding to
238 Mediterranean climate (Csa) are found in North Africa and the southwestern part of
239 South Africa. Thus, the selected river basins are representative of most of the climate
240 zones in Africa. It must be noted that for large basins, such as the Congo, Niger or even
241 the Orange rivers, the climate type at the outlet may not be representative of the whole
242 catchment, that may span over diverse climate zones.

244 To document the mean annual precipitation and evapotranspiration at the catchment
245 scale, the CRU4 dataset has been considered (Harris et al., 2020). However, without
246 long-term and homogeneous ground monitoring networks over the African continent, no
247 best precipitation database could be identified for Africa as a whole (Sylla et al., 2013;
248 Beck et al., 2017; Awange et al., 2019; Satgé et al., 2020). For some regions, such as
249 Northern or Equatorial Africa, there are large differences between different remote
250 sensing or gauged-based precipitation products (Gehne et al., 2016; Harrison et al.,
251 2019; Nogueira, 2020), in particular for extreme precipitation events. This is the reason
252 why we choose to provide only mean annual precipitation, evapotranspiration and
253 temperature. This implies that the ADHI dataset does not provide metrics relying on
254 time series of precipitation or evapotranspiration, such as the runoff ratio, streamflow-
255 precipitation elasticity or catchment response time. To calculate these indices requiring
256 climatic time series for a given catchment, the user is advised to check first the best
257 available data for that area.

259 **2.4 Catchment delineation**

261 Station catchments areas have been delineated with the Hydroshed Digital Elevation
262 Model (DEM) at 15 sec resolution using the TopoToolbox2 algorithm (Schwanghart and
263 Scherler, 2014). The map of the catchments is shown in Figure 3. Despite a careful
264 check of the geographic coordinates of the stations, this type of automatic catchment
265 delineation procedure is prone to some errors, in particular in regions with low elevation
266 and flat terrain properties. This is particularly the case of catchments with endoreic
267 areas, such as the Niger, Chari and Logone basins, where the precision of the DEM is
268 crucial to identify these areas. Since the gauge locations are not necessarily located on
269 the streams derived from the DEM, The TopoToolbox2 makes possible to re-locate
270 automatically the gauges on the nearest river stream. However, this procedure did not
271 work for 61 catchments, with a catchment area error exceeding 10% compared to the
272 available metadata. For these basins, a manual procedure with the Arcmap® software
273 has been implemented to delineate the catchment boundaries from flow direction maps.
274 In addition, fFor several hundred of catchments, it is was possible to compare the
275 results of the automaticcatchment delineation procedure with the catchment areas
276 available in the SIEREM database and the ORSTOM reports (available online at the

277 adress: https://horizon.documentation.ird.fr), which have been most often individually
278 delineated and carefully checked from ground knowledge over the years (Dieulin and
279 Boyer, 2005). ~~For 37 stations in the SIEREM database, the catchment areas where not~~
280 ~~correct in the metadata, by comparing the delineated catchments.~~
281
282 From the catchment delineated, the mean, maximum and minimum altitude from the
283 Hydroshed DEM have been extracted and included in the metadata. In addition, the
284 European Space Agency Climate Change Initiative Land cover data (ESA-CCI LC)
285 (ESA, 2017) has been extracted for each catchment for the year 2015. This database
286 contains land cover maps at a 300m spatial resolution for 38 classes, compliant with the
287 UN Land Cover Classification System (LCCS). The classes have been grouped into 8
288 new classes: forest, urban areas, cropland, irrigated croplands, grassland, shrubland,
289 sparse vegetation and bare land. Overall, the basins are characterized by a low
290 proportion of urban areas, a large proportion of forests, especially in the intertropical
291 zone (mean = 41%, median = 37%), and a majority of non-irrigated cultivated area, on
292 average covering 31% of the total area of the basins. Indeed, the irrigated crops
293 represent only 0.43% on average.
294
295 **2.5 River regulation**
296
297 Dams and reservoirs have also been extracted and added in the metadata of the
298 stations. The Global Reservoir and Dam Database (GRanD) v1.3 (Lehner et al., 2011)
299 has also been considered to identify regulated basins. The number of dams included in
300 each river basin has been extracted using the catchment boundaries. As shown in the
301 metadata of GRanD, most of the dams in Africa basins have been constructed around
302 the 1970s (Figure 4). The rivers could be considered regulated if at least one dam exists
303 in the catchment area, otherwise the river is considered natural (Figure 5). However, the
304 influence of dams and reservoirs on the flow regime are linked to the location of the
305 regulation structure, the portion of the basin controlled, and the management strategies.
306 For instance, in a large basin with only one dam located on a small headwater
307 catchment, its influence may not be distinguishable at the river outlet. On the other
308 hand, a station located immediately downstream a dam outlet may have its flow regime
309 strongly impacted by dam operations. It should be also noted that other regulation
310 structures like small dams or water diversion channels that may not be included in the
311 GRanD database could be present in the catchments considered natural (Lehner et al.,
312 2011; Pekel et al., 2016). This is particularly the case in semi-arid areas where earthen-
313 made channels, often informal, draw their water supply from the river itself, by building
314 small diverting structures (Underhill, 1984; Kimmage, 1991). They can represent a large
315 number of structures, but a variable amount of water withdrawal at the basin scale
316 (Barbier et al., 2009; Bouimouass et al., 2020). Similarly, no data is available yet on the

317 importance and impact of groundwater abstraction, if any, on the flow regime measured
318 at the stations.
319

3. Hydrometric indices

321

322 Here is presented the list of indices computed from daily discharge data. While
323 hydrological indices refer to standard statistical metrics, such as the mean, maximum,
324 or percentiles computed from time series of discharge data, hydrological signatures can
325 be defined as metrics describing the hydrological behavior and the dominant processes
326 in a river basin (Addor et al., 2018). Most of the indices are computed with the Toolbox
327 for Streamflow Signatures in Hydrology (TOSSH, available at the address:
328 https://github.com/TOSSHtoolbox/) (Gnann et al., 2021). The indices and signatures
329 selected spans a large variety of runoff characteristics from high to low flows, from
330 previous literature (Poff et al., 1997; Richter et al., 1996; Baker et al., 2004; Yadav et
331 al., 2007; Clark et al., 2009; Estrany et al., 2010; Sawicz et al., 2011; Euser et al., 2013;
332 Safeeq et al., 2013; Addor et al., 2018; McMillan, 2020).

333

334 **3.1 Available streamflow signatures and indices derived from daily**
335 **dischargeMethodological considerations**

336

337 Several signatures charactering baseflow rely on the application of a base flow filter.
338 Since the choice of the baseflow separation method can introduce uncertainties in the
339 calculation of these signatures (Su et al., 2016), two baseflow filtering methods are
340 compared: the Lyne and Hollick recursive digital filter (Ladson et al., 2013), with the
341 default values for the filter parameter (0.925) and the number of passes (3), and
342 alternatively the UKIH smoothed minima method (UKIH, 1980), that does not require
343 any calibration parameter. The base flow index (BFI) is the ratio between the baseflow
344 volume and the total streamflow volume. The baseflow recession (BaseflowR) is the
345 baseflow recession constant assuming an exponential recession behavior (Safeeq et
346 al., 2013). The base baseflow magnitude calculates the difference between the
347 minimum and the maximum of the baseflow regime, defined as the average baseflow on
348 each calendar day. The two base flow separation method compared to compute the
349 baseflow-related indices provide very similar results, with a correlation above 0.9 for all
350 indices obtained with the two approaches.

351

352 To compute the mean half flow date and the mean half flow interval, the beginning of
353 the hydrological year has been defined as the month following the month with the
354 minimum average runoff. Indeed, the hydrological year has different starting dates
355 across the African continent, in North Africa the hydrological year usually starts in
356 September, in western Africa around March-April and in January for southern Africa.

357 The mean half flow date is the day when the cumulative discharge reaches half of the
358 annual discharge. The mean half flow interval is the time span between: i) the date on
359 which the cumulative discharge since the start of water year reaches a quarter of the
360 annual discharge and ii) the date on which the cumulative discharge since the start of
361 water year reaches three quarters of annual discharge.

362

363 Some metrics are derived from the calculation of the Flow duration Curve (FDC), such
364 as its slope between the 33rd and 66th flow percentiles (McMillan et al., 2017), the peak
365 distribution, the slope between the 10th and the 50th percentiles of the FDC constructed
366 only with hydrographs peaks (Euser et al., 2013) and the variability index, the standard
367 deviation of the logarithms of discharge from 10th to the 90th percentiles of the FDC
368 (Estrany et al., 2010). It must be noted that 194 rivers have more than 50% of days with
369 zero-flow and for these stations, but also all the others with an intermittent regime,
370 several metrics derived from the Flow Duration Curve (FDC) are not adapted. For these
371 basins, specific methods to estimate the FDC should be applied (Rianna et al., 2013).
372 Similarly, there is no baseflow in these basins. Consequently, the indices relying to base
373 flow or the flow duration curve are not computed for these basins.

374

375 In addition, different hydrological signatures describing the hydrologic responses of the
376 basins are also provided. The flashiness index is defined as the sum of absolute
377 differences between consecutive daily flows (Baker et al., 2004), it reflects the
378 frequency and rapidity of short term changes in streamflow, especially during high runoff
379 events. The number of master recession curves (MRC) is computed from the changes
380 in recession slopes, and represent different reservoirs contributing to the runoff
381 response (Clark et al., 2009; Estrany et al., 2010). This signature can help to
382 understand the functional forms of storage–discharge relationships and identify model
383 structures adapted to represent it. The rising limb density is the ratio between the
384 number of rising limbs and the total amount of timesteps in the hydrograph (Sawicz et
385 al., 2011). It is a descriptor of the hydrograph shape and smoothness, without
386 consideration for the flow magnitude. Small values of the rising limb density indicate a
387 smooth hydrograph.

388

389 From the supplied indices, some other useful indicators could be derived. For example,
390 for hydrogeology applications it would be interesting to compute the low stage specific
391 discharge that is the ratio between the low-stage discharge and the area of the
392 watershed. This can be an indicator of aquifers' contribution to river discharge. The
393 main issue is related to the definition of the low-stage discharge. From the indices
394 proposed in the present database, it could be 5th percentiles of daily streamflow or the
395 minimum of 7-days consecutive streamflow, per year. Similarly, the low-flow index could

396 be computed from the ratio of the 90th and 50th percentiles of daily streamflow
397 (Smakhtin, 2001).

398

399 **3.2 Indices computed on the whole record**

400

401 These indices have been computed using the whole time series available for each
402 station. Consequently, they are computed on different base periods depending on the
403 stations, with the period of record for each station being made available in the
404 metadata. These indices are listed in table 1include.:

405

406 Table 1: Hydrometric indices in the ADHI database

Hydrological regime	Mean daily streamflow, the arithmetic mean of daily data
	Standard deviation of daily streamflow
	Minimum daily streamflow
	Maximum daily streamflow
	Mean monthly streamflow (12 values from January to December)
	5th, 10th, 25th, 50th, 75th, 90th, 95th and 99th percentiles of daily streamflow
	Frequency of zero-flow days
Baseflow	Baseflow index
	Baseflow magnitude
	Baseflow recession
Seasonality	Mean half flow date
	Mean half flow interval
Variability	lag-1 autocorrelation of flow
	lag-7 autocorrelation of flow
	Slope of flow duration curve
	Coefficient of variation of runoff
	Peak distribution
	Variability index
	Variance of runoff
Hydrological response	Richards-Baker flashiness index
	Skewness of runoff
	Rising limb density
	Number of master recession curves

407
408

409 The basins included in the ADHI database include a wide range of catchment areas,
410 from a few square kilometers to several hundred thousand, in the case of large rivers
411 such as the Congo, Niger, Orange, Zambezi, Senegal, Okavango and Volta. As shown
412 in Figure 6, the average runoff is generally well correlated to the size of the basins with
413 nevertheless a variability linked to local climatic and geological conditions. The mean
414 annual precipitation is one of the explanatory factors of the observed ranges of mean

415 river runoff, but also strongly modulated by local conditions. A large number of basins
416 have an aridity index (ratio between precipitation and potential evapotranspiration) of
417 less than 0.60, indicative of arid to semi-arid conditions (figure 7a). The varying degrees
418 of aridity encountered in the basins are an important explanatory factor for the
419 hydrological response at the African scale. For instance, the coefficient of variation of
420 runoff (figure 7b) or the flashiness index (figure 7c) have greater values under
421 conditions of increasing aridity.
422
423 **3.3 Indices computed on monthly or annual basis**
424
425 These indices have been computed for each calendar year, for consistency with other
426 databases such as GSIM (Do et al., 2018; Gudmundsson et al., 2018). These indices
427 have been computed for the years with less than 5% missing data:
428
429   1. Mean annual runoff
430   2. Minimum of 7-days consecutive streamflow, per year, and corresponding date
431   3. Annual maximum runoff, and the corresponding date
432   4. Annual values for the 5th, 10th, 25th, 50th 75th, 90th, 95th and 99th percentiles
433   of daily streamflow
434
435 In addition to these annual series, the monthly time series contains for each month the
436 mean, maximum and minimum runoff, the last column being the number of missing
437 days per month. There is one file per station. It is advised to consider the monthly
438 values only for the months with no missing values, or missing values less than 10% or
439 5%.
440
441 These time series make it possible to analyze the long-term evolution of mean and
442 extreme runoff (Tramblay et al., 2020), but can also be useful to validate hydrological
443 modelling results. Focusing on extreme high and low runoff, very different seasonal
444 patterns of occurrence could be observed for different regions of Africa. On figure 8 are
445 plotted the mean dates of annual maximum runoff and the annual minimum of 7-day
446 runoff. This seasonal analysis has been performed with directional statistics (Burn,
447 1997; Mardia et al., 2015): the dates of occurrence were converted into angular values
448 to compute the mean date of occurrence (θ) together with the concentration index (r),
449 which is a measure of the flood occurrences variability around the mean date. The
450 annual maximum runoff shows three distinct patterns (Figure 8): First, stations with
451 floods occurring during December-February in northern and southern Africa, with a
452 strong variability of their date of occurrence. Second, the stations in western Africa with
453 floods occurring during summer and a low seasonal variability. Third, the stations in
454 central-south Africa, with floods occurring in boreal spring and early summer with

455 various degrees of variability depending on the sub-region considered and the level of
456 aridity. For annual minimum runoff, the patterns are usually reversed, with the low flow
457 period spanning on average during June to October in North Africa, January-March in
458 western Africa, and between September and November in southeast Africa. Yet this
459 global picture hides local behaviors such East-West contrast in southern Africa or the
460 North-South gradient in West Africa (Mahe et al., 2013). Similarly, the observed
461 variability even for some neighboring catchments reflects the local influences of
462 topography, soils and land cover. As noted previously, the seasonal variability of
463 extreme high or low runoff events is also strongly related to the catchment aridity.
464

465 ## 4. Data availability

466

467 The ADHI database is available for download at: https://doi.org/10.23708/LXGXQ9
468 (Tramblay and Rouché, 2020). ~~These D~~different files are supplied in the AHDI
469 database. The ADHI_stations.tab file contains the station metadata (Table 2) and the
470 ADHI_summary.~~dat~~ tab file contains for each station the variables described in table 3.

471

472 Table 2: Catchment metadata in the file ADHI_stations.tab

473

Catchment characteristics	Description
Unique identifier for each station	
Station code	native code from the original data source
Station Name	
Data source	SIEREM or GRDC
Catchment area (km^2)	Computed from HydroShed DEM
Mean Altitude (m)	Computed from HydroShed DEM
Maximum Altitude (m)	Computed from HydroShed DEM
Minimum Altitude (m)	Computed from HydroShed DEM
Mean annual precipitation (mm)	CRU4
Mean annual evapotranspiration (mm)	CRU4
Mean annual temperature (°C)	CRU4
Forest cover (%)	ESA-CCI Land Cover 2015
Urban areas (%)	ESA-CCI Land Cover 2015
Cropland (%)	ESA-CCI Land Cover 2015
Cropland, irrigated (%)	ESA-CCI Land Cover 2015
Grassland (%)	ESA-CCI Land Cover 2015
Shrubland (%)	ESA-CCI Land Cover 2015
Sparse vegetation (%)	ESA-CCI Land Cover 2015
Bare land (%)	ESA-CCI Land Cover 2015
Starting year of the data records	
Ending year of the data records	
Longitude of the station (WGS84)	

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Latitude of the station (WGS84)	
Number of dams	GrandD v1.3
Country	
Flag	0: no identified data issue, 1: some gap filling detected, 2: suspicious data, 3: Obvious regime break

474

475   Table 3: Hydrometric indices in the file ADHI_summary.tab

476

Variable Name	Description
Mean_q	Mean daily streamflow (m3/s)
Std_q	Standard deviation of daily streamflow
Mini_q	Minimum daily streamflow
Maxi_q	Maximum daily streamflow
Jan_q, Fev_q... Dec_q	Mean monthly streamflow (12 values from January to December)
q5th, q10th, q25th, q50th q75th, q90th, q95th and q99th	percentiles of daily streamflow
BFI_LH	Baseflow index, with the Lyne and Hollick baseflow separation method
BFI_UKIH	Baseflow index, with the UK Institute of Hydrology baseflow separation method
BaseflowR	Baseflow recession
BaseflowM_LH	Baseflow magnitude, with the Lyne and Hollick baseflow separation method
BaseflowM_UKIH	Baseflow magnitude, with the UK Institute of Hydrology baseflow separation method
CoV	Coefficient of variation of runoff
HFD_mean	Mean half flow date
HFI_mean	Mean half flow interval
AC1	lag-1 autocorrelation of flow
AC7	lag-7 autocorrelation of flow
FDC_slop	Slope of flow duration curve
PeakDistri	Peak distribution
FlashI	Richards-Baker flashiness index
MRC_num	Number of master recession curves
Q_skew	Skewness of runoff
Q_var	Variance of daily runoff
RLD	Rising limb density
VariI	Variability index
Freq_0	Frequency of zero-flow days

477

478
479 The compressed folders AnnualMean.zip, AnnualMax.zip, Annual7DayMin.zip,
480 AnnualPercentiles.zip contains time series for mean annual runoff, annual maximum
481 runoff, annual minimum of 7-day discharge and annual values for the 5th, 10th, 25th,
482 50th 75th, 90th, 95th and 99th percentiles of daily streamflow. There is one file per
483 station.
484
485 The compressed folder MonthlySeries.zip contains for each month the mean, maximum
486 and minimum runoff, the last column is the numer of missing days per month. There is
487 one file per station.
488
489 The compressed folder Plots.zip contains for each station a plot of the daily discharge
490 data available.
491
492 The compressed folder Catchment_boundaries.zip contains the catchment boundaries
493 in the shapefile format (one .shp file per basin).
494
495 The compressed folder Catchment_plots.zip contains for each basin a plot of the
496 catchment area in .PNG format.
497

498 ## 5. Conclusions and perspectives

499
500 This new hydrological database brings together the largest number of African river flow
501 measurement stations, in comparison with other previously published datasets. In this
502 ADHI dataset, we included a total of 1466 stations with at least 10 years of discharge
503 data between 1950 and 2018, for a mean record length of 33.3 years. Half of the
504 stations have more than 30 years of data. By comparison, the recent GSIM database
505 contains 979 stations in Africa, with a record length varying from 1 year to 110 years
506 until 2015, and a mean record length of 33.8 years. This ADHI database results from a
507 pooling of the GRDC and SIEREM databases, built from contributions of several
508 agencies in African countries in charge of the management of hydrological
509 measurement networks. This database will be regularly updated with data from SIEREM
510 and GRDC. Since most of the pre-processing steps have been automated, it would be
511 possible to increase the number of stations considered or the length of the data series,
512 if more data would become available. The data from the SIEREM database is already
513 regularly updated from contributions of different institutes. In the future, individual
514 contributions from researchers or institutes will be also welcome to increase the spatio-
515 temporal coverage of the data. The FRIEND program (UNESCO/IHP) will also
516 contribute to increase the number of stations through coordinated efforts at the regional
517 level. The dataset provides a series of indices that describes a wide range of mean and

extreme runoff properties, allowing the characterization of the hydrological regime and applications linked to the management of water resources and hydrological risks. This database includes different catchment sizes and rivers with different hydrological regimes that makes possible to analyze the behavior of rivers in very different contexts for a wide range of scales.

More broadly, this ADHI database could contribute to a better knowledge on African hydrology. For instance, the impacts of dams on river discharge remains largely unquantified at the scale of Africa (Biemans et al., 2011). From these indices, various applications can be sought. For example, the percentiles of the daily streamflow could be useful to calibrate hydrological models using the flow duration curve (McMillan et al., 2017) and to constrain model outputs (Tumbo and Hughes, 2015; Ndzabandzaba and Hughes, 2017). Flow duration curves are also useful for catchment classification according to their rainfall-runoff response (Cheng et al., 2012). In the recent years, global runoff simulations have been provided by the Global Flow Awareness System, with land surface or global hydrological model driven by reanalysis data (Alfieri et al., 2020; Harrigan et al., 2020). Yet, due to the small number of stations representing African basins in the currently available databases preventing a robust calibration of the models, the hydrological simulations have a poor performance (Harrigan et al., 2020). More generally, this new ADHI database could open perspectives to apply hydrological models in African basins, in particular combined with recent remote sensing data products (Brocca et al., 2019; Satgé et al., 2020). Beside deterministic hydrological modelling approaches, several statistical methods to estimate the return levels of floods have been proposed, in order to safely design dams, reservoirs, sewers or other water regulation structures. Regional frequency analysis methods have been applied to estimate floods in ungauged basins in several African countries such as Morocco (Zkhiri et al., 2017), Tunisia (Ellouze and Abida, 2008), South Africa (Nathanael et al., 2018; Smakhtin et al., 1997), or the Volta basin (Komi et al., 2016). However studies at a larger regional scale remain very scarce (Farquharson et al., 1992; Padi et al., 2011) while there is a strong need to improve the knowledge on hydrological hazards in African countries (Di Baldassarre et al., 2010). With this recent database becoming available, it could be possible to develop regional frequency analysis techniques for floods or low flows tailored for the African context, taking also into account the impacts of global changes.

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564 The database is available from the online repository: https://doi.org/10.23708/LXGXQ9
565 Additional indices could be computed upon reasonable request to the corresponding
566 author.

568 This work is dedicated to the memory of Claudine Dieulin who passed away in January
569 2020 during the course of this project

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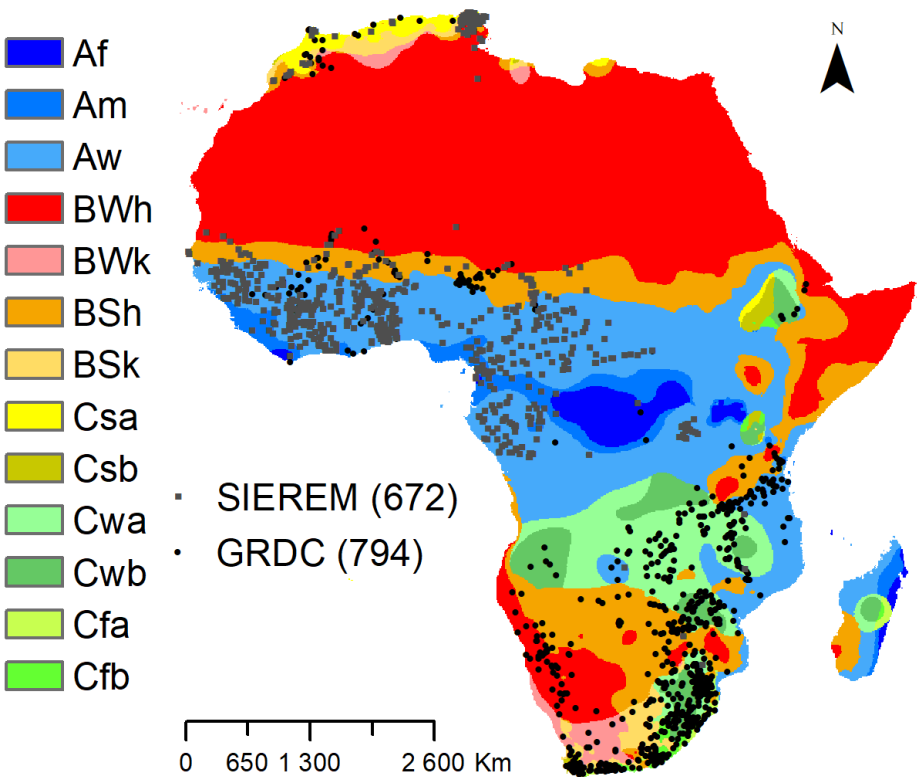
Figures

Figure 1: Map of the selected stations for the ADHI database from the SIEREM and GRDC datasets. The different colors represent the main climate zones in Africa from the Köppen-Geiger climate classification (Peel et al., 2007)

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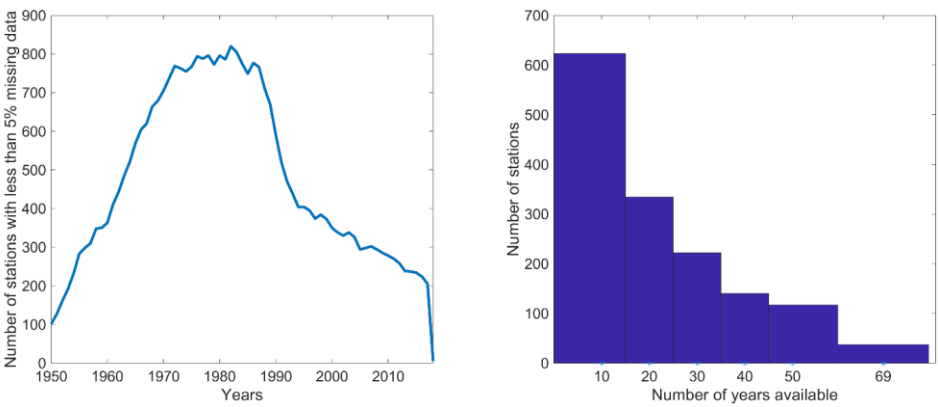
Figure 2: Number of available stations per year with less than 5% missing data (left) and number of stations available for different record lengths (right)

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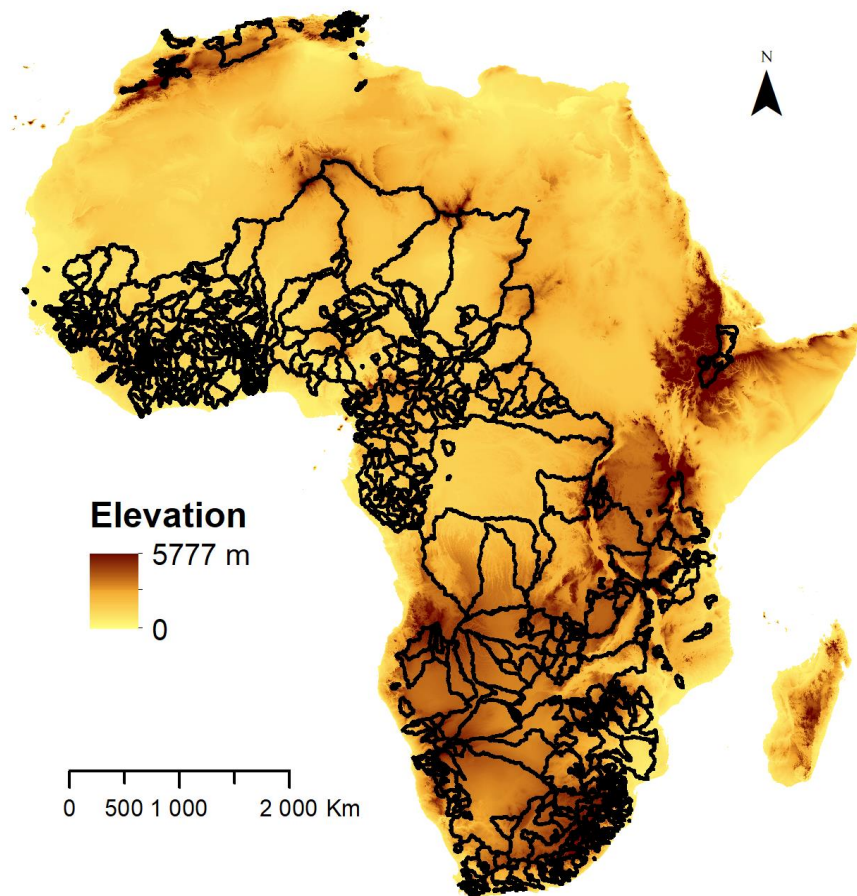
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893 Figure 3: Map of the delineated catchment boundaries in black, with elevation from
894 HydroSheds digital elevation model (https://www.hydrosheds.org/).
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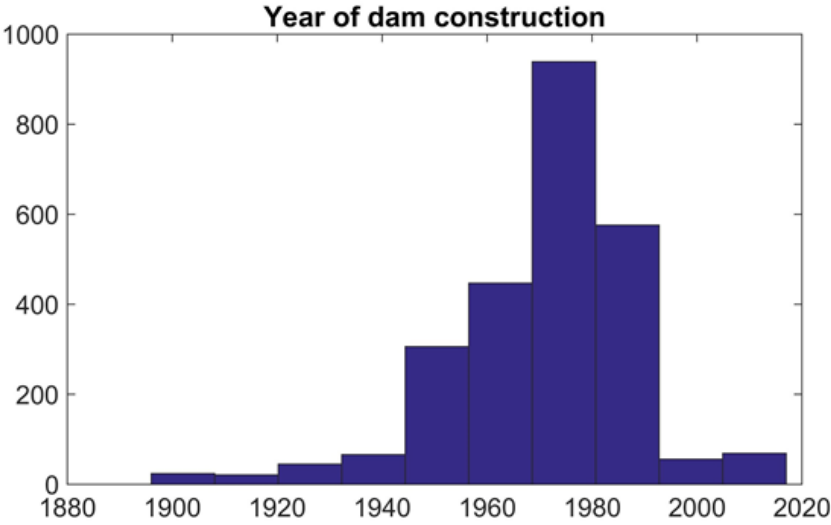
Figure 4: Years of building date for dams located in the catchment database (data from the Global Reservoir and Dam Database v1.3)

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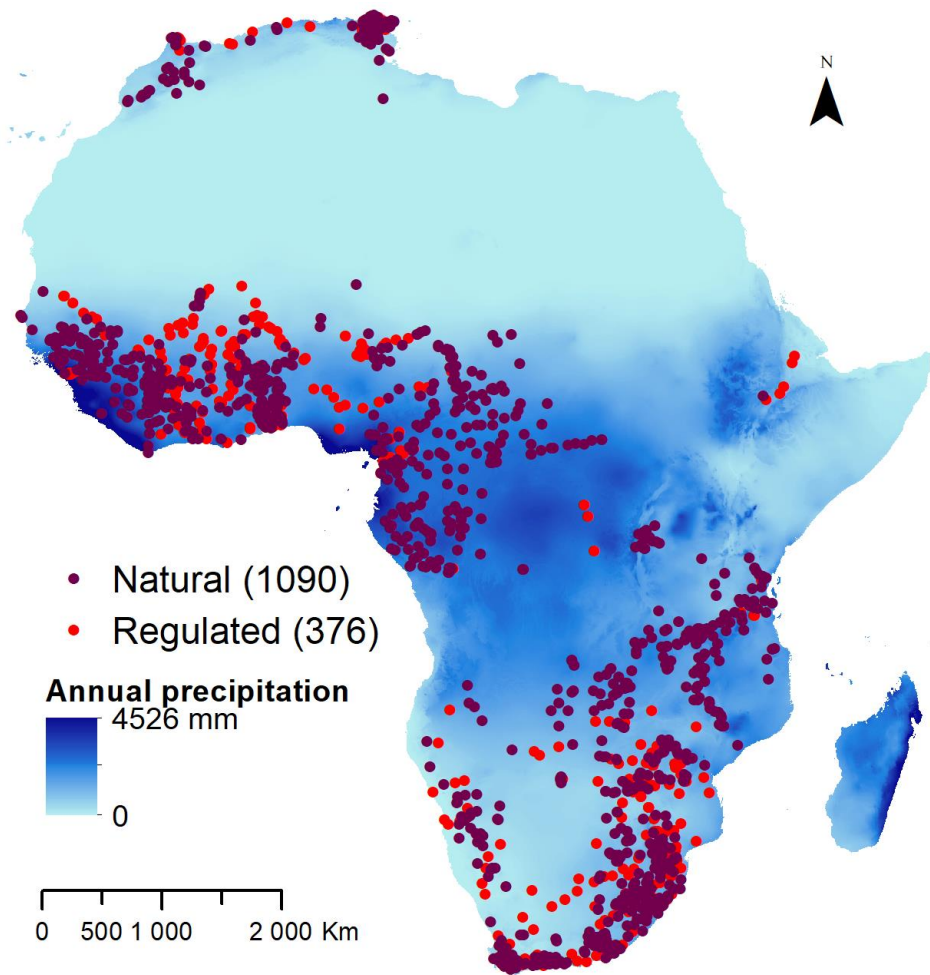
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911 Figure 5: Map of stations with a natural or regulated flow regime. Basins are considered
912 regulated if they contain at least one dam or reservoir from the GRanD database
913 (Lehner et al., 2011). Mean annual precipitation between 1970 and 2000 is provided
914 from the WorldClim database (Fick and Hijmans, 2017).
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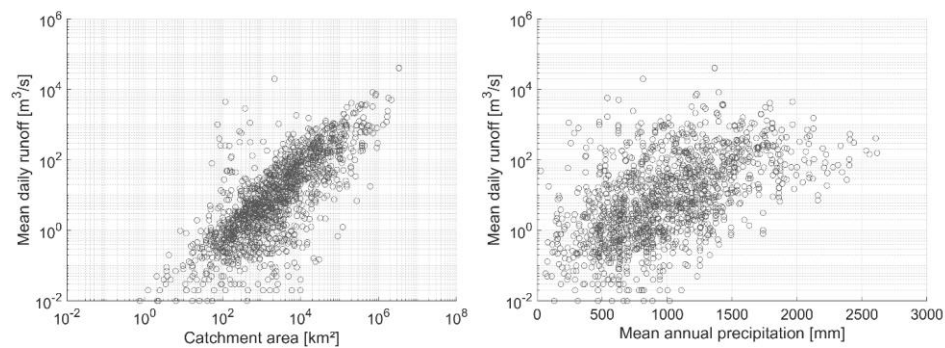
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923 Figure 6: Relationship between mean daily river discharge and catchment area (left)
924 and mean annual precipitation (right)
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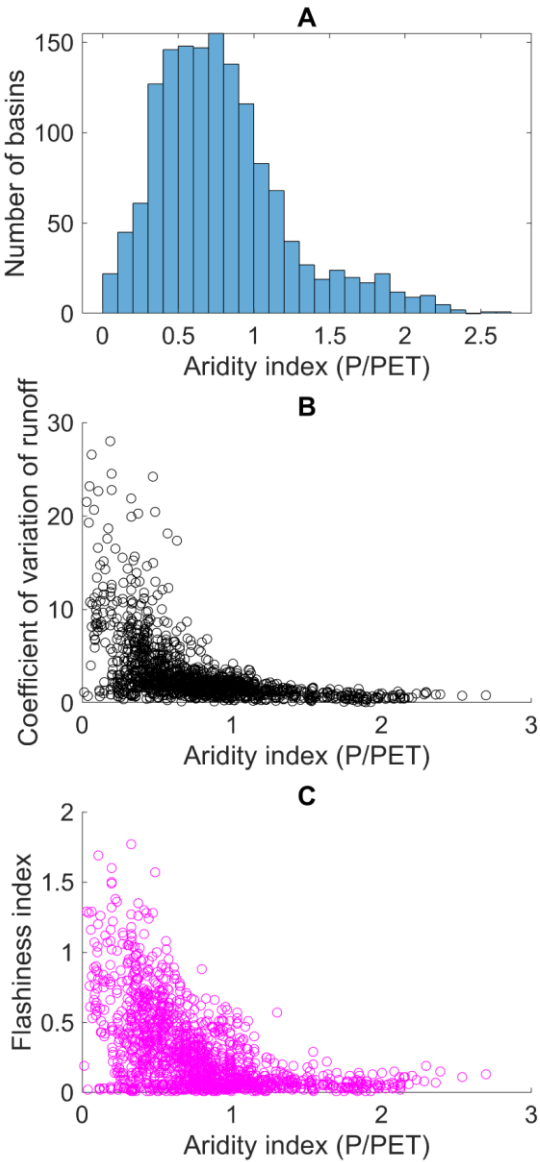
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929   Figure 7: histogram of the aridity index per basin (A), relationship between the aridity
930   index and the coefficient of variation of runoff (B), relationship between the aridity index
931   and the flashiness index (C)
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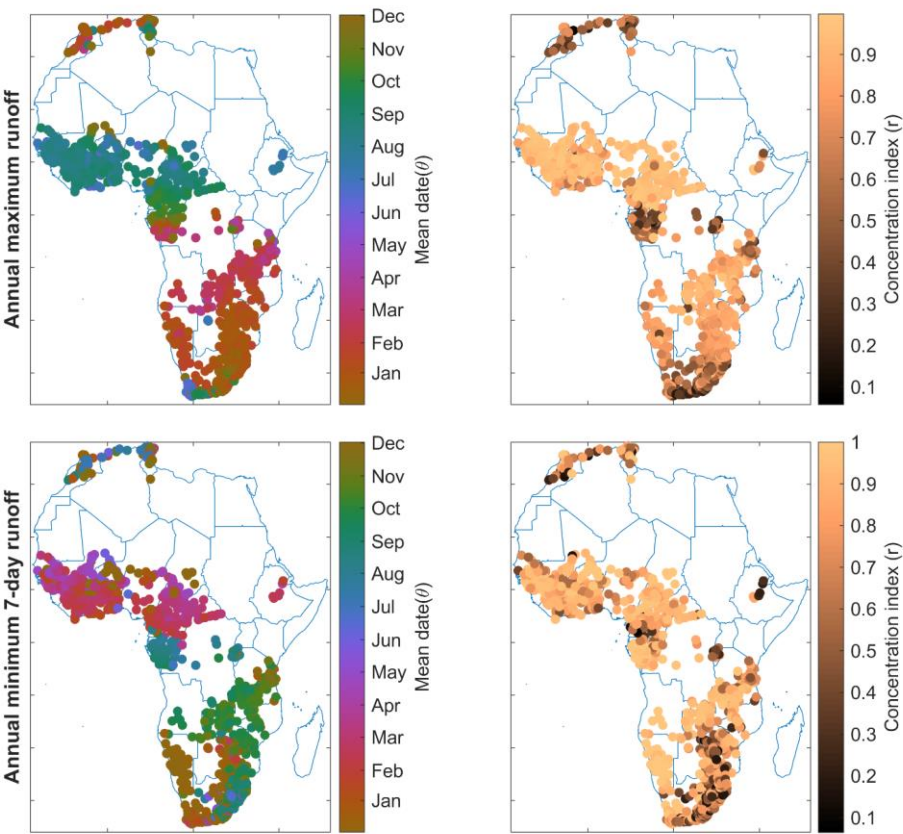
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935 Figure 8: Mean date of occurrence (left) of annual maximum runoff and annual minimum
936 of 7-day runoff, together with the variability around the mean date (right) represented by
937 the concentration index