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River runoff estimation with satellite rainfall in Morocco

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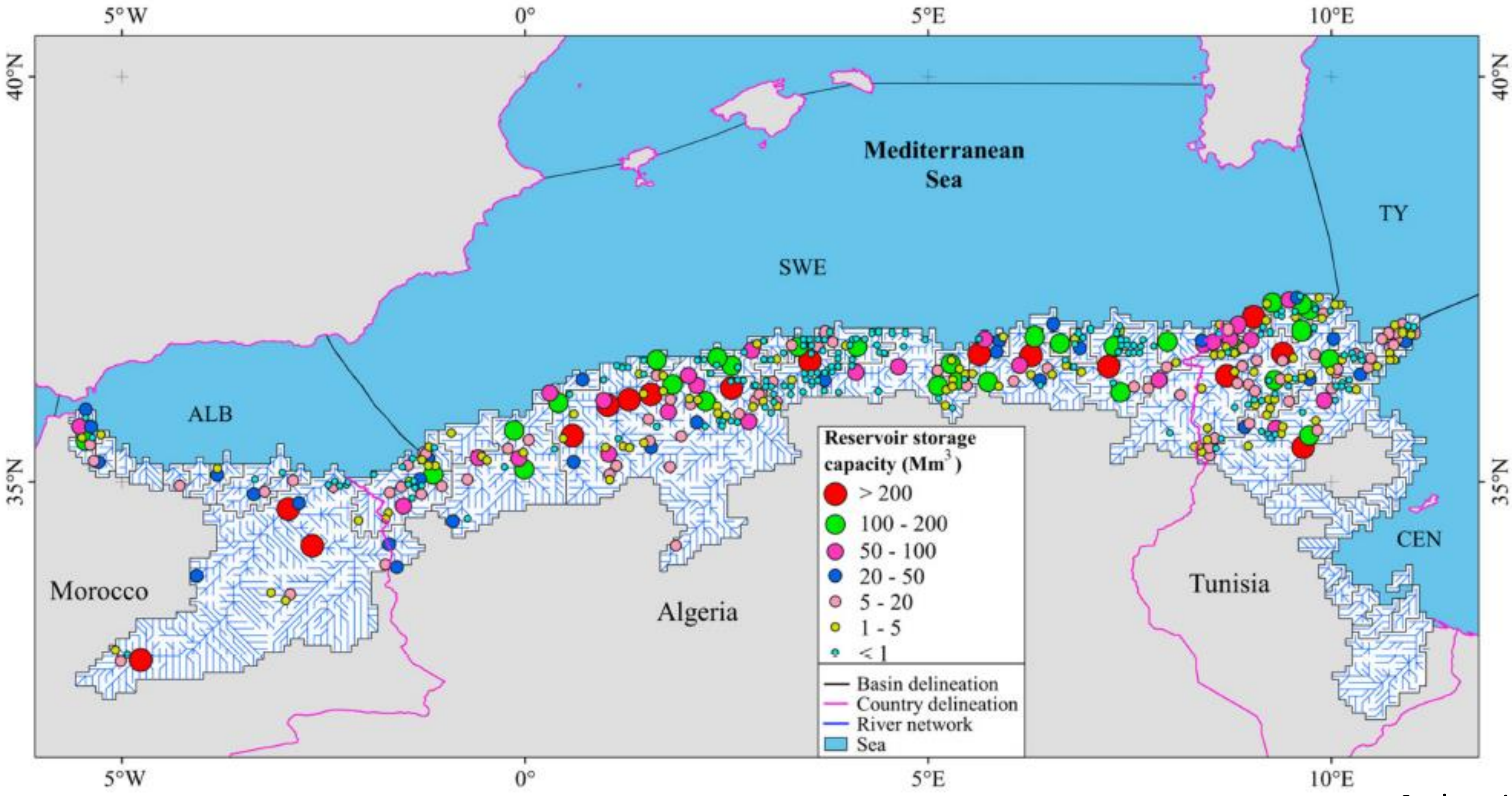
H SAF Associated/Visiting Scientist Activity ref. H_AVS20_02

4124 death due to floods in Algeria, Morocco, Tunisia between 1958 and 2007

2142 during the same period in France, Italy and Spain

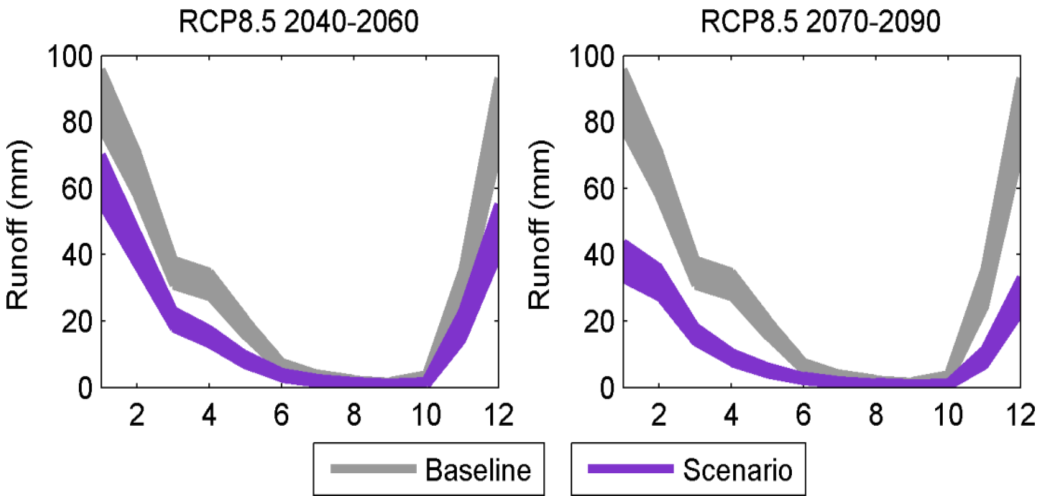
670 dams in Maghreb



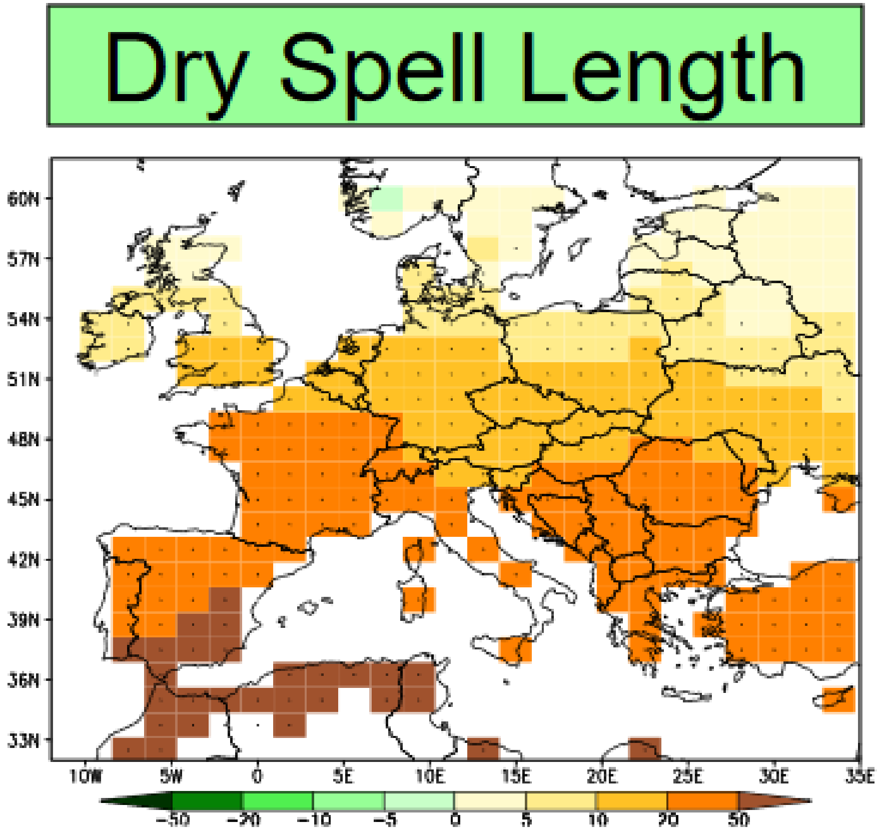
Sadaoui et al. 2018

Many (most) of them do not have a monitoring of surface water resources mostly due to a lack of observed precipitation

What are the climate change impacts on water resources ?



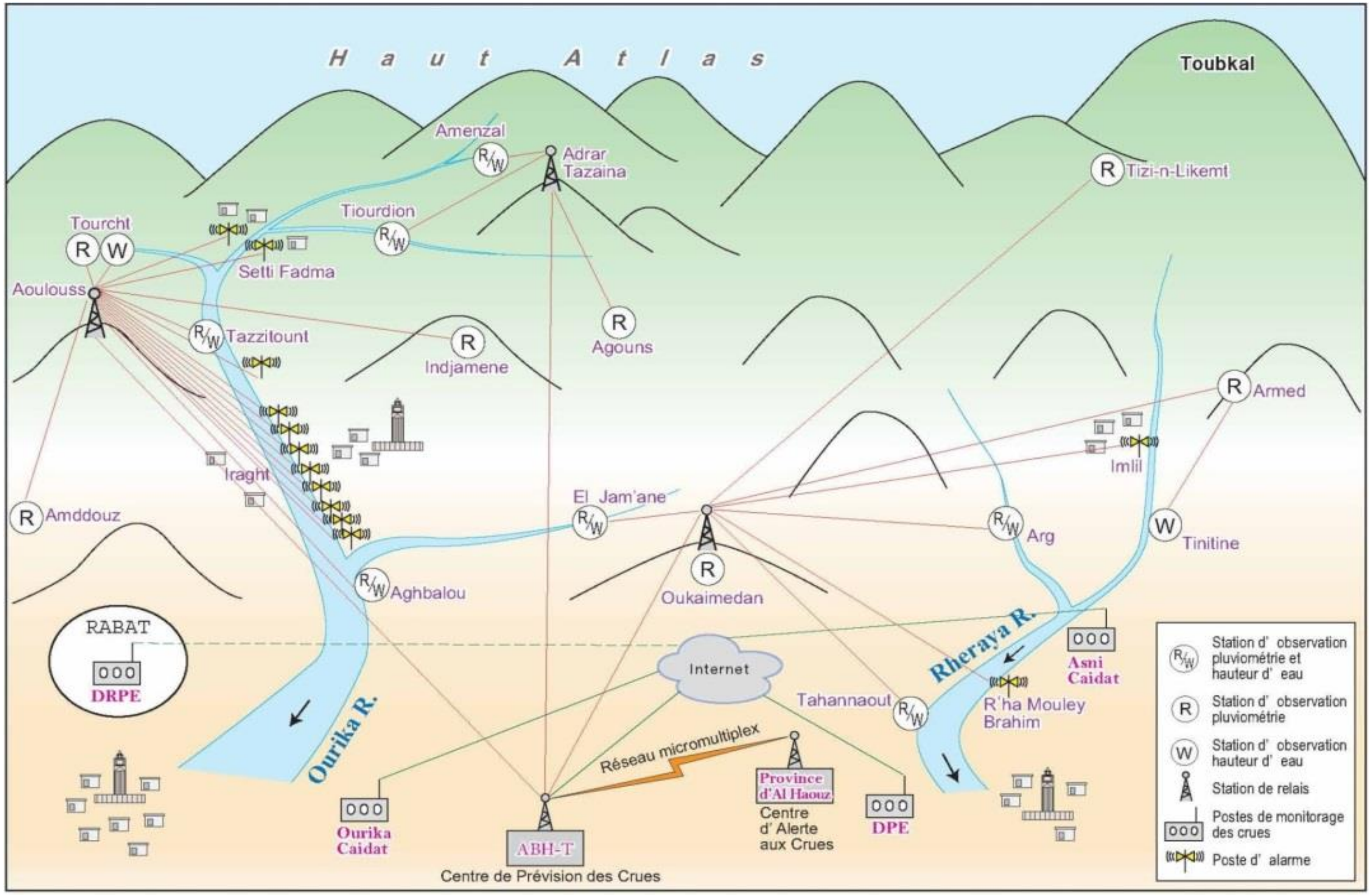
Tramblay et al., 2016



CMIP5, F. Giorgi

Only a few river basins have operational flood alert systems

Example of the High-Atlas basins, upstream of Marrakech, installed in 2012



Based on pre-defined thresholds (rainfall and discharge)

Real time data transmission and alert systems in the valleys

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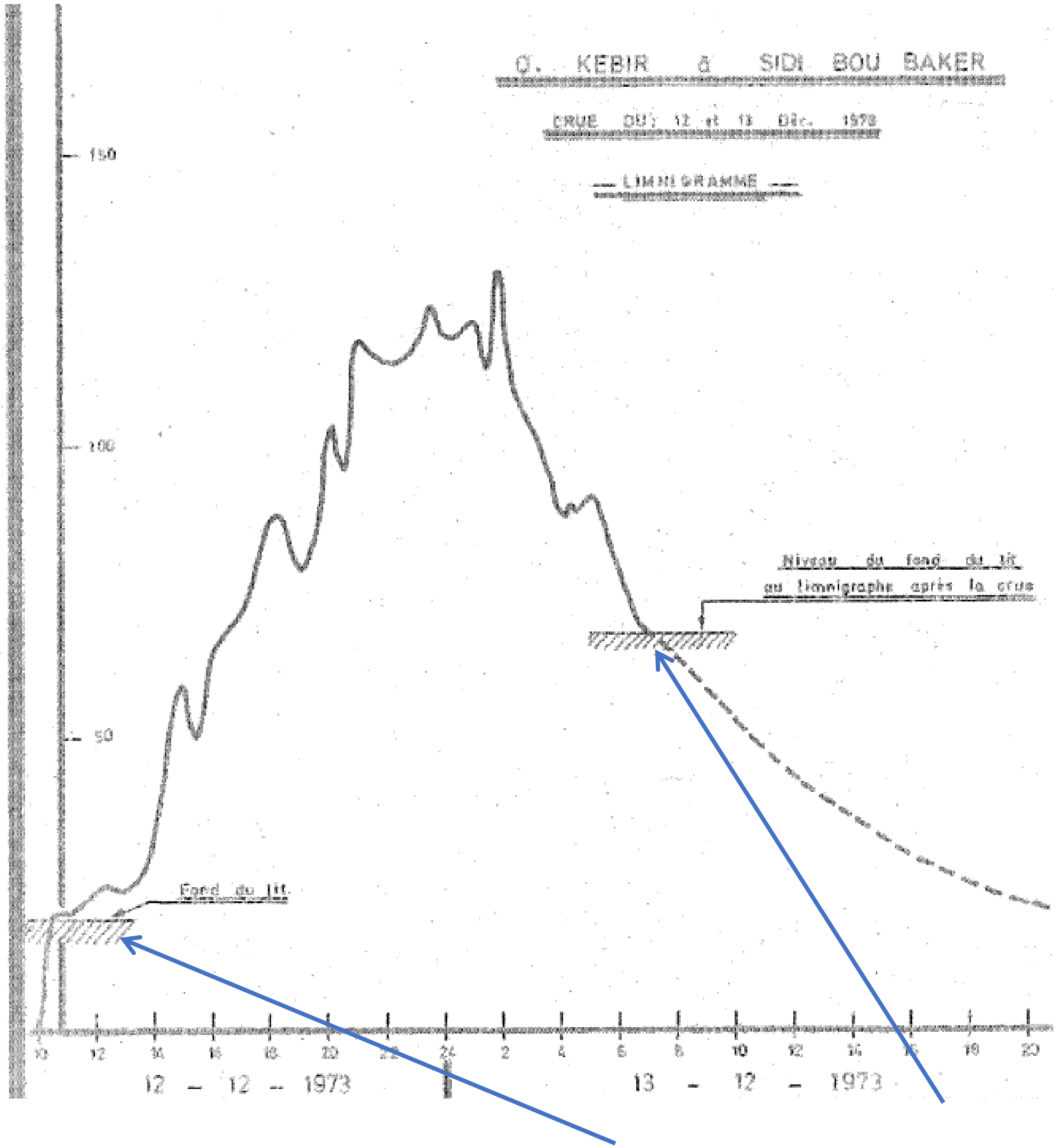
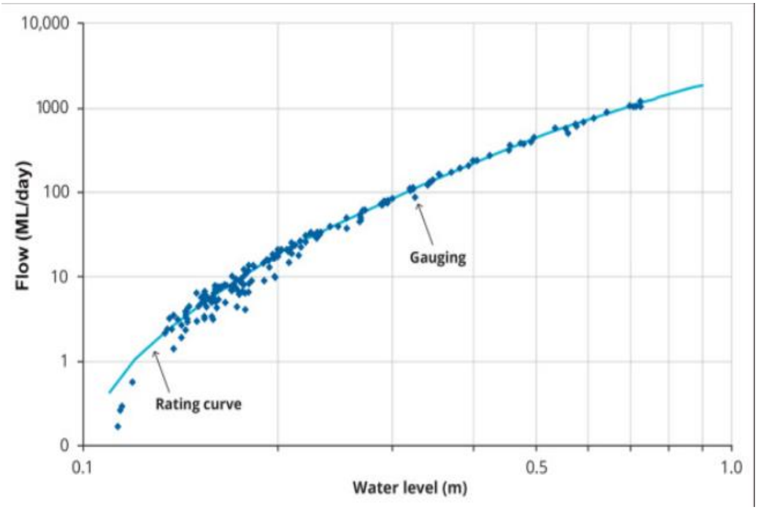
One cause of missing data….

Maintenance costs could be high



Floods can often change the river beds in semi-arid rivers, if the rating curves are not updated it can lead to strong uncertainties in measured river discharge

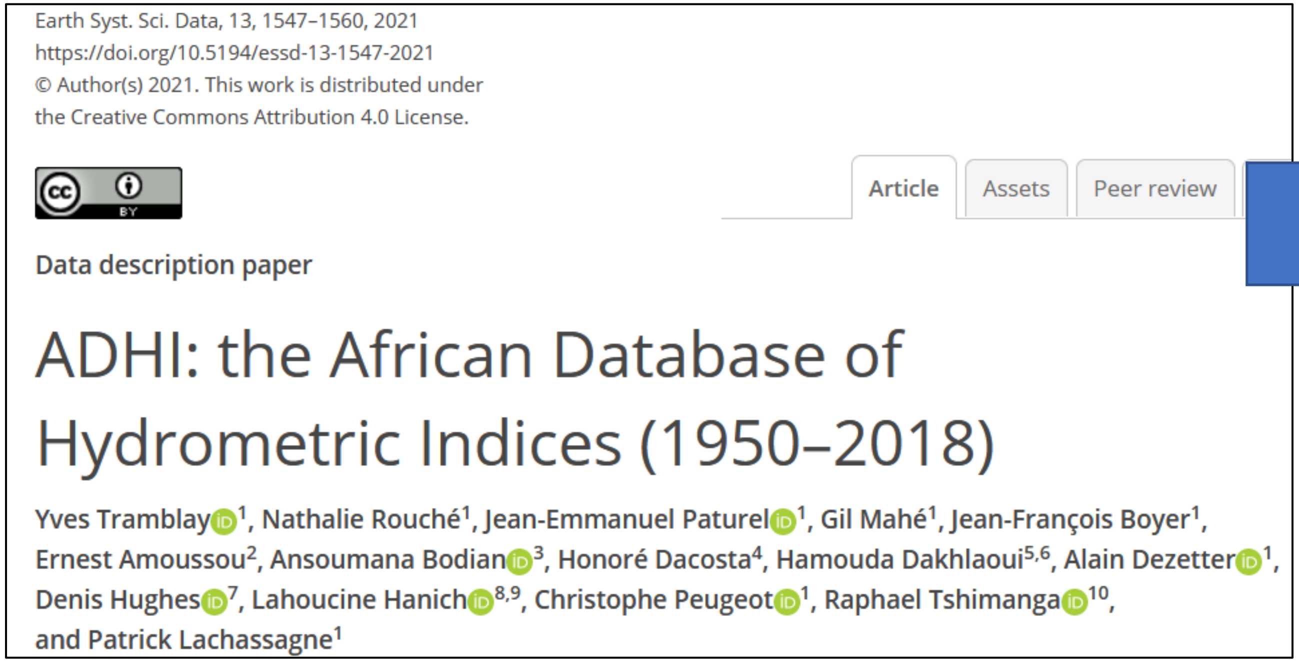


River bed elevation **before** and **after** a large flood

The challenge of river discharge data accessibility

No public sharing of data in Morocco, Algeria, Tunisia

Data quality issues and discontinuity in the records

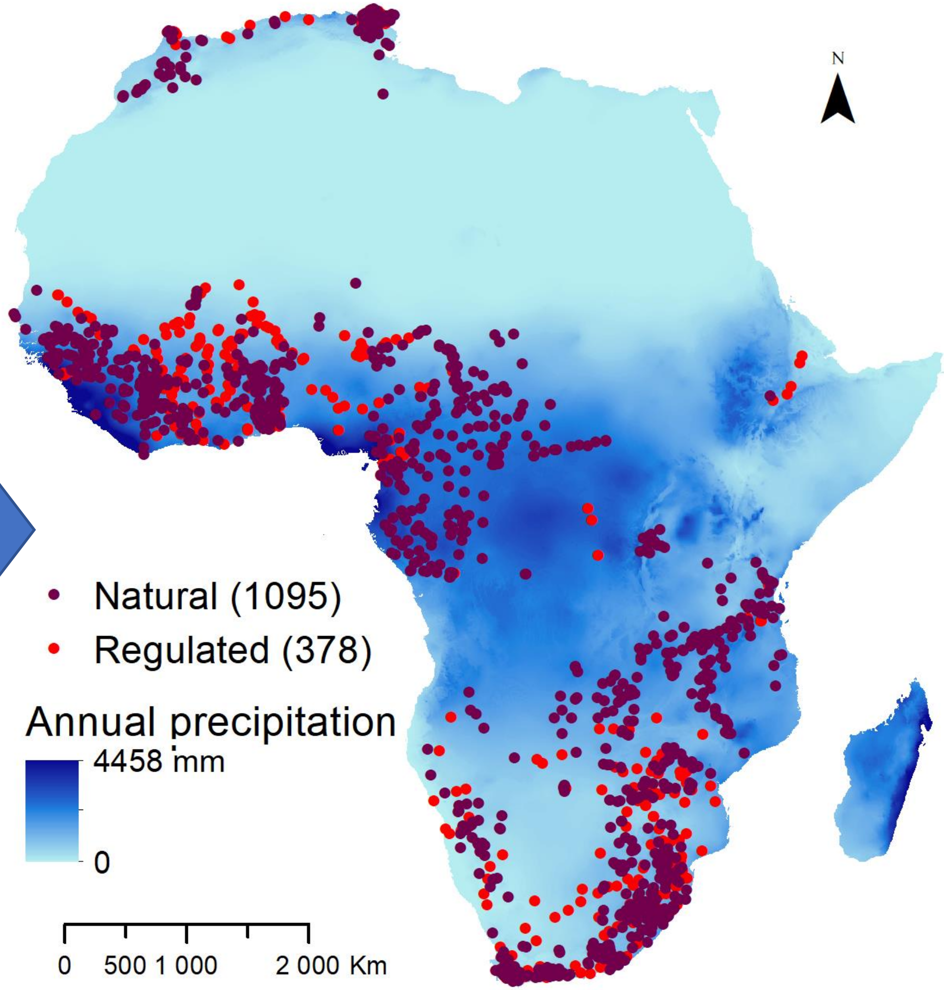

Earth Syst. Sci. Data, 13, 1547–1560, 2021
https://doi.org/10.5194/essd-13-1547-2021

Article Assets Peer review

Data description paper

ADHI: the African Database of Hydrometric Indices (1950–2018)

Yves Tramblay[1], Nathalie Rouché[1], Jean-Emmanuel Paturel[1], Gil Mahé[1], Jean-François Boyer[1], Ernest Amoussou[2], Ansoumana Bodian[3], Honoré Dacosta[4], Hamouda Dakhlaoui[5,6], Alain Dezetter[1], Denis Hughes[7], Lahoucine Hanich[8,9], Christophe Peugeot[1], Raphael Tshimanga[10], and Patrick Lachassagne[1]



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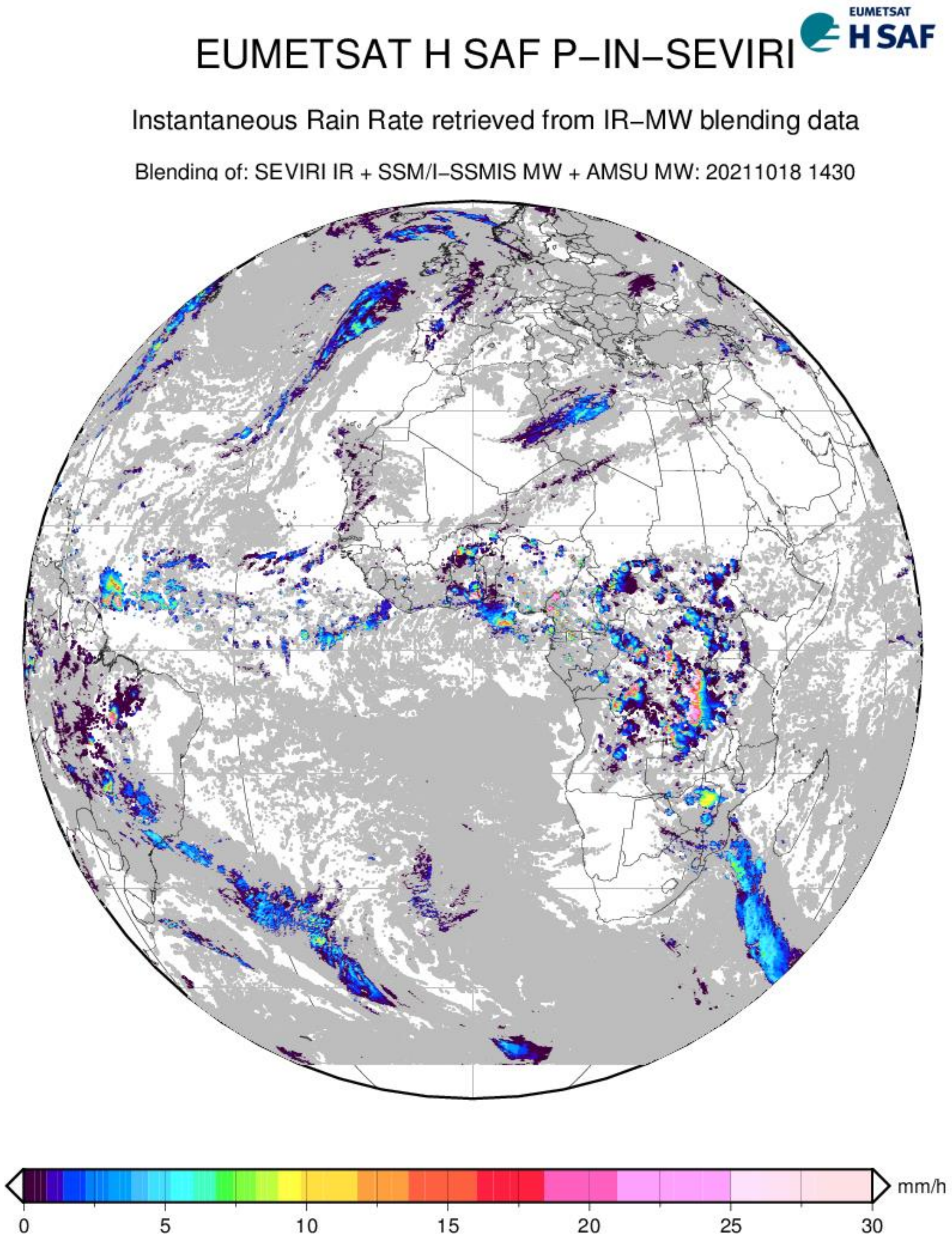
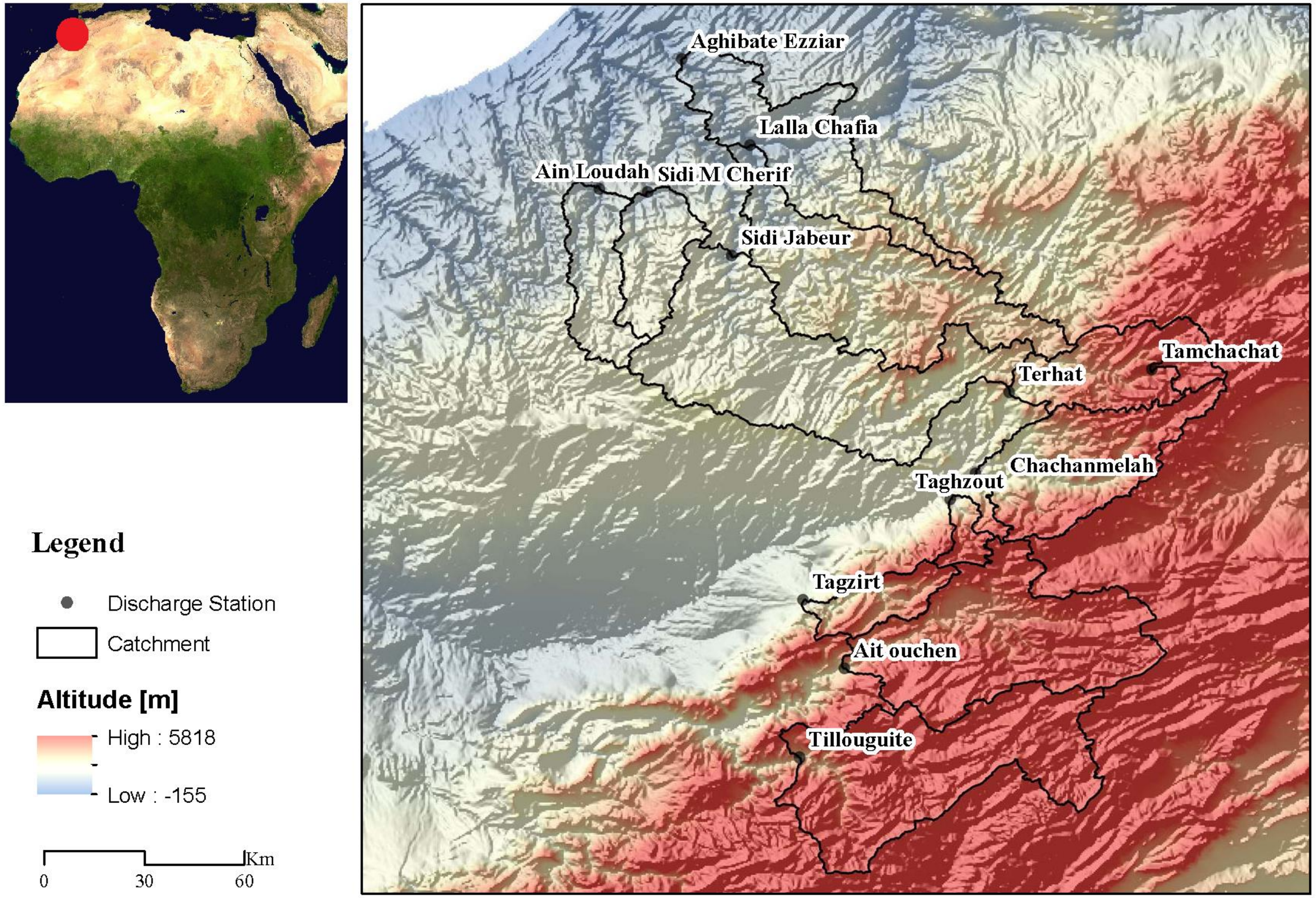
Could remote sensing estimates of rainfall be used to estimate river discharge for:
- Flood warning systems?
- Surface water resources monitoring ?

There is need first to assess their relevance for hydrological applications



Datasets

Selected basins



Basins	Area [km²]	Alt_{min} [m]	Alt_{max} [m]
1- Aghibate Ezziar	3659,5	86	1622
2- Ain Loudah	698,3	158	951
3- Ait Ouchene	2402,5	960	3243
4- Chachanmelah	1424	697	2329
5- Lalla Chafia	2234,9	202	1622
6- Sidi Jabeur	3110	373	936
7 -Sidi M Cherif	646,6	277	1001
8- Taghzout	171,9	693	2231
9- Tagzirt	531,9	430	2266
10- Tamchachat	133,3	1682	2403
11- Terhat	1013,3	868	2404
12- Tillouguite	2502,6	1061	3433

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Satellite rainfall products

6 different products are considered, available in near real time (no bias correction with rain gauges)

#	Precipitation products	Spatial/temporal resolution	Time period availability	Latency
1	GPM-IMERG Early	0.1°/30min	2000-present	4 hours
2	HSAF H03	0.03°-0.08°/15min	2011-2018	15 minutes
3	HSAF H05	0.03°-0.08°/15min	2013-2019	30 minutes
4	HSAF H64	0.25°/daily	2014-2019	16 hours
5	HSAF H67	0.25°/daily	2014-present	3.5 hours
6	$\text{SM2RAIN}_{\text{ASCAT}}$	0.125°/daily	2007-2020	16 hours

To provide a consistent validation, all products are considered for the period 2014-2018

Statistical evaluation

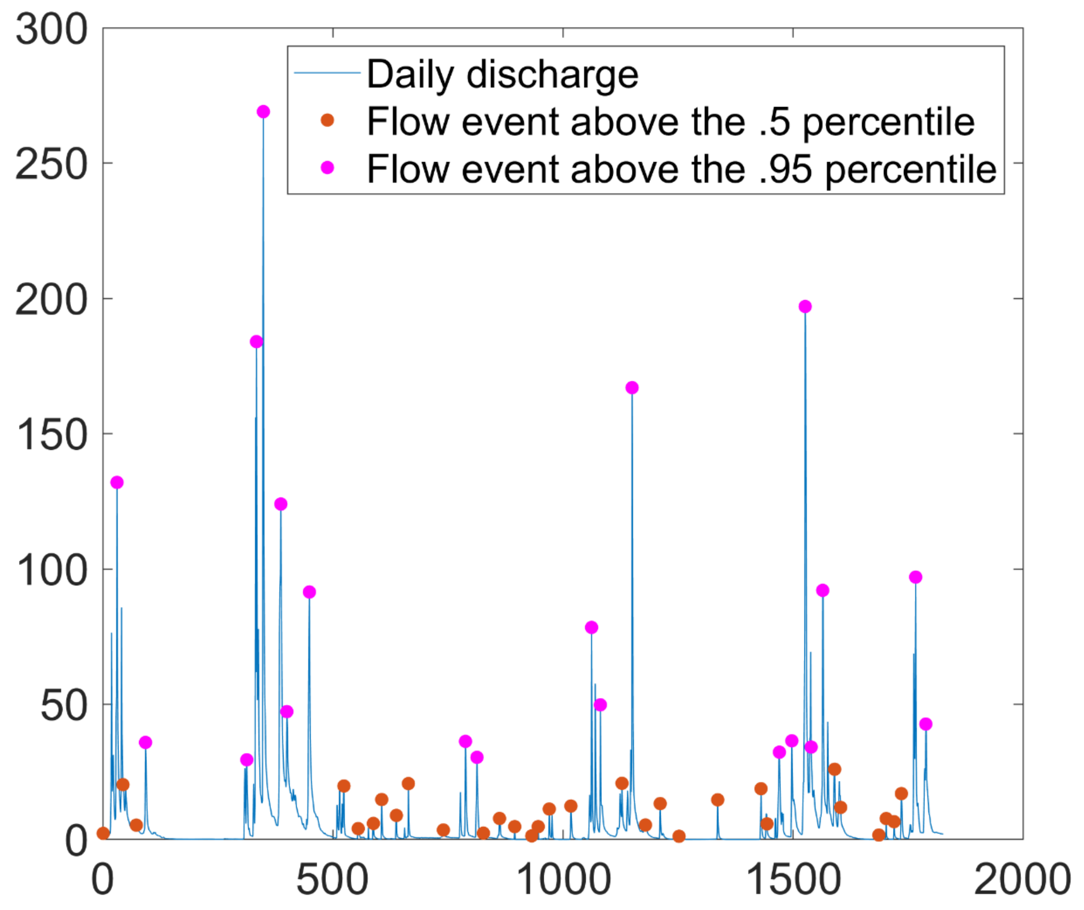
A direct correlation of rainfall and river discharge would make no sense

Extraction of runoff events, above a threshold (the median, or the 95th percentile)

De-clustering, to remove the serial correlation. Rules of Lang et al. 2009:

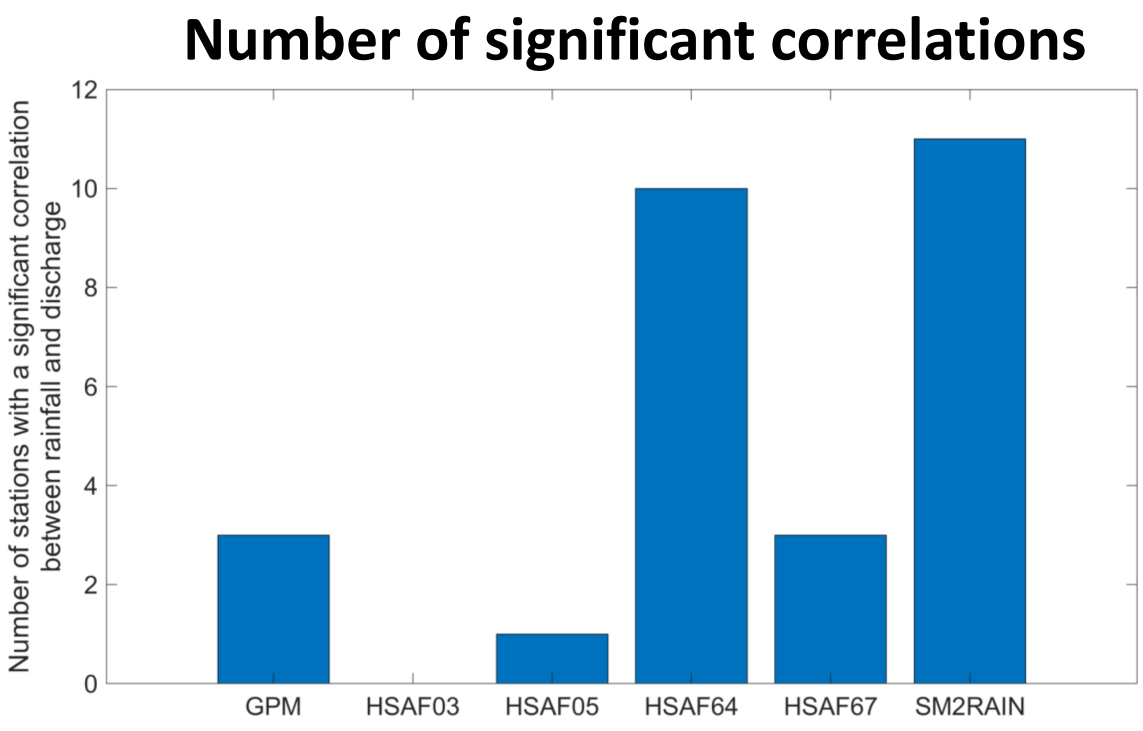
1. a minimum of *n* days between events, with *n* = 5 + log(catchment area)
2. between two consecutive peaks, runoff must drop below ⅔ of the smallest peak

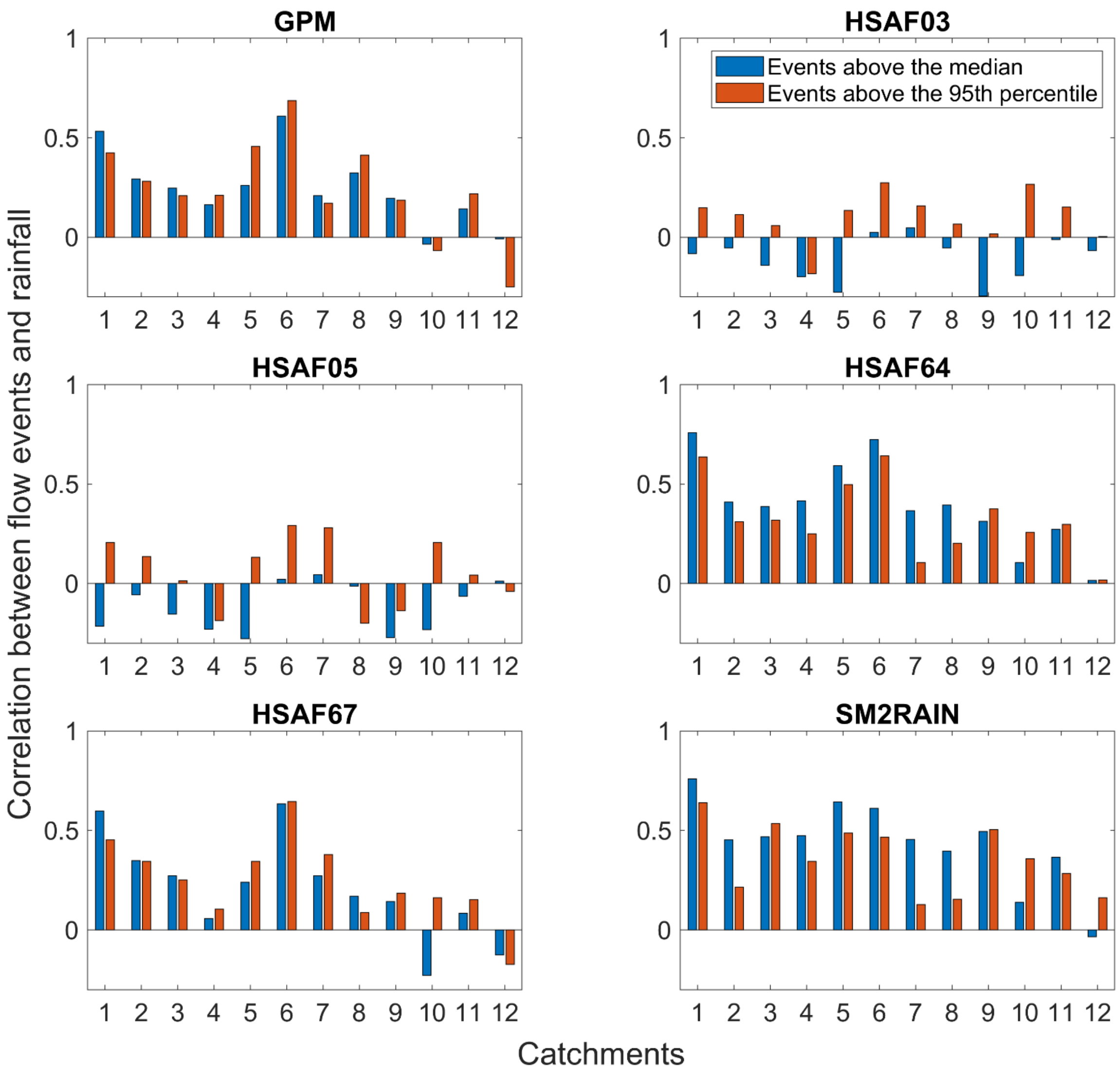
For each runoff event, the rainfall is extracted the previous days (the sum stops until 0 rainfall)



The Sperman correlation coefficient is computed between previous rainfall and runoff events

Statistical evaluation results





Hydrological modelling

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Hydrological modelling

- IHACRES (5 parameters) - Australian
- GR4J (4 parameters) - French
- CREST (5 parameters) - USA
- MISDc (8 parameters) - Italy

Potential Evapotranspiration computed from ERA5 (Tmin-Tmax) with the Hargreaves-Samani equation

Same algorithm for model calibration using bounded parameter ranges (using realistic values for the catchments in North Africa)

Calibration using the KGE criterion (that combines bias, correlation and variability)

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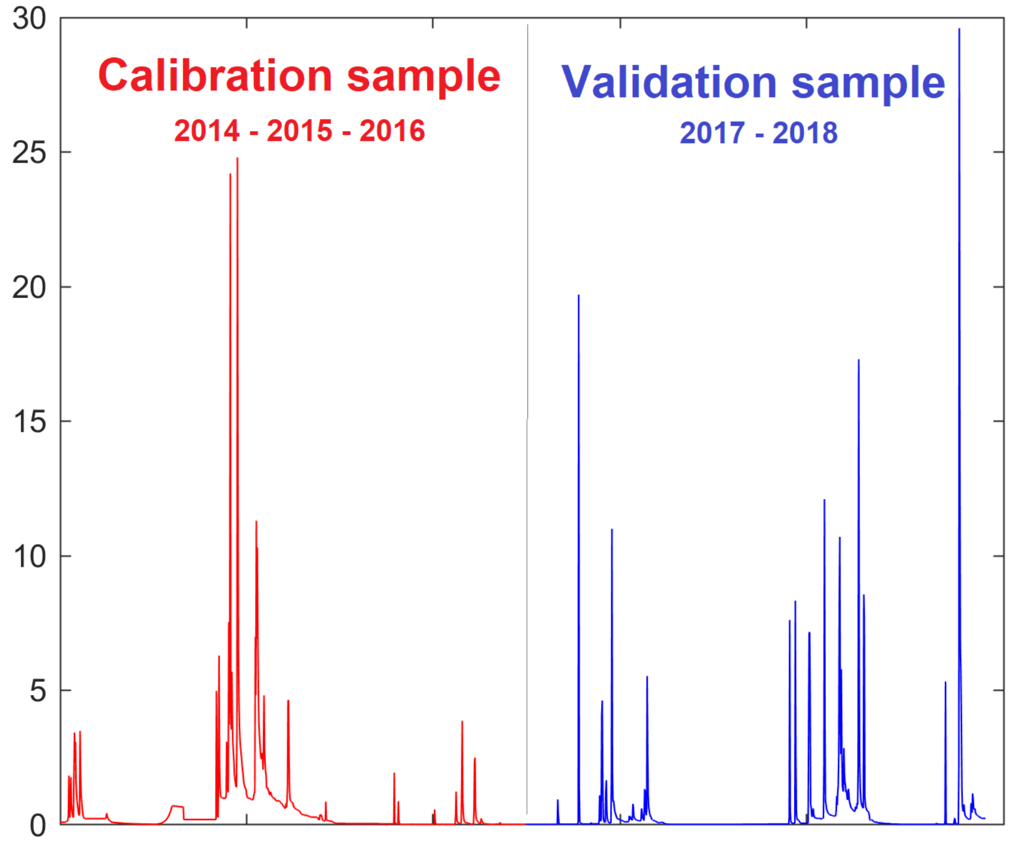
Two different validation schemes

Split-sample validation



Sequential validation

Day 1	Day 2	Day 3	Day 4	Day 5	Day 6				
Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7			
Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8		
Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9	
Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9	Day 10

Calibration Validation

Calibration from 2014 to 2016, then each day *n* is added until 2018, models are validated at the *n+1* day

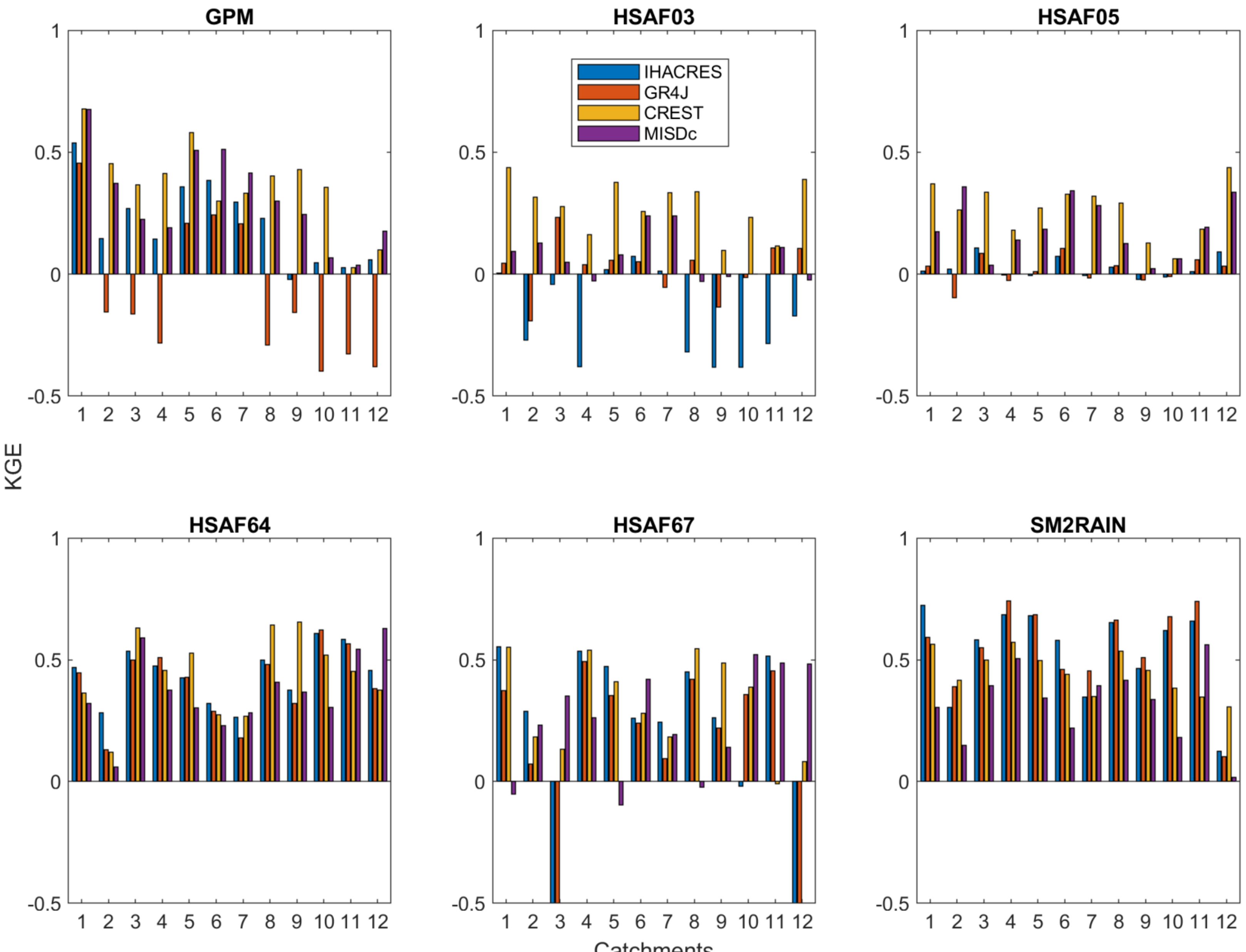
KGE is meaningless here, evaluation with :

1. Probability of Detection (POD)
2. False Alarm Ratio (FAR)

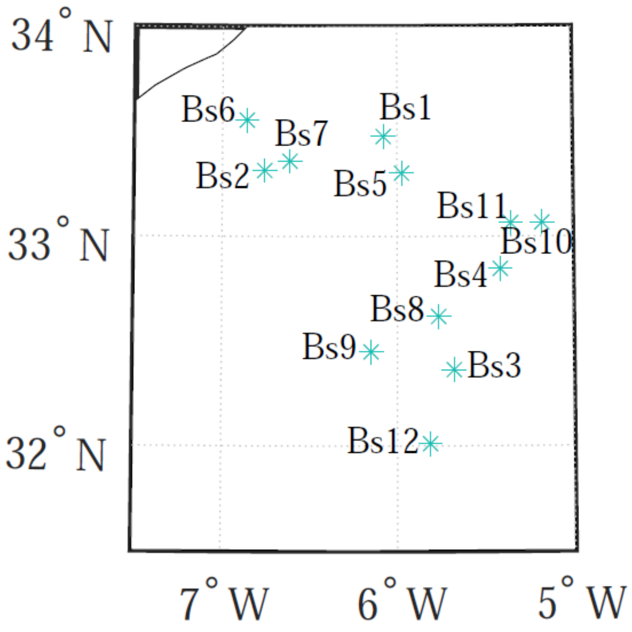
For events above the median and above the 95^{th} percentile

=> test the potential usefulness for hydrological now-casting

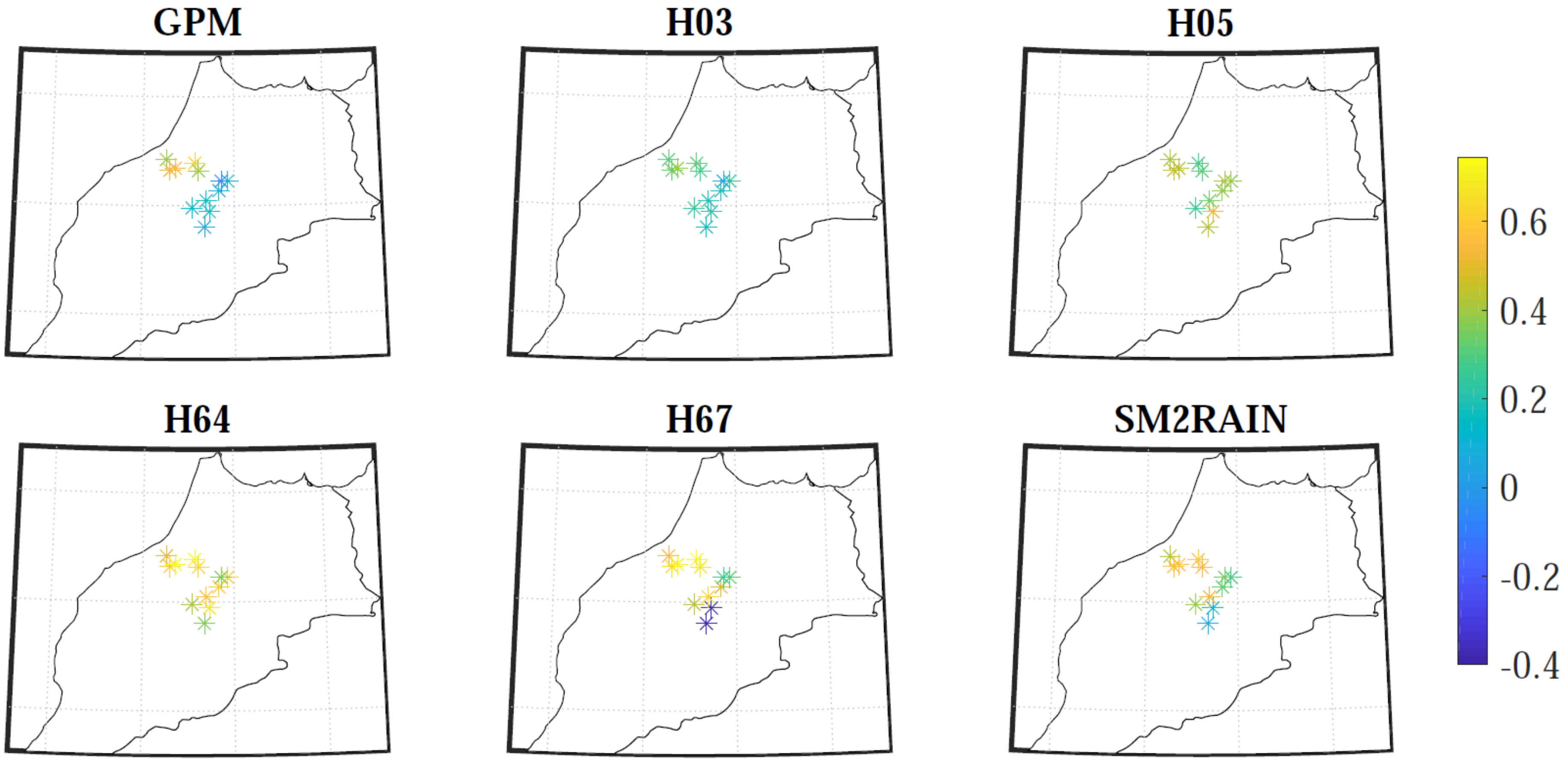
Calibration results



Calibration results



Average KGE of the 4 hydrological model simulations



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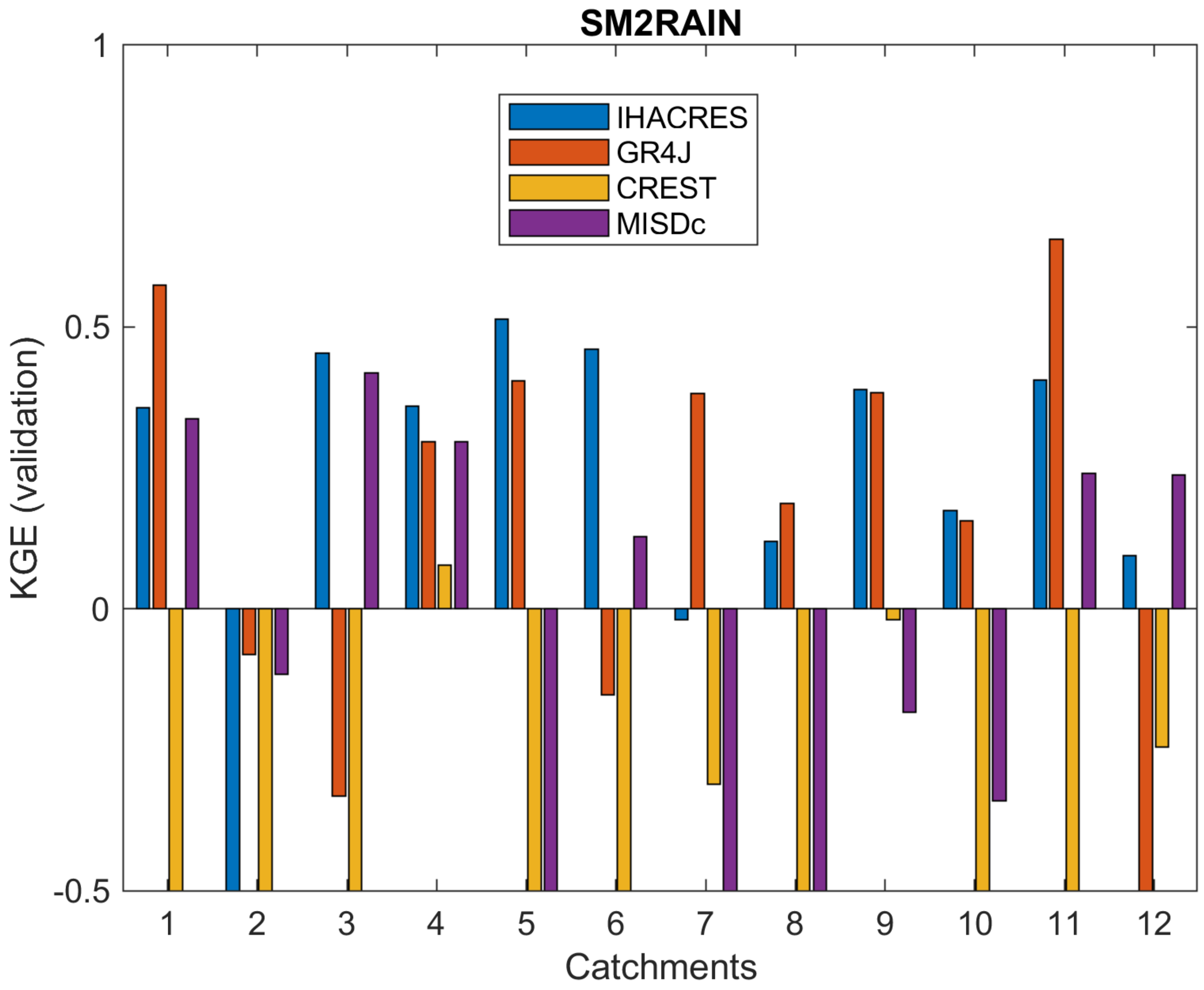
Split-sample validation

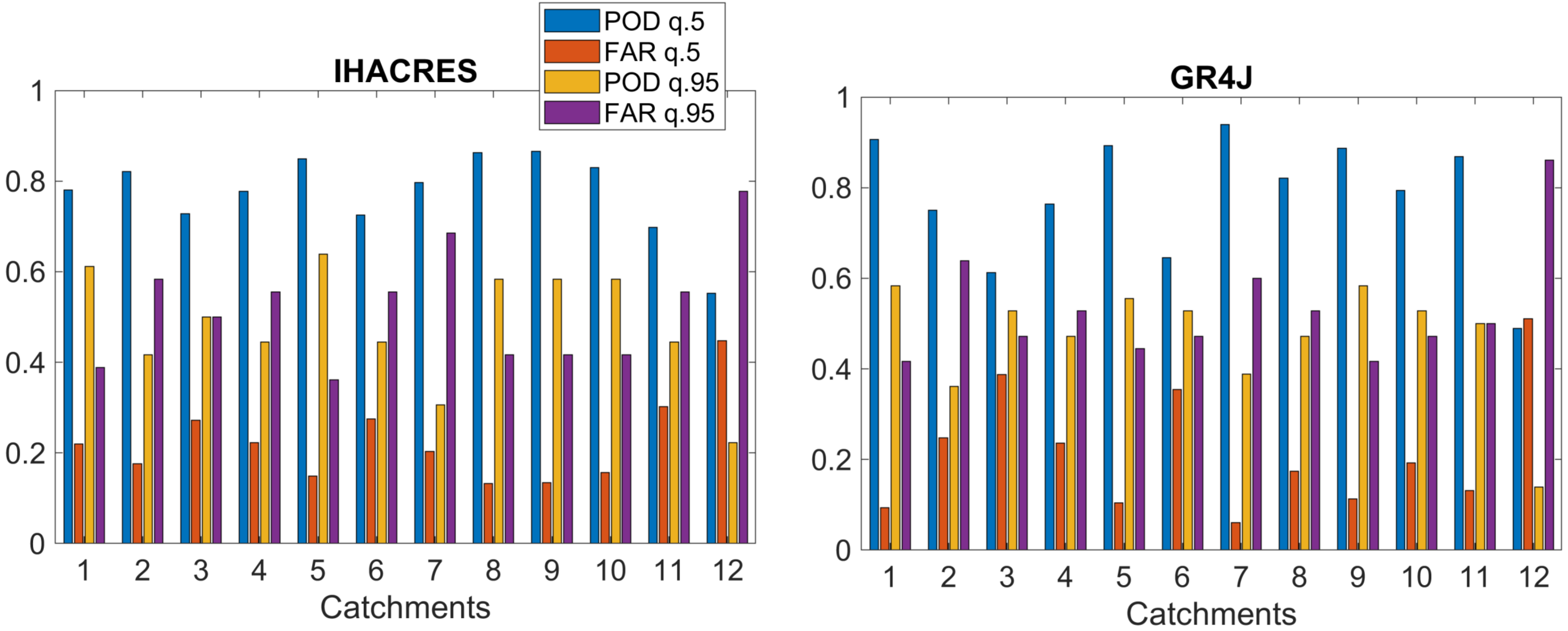
Bad performances (KGE<0) for GPM, H03, H05, H64, H57

Difficult test with small sample sizes considering the strong interannual variability of rainfall in this semi-arid area



Sequential validation

SM2RAIN

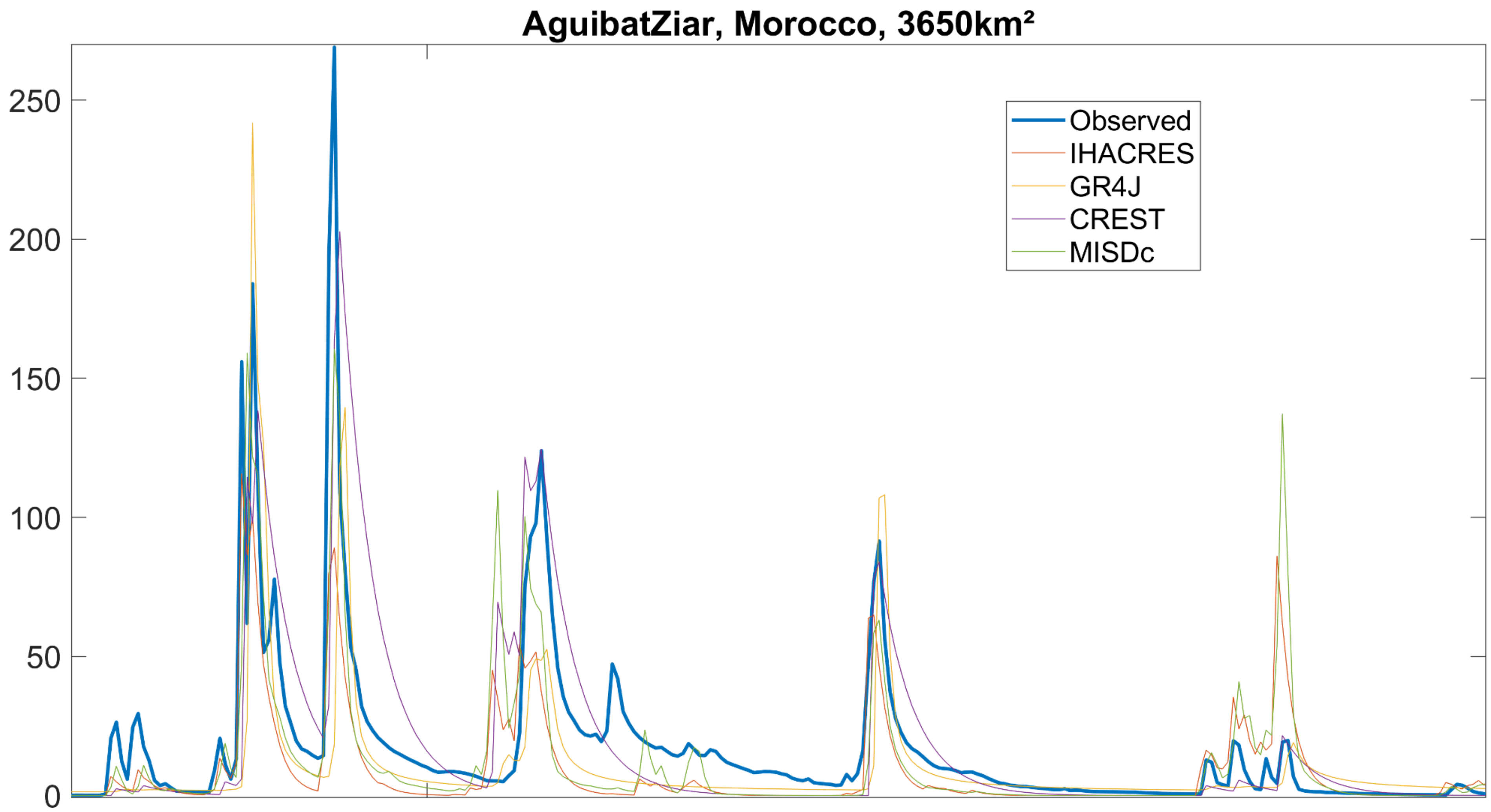


Good performances for events above the median, more variable for the most extreme events

Behind the model scores

KGE IHACRES = 0,54
KGE GR4J = 0,42
KGE CREST = 0,65
KGE MISDC = 0,64

GPM Rainfall as input



For a given satellite rainfall product, there is a need to carefully select the hydrological model for the intended application !

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Conclusions

First hydrological validation of satellite rainfall over several basins in North Africa

Promising results for rainfall estimates incorporating soil moisture (SM2RAIN and H64)

Results are not hydrological-model dependent, but there is a need to select models adapted to the local context

With the constant improvement in satellite rainfall estimates, this open interesting perspectives for operational applications

… and perspectives

Expand the database with more recent records, over Morocco but also Algeria and Tunisia => Investigate in more details the links with catchment properties to provide guidelines on the use of satellite rainfall products

Challenges for river flow estimation :

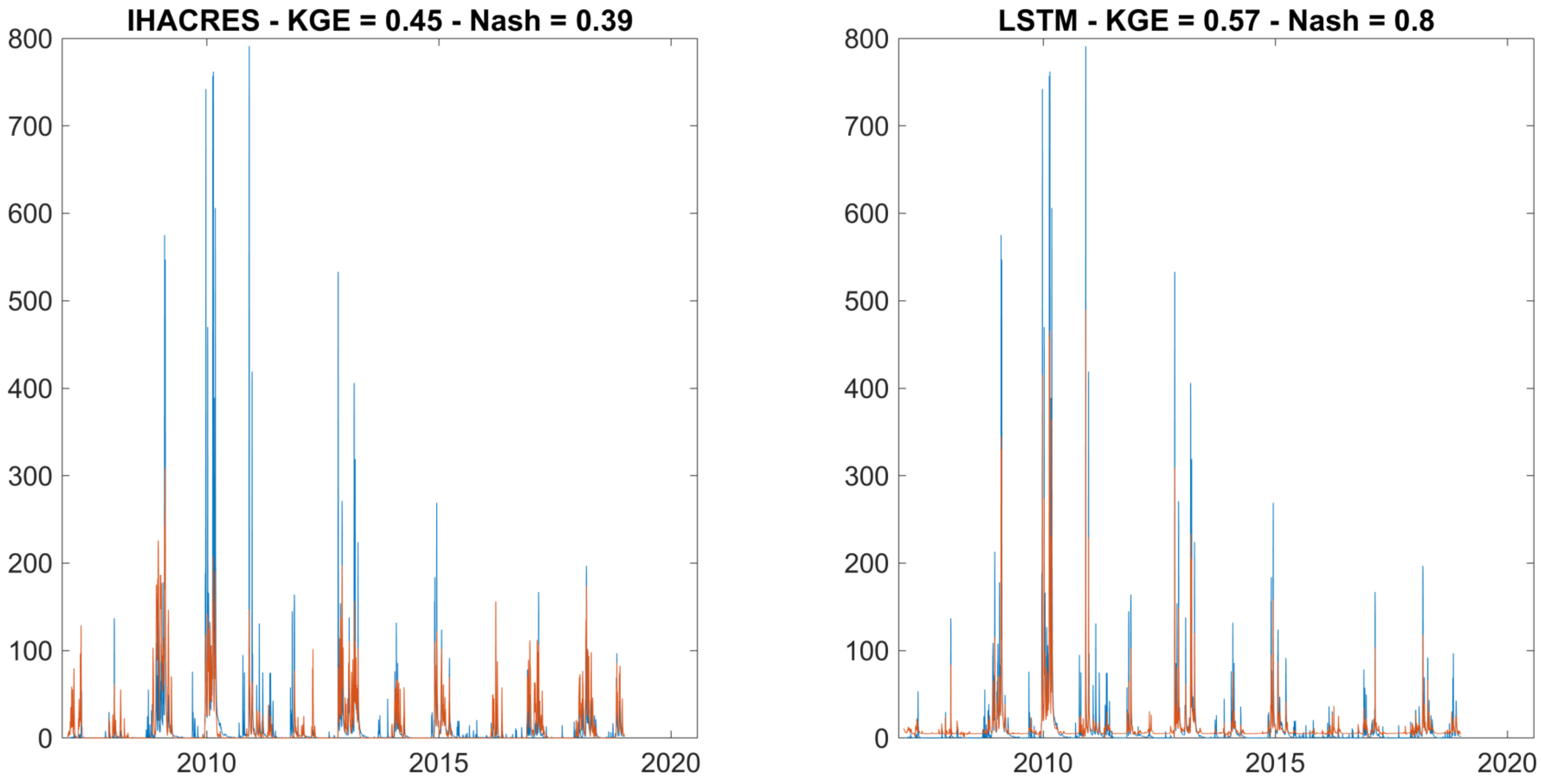
1/ Access of to observations to validate the estimates

2/ To be applied everywhere, how to calibrate hydrological models?

- "Physically" based approaches could be relevant ?
- Regional implementation of Machine Learning methods, such as LSTM ?

Preliminary tests with LSTM = failure to adapt to the intermittent nature of rivers (too much "base flow") and limited performance outside the training set, due to the strong interannual variability ?

Bassin 1, with data from 2007-2018, SM2RAIN



Local issues to be resolved (base flow, low validation performances), but the main interests with LSTM:

Regional model with simultaneous simulation at different sites (Kratzert, F. et al. : Towards learning universal, regional, and local hydrological behaviors via machine learning applied to large-sample datasets, HESS, 2019)

Multiple precipitation inputs (Kratzert F. et al.: A note on leveraging synergy in multiple meteorological data sets with deep learning for rainfall–runoff modeling, HESS, 2021)