Second International NatRiskChange Conference

5-6 October 2021, Potsdam (Germany)

What controls step changes in flood frequency curves? Insights from a physically-based stochastic model (PHEV)

A. Miniussi[1], L. Kaule[1,2], R. Merz[1] and S. Basso[1]

[1] Department Catchment Hydrology, Helmholtz Centre for Environmental Research - UFZ, Halle (Saale), Germany

[2] Department of Hydrology, University of Bayreuth, Bayreuth, Germany

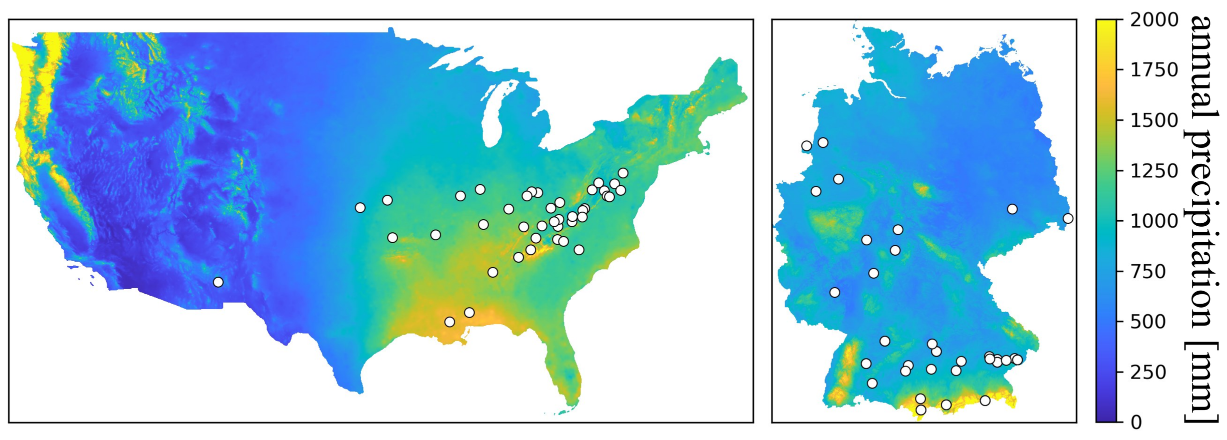
1. Aim of the work

a) Develop an objective methodology to identify discontinuities (aka step changes, Rogger et al., 2012) in observed flood frequency curves and evaluate the ability of a PHysically-based Extreme Value (PHEV) distribution or river flows to detect them.

b) Understand the physical controls that govern the occurrence of step changes.

2. Data and Methodology

2.1 Case studies

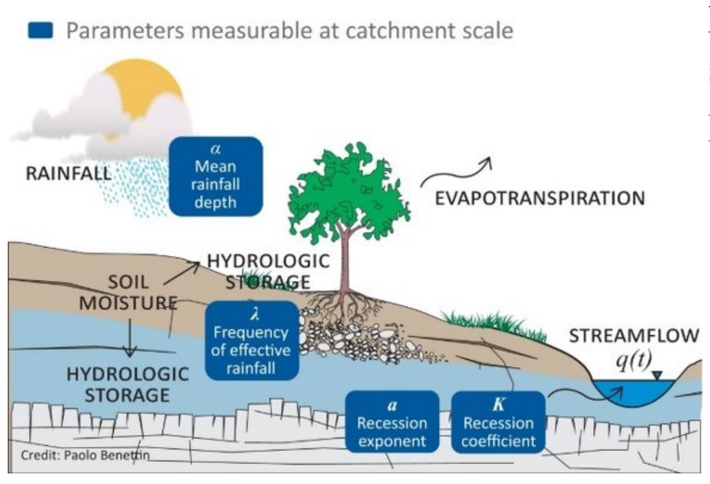


101 US and German stations with daily streamflow and rainfall data.

Criteria for catchment selection:

- low human-impact
- weak inter-seasonal snow dynamics
- good PHEV performance (limited error between observed and PHEV flood frequency curve)

2.2 The PHysically-based Extreme Value (PHEV) distribution of river flows



Mathematical description of catchment-scale daily soil moisture and streamflow dynamics (Basso et al., 2016; Basso et al., in review).

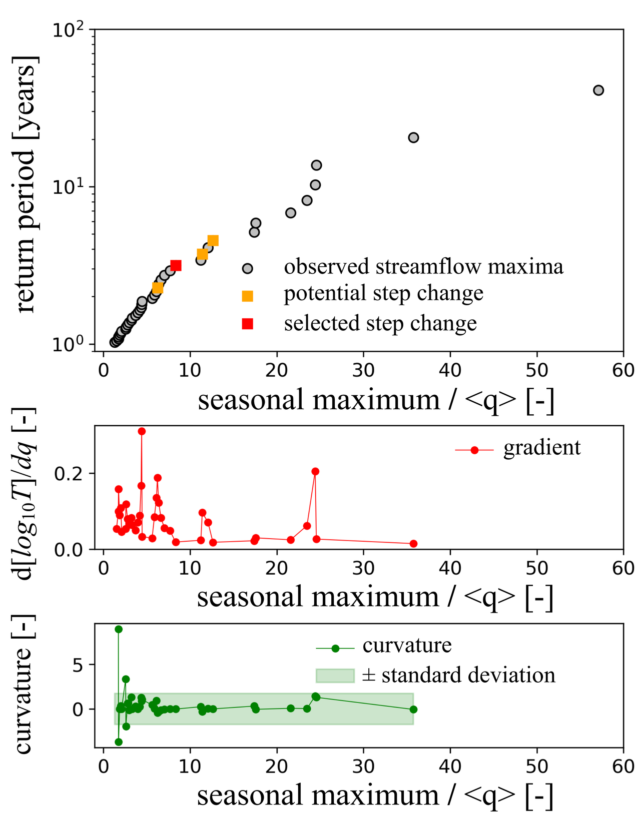
Parameters measurable at the catchment scale:

- average rainfall depth α
- frequency of effective rainfall λ
- recession exponent a
- recession coefficient K

(average rainfall depth, frequency of effective rainfall, recession exponent: computed from rainfall/streamflow time series; recession coefficient: calibrated via maximum likelihood)

$Tr(q)=f(\alpha, \lambda, a, K)$

2.3 Step changes detection

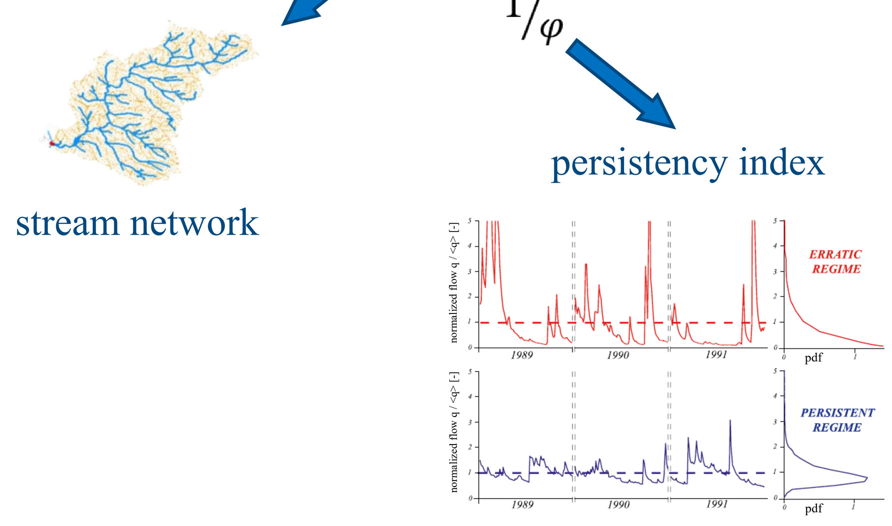


2.4 Physical controls identification

Pi theorem (Buckingham, 1914) to seek a relation between streamflow and landscape/climatic properties:

$$\frac{q}{<q>} = f(a; K\lambda^{a-2}\alpha^{a-1})$$

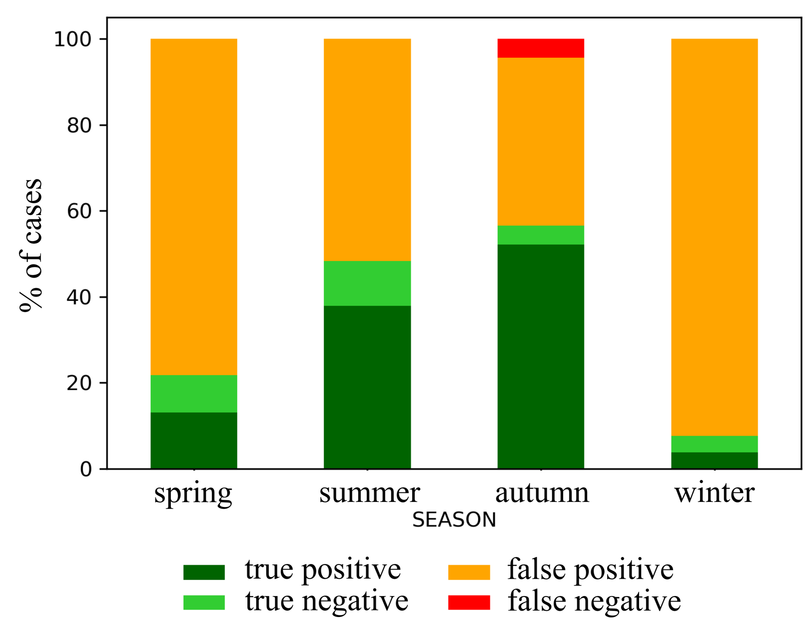
$1/\varphi$

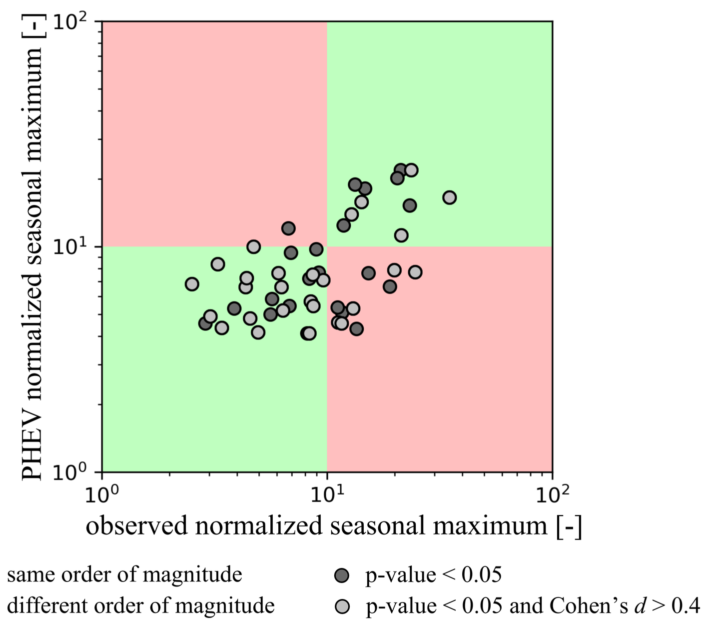


From: Botter et al. (2013)

3. Results

3.1 PHEV capability in step changes detection

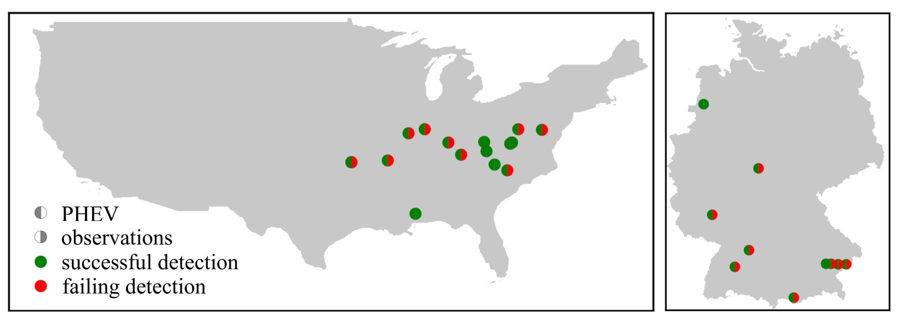


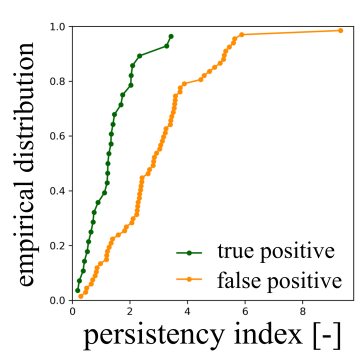


3.2 Why so many false positives? A deeper look into it

Hp: PHEV indicates the emergence of a step change not yet displayed by the observations.

Experiment: shorten the time series of the true positives cases (max return period = 5 years) and repeat the step changes detection procedure.



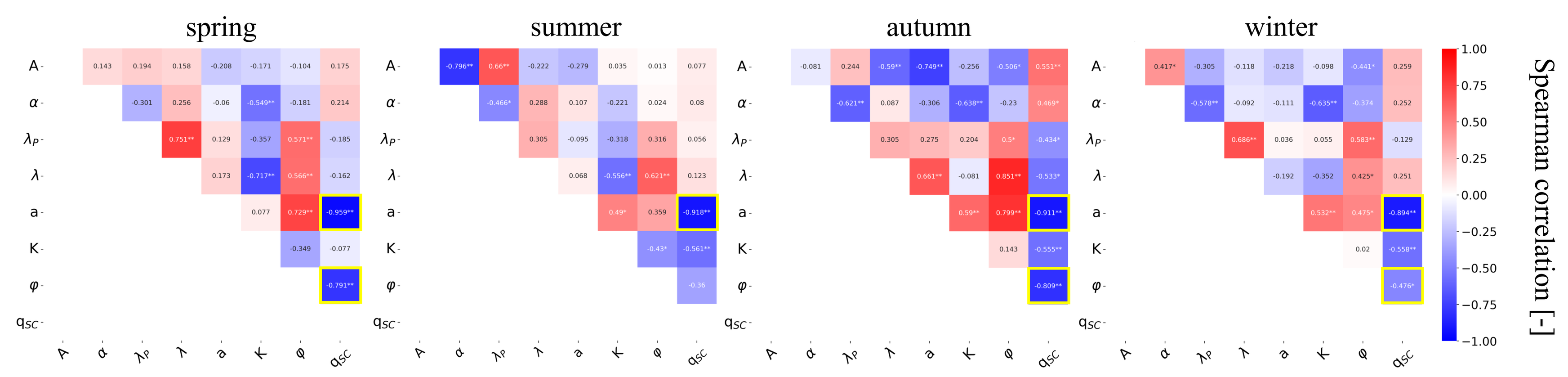


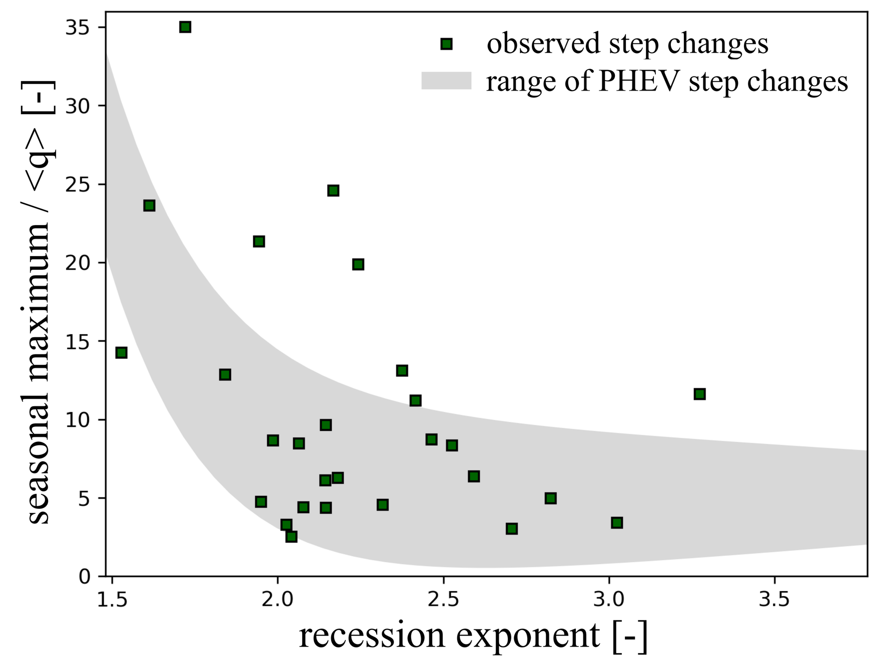
Step changes correctly detected:

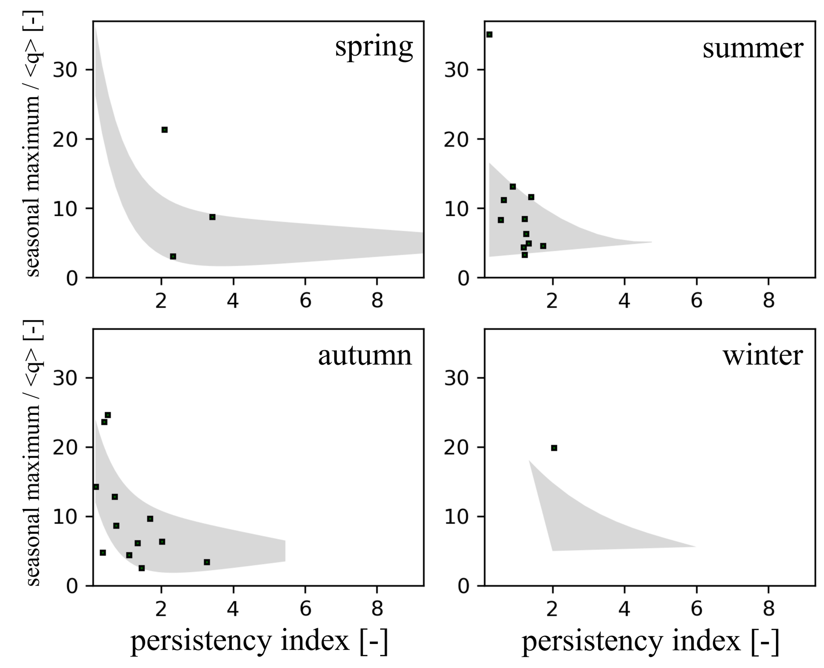
- from observations: 37%
- from PHEV: 100%

False positives occur mostly for strong persistent regimes.

3.3 Physical controls - data analysis

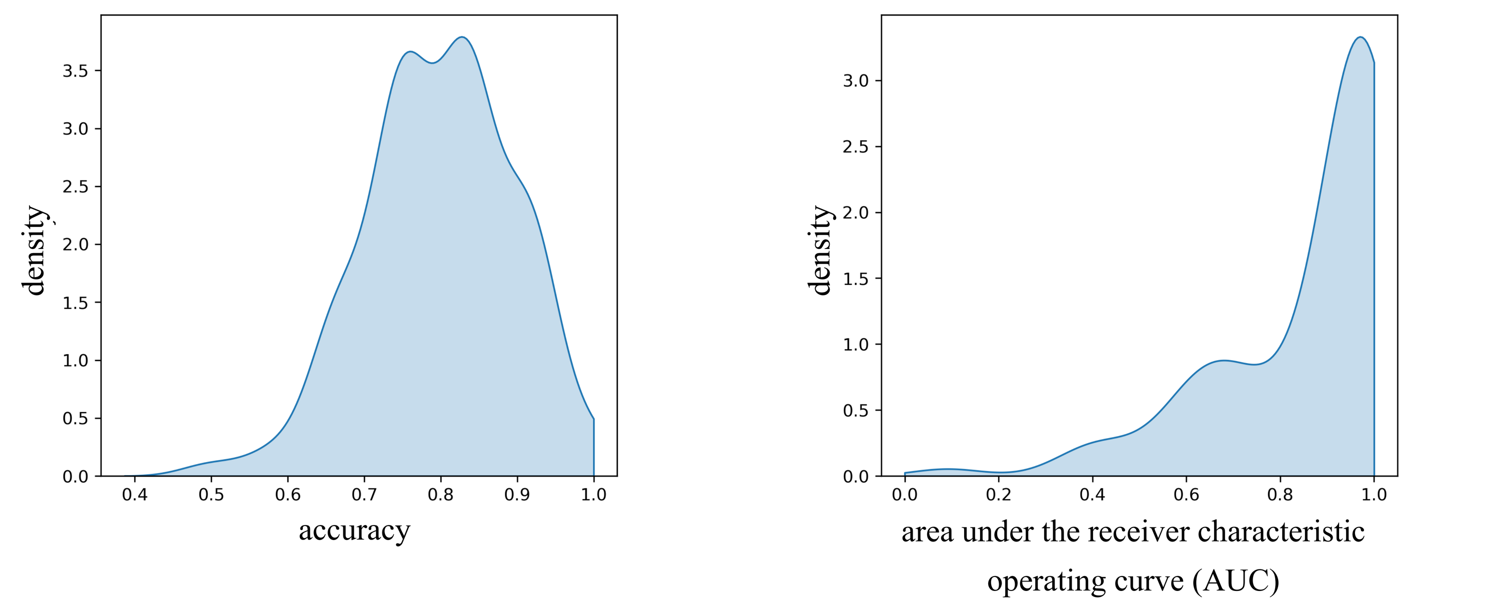






3.4 Prediction of step changes occurrence

Binary logistic regression with a and φ as explanatory variables to identify catchments more prone to step changes emergence. 100 random extractions of catchments from the pool "true positives+true negatives", 2/3 samples used for training.



	Accuracy	Area under the receiver characteristic operating curve
Description	Fraction of correct predictions	Summarizes the diagnostic accuracy of a test (AUC=0.5 indicates a random classifier)
Median value	0.83	0.95

4. Take home messages

1) The PHysically-based Extreme Value (PHEV) distribution of river flows is able to detect the step change emergence in flood frequency curves.

2) The predominance of false positives should not be misleading, as most of these cases are characterized by a persistent regime (less likely occurrence of extreme flow values in short time series).

3) The strongest control on the step changes emergence is the stream network, modulated by the characteristic streamflow dynamics embodied by the persistency index.

4) Using the identified physical controls as explanatory variables we are able to predict the propensity of a river to extreme floods in a fairly accurate way.

References

Basso, S., Schirmer, M. and Botter, G. (2016). A physically based analytical model of flood frequency curves. *Geophys. Res. Letters*, *43(17)*, 9070-9076. doi: 10.1002/3732016GL06991

Basso, S., Botter, G., Merz, R. and Miniussi, A. (under review). PHEV! The Physically-based Extreme Value distribution of river flows. Submitted to *Environ. Res. Letters*.

Botter, G., Basso, S., Rodriguez-Iturbe, I. and Rinaldo, A. (2013). Resilience of river regimes. *Proceedings of the National Academy of Sciences*, *110(32)*, 12925-12930. doi:38610.1073/pnas.13119201

Buckingham, E. (1914). On physically similar systems; illustrations of the use of dimensional equations. *Physical Review*, *4(4)*, 345-376. doi:10.1103/PhysRev.4.345

Rogger, M., Pirkl, H., Viglione, A., …, and Blöschl, G. (2012). Step changes in the flood frequency curve: process controls. *Wat. Resour. Res.*, *48*, W05544. doi: 10.1029/2011WR011

DFG Deutsche Forschungsgemeinschaft

This work is funded by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) - Project number 421396820 "Propensity of rivers to extreme floods: climate-landscape controls and early detection (PREDICTED)".

Scan the QR code for the preprint!

Follow-ups: stefano.basso@ufz.de

@catchlab1