UFZ HELMHOLTZ Centre for Environmental Research

Università degli Studi di Padova

The Physically-Based Extreme Value (PHEV) distribution of river discharges

EGU General Assembly 2022

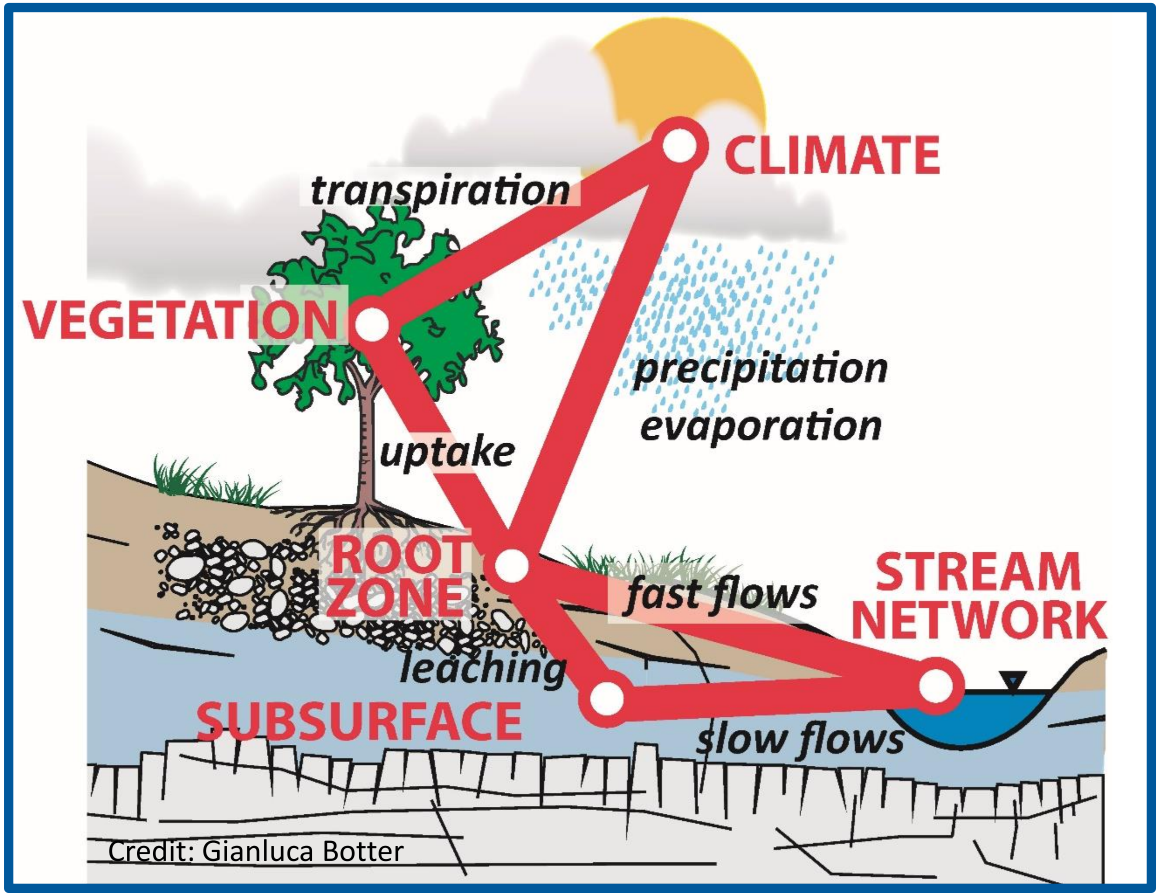
Stefano Basso
Gianluca Botter, Ralf Merz, Arianna Miniussi

Assessment of the long term **flood hazard**

Simple as a statistical distribution

Stochastic as nature

Mechanistic as a fully-fledged model

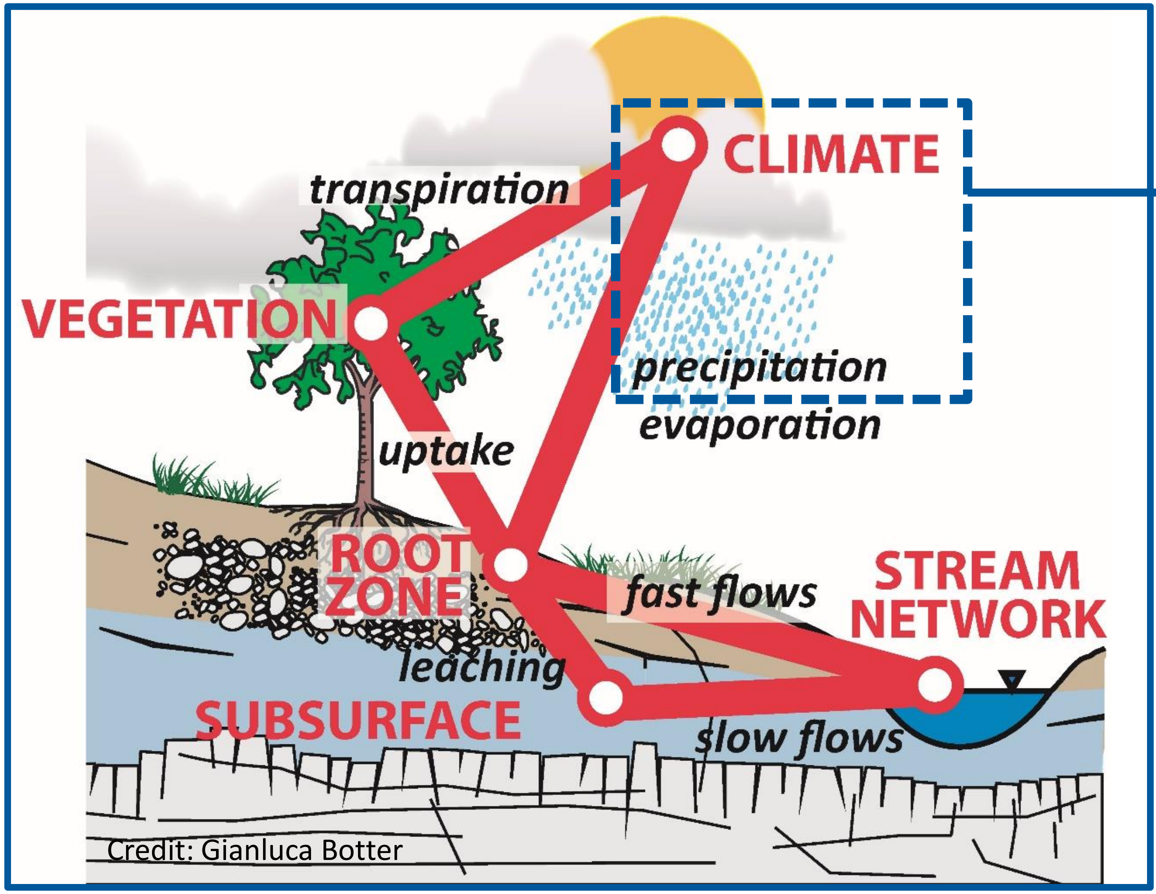


Minimalist eco-hydrological conceptualization of watershed functioning and dynamics

Climate-soil-vegetation interactions at basin scale

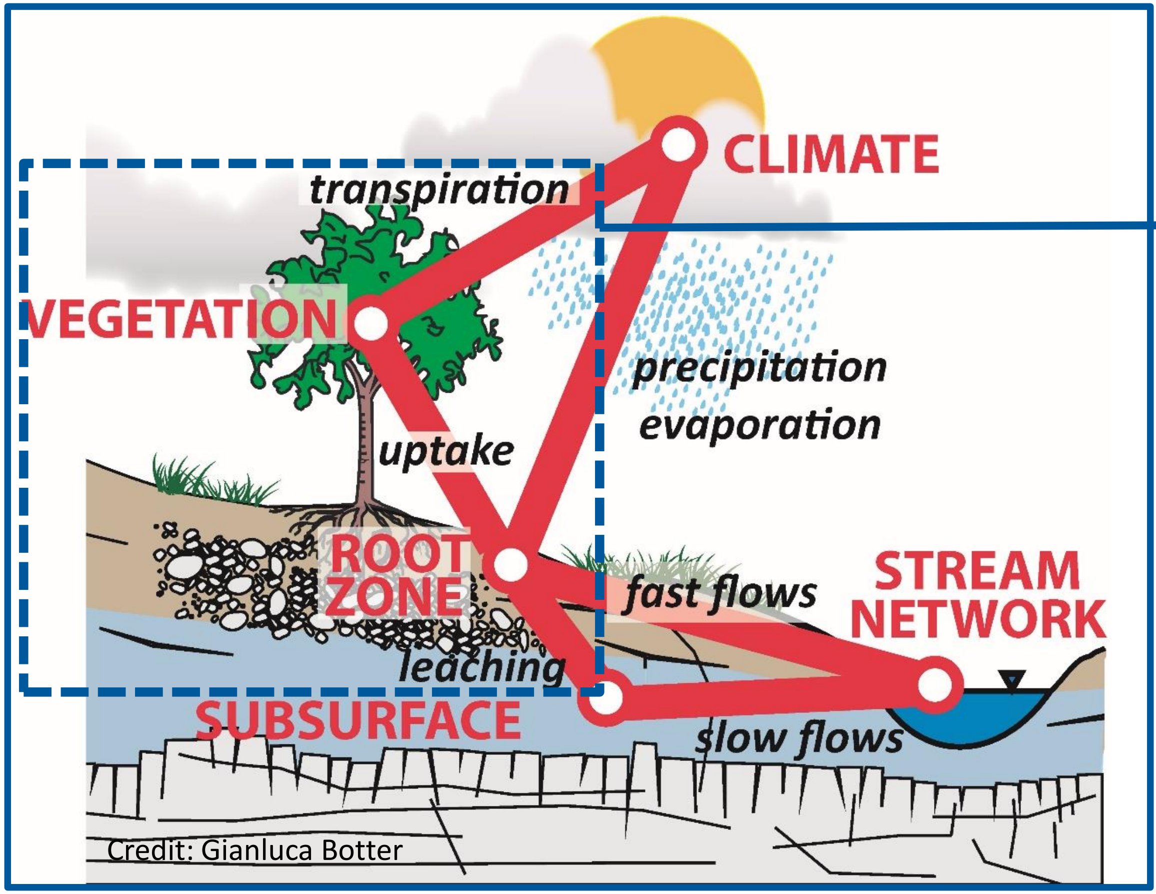
+

Hydrological response of catchments



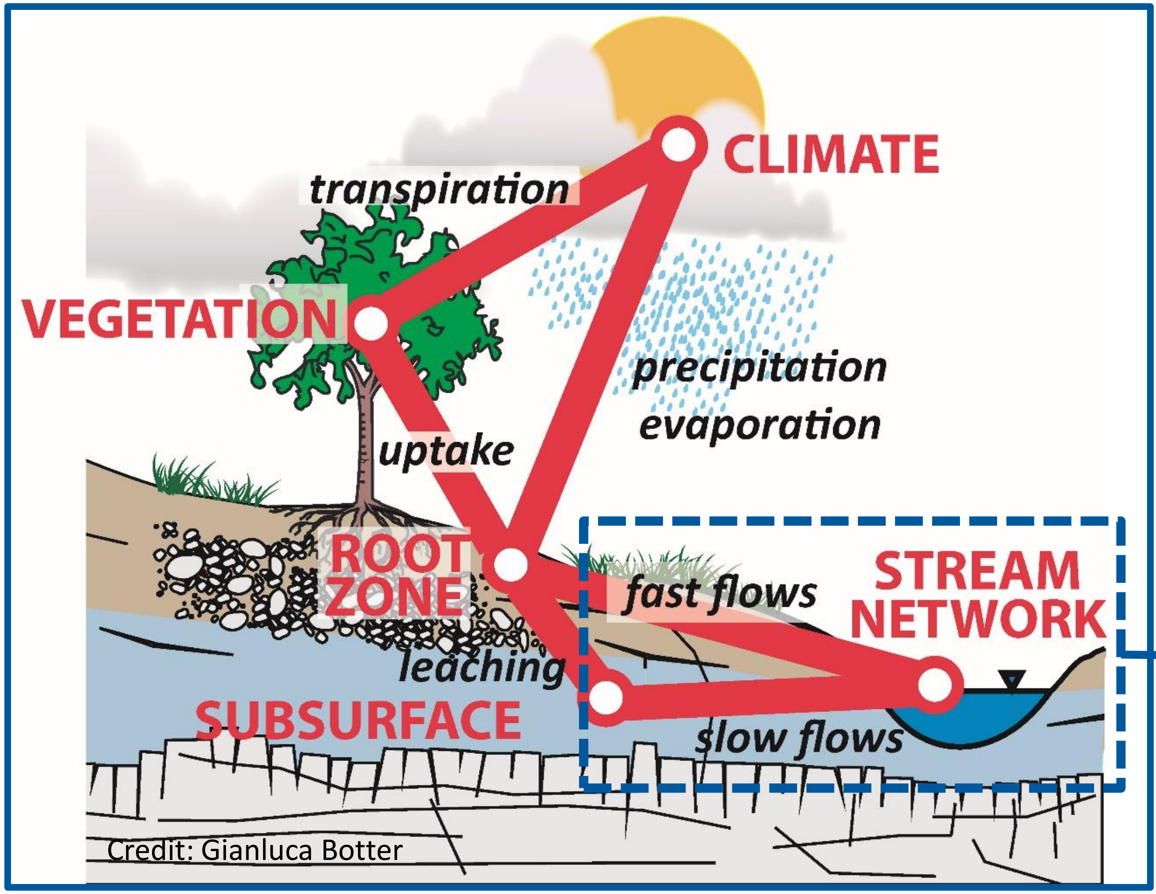
Stochastic **precipitation**

Poisson process



Rainfall-runoff transformation

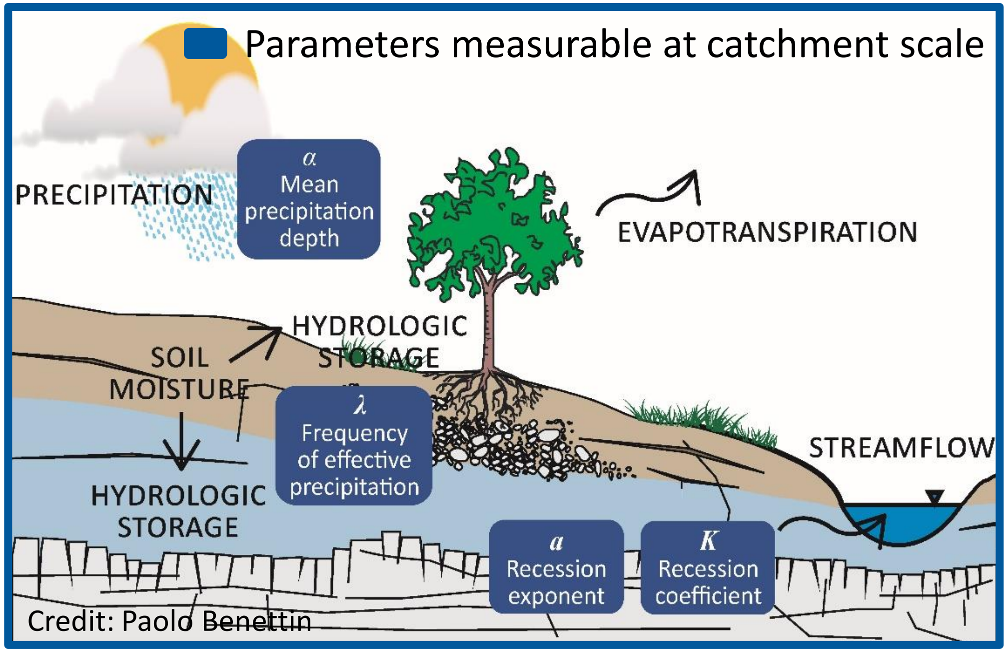
- Evapotranspiration
(linear function of soil moisture)
- Soil moisture dynamics
- Triggering of runoff
(crossing of saturation threshold)



Basin's **response time** / runoff routing

Linear reservoir ←→ Exponential random variable

Non-linear reservoir ←→



Master equation for the probability distribution of streamflow

(i.e., equation which describes the evolution in time of the probability of occurrence of streamflow values)

$$\frac{\partial p(q,t)}{\partial t} =$$

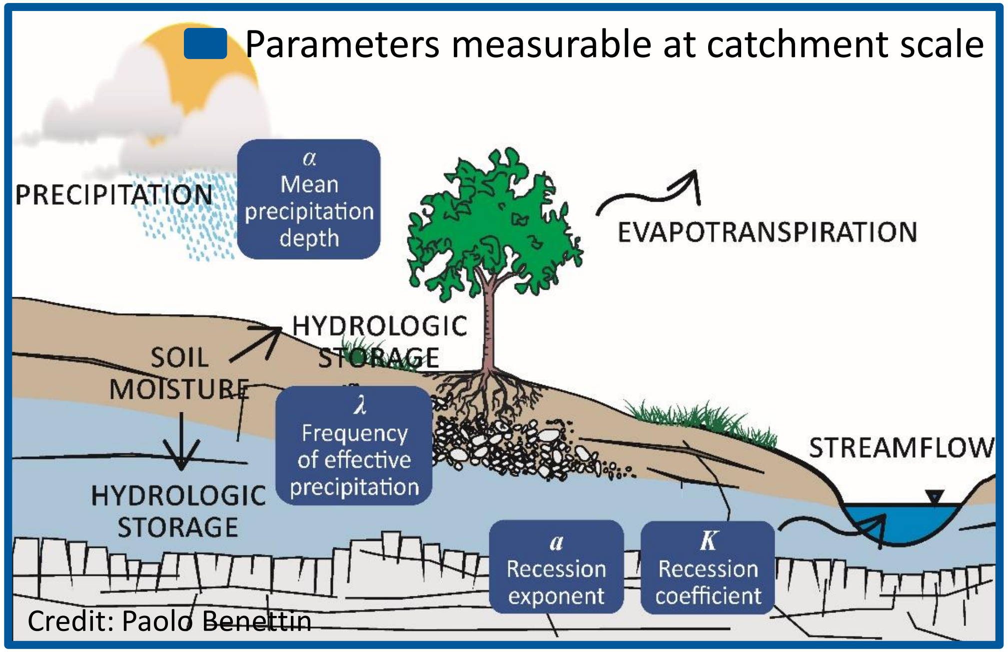
Probability gain due to deterministic streamflow recessions

-

Probability loss due to stochastic runoff jumps away from *q*

+

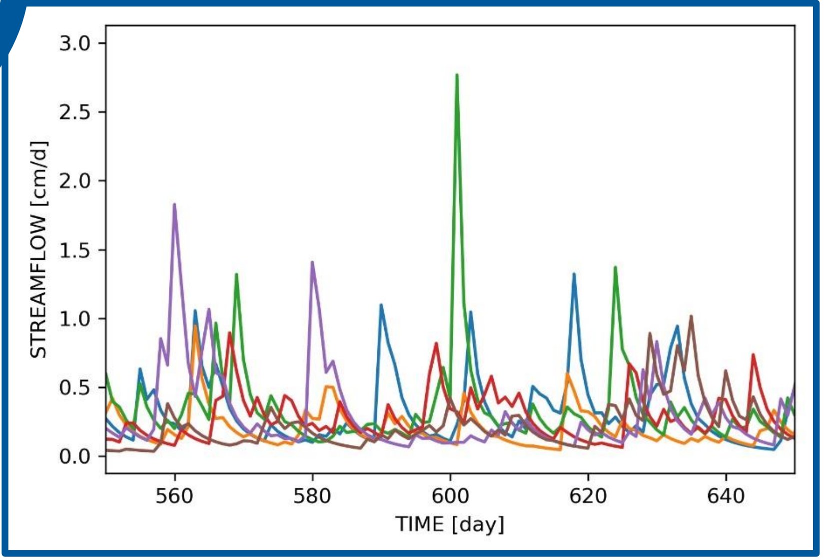
Probability gain due to stochastic runoff jumps from lower streamflow to *q*



Master equation for the probability distribution of streamflow

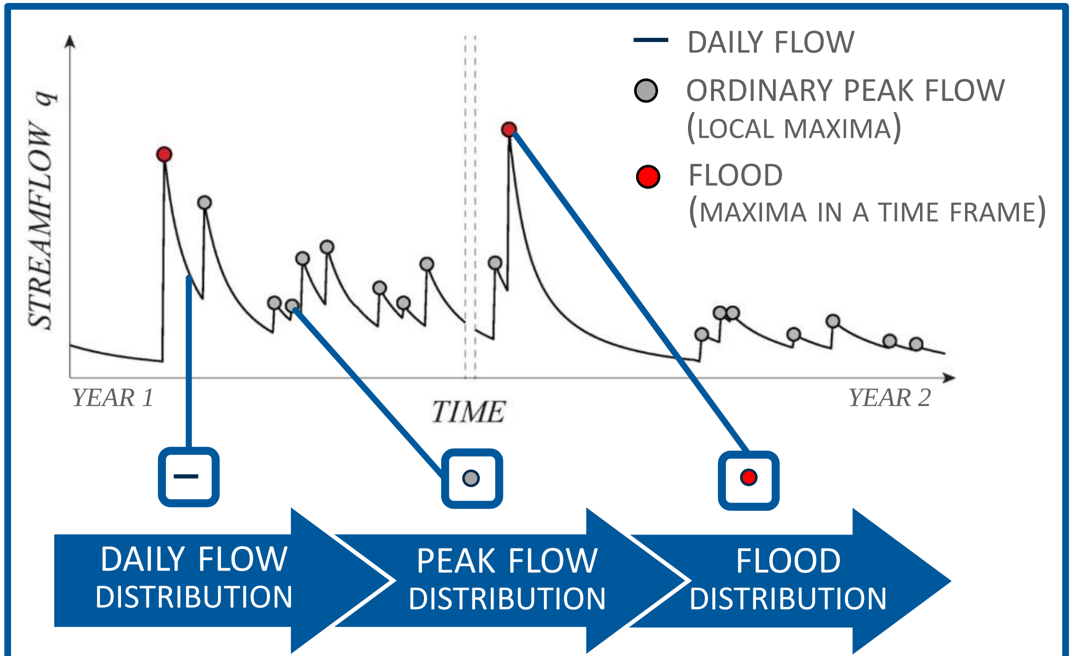
(i.e., equation which describes the evolution in time of the probability of occurrence of streamflow values)

$$\frac{\partial p(q,t)}{\partial t}$$



$$p(q, t \to \infty)$$

PHEV resembles the outputs of hydrological models forced by large ensemble of varied hydrometeorological scenarios (but it is analytic!)



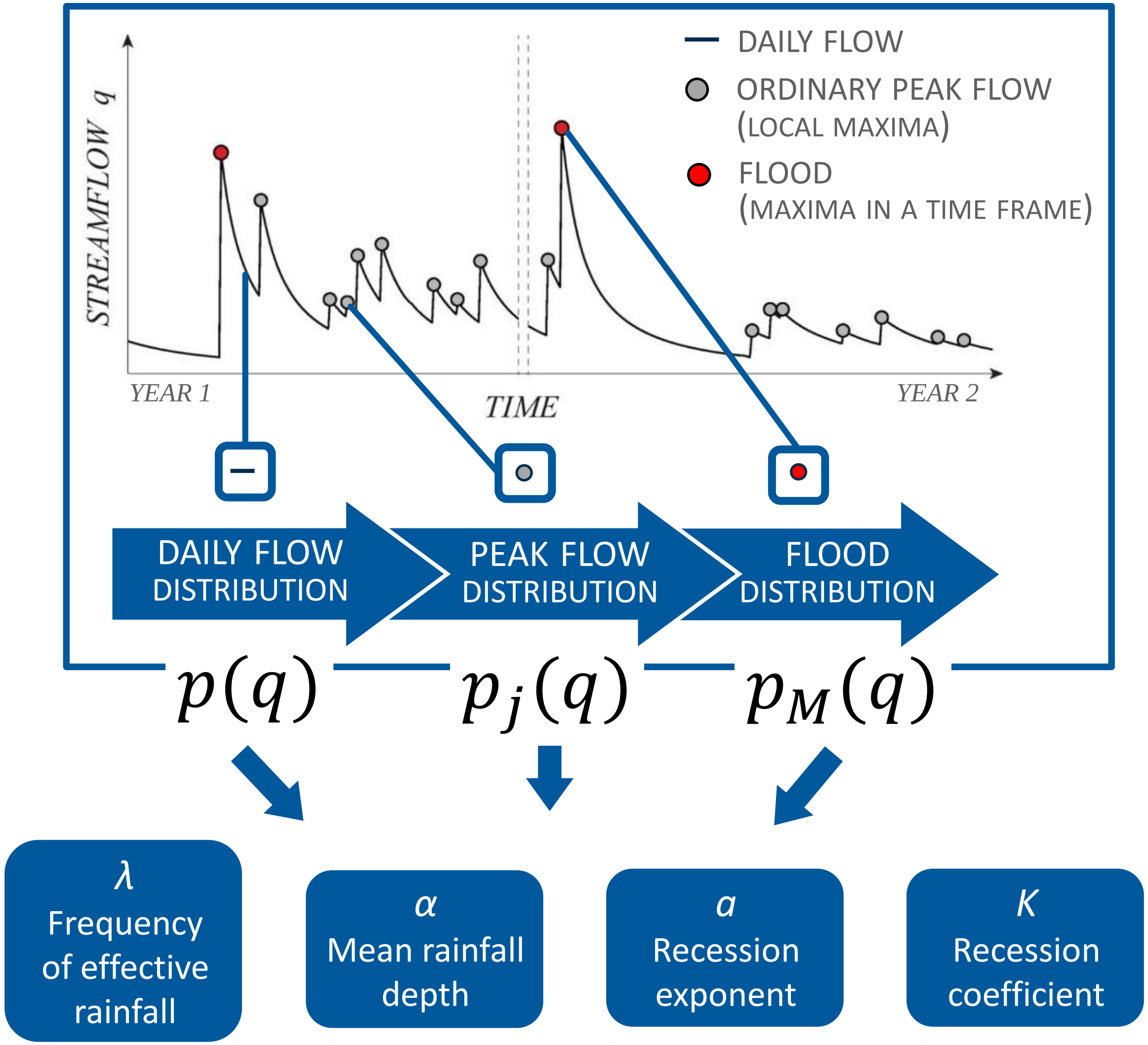
$$p(q) \qquad p_j(q) \qquad p_M(q)$$

$$f(\alpha, \lambda, a, K)$$

Basso et al., A physically based analytical model of flood frequency curves, *GRL* 2016

Basso et al., PHEV! The PHysically-based Extreme Value distribution of river flows, *ERL* 2021

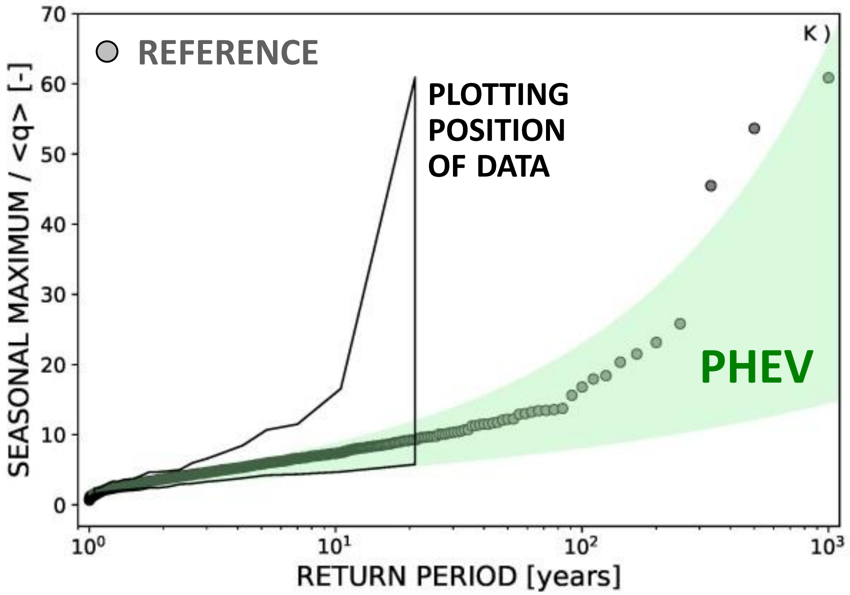
RESULTS | PHYSICALLY - BASED & CONSISTENT EXPRESSIONS

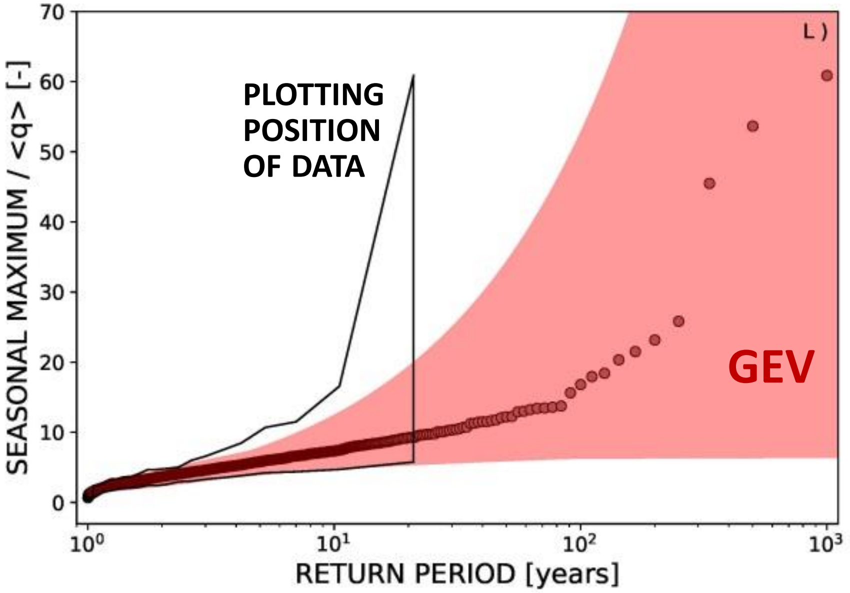


Parameters measurable at catchment scale

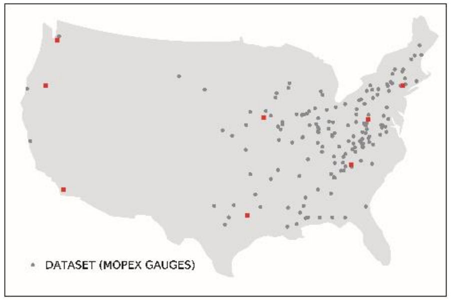
Basso et al., A physically based analytical model of flood frequency curves, *GRL* 2016

Basso et al., PHEV! The PHysically-based Extreme Value distribution of river flows, *ERL* 2021

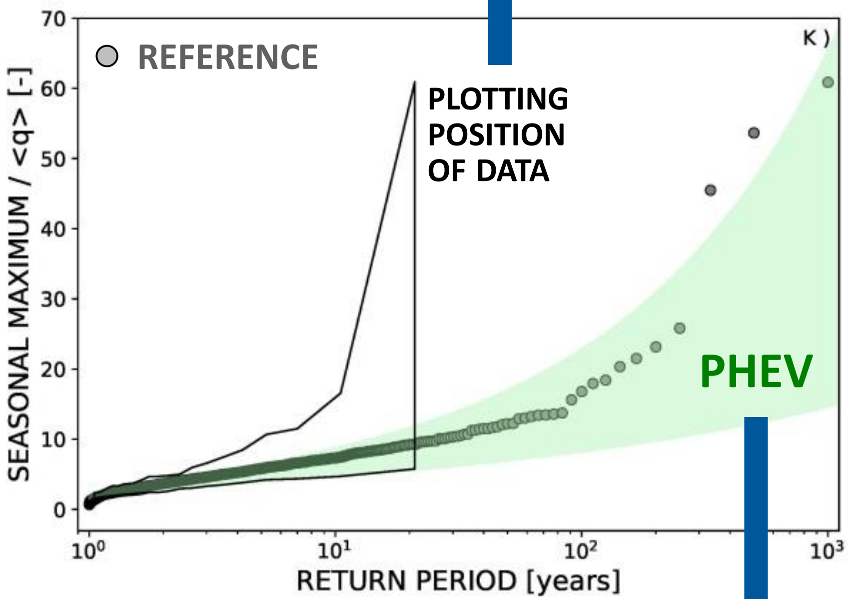


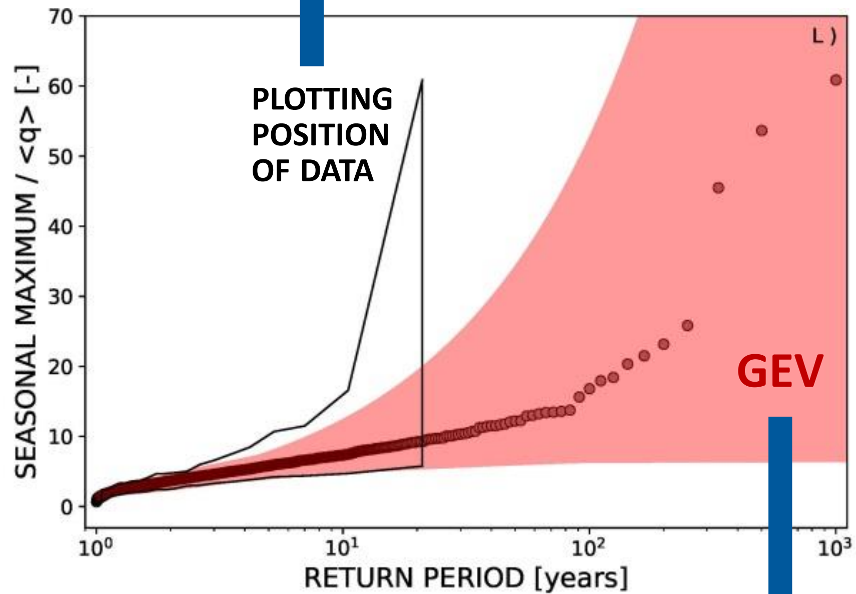


- Long synthetic streamflow series (1000 years)
- Calibration sample size: 10, **20** (in the figures), 30, 60 years
- Resampling without substitution: 1000 times



Estimates highly depend on the specific set of sampled flood events

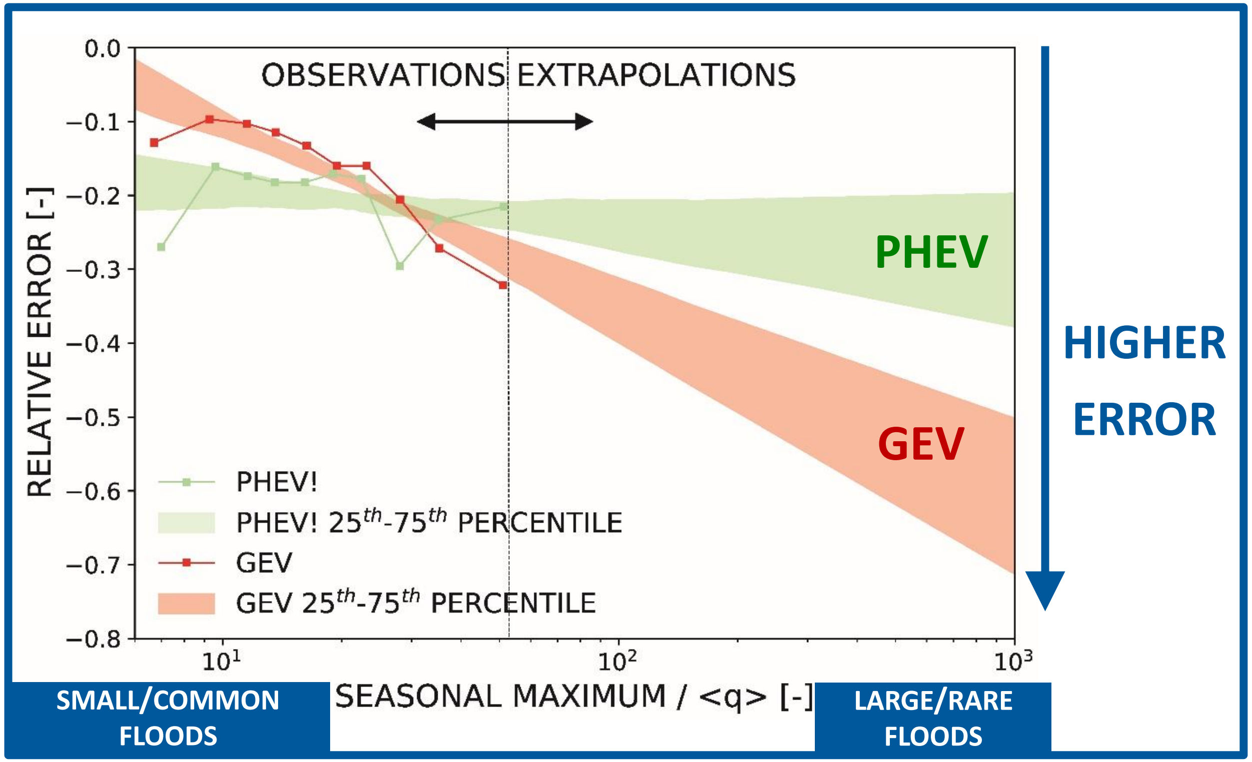




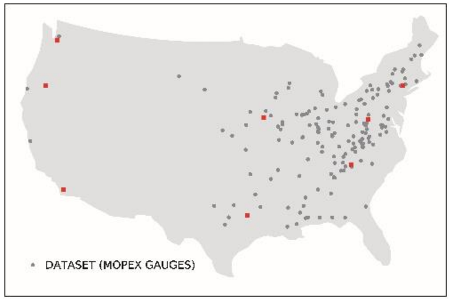
Estimates less affected by the specific set of sampled flood events

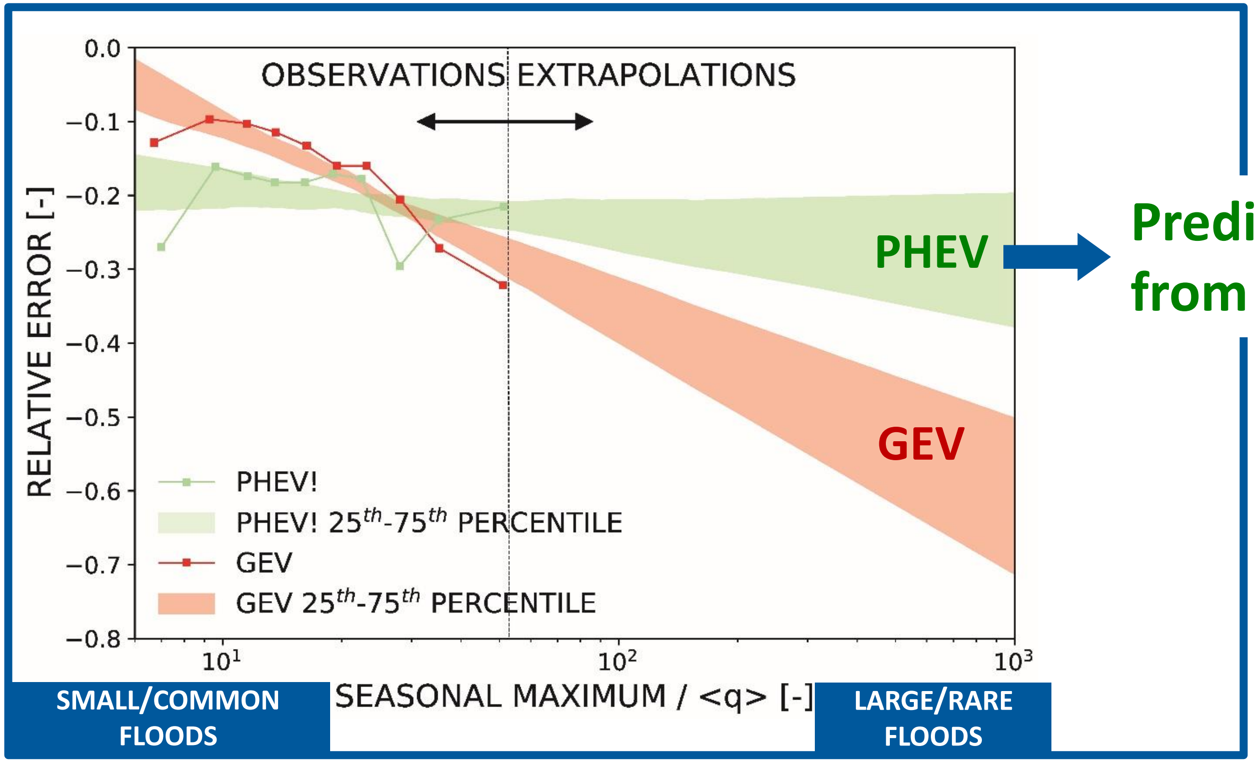
Estimates as variable as the empirical ones for slightly larger return periods

VANTAGE POINT #2 | PREDICTION FROM SHORT DATA RECORDS



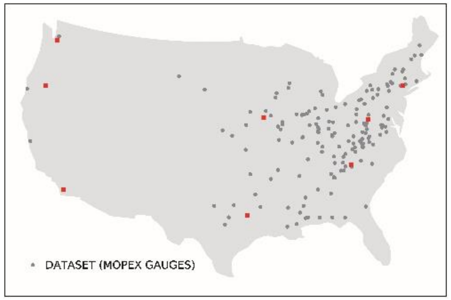
- Observed streamflow series (35-55 years)
- Calibration sample size: 10 years
- Resampling without substitution: 100 times
- Median performance for deciles of all observed flood quantiles



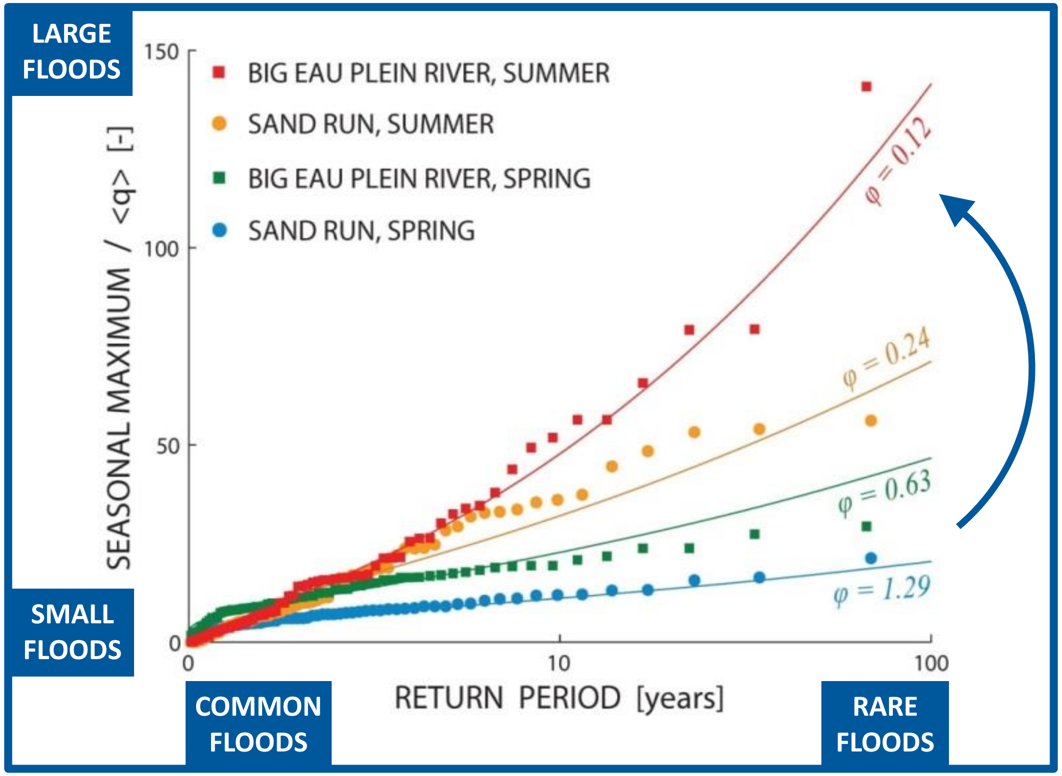


Prediction of large/rare floods from short data records

- Observed streamflow series (35-55 years)
- Calibration sample size: 10 years
- Resampling without substitution: 100 times
- Median performance for deciles of all observed flood quantiles



The ratio of mean **basin response time** and mean **interarrival of runoff events** controls **flood magnitude and probability**



$$\varphi = \frac{\lambda}{k} = \frac{\textit{basin response time}}{\textit{event interarrival}}$$

λ = frequency of runoff events
= 1 / mean event interarrival

k = *f* (a, K)
= hydrograph recession rate
= 1 / basin response time

A physically based analytical model of flood frequency curves,
Geophysical Research Letters, 2016.

PHEV! The PHysically-based Extreme Value distribution of river flows,
Environmental Research Letters, 2021.

Want to know more?

Identifying discontinuities of flood frequency curves, *ESSOAr*, 2021.

Risky rivers: physioclimatic controls of basins' penchant for extreme floods,
IAHS Conference 2022 (next week in Montpellier, France).

Stay tuned or contact us!

stefano.basso@ufz.de