Universal scaling in precipitation and river flows

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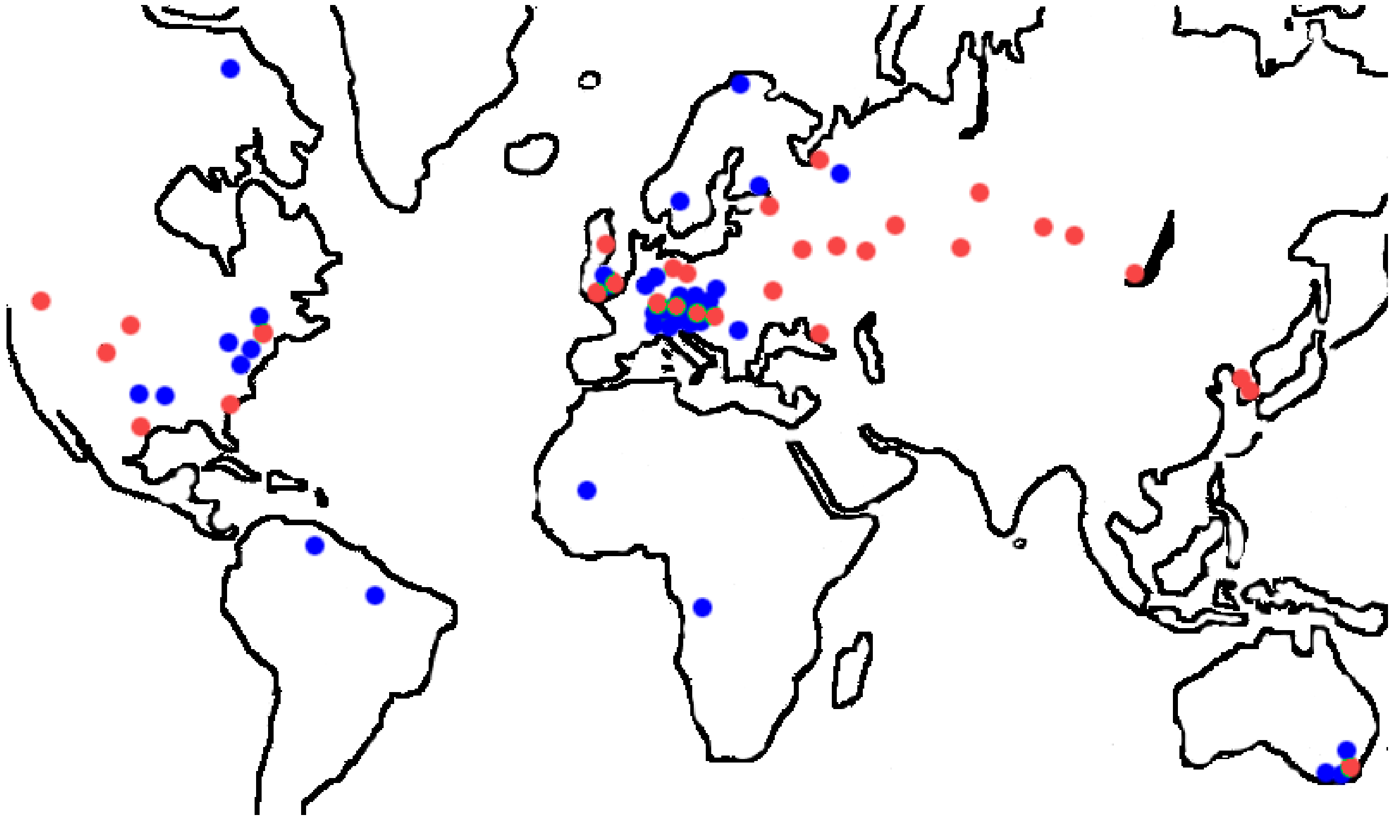
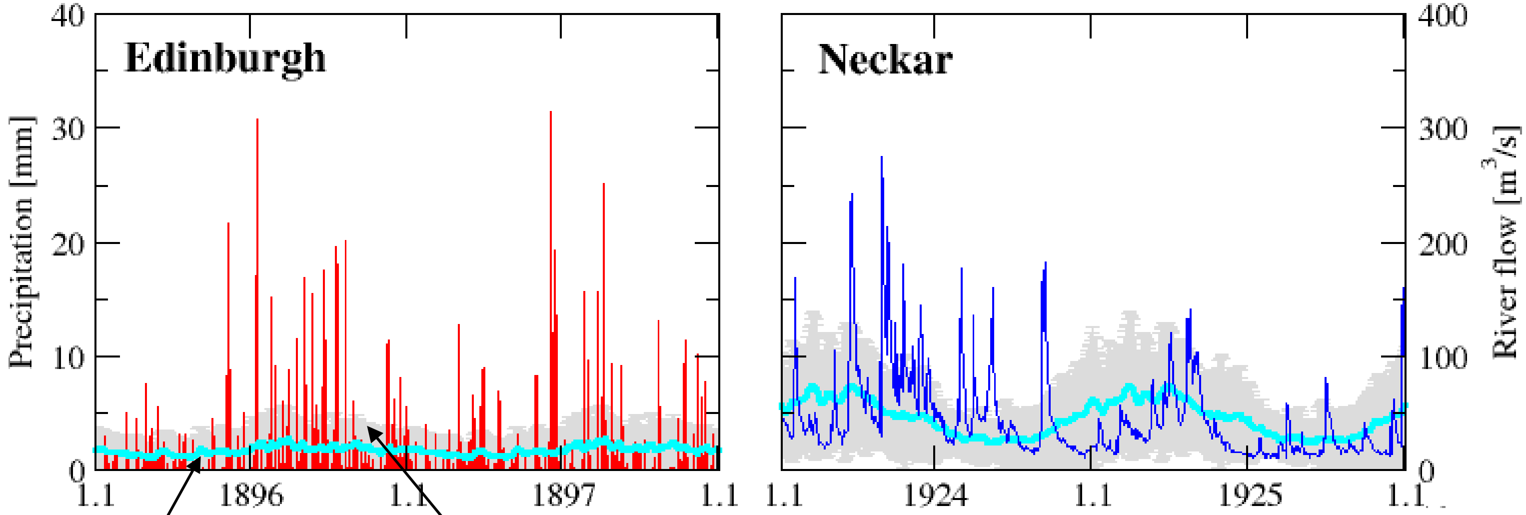
Can the complex interplay between linear and nonlinear correlations in precipitation and river flows give rise to universal behavior?



River flows: 25 records. The basin areas vary between 390 and 613,830 km^2, different climate zones, different soil conditions

Precipitation: 32 records. Different climate zones

Precipitation and river flows



Seasonal trend

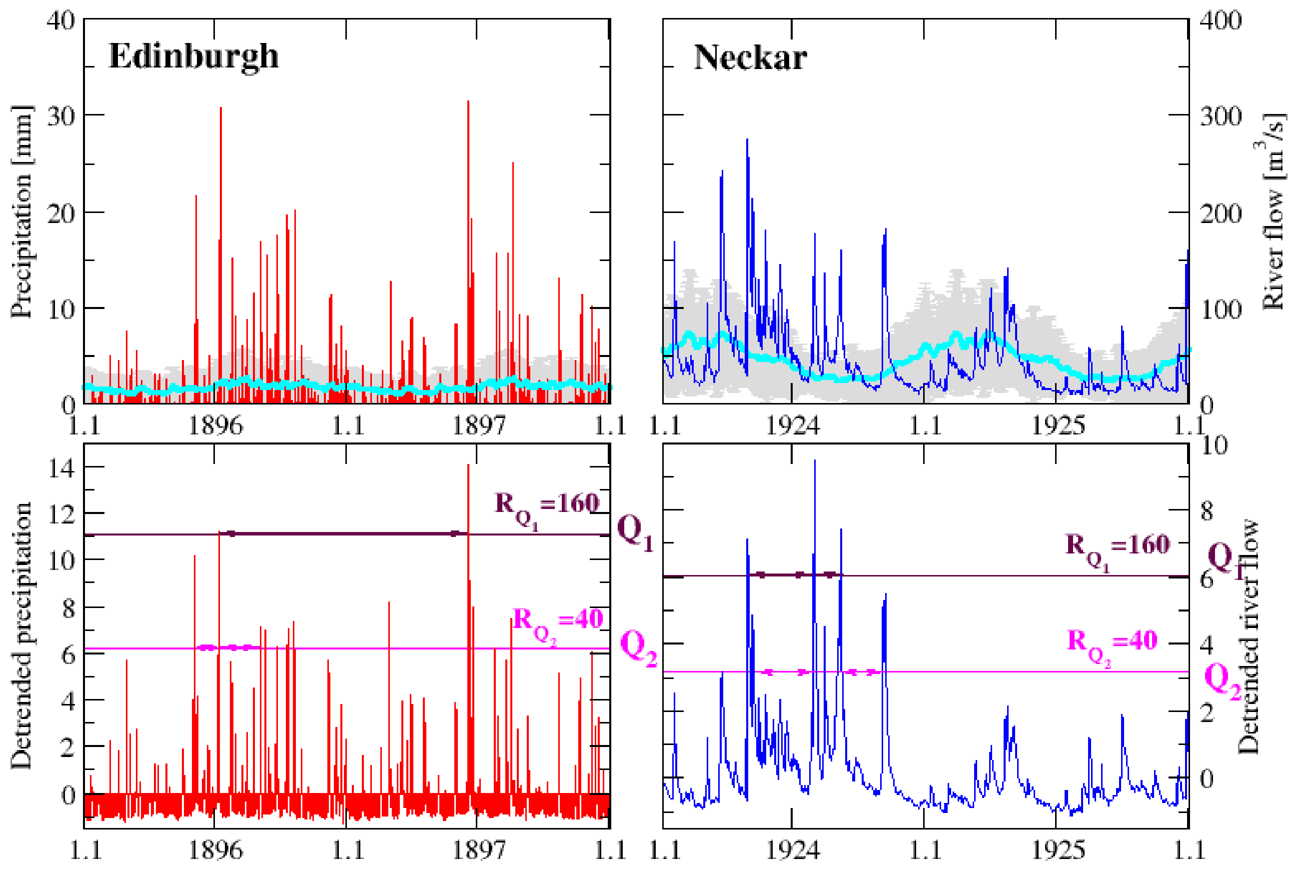
Seasonal standard deviation

Standardizing by seasonal detrending

$$\tau_i = \frac{x_i - \langle x_i \rangle}{\sigma_i}$$

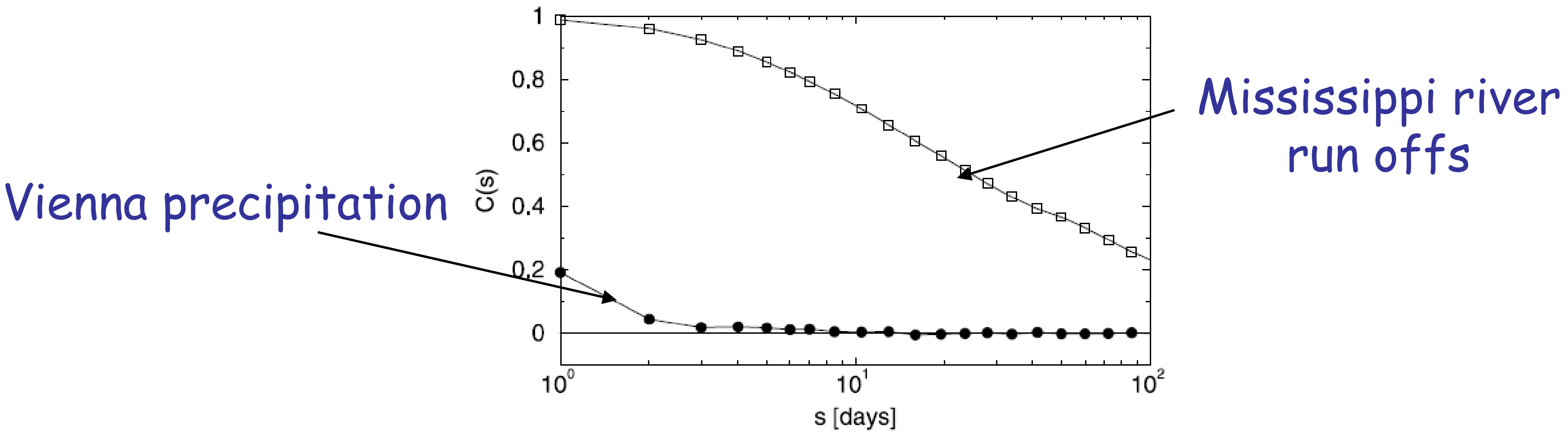
← Seasonal mean

← Seasonal standard deviation



Persistence in Precipitation and River Flows

$$C(s) \equiv \langle \tau_i \tau_{i+s} \rangle = \frac{1}{N-s} \sum_{i=1}^{N-s} \tau_i \tau_{i+s} \sim (1-\gamma)(1-\gamma/2)\, s^{-\gamma}$$



Vienna precipitation: Short-term persistence $\gamma \approx 1$

Mississippi river flows: Long-term persistence $\gamma \approx 0.4$

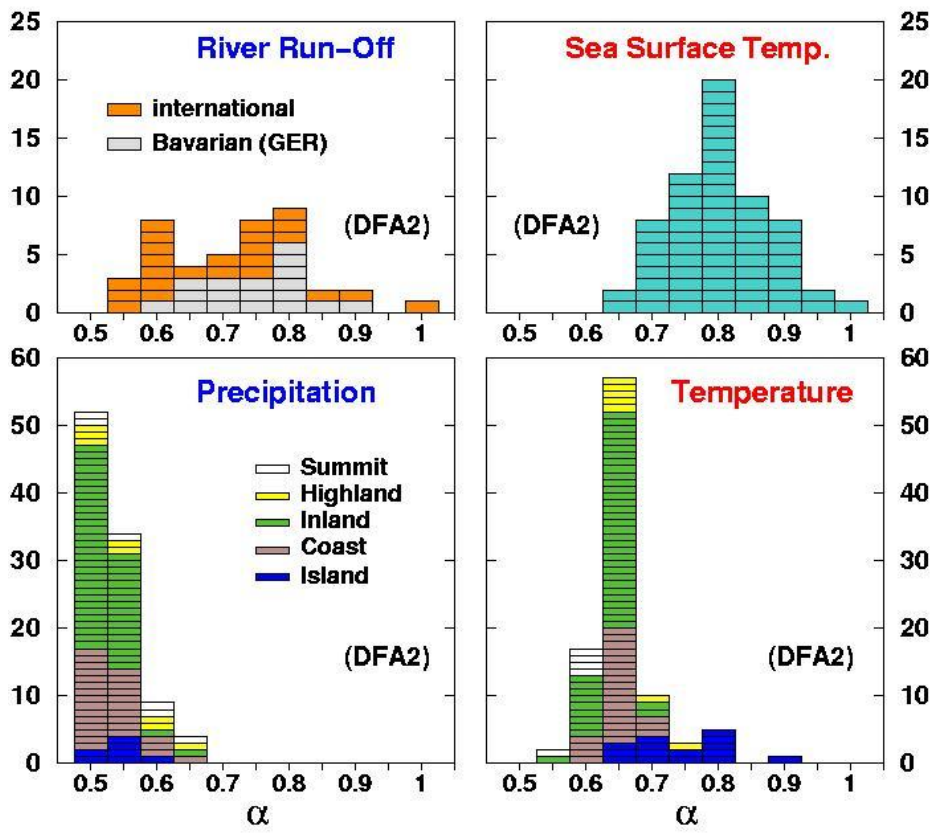
Alternative method: Fluctuation function

$$F(s) \equiv F_2(s) \equiv \left\langle \left| \sum_{i=1}^{s} \tau_i \right|^2 \right\rangle^{1/2} \sim s^{\alpha}, \quad \alpha = 1 - \gamma / 2$$

Advantage: Modifications allow to eliminate systematically polynomial trends and to distinguish between short and long-term correlations :

(i) Wavelet methods WT0, WT1, WT2,...

(ii) Detrended Fluctuation Analysis: DFA0, DFA1, DFA2



$$\alpha = 1 - \gamma / 2$$

Eichner et al, 2003, Rybski et al, 2003, 2006, Koscielny-Bunde et al, 1996, 1998, 2004

Multifractality: Generalized fluctuation function

$$F_q(s) \equiv \left\langle \left| \sum_{i=1}^{s} \tau_i \right|^q \right\rangle^{1/q} \sim s^{\alpha(q)}$$

$$\alpha(2) = 1 - \gamma / 2$$

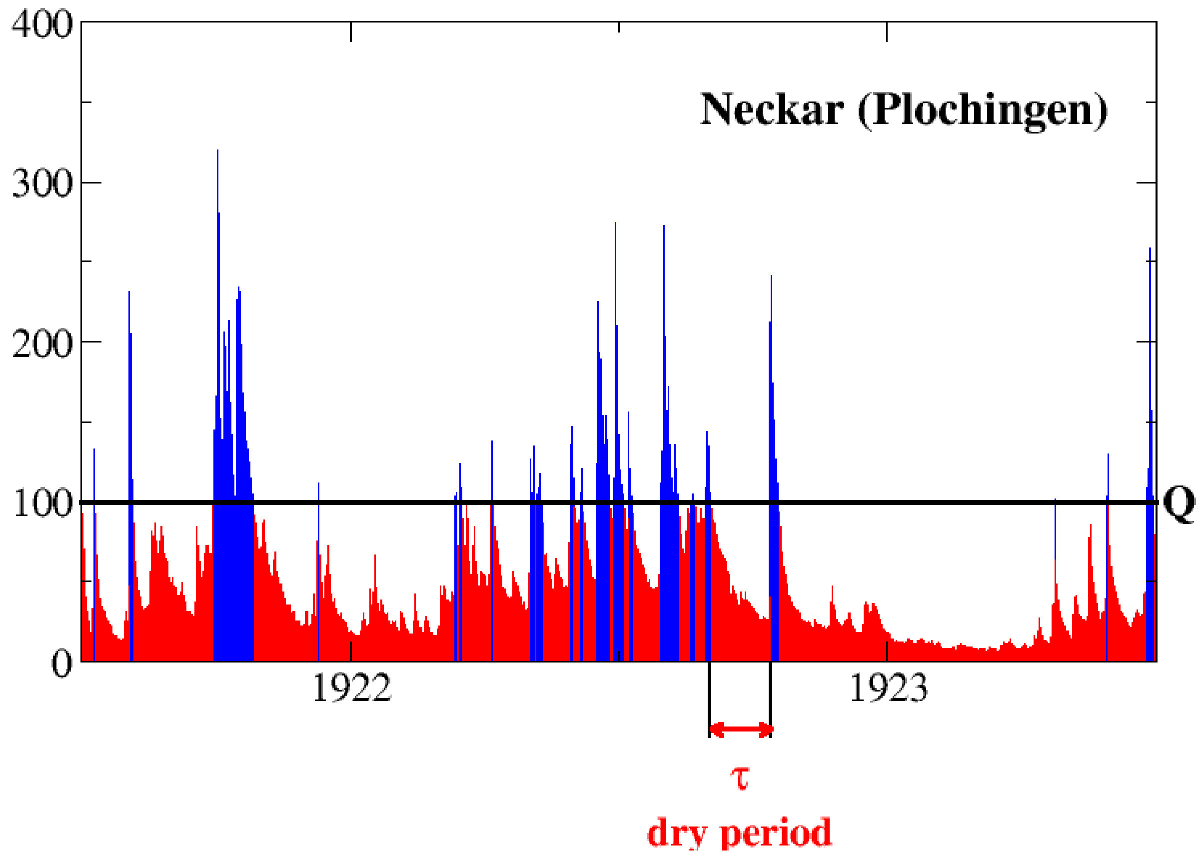
Monofractal: $\alpha(q) = \alpha$ independent of q

Multifractal: $\alpha(q)$ dependent on q

Precipitation and river flows exhibit multifractality,

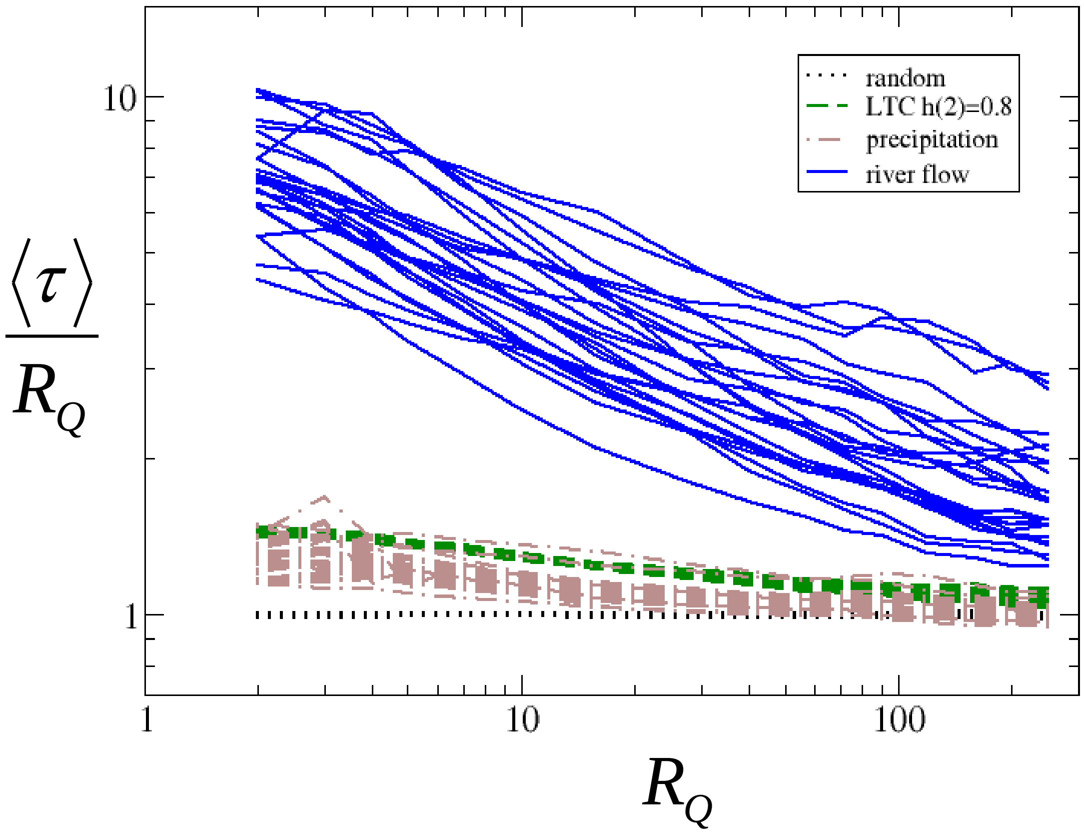
with nonuniversal exponents $\alpha(q)$

Searching for universal behavior: Low water periods

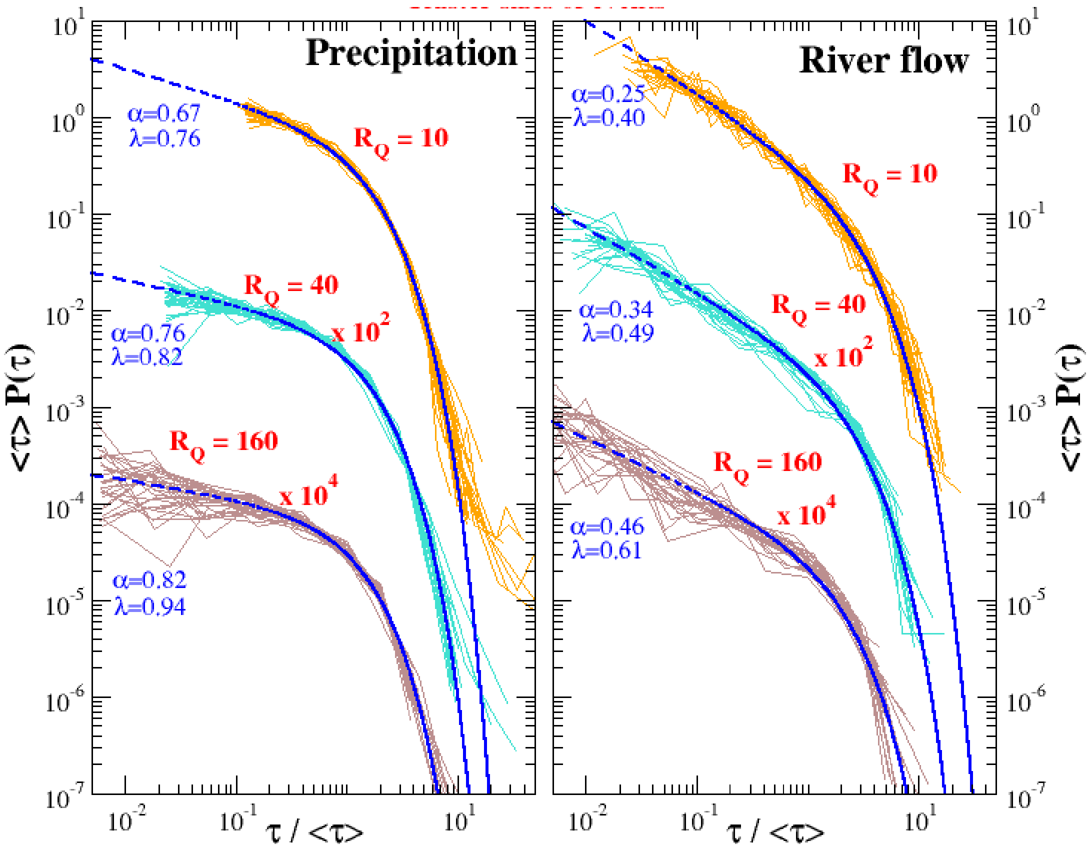


$$Q \Leftrightarrow R_Q \leftarrow$$ Mean return time between events above Q

Mean duration of dry periods in precipitation and river flows



Universal scaling



Functional forms of the PDFs are described by GAMMA-distributions:

$$P(r) \propto r^{\alpha-1}\, e^{-\lambda r}$$

Scaling function depends on threshold:

Signature of MULTIFRACTALITY