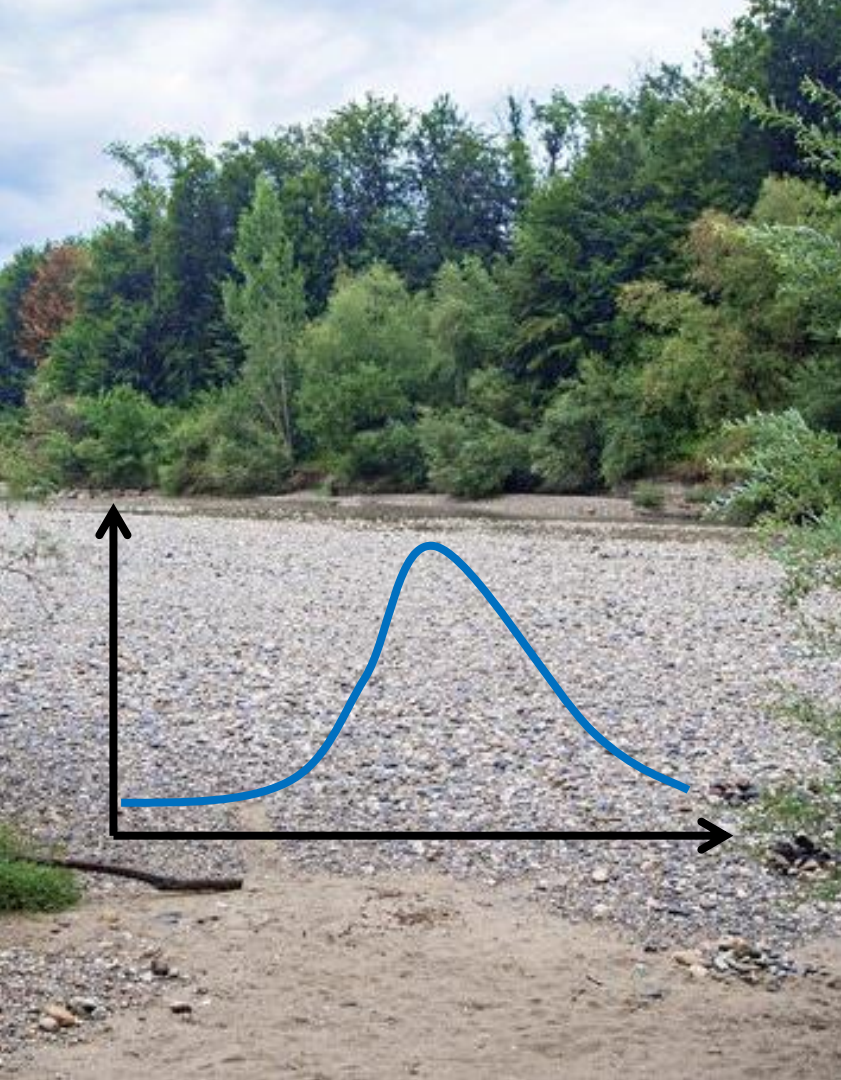




Functional clustering as a powerful tool to group streamflow regimes and flood hydrographs

Manuela I. Brunner, Reinhard Furrer, and Eric Gilleland

EGU 2021: Clustering in hydrology



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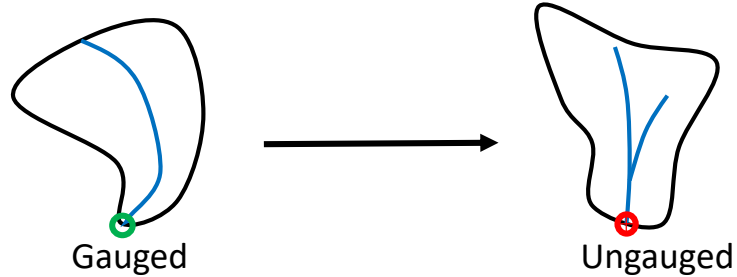


@ManuelaIBrunner

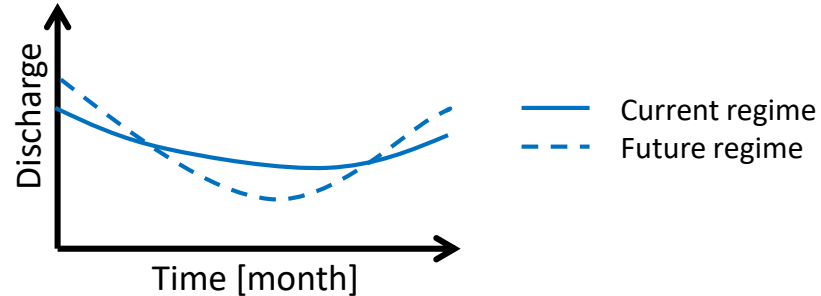


Hydrograph clusters are useful for ...

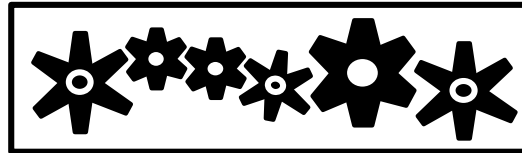
Regionalization



Climate impact assessments

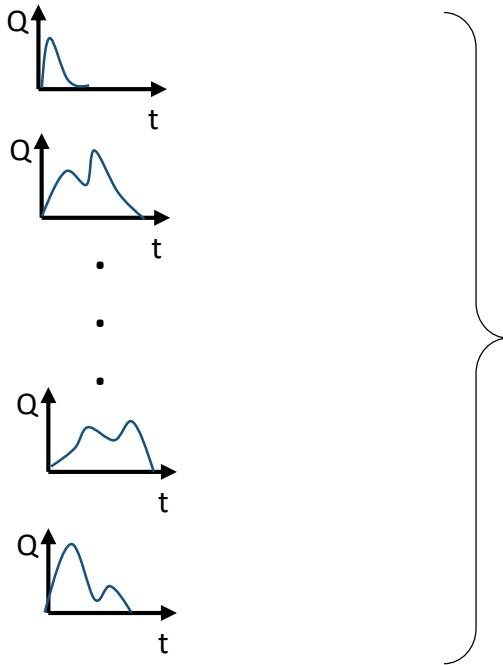


Model choice and evaluation

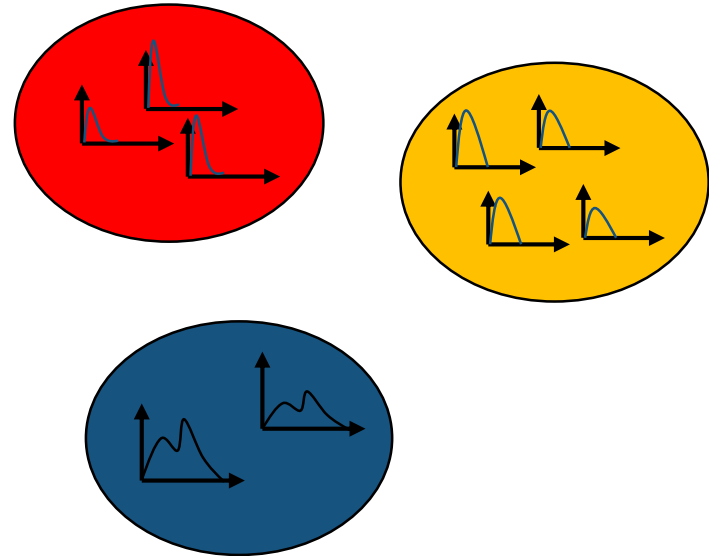


Group hydrographs

What we have: Different hydrographs such as streamflow regimes or flood hydrographs

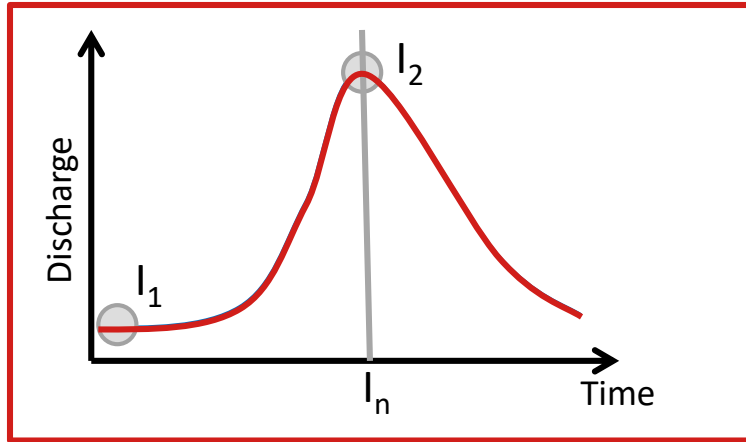


What we want: Groups/clusters of similar hydrograph shapes



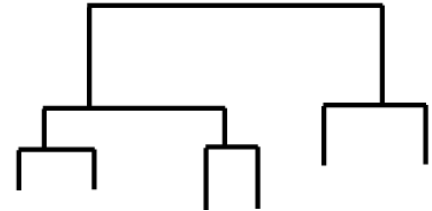
Classical hydrograph clustering

(1) Determine indices (I) for all objects (O) (2) Derive a distance matrix



	O_1	O_2	...	O_m
I_1	d_{11}	d_{12}	...	d_{1m}
I_2	d_{21}	d_{22}	...	d_{2m}
...	...	...	...	...
I_n	d_{n1}	d_{n2}	...	d_{nm}

(3) Apply a clustering procedure such as hierarchical or k-means clustering



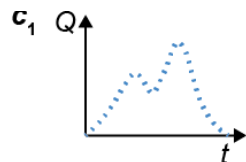
Problem with classical index-based clustering procedures: temporal auto-correlation information is neglected

Functional clustering overcomes this limitation by considering the whole information stored in a hydrograph

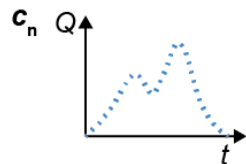
Functional clustering

(1) Functional data representation

(a) Discrete observations



⋮

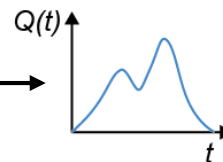
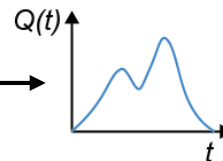


(b) Representation by set of basis functions

$$Q(t) = a_{11} \begin{array}{c} \uparrow \\ \text{basis 1} \end{array} + a_{21} \begin{array}{c} \uparrow \\ \text{basis 2} \end{array} + a_{31} \begin{array}{c} \uparrow \\ \text{basis 3} \end{array} + a_{41} \begin{array}{c} \uparrow \\ \text{basis 4} \end{array} + a_{51} \begin{array}{c} \uparrow \\ \text{basis 5} \end{array}$$

$$Q(t) = a_{1n} \begin{array}{c} \uparrow \\ \text{basis 1} \end{array} + a_{2n} \begin{array}{c} \uparrow \\ \text{basis 2} \end{array} + a_{3n} \begin{array}{c} \uparrow \\ \text{basis 3} \end{array} + a_{4n} \begin{array}{c} \uparrow \\ \text{basis 4} \end{array} + a_{5n} \begin{array}{c} \uparrow \\ \text{basis 5} \end{array}$$

(c) Functional hydrograph representation

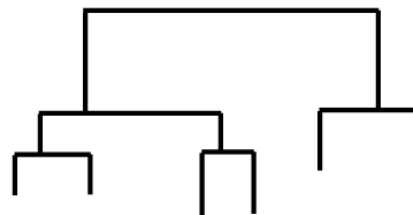


(2) Functional data clustering

(a) Distance computation spline coefficients

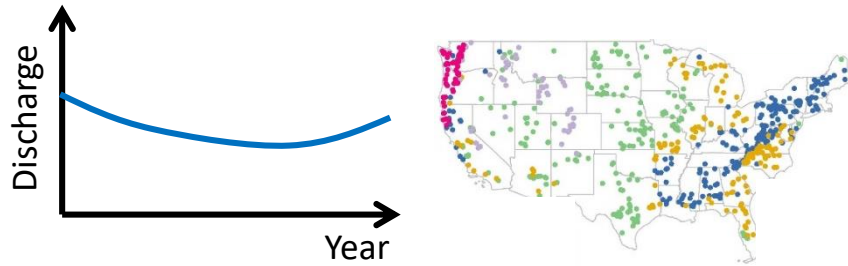
$$\begin{bmatrix} a_{11} & a_{21} & \dots & a_{51} \\ a_{12} & & & \vdots \\ \vdots & & & \vdots \\ a_{1n} & \dots & & a_{5n} \end{bmatrix}$$

(b) Hierarchical clustering

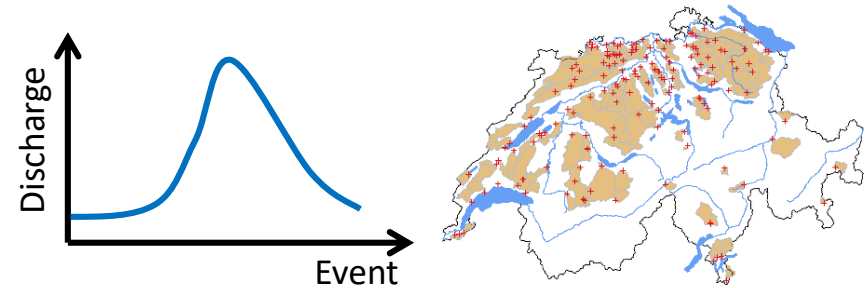


Applications

(1) Regime clustering United States:
identify catchments with similar
annual hydrographs



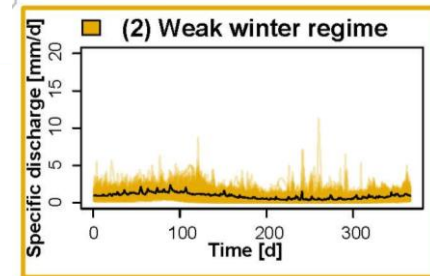
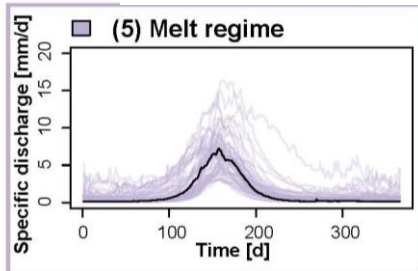
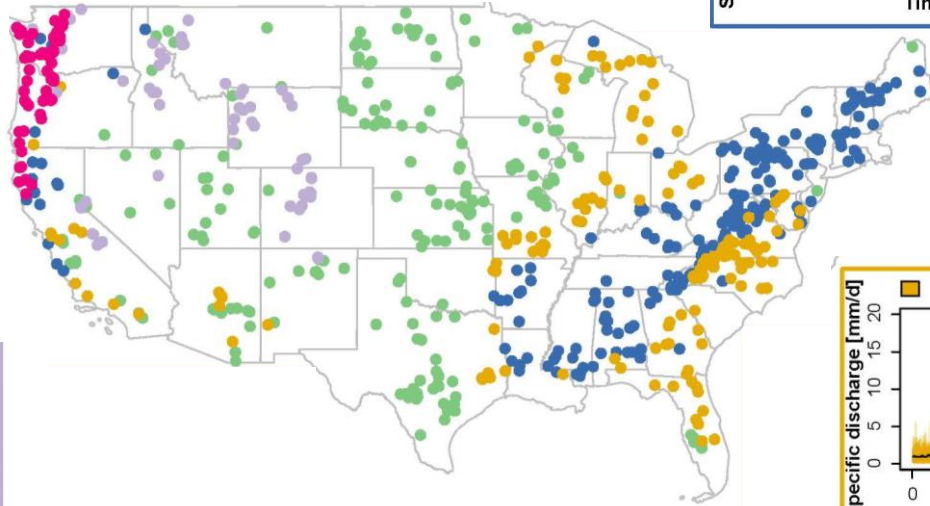
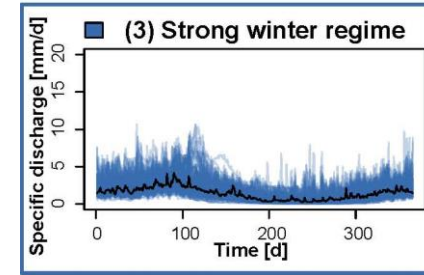
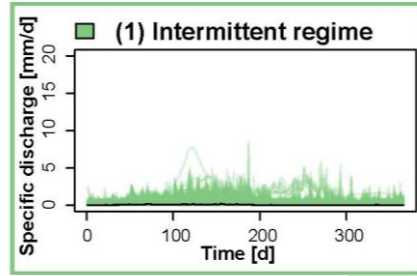
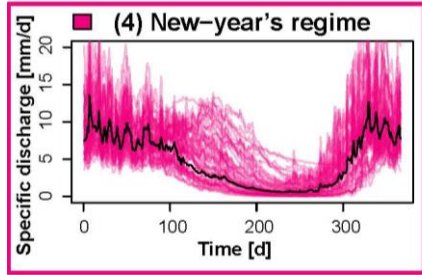
(2) Flood hydrograph clustering Switzerland:
identify groups of representative hydrograph
shapes



Brunner et al. 2020. HESS: Future streamflow regime changes in the United States: assessment using functional classification:
<https://hess.copernicus.org/articles/24/3951/2020/hess-24-3951-2020.html>

Brunner et al. 2018. WRR: Identification of flood reactivity regions via the functional clustering of hydrographs:
<https://aquapubs.onlinelibrary.wiley.com/doi/full/10.1002/2017WR021650>

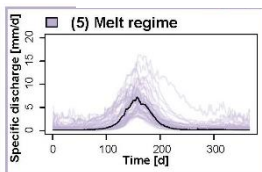
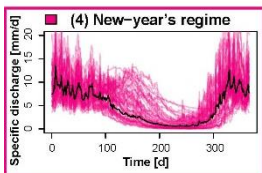
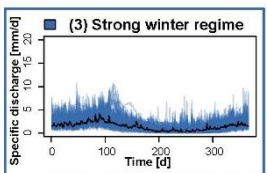
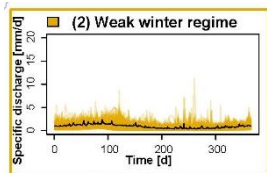
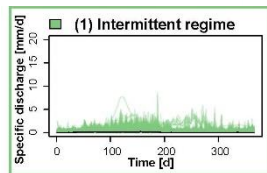
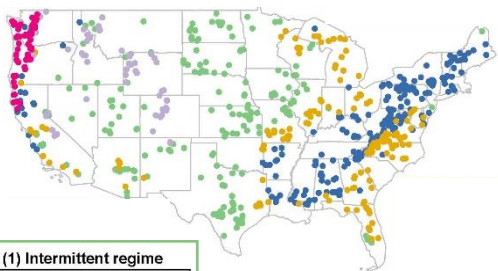
Regime clusters



Five clusters similar in terms of the mean annual hydrograph

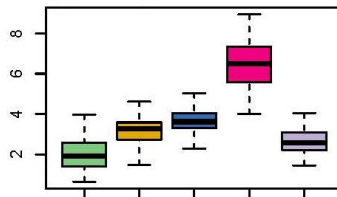
Characteristics

Regime classes

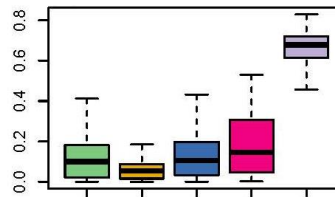


Catchment characteristics

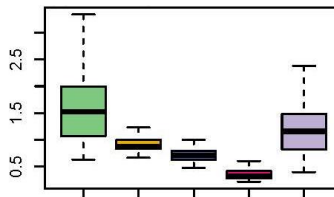
Precipitation [mm/d]



Fraction of snow [-]

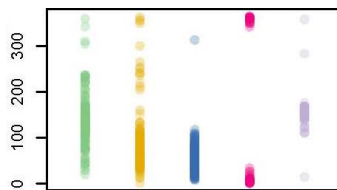


Aridity [-]

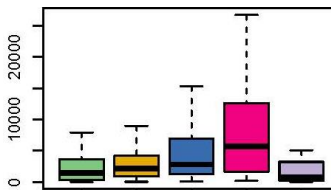


Hydrologic extremes

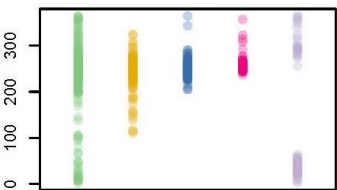
Mean flood timing [d]



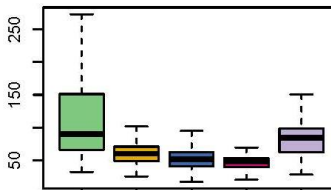
Mean flood magnitude [ft³/s]



Mean drought timing [d]



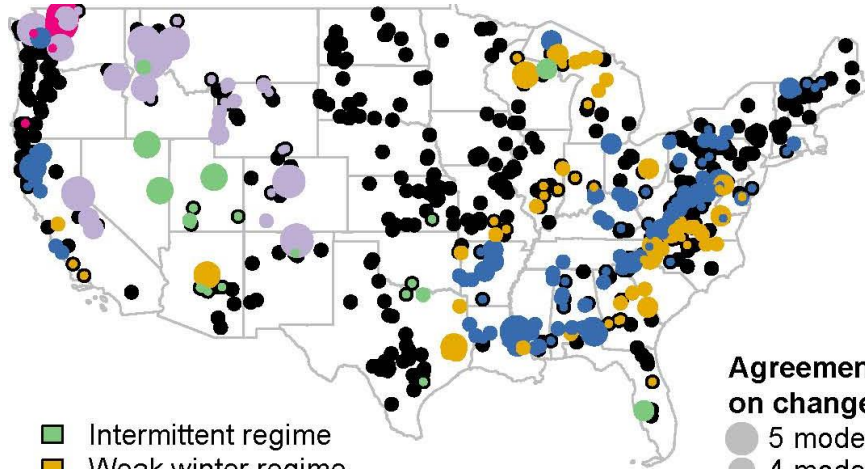
Mean drought duration [d]



Clusters are similar in terms of climate, flood and drought characteristics

Regime changes

Current regimes

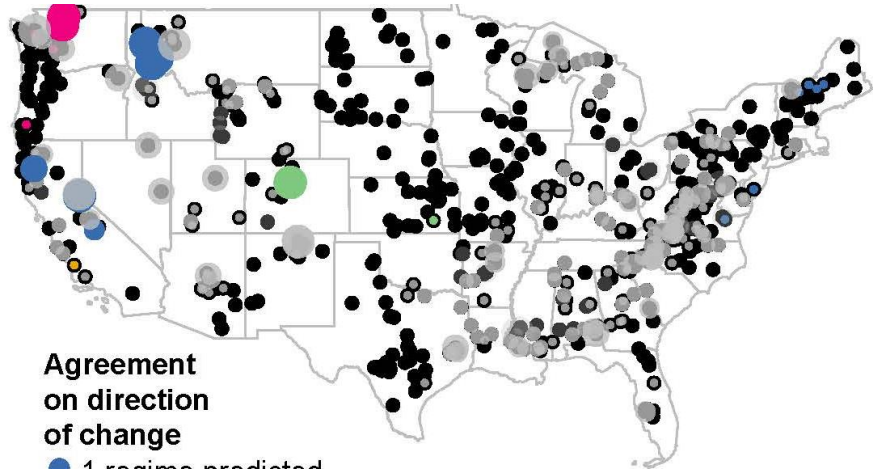


- Intermittent regime
- Weak winter regime
- Strong winter regime
- New-year's regime
- Melt regime

Agreement on change

- 5 models
- 4 models
- 3 models
- 2 models
- 1 model
- No regime change

Future regimes



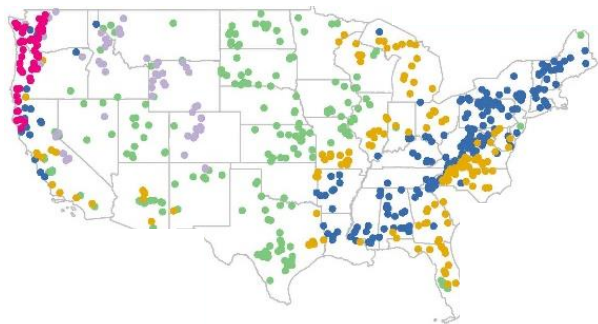
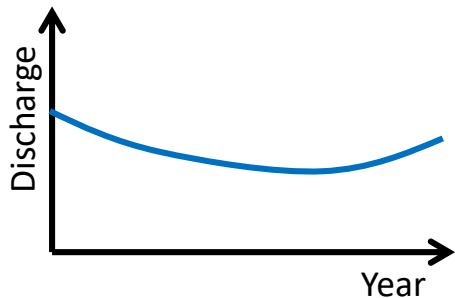
Agreement on direction of change

- 1 regime predicted
- 2 different regimes predicted
- 3 different regimes predicted

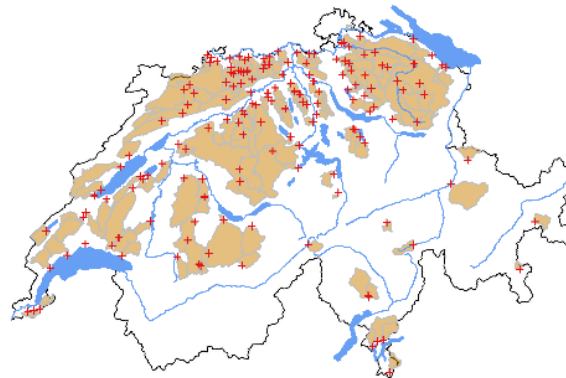
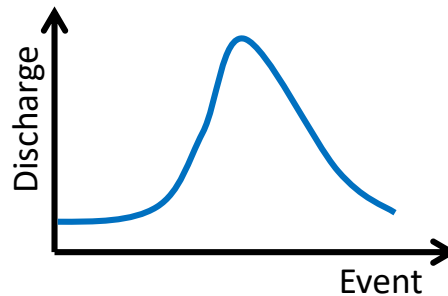
Robust regime changes are only expected for currently snow-dominated flow regimes

Applications

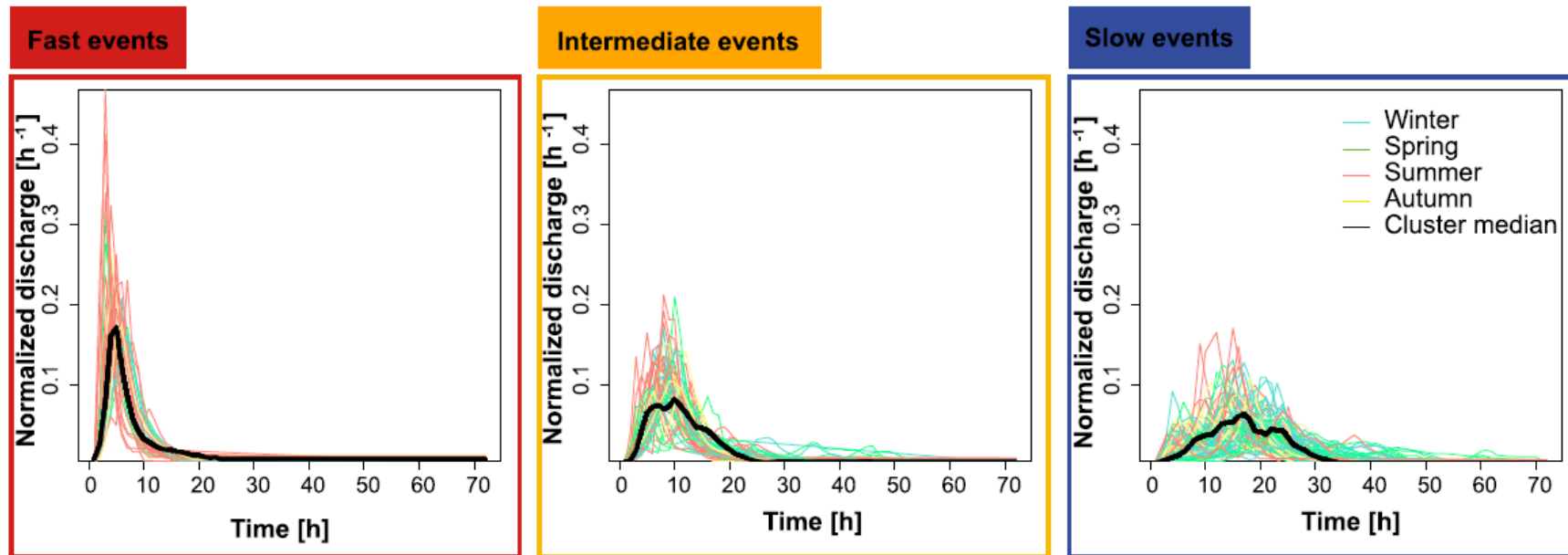
(1) Regime clustering United States



(2) Flood hydrograph clustering Switzerland



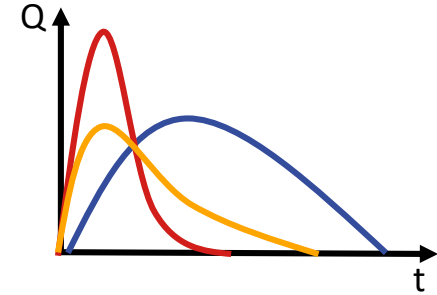
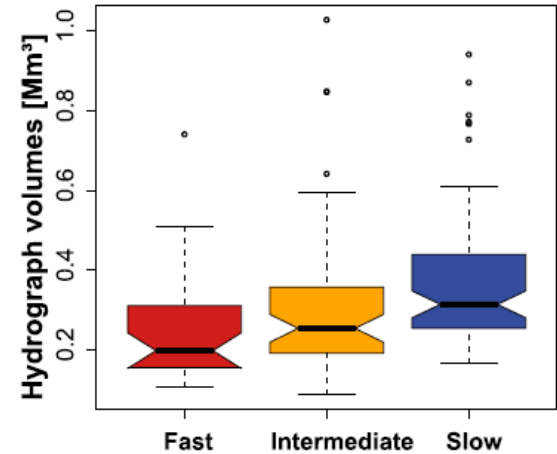
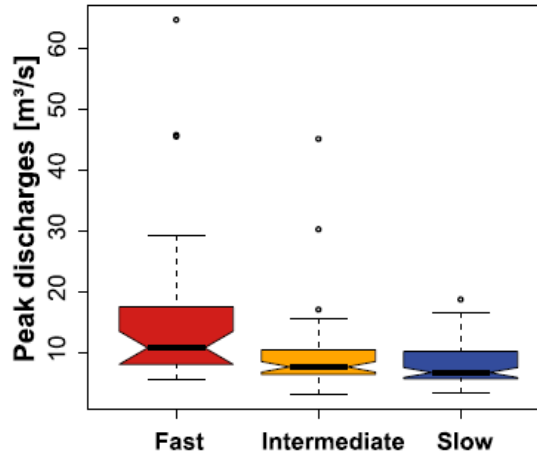
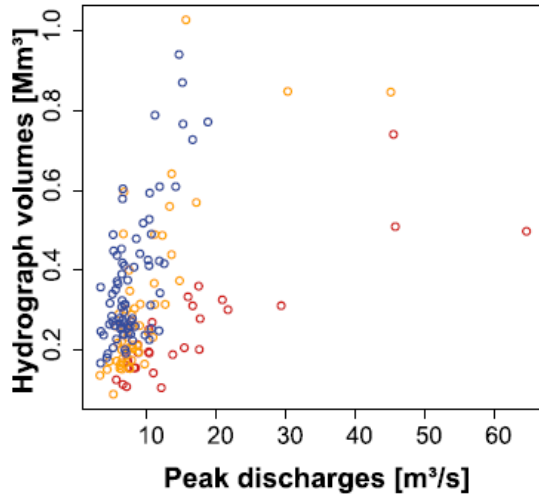
Flood hydrograph clusters



Three hydrograph clusters characterize the variability in flood hydrographs: hydrographs with a fast rising and falling limb, hydrographs with a fast rising but slow falling limb, and hydrographs with a slow flood response

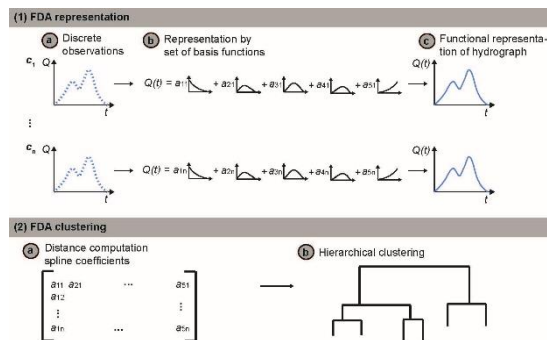
Flood hydrograph clusters

Flood hydrograph clusters are similar in terms of peak discharge and flood volume

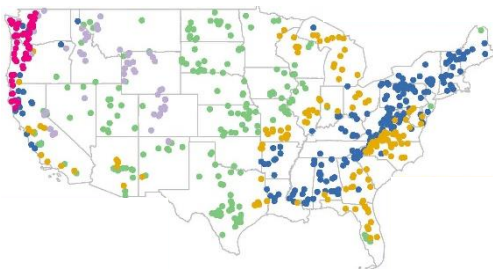


Conclusions

Functional clustering exploits temporal information

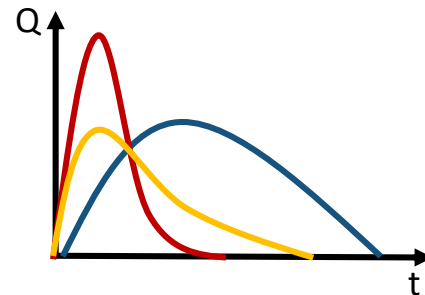


Five regimes characterize streamflow behavior in the United States



Download HydroShare: [Streamflow regimes for CAMELS dataset](#)

Three hydrograph shapes characterize flood hydrograph variability in Switzerland



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Brunner et al. 2020. HESS: Future streamflow regime changes in the United States: assessment using functional classification: <https://hess.copernicus.org/articles/24/3951/2020/hess-24-3951-2020.html>

Brunner et al. 2018. WRR: Identification of flood reactivity regions via the functional clustering of hydrographs: <https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/2017WR021650>