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Hydrological climate classification: improving on Köppen-Geiger

Connecting seasonal streamflow patterns and hydrological statistics to climate forcing on a global scale

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To transfer knowledge from basin to basin, hydrology needs its own structured way to think about climates

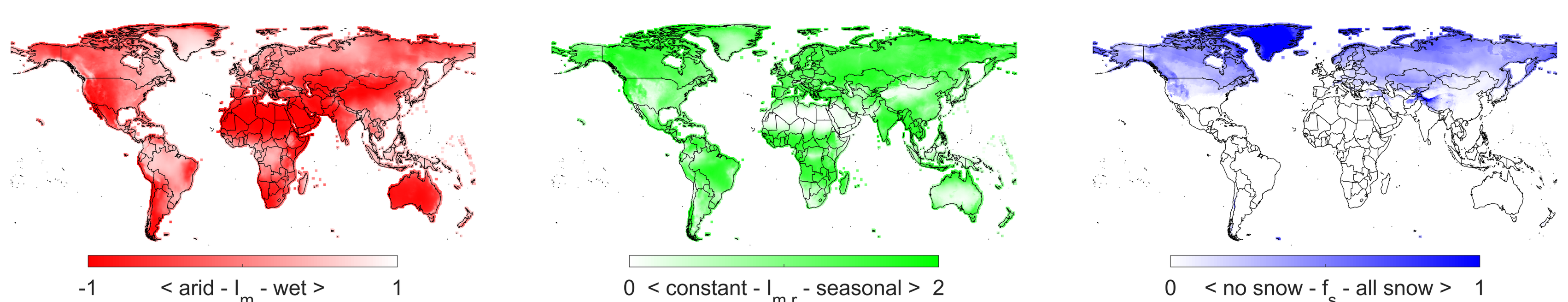
The Köppen-Geiger classification is widely used in earth sciences[1] but has limited applicability in hydrology[2,3]. It is **bioclimatic** in origin and uses **thresholds** to create **categorical, discrete** climate classes. To transfer knowledge from one basin to another, hydrology needs a climate classification that has a **hydrologic** basis, uses **deterministic, easy-to-use numbers**, and acknowledges the **gradual spatial change** in climatic conditions that occurs in reality.

This works show that ...

- Aridity, seasonality of aridity and snowfall indices can define the global hydro-climate (fig 1,3)
- Spatial changes in flow regimes follow spatial changes in hydro-climate (fig 2, 3, 4)
- 3 indices outperform the Köppen-Geiger classification, especially in colder regions (fig. 5,6)

Method

We use monthly rainfall, temperature and potential evapotranspiration data for 1984-2014[4] to define indices for annual average aridity[5], seasonal changes of aridity[5] and snowfall[6]:

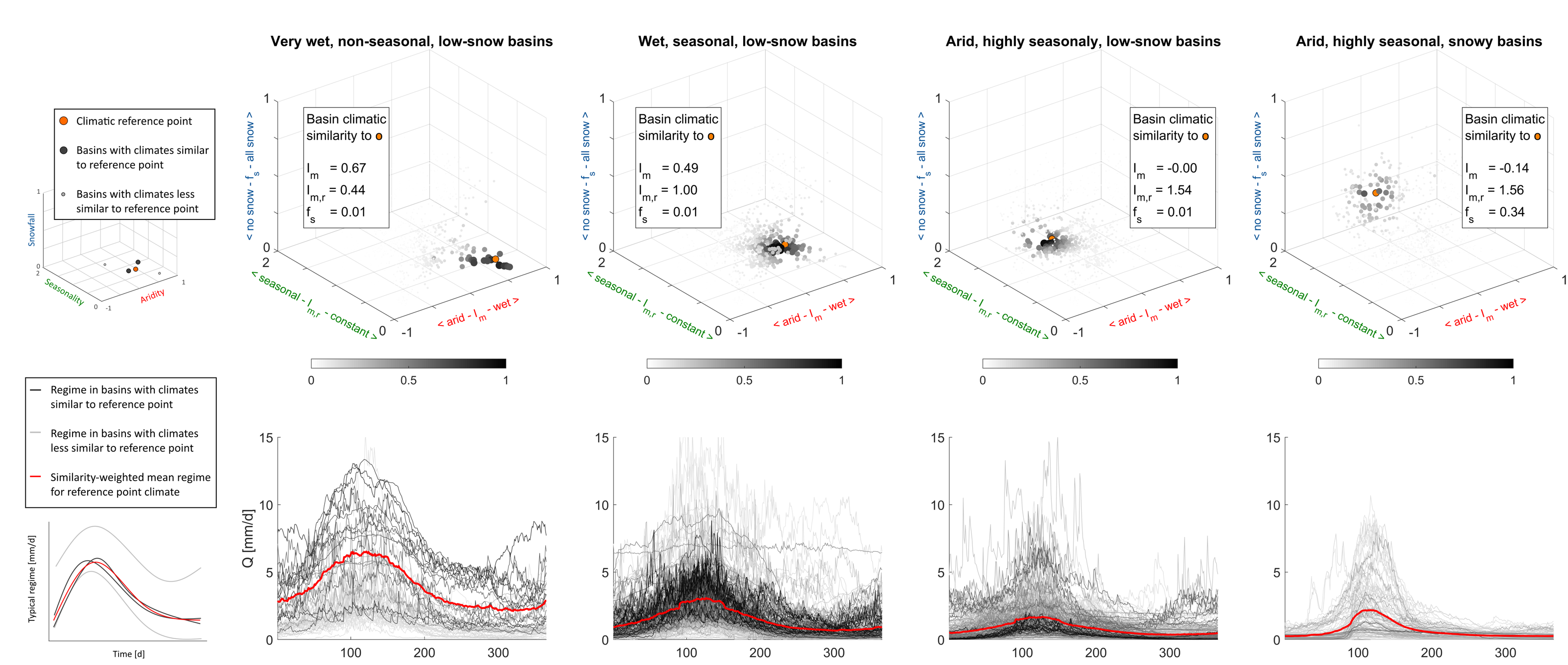


(fig. 1a): annual average aridity [mean of monthly: 1-PET/P *or* P/PET-1]
(fig. 1b): aridity seasonality [max aridity month —min aridity month]
(fig. 1c): annual snow fraction [*if* T < 0°C, P is snow]

We compare the **similarity in climate** and the **similarity of flow regimes** in 1103 basins[7], using:

- Each basin's mean hydro-climate in terms of aridity, seasonality and snowfall
- Each basin's 'typical regime' (e.g. the typical 1-Jan is the median of all 1-Jan's in the flow data)

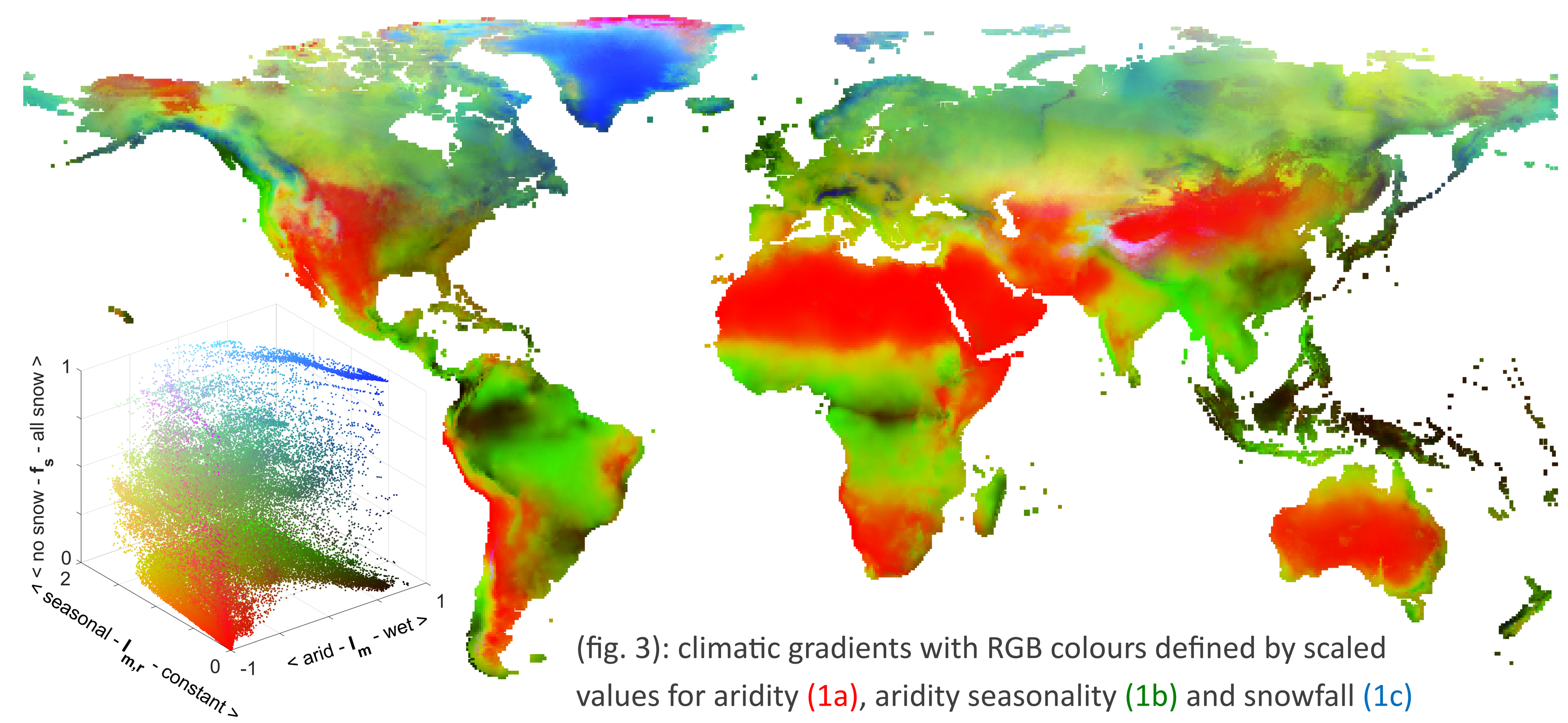
Spatial changes in flow regimes follow spatial changes in hydro-climate



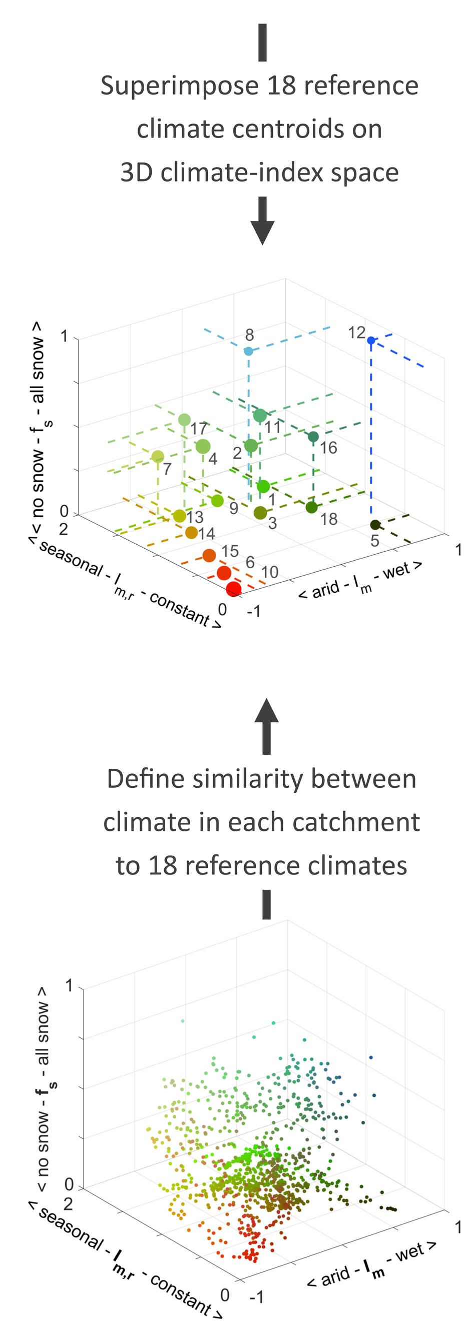
(fig. 2): typical flows in basins with varying degrees of aridity, seasonality and snowfall

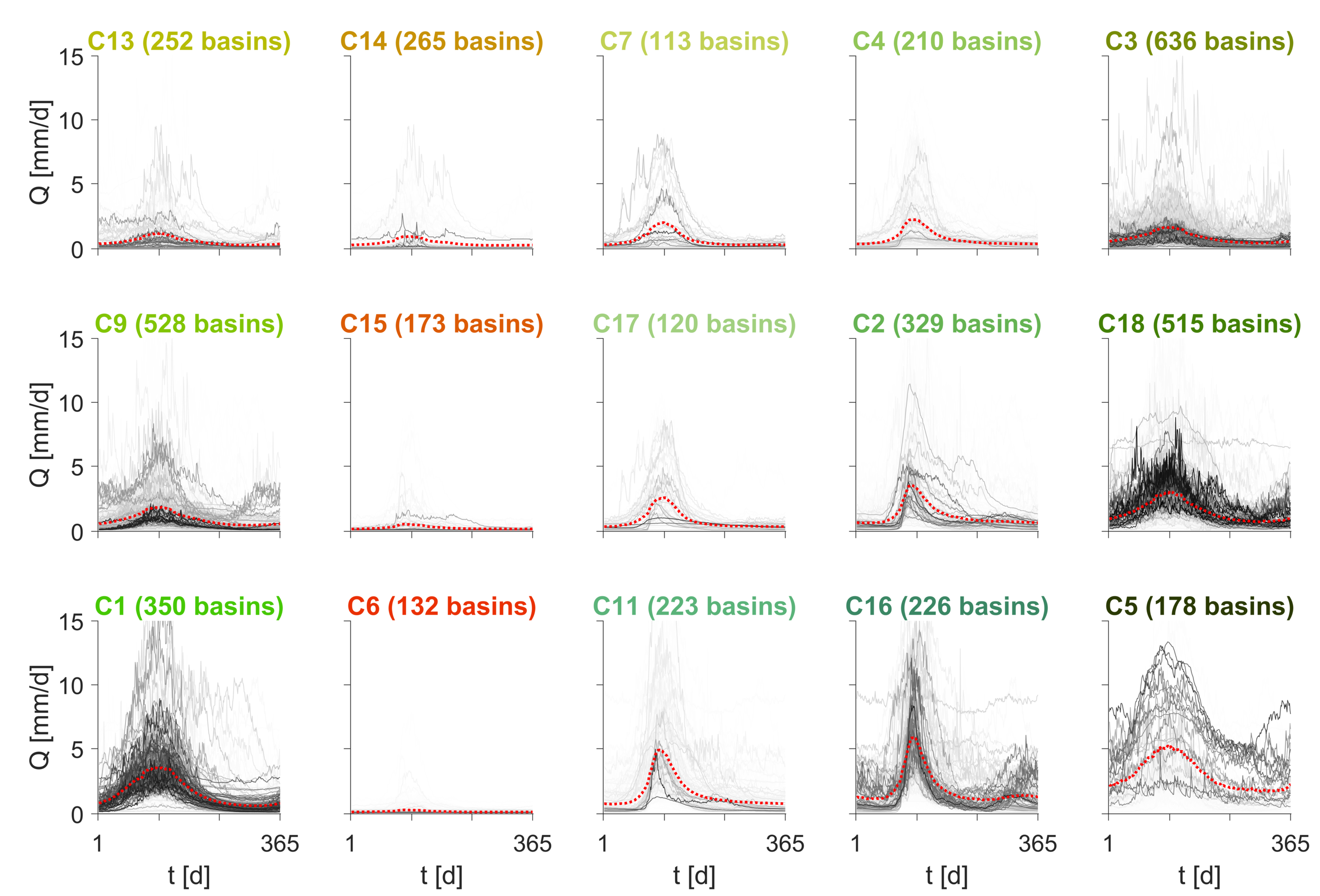
Global flow regimes evolve along climatic gradients. Similar hydro-climates have similar flow regimes

Fig.3 shows the combination of the 3 climate indices (fig. 1) into a single map. We superimpose 18 reference climates on the 3D-climate index space and calculate the degree of similarity between the average climates of the 1103 river basins and these 18 reference points. We find that flows evolve along climatic gradients (fig. 4). Statistical tests on 16 streamflow signatures (not shown) confirm that using the similarity in aridity, seasonality and snowfall is well-suited to group hydrologically similar regimes.



(fig. 3): climatic gradients with RGB colours defined by scaled values for aridity (1a), aridity seasonality (1b) and snowfall (1c)

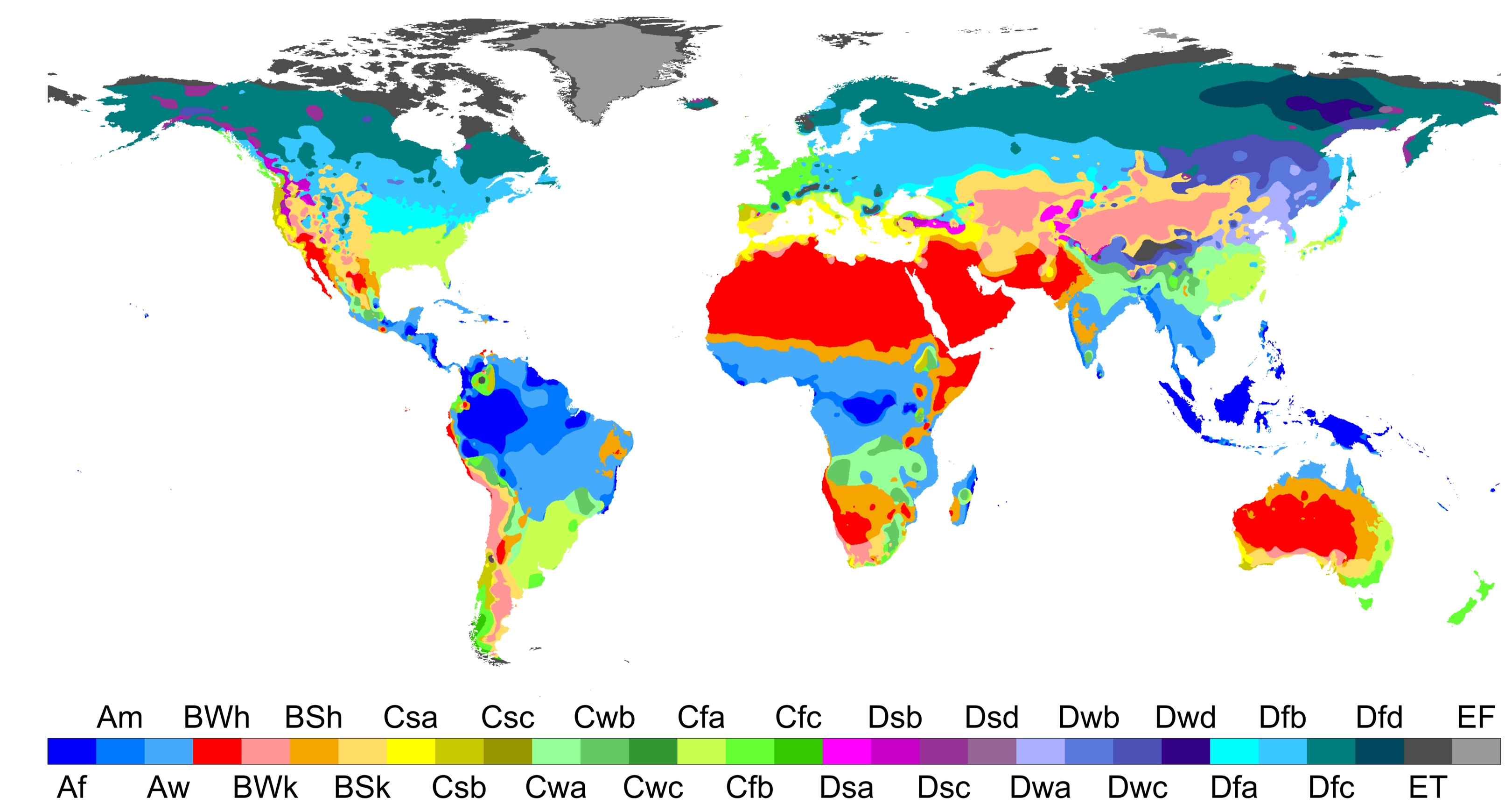




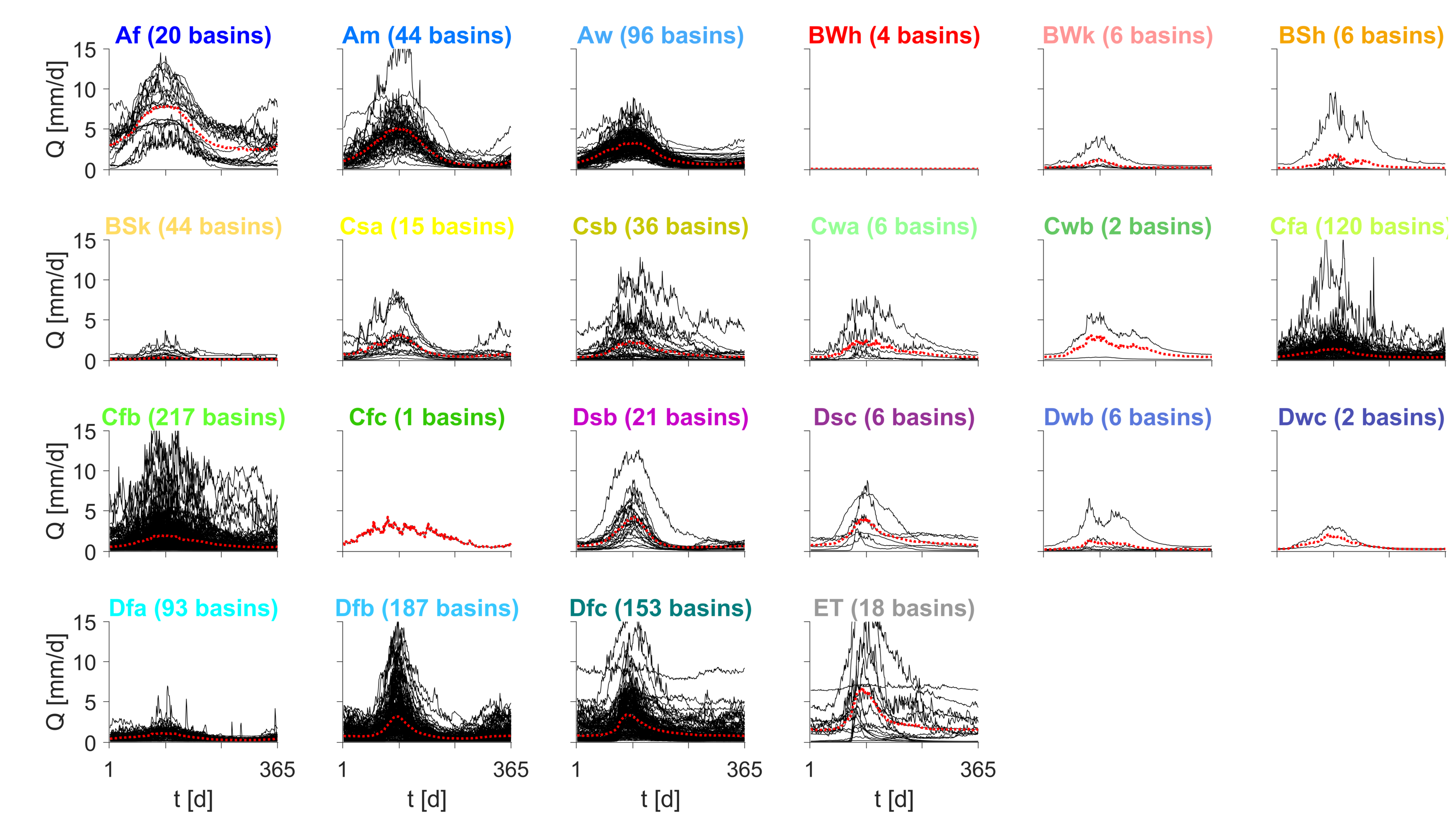
(fig. 4): flows grouped and shaded by climatic similarity between each basin and each reference climate. Per reference climate, only flows with similarity > 0.1 are shown, along with the similarity-weighted mean (...). Columns show how various gradients in climate space affect seasonal flow regimes in basins associated with these climates.

Köppen-Geiger groups show large within-class variability of streamflow regimes, even though it uses many classes

We repeat the analysis and now use the Köppen-Geiger classification (fig. 5) to group flow regimes (fig. 6). Qualitatively, we find that Köppen-Geiger main classes A (tropical) and B (arid) sort flows into groups similar to some of our index-based clusters. The colder C (temperate), D (continental) and E (polar) Köppen-Geiger classes are less able to group hydrologically similar river basins. Quantitative analysis of the values of 16 streamflow signatures confirms this (not shown).



(fig. 5): Köppen-Geiger classification[1]



(fig. 6): flows grouped by Köppen-Geiger class, and the class mean (...). Flows in main classes A are comparable to our "non-arid, varying-seasonal, no-snow" reference climates (i.e. centroids 5, 18 & 1). Flows in main class B are comparable to our "arid, non-seasonal, no-snow" reference climates (i.e. 10, 6, 15, 14). Classes C, D and E do not sort regimes well.

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