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The recurrence of unseasonable and rare flood dynamics

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The question whether a certain flood is rare/ unusual or not is often evaluated from the frequency curve analysis (also called growth curve) of flood discharge peaks and their corresponding recurrence interval (return period). Flood discharge peak and maximum depth are some of the hydrological signatures (i.e. an element of hydrograph) and are popular choice for flood risk assessment due to their close relationship with socio-economic impact of flood and often used for damage modeling. However what if our question now is whether the flood process dynamics is rare (influenced by unusual or more driving mechanism, e.g. ice jam, dam break, clogged drain, etc) and especially if hydrological boundary condition is no longer the same as before.

The confinement of flood peaks reduces the information about the flood dynamics inferred by the shape of hydrograph, especially should one be interested to evaluate a rarity/ extremity of a flood process dynamics since flood peak is just one element of a flood hydrograph. Although other indices derived from hydrological signature (e.g. volume, slopes, base flow index, etc) are useful descriptors of a process dynamics, most of them are still either just a part of hydrograph, or derived as an aggregate (e.g. slopes and volume) and therefore unable to provide bigger picture of the flood dynamics and suffer from statistical uncertainty. Furthermore, with singular descriptor from the mentioned, different flood dynamics (i.e. resulted from different processes/ boundary conditions) could be mistaken as the same and might lead to misinterpretation (e.g. snow melt and rainfall triggered runoff may easily share similar flood peak and volume). Moreover, stationarity in season is often assumed in flood frequency analysis, that different flood processes are classified to follow strict calendar month seasons. Such practice could fail to analyze the occurrence of unusual climatic event such as early or late snow melt and unseasonably heavy rainfall in winter.

In this study, we focus on the utilization of hydrological signature to characterize temporal flood event dynamics with the objective to analyze their recurrences and to be able to evaluate if a process dynamic of a certain flood is rare or perhaps unprecedented. We propose using the analysis of phase space trajectories reconstructed through time delay embedding of a time series to characterize different flood events. To allow the visualization and analysis of high embedding dimension (i.e. above 3), we suggest the use of recurrence plot (RP) and quantification (RQA) as similarity measures between the flood dynamics of one event to another and allow non-stationarity occurrence of their typology.