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Linear and nonlinear spatio-temporal dependences of precipitation and river runoffs in a catchment

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Hydro-meteorological processes are characterised by spatio-temporal patterns with distinct correlations in both time and space. Thus, time series of relevant observables such as precipitation and runoff – recorded at different locations – show relevant correlations if these locations are influenced by the same variability patterns (i.e. the same atmospheric regimes) and/or belong to the same catchment. The actual strength and temporal as well as spatial extensions of these correlations depend crucially on the considered variable.

Here, we investigate the significance of the corresponding interrelationships and their possible temporal changes in the presence of changing environmental conditions. For this purpose, a variety of linear as well as nonlinear measures for the statistical dependence between univariate time series is applied to spatial fields of runoff and precipitation records taken from an intermediate-size (about 4.200 km^2) river catchment in Southern Germany [1]. The qualitative behaviour of spatial correlations during extreme weather events is characterised by a variant of the LVD dimension density, a complexity measure for multivariate (or spatially distributed univariate) time series [2,3].

As a further research question, we investigate the mutual interplay between precipitation and runoff for the same catchment. We demonstrate that at the different gauges under consideration, runoffs react to precipitation patterns in the source region with a time delay of 1-3 days, depending on the gauge position and the considered measure of interdependence. Specifically, we find that Hilbert transform based phase synchronisation measures show a clear tendency towards shorter delays, whereas mutual information and event synchronisation [4,5] indicate the strongest interrelationships at somewhat larger delays. The latter observation points to different time scales relevant for weak/moderate and strong precipitation scenarios, respectively, and a temporal clustering of heavy rainfall events. In addition to the obvious dependence on the gauge position, we discuss the relationship of the observed spatio-temporal correlations on further relevant factors such as soil properties and hillslope.

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