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Analysis of long-term catchment data: a nonlinear perspective

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We analyze time series from several forested headwater catchments located adjacent to each other in the Bramke valley, Harz mountains (Germany) which are monitored since decades for hydrology, hydrochemistry and forest growth. The data sets include meteorological variables, runoff rates, streamwater chemical concentrations, and others. The basic temporal resolution is daily for hydrometeorology and two-weekly for streamwater chemistry (in addition, standing biomass of a Norway spruce stand is measured every couple of years).

A model was calibrated and run for the streamflow from one of the catchments, based on precipitation, temperature and (simulated) evapotranspiration of the growing trees, to elucidate the effect of forest growth on catchment hydrology.

The catchments exhibit long-term changes and spatial gradients related to atmospheric deposition, management and changing climate. After providing a short multivariate summary of the dataset, we present several nonlinear metrics suitable to detect and quantify subtle changes and to describe different behavior, both between different variables from the same catchment, as well as for the same variable across catchments. The methods include, but are not limited to: Tarnopolski analysis, permutation entropy and complexity, q- and α -complexities, and Horizontal Visibility Graphs.

The detection of these changes is remarkable, because linear trends have already been removed prior to analysis. Hence, their presence reflects intrinsic changes in the patterns of the time series. The metrics also allow for a detailed model evaluation from a nonlinear perspective.

An important methodological aspect is the temporal resolution of the time series. We investigate the scaling behavior of the nonlinear metrics through aggregation or decimation to coarser resolutions and conclude on what the scaling behavior may imply for inverse (hydrological) modelling tasks.