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Understanding trends and changes in European streamflow and drought: circulation vs precipitation and temperature changes

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As hydrological processes governing streamflow generation are influenced by several climatic variables and most importantly temperature and precipitation, weather and circulation types (CTs) are frequently applied as a simple characterisation of the atmospheric situation. CTs characterise the atmospheric situation of a large region as a single nominal variable. Even though they are typically based on one or few atmospheric variables only, they are usually strongly related to a number of local climatic variables. CTs have, for instance, previously been found useful in studying hydroclimatological processes involved in the development of regional hydrological drought in Europe. In particular air pressure based CTs are an attractive potential tool for the estimation of future changes in streamflow, as larger-scale air pressure and geopotential height data are usually better modelled by general circulation models (GCMs) than local precipitation and temperature (the most important input variables for hydrological models). A prerequisite for this application is, however, that the hydrothermal properties of CTs are stationary or that the possible changes are known. This study assesses the degree to which observed trends in European precipitation, temperature and streamflow can be attributed to circulation changes as opposed to changes in the hydrothermal properties of circulation types (so called within-type changes). Special focus is given to the changes in the frequencies and the hydrothermal properties of drought generating CTs.
CTs are defined in terms of the objective circulation type classification SynopVis Grosswetterlagen (SVG), which defines 29 CTs corresponding to the 29 European Grosswetterlagen by Hess and Brezowsky. Daily CTs for the study period 1964 – 2000 are here assigned based on mean sea level pressure and 500 hPa geopotential height from the ERA-40 reanalysis data. Furthermore, gridded (0.5° x 0.5°) time series of bias-corrected re-analysis precipitation (P) and temperature (T) from the WATCH Forcing Data (eu-watch.org) and daily streamflow series of about 400 small near-natural European catchments are used. These are aggregated into gridded streamflow series (Q) corresponding to the grid cells of the WATCH Forcing Data (resulting in 263 grid cells with Q data).
Trends in monthly CT frequencies as well as mean monthly P, T, and Q data are calculated for each calendar month separately. The ratio of circulation-related vs within-type change in P, T, and Q are determined for the grid cells and months with a significant trend only. The ratios of wet and dry CTs are compared. For each grid cell drought supporting CTs are identified (mean daily $P < 2$ mm) and the observed regional changes in the hydrothermal properties of drought supporting CTs are discussed.