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Modelling hydrological extremes under non-stationary conditions using climate covariates

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Extreme value theory is a probabilistic theory that can interpret the future probabilities of occurrence of extreme events (e.g. extreme precipitation and streamflow) using past observed records. Traditionally, extreme value theory requires the assumption of temporal stationarity. This assumption implies that the historical patterns of recurrence of extreme events are static over time. However, the hydroclimatic system is nonstationary on time scales that are relevant to extreme value analysis, due to human-mediated and natural environmental change. In this study the generalized extreme value (GEV) distribution is used to assess nonstationarity in annual maximum daily rainfall and streamflow timeseries at selected meteorological and hydrometric stations in Greece and Cyprus. The GEV distribution parameters (location, scale, and shape) are specified as functions of time-varying covariates and estimated using the conditional density network (CDN) as proposed by Cannon (2010). The CDN is a probabilistic extension of the multilayer perceptron neural network. Model parameters are estimated via the generalized maximum likelihood (GML) approach using the quasi-Newton BFGS optimization algorithm, and the appropriate GEV-CDN model architecture for the selected meteorological and hydrometric stations is selected by fitting increasingly complicated models and choosing the one that minimizes the Akaike information criterion with small sample size correction. For all case studies in Greece and Cyprus different formulations are tested with combinational cases of stationary and nonstationary parameters of the GEV distribution, linear and non-linear architecture of the CDN and combinations of the input climatic covariates. Climatic indices such as the Southern Oscillation Index (SOI), which describes atmospheric circulation in the eastern tropical pacific related to El Niño Southern Oscillation (ENSO), the Pacific Decadal Oscillation (PDO) index that varies on an interdecadal rather than interannual time scale and the atmospheric circulation patterns as expressed by the North Atlantic Oscillation (NAO) index are used to express the GEV parameters as functions of the covariates. Results show that the nonstationary GEV model can be an efficient tool to take into account the dependencies between extreme value random variables and the temporal evolution of the climate.