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Unbalanced four-way ANOVA for uncertainty analysis of the Standardized Precipitation Index (SPI)

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Drought is a creeping natural phenomenon with highly destructive power, which unfolds its impacts on different temporal and spatial scales. Several studies showed the enormous financial costs droughts are causing. The damages range from e.g. food scarcity, to loss of hydropower and wildfires. To improve monitoring and forecasting systems of droughts, over a hundred drought indices have been developed with different complexity. Some of them can be summarized in Standardized Drought Indices (SDI) as they use similar statistical methodological approaches, like the Standardized Precipitation Index (SPI), the Standardized Streamflow Index (SSI) or the Standardized Precipitation and Evapotranspiration Index (SPEI). Especially the SPI has been applied in a great number of studies. The underlying statistical methods imply several uncertainties, in particular the choice of the probability distribution is frequently discussed in literature. This study attempts to fill the gap of an overall uncertainty assessment of the individual computation methods of the SPI.

For the Austrian study area, 48 meteorological stations with at least 105 years of monthly precipitation data were selected. In the present study, we identified five major uncertainties in the SPI framework – sampling uncertainty, varying sample size, different reference periods, parameter estimation and the choice of distribution. We used a bootstrapping approach to estimate confidence intervals for each source of uncertainty and additionally analyzed the impact of outliers on the SPI values. The overall uncertainty assessment is based on an unbalanced four-way ANOVA that considers 8 distributions, 3 parameter estimation methods, 20 variations of sample size, and 15 different reference periods (7200 combinations) for a sequence of SPI values based on 6 different accumulation periods (k = 1,2,3,6,12 and 24 months). We first analyzed the main effects and, in a supplemental run, we added interactions between the uncertainties to account for possible dependencies between the factors. Results indicate the choice of the distribution as the dominant source of uncertainty and an high overall uncertainty of the SPI. Therefore, the results of drought monitoring and forecasting received by the SPI should be treated carefully.