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Simulating extreme low-discharge events for the Rhine using a stochastic model

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The specific features of hydrological droughts make them more difficult to be analysed than other water-related phenomena: longer time scales (months to several years) so less historical events are available, and the drought severity and associate damage depends on a combination of variables with no clear prevalence (e.g., total water deficit, maximum deficit and duration). As part of drought risk analysis, which aims to provide insight into the variability of hydrological conditions and associated socio-economic impacts, long synthetic time series should therefore be developed.

In this contribution, we increase the length of the available inflow time series using stochastic autoregressive modelling. This enhancement could improve the characterization of the extreme range and can define extreme droughts with similar periods of return but different patterns that can lead to distinctly different damages. The methodology consists of: 1) fitting an autoregressive model (AR, ARMA…) to the available records; 2) generating extended time series (thousands of years); 3) performing a frequency analysis with different characteristic variables (total, deficit, maximum deficit and so on); and 4) selecting extreme drought events associated with different characteristic variables and return periods.

The methodology was applied to the Rhine river discharge at location Lobith, where the Rhine enters The Netherlands. A monthly ARMA(1,1) autoregressive model with seasonally varying parameters was fitted and successfully validated to the historical records available since year 1901. The maximum monthly deficit with respect to a threshold value of 1800 m3/s and the average discharge for a given time span in m3/s were chosen as indicators to identify drought periods. A synthetic series of 10,000 years of discharges was generated using the validated ARMA model. Two time spans were considered in the analysis: the whole calendar year and the half-year period between April and September (the summer half year, where water demands are highest). Frequency analysis was performed for both indicators and time spans for the generated time series and the historical records. The comparison between observed and generated series showed that the ARMA model provides a good reproduction of the maximum deficits and total discharges, especially for the summer half-year period. The resulting synthetic series are therefore considered credible. These synthetic series, with its wealth of information, can then be used as inputs for the damage assessment models, together with information on precipitation deficits, in order to estimate the risk that lower inflows can have on the urban, the agricultural, the shipping sector and so on. This will help in associating economic losses and periods of return, as well as for estimating how droughts with similar periods of return but different patterns can lead to different damages.

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