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Drought probabilities and return period for autocorrelated streamflow series

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Several problems in water resources planning and management require the knowledge of the probability distribution of drought characteristics. The exact derivation of the probabilistic structure of drought characteristics is still an open problem, especially when both duration and accumulated deficit (or intensity) are taken into account. The present work focuses on the derivation of the probability distribution of drought episodes considering both drought duration and accumulated deficit (or intensity) as well as of the ensuing return period, when the underlying hydrological variable is autocorrelated. First, the marginal distribution of drought length is investigated, showing that the simple Markov chain, widely used to model the sequence of deficits and surpluses, is not adequate when the underlying series exhibits a significant autocorrelation. Thus, on the basis of previous studies, a DARMA(1,1) (Discrete Autoregressive Moving Average) model is proposed to better model drought length. Then, the moments of accumulated deficit conditioned on a fixed drought length are derived. It is shown that the deficit series that is obtained by clipping an autocorrelated stationary series with a constant threshold is not i.i.d., and therefore not stationary. Thus, a fully multivariate approach, based on a truncated multivariate normal model, is applied to derive the moments of accumulated deficit as a function of the distribution of the underlying variable and of the threshold. In order to overcome numerical difficulties related to the integration of the multivariate distributions, empirical approximations are also proposed. Such moments are then used to derive approximate expressions of the bivariate distributions of accumulated deficit (or intensity) and length, based on the assumption that the distribution of accumulated deficit conditioned on a fixed length is beta, and expressions to compute the return period of drought events. The proposed procedure is illustrated by applying it to four streamflow data characterized by different levels of autocorrelation and skewness.