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Non-stationary probabilistic characterization of drought events

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Probabilistic characterization of droughts is an essential step for designing and implementing appropriate mitigation strategies. Traditionally, probabilistic characterization of droughts has been carried out assuming stationarity for the underlying hydrological series. In particular, under the stationary framework, probability distributions and moments of hydrological processes are assumed to be invariant with time. However many studies in the past decades have highlighted the presence of non-stationary patterns (such as trends or shifts) in hydrological records, leading to question the stationarity paradigm. Regardless of the causes (either anthropogenic or natural), the need arises to develop new statistical concepts and tools able to deal with such non-stationarity.

In the present work, an analytical framework for deriving probabilities and return periods of droughts, assuming non-stationarity in the underlying hydrological series, is developed. In particular, exact and approximate analytical expressions for the moments and probability distributions of drought characteristics (i.e. length and accumulated deficit), are derived as a function of the non-stationary probability distribution of the hydrological process under investigation, as well as of the threshold level. Furthermore, capitalizing on previous developments suggested in the statistical and climate change literature, the concept of return period is revisited to take into account non-stationarity, as well as the multivariate nature of droughts which requires to consider different characteristics simultaneously.

The derived expressions are applied to several precipitation series in Sicily Italy, exhibiting trends. Results indicate the feasibility of the proposed methodology to compute probabilities and return periods of drought characteristics in a non-stationary context.