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Uncertainty and variability in bivariate modeling of hydrological droughts

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There are two kinds of uncertainty factors in modeling the bivariate distribution of hydrological droughts: the alteration of predefined critical ratios for pooling droughts and excluding minor droughts and the temporal variability of univariate and/or bivariate characteristics of droughts due to the impact of human activities. Daily flow data covering a period of 56 hydrological years from two gauging stations from a humid region in South China are used. The influences of alterations of threshold values of flow and critical ratios of pooling droughts and excluding minor droughts on drought properties are analyzed. Six conventional univariate models and three Archimedean copulas are employed to fit the marginal and joint distributions of drought properties, the Kolmogorov–Smirnov and Anderson–Darling methods are used for testing the goodness-of-fit of the univariate model, and the Cramer-von Mises method based on Rosenblatt's transform is applied for the test of the bivariate model. The change point analysis of the copula parameter of bivariate distribution of droughts is first made. Results demonstrate that both the statistical characteristics of each drought property and their bivariate joint distributions are sensitive to the critical ratio of excluding minor droughts. A model can be selected to fit the marginal distribution for drought deficit volume or maximum deficit, but it is not determined for drought duration with the lower ratios of the pooling and excluding droughts. The statistical uncertainty of drought duration makes the modeling of bivariate joint distribution of drought duration and deficit volume or of drought duration and maximum deficit undermined. Change points significantly occurred in the period from the late 1970s to the middle 1980s for a single drought property and the copula parameter of their joint distribution due to the impact of human activities. The difference between two subseries separated by the change point is remarkable in the magnitudes of drought properties and the joint return periods. A copula function can be selected to optimally fit the bivariate distribution, provided that the critical ratios of pooling and excluding droughts are great enough such as the optimal value of 0.4 in the case study. It is valuable that the modeling and designing of the bivariate joint correlation and distribution of drought properties can be performed on the subseries separated by the change point of the copula parameter.