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Entropy and multi-objective method based optimization for hydrometric network

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Hydrometric information, which is mainly collected by monitoring networks, constitutes the hydrologic time series with temporal and spatial variability. Analysis of randomness, fuzziness, nonstationarity and nonlinearity relating to the series can be conducted with the information collected. A well-designed hydrologic network can reflect the spatial-temporal variability of hydrologic variables adequately at catchment scale and reveal the hydrologic regularities systematically and precisely. Hydrologic network optimization requires a minimum number of sites to gather abundant and accurate information. In this study, a multi-objective optimization model based on entropy theory for hydrologic networks was established. Firstly, based on the information entropy theory, the sites were sorted under the principle of the maximum total information and the minimum mutual information and a new series is formed. Then different number of sites composed several sites' combinations. Secondly, in order to evaluate the information carrying capacity of these combinations, an objective function composed of joint entropy percentage, average mutual information and Nash-Sutcliffe Efficiency Coefficient (NSC) was constructed, which is the core of the network optimization model. Finally, based on the multi-objective decision-making method, a Pareto solution set was determined and an optimum solution was chosen through the ideal point method. Taking the monthly runoff data of the Yiluo River—a tributary of the Yellow River—as a sample, this study analyzed the utility of the hydrologic network of the Yiluo River Basin. Results show that the network of the Yiluo River contains overlapped information, and can be optimized by removing redundant sites. The optimized hydrologic network still provides sufficient information, which is over 95% of the previous network, but the cost of network construction and maintenance is reduced due to the reduction of sites. As a result, the network's utility is maximized. The model proposed in this study constructed a multi-objective function which took three targets into account and integrated the function with multi-objective decision making method. The three targets—joint entropy percentage, average mutual information and NSC evaluate the information carrying capacity of the sites combination from three aspects respectively, which include the total information, the overlapped information and the residual of the hydrologic time series. This model based on entropy meets the requirement of quantitative analysis of information. Multi-objective optimization applies to finding a network optimization solution under multiple objectives. After practical example validating, the model is proved effective and rational. As the fundamental unit for collecting hydrometric data, optimized networks will provide more reasonable information that reflects the temporal and spatial variability of the hydrologic time series and will play an important role in water resources management and policy-making