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Optimization of rainfall network based on information entropy theory and its spatio-temporal nonstationarity

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Nonstationarity exists widely in a variety of time series in natural process, and hydrological time series is one of them. As observational records in hydrology are assumed to be a realization of stochastic processes, the information of nonstationarity in hydrological variables, such as precipitation, evaporation and streamflows, reflects regular pattern in changes of driven mechanism inside the system. Annual fluctuations of hydrological variables, such as rainfall, reflect meteorological and hydrological characteristics of the region to a certain extent. As the most important and direct sources of precipitation data, the optimization of regional rainfall network is an important topic. Information entropy theory has been used widely in hydrology science because of quantification of uncertainty in random variables. Information entropy as a measuring approach, can not only represent inner uncertainty of rainfall distribution, but also well reflect the correlation and information transmission between rainfall stations, as well as nonstationarity characteristics in the regional rainfall process. Taihu Lake basin is one of the highly developed areas in Yangtze River Delta region in China. The west region of Taihu Lake basin is a typical area influenced by subtropical monsoon climate, with hilly area covering the southern part and plain area covering the northern part. Rainfall characteristics study of this area is particularly valuable and important for reasonable utilization and planning of water resources, as well as efficient hydrological forecasting under changing environment. By using information entropy as a measure of uncertainty of the rainfall distribution, we investigate the differences in information content that each rainfall station contains under different sampling intervals. Also, fluctuations in the information entropy of each rainfall station, with different start dates of different time windows under the same sampling interval are studied, to investigate nonstationarity in the information content of rainfall stations under small time scale, e.g., annual rainfall process. At the same time, we use the modified MIMR greedy ranking algorithm, which is based on the criterion of maximum information and minimum redundancy, to evaluate the importance of the regional rainfall stations. It is found that nonstationarity caused by sampling frequency has a corresponding impact on the optimization results. Additionally, the fluctuations in the hilly and plain area are also different. Through the discussion on the temporal and spatial distribution and optimization of rainfall network based on information entropy theory, we can conclude that geomorphological conditions should be considered during spatial optimization of rainfall network; meanwhile, in respect of temporal optimization, we investigate nonstationarity during annual precipitation process of rainfall stations using sliding time windows with different window widths. Also, we can find that information content of each site changes within different hydrological periods. In general, the evaluation of information content and rankings of importance for all stations based on sliding time windows not only consider nonstationarity in the entropy calculation of precipitation distribution for different time intervals, but will also provide reference for the choice of sampling frequency for rainfall network. Nonstationarity in the annual rainfall process, geographical characteristics of watershed and seasonal variability should be taken into account in the optimal design of rainfall network.