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Optimization of hydrological parameters of a distributed runoff model based on multiple flood events

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The error sources of flood forecasting by a runoff model commonly include input data, model structures, and parameter settings. This study focused on a calibration procedure to minimize errors due to parameter settings. Although many studies have been done on hydrological parameter optimization, they are mostly about individual optimization cases applying a specific optimization technique to a specific flood. Consequently, it is difficult to determine the most appropriate parameter set to make forecasts on future floods, because optimized parameter sets vary by flood type. Thus, this study aimed to develop a comprehensive method for optimizing hydrological parameters of a distributed runoff model for future flood forecasting.

A distributed runoff model, PWRI-DHM, was applied to the Gokase River basin of 1,820km2 in Japan in this study. The model with gridded two-layer tanks for the entire target river basin includes hydrological parameters, such as hydraulic conductivity, surface roughness and runoff coefficient, which are set according to land-use and soil-type distributions. Global data sets, e.g., Global Map and DSMW (Digital Soil Map of the World), were employed as input data such as elevation, land use and soil type. Thirteen optimization algorithms such as GA, PSO and DEA were carefully selected from seventy-four open-source algorithms available for public use. These algorithms were used with three error assessment functions to calibrate the parameters of the model to each of fifteen past floods in the predetermined search range. Fifteen optimized parameter sets corresponding to the fifteen past floods were determined by selecting the best sets from the calibration results in terms of reproducible accuracy. This process helped eliminate bias due to type of optimization algorithms.

Although the calibration results of each parameter were widely distributed in the search range, statistical significance was found in comparisons between the optimized parameters and the flood runoff characteristics. Particularly, the comparisons between runoff coefficient and runoff rate and between runoff coefficient and API (Antecedent Precipitation Index) showed a significant correlation. It is inferred that the significance in correlation between runoff coefficient and API is due to the initial water level of the lower tank applied as a common value in this study.

The predictive accuracy of the optimized parameter sets was also validated by applying them to an additional ten floods. The fifteen optimized parameter sets were classified into three categories, i.e. Low, Middle and High, in terms of flood runoff rate, because flood discharges forecasted by using the fifteen parameter sets showed a wide variation. Comparisons between the averages of the forecasted discharges in each category and the observed discharges of the ten floods showed the effectiveness of the classification based on flood runoff rate. The discharges forecasted by using the parameter sets in each category matched the observed discharges with high accuracy when they were applied to similar cases among the ten floods in terms of runoff rate. The results of this study suggested the possibility of improved future flood forecasting based on categorization of flood by runoff rate.