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Estimation of a small number of combinations of parameter sets to describe multiple hydrographs by combinatorial optimization

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A novel procedure is introduced to estimate a small number of combinations of parameter sets for describing multiple hydrographs through combinatorial optimization, and an optimization result is presented to explain twenty-seven hydrographs with eight combinations of parameter sets of a distributed hydrological model.

An interesting approach is to make a small number of groups of discharges and estimate the parameter sets for such groups of discharges. To realize this approach through mathematical optimization, the constraint conditions and objective function need to be clarified. In order to use this procedure for the prevention and mitigation of floods, the parameters for estimating the discharges should satisfy the following two constraints: the estimated maximum discharge should be between the maximum observed discharge and the maximum with a certain tolerance; the discharge should be overestimated when there is an increase in the observed discharge. An objective function is used to minimize the sum of the mean squared error between the observed and simulated discharges of the multiple hydrographs with a penalty for not underestimating the duration of the floods. Increasing the number of groups and executing the optimization calculation reveals the minimum number of groups needed to estimate the multiple hydrographs.

The effectiveness of the proposed optimization procedure is examined using twenty-seven hydrographs observed in the Abe River basin in Japan. The hydrographs are comprised of the observed discharges from nine flood events and three water level stations, namely Ushizuma, Tegoshi, and Narama. The discharges are calculated with a PWRI distributed hydrological model. The parameters include final infiltration rate, roughness coefficient, runoff coefficients of slow saturated flow and base flow, and initial water levels of the surface and aquifer tanks. The initial water levels of the tanks considerably affect the overestimation of discharges. Therefore, 10,001 combinations of the parameters are uniformly sampled for each from five different settings of initial water levels of the surface and aquifer tanks {(0 cm, 1 m), (0 cm, 2 m), (1 cm, 1 m), (1 cm, 2 m), and uniform sampling}. Thus, the discharges for 50,005 combinations of parameter sets are calculated for the combinatorial optimization.

The optimization result is summarized as follows. The parameter sets {A, B, C, D, E, F, G, H} estimate the groups of hydrographs {(U3,U8), (U4,T4,U5,U7), (N3,N9), (N4,N6,N8), (T1,N1,N2,T3,T5,T8,U9), (T6,T9), (U1,U2,N5), (T2,U6,T7,N7)}. U, T, and N denote the water level stations Ushizuma, Tegoshi, and Narama, respectively, and the numbers from 1 to 9 denote the flood events. Parameter set E estimates as many as seven hydrographs, and is recognized as the most common. Parameter sets A, F, and (C, D) only estimate the hydrographs observed at the water level stations Ushizuma, Tegoshi, and Narama respectively. The advantages of the proposed optimization procedure are as follows: it provides the number of combinations of parameter sets needed to estimate multiple hydrographs, it shows the correspondence between the parameter sets and groups of multiple hydrographs, and it provides valuable information to understand the relationship among the parameters, flood events, and water level stations.