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Addressing Identifiability and Equifinality in Calibration of a Distributed Rainfall-Runoff Model Using Genetic Algorithms

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Abstract

Conceptual rainfall-runoff models have been widely applied in hydrological modeling, while their parameters are estimated through calibration against observed data. The purpose of identifiability analysis in calibration is the identification of the model structure and a corresponding parameter set that are most representative of the catchment under investigation. A genetic algorithm is applied to calibrate rainfall-runoff process in WetSpa model. Identifiability of the model parameters is investigated through comparison between different parameter sets obtained through 10 different runs (populations) and also along a single run, employing equifinality concept. Variability of optimum parameter sets within different obtained best solutions serves as a measure to assess parameters identifiability. The obtained results revealed appropriate model efficiency to simulate streamflows in the case study. Moreover, based on the identifiability results, it was concluded that some of model parameters are better definable than others. More advanced approaches for calibration such as multi-population search methods may serve to improve identifiability of the parameters.

Keywords: Rainfall-runoff, Genetic Algorithm, Optimization, Identifiability, Equifinality.

1. INTRODUCTION

Computer-based, conceptual rainfall-runoff models have been widely applied in hydrological modeling since they were first introduced in the late 1960s and early 1970s. They range from lumped models to distributed ones of which the latter describe the catchment more precisely. However, it is not generally possible, even in distributed models, to determine all the. Thus, the final parameter estimation must be performed by calibration against observed data where the model parameters are adjusted so that the model outputs match as closely as possible to measurements. In recent years, several automatic global search algorithms have been developed that are especially designed for locating the global optimum on a response surface (Duan et al., 1992). Popular global search methods are the population-evolution-based optimization algorithms such as, amongst others, genetic algorithms (GAs) (Wang, 1991), shuffled complex evolution (SCE) (Duan et al., 1992), and simulated annealing (Sumner et al., 1997). A large number of studies have been conducted that compare different automatic algorithms for calibration of rainfall-runoff models (e.g. Kuczera, 1997; Franchini et al., 1998). The main conclusion from these studies is that the global population-evolution-based algorithms are more effective than multi-start local search procedures, which in turn perform better than pure local search methods.

The purpose of identifiability analysis in conceptual rainfall-runoff modeling is the identification of the model structure and a corresponding parameter set that are most representative of the catchment under investigation, while considering aspects such as modeling objectives and available data (Wagener et al., 2001). For a particular model structure, estimation of a suitable parameter set, i.e. the actual calibration of the model structure, is an important stage in the model identification process. Practically, through parameters identifiability analysis, it is supposed to show how uniquely the optimum parameter sets can be located within the feasible parameters space.

The issue of “equifinality”, suggested in the literature (Beven, 1993), indicates different parameter sets within the model structure can be equally acceptable in reproducing behavior of the system. Based on this concept, Beven and Binley (1992) proposed the Generalized Likelihood Uncertainty Estimation (GLUE) methodology whereby parameter uncertainty is assessed based on determination of a set of good (behavioral) models, not a single one. Considering equifinality would enable us to get an insight into the level of identifiability of the parameters, as well. Wagener et al. (2001) have extended the GLUE method to deal with parameter identifiability analysis. As a rule of thumb, lower level of equifinality (i.e. lower unmber of