# Assessing model calibration adequacy via global optimisation

**JG Ndiritu[1]* and TM Daniell[2]**

[1] *Civil Engineering Department, University of Durban-Westville, Private Bag X54001, Durban 4000, South Africa*
[2] *Civil and Environmental Engineering Department, University of Adelaide, SA 5005, Australia*

## Abstract

An assessment of the application of varying levels of optimisation on model simulation performance and parameter identification was done using the genetic algorithm (GA) and a 10-parameter version of the MODHYDROLOG rainfall-runoff model. Four levels of optimisation were obtained through the use of two GA formulations, the traditional and an improved GA, and by varying the optimisation parameters with each formulation. Sixteen years of data from a 27 km$^2$ Australian catchment was used. With each level, ten randomly initialised optimisation runs were made. The differences in simulation performance quantified by the coefficient of efficiency, bias, absolute deviation and a residual mass curve coefficient were not considerable although the performance improved as the level of optimisation effort increased. Superior parameter identification, and consequently a better detection of parameter correlations was achieved with the higher optimisation levels. Based on the objective function values, the highest level of optimisation practically located the global optimum in all the ten runs. The second level achieved this in nine of the ten runs while the lower two levels did not locate the global optimum in any of the ten runs. It is proposed that the systematic verification of the adequacy of optimisation should be an integral part of model calibration exercises. The form of verification should depend on the specific problem at hand.

## Introduction

The rainfall-runoff process is the component of the hydrological cycle involving the time-space conversion of precipitation into runoff on land. The process is very complex considering the large number of factors involved and their variability. Rainfall-runoff models idealise the rainfall-runoff process to varying degrees and in various forms. A plethora of rainfall-runoff models exist with Wheater et al. (1993) putting the number into the hundreds. Some of the applications of rainfall-runoff modelling include:

- Creating, extending or filling in missing runoff data for water resources assessments
- Flood peak estimation and flood forecasting
- Investigating the hydrological and water quality impacts of land use and climate change on catchments
- Studying and modelling specific processes in the catchment such as sedimentation.

A common mode of classification based on model complexity, groups rainfall-runoff models into: empirical, conceptual and process models (Grayson and Chiew, 1994, Wheater et al., 1993). Empirical models mimic the rainfall-runoff process to a slight degree while conceptual models mimic the processes more closely by using interconnected storages and simple equations to represent the water movement among them.

Empirical and conceptual rainfall-runoff models are not designed to use parameters that are directly measurable in the field and their parameters are usually obtained by calibration. Process models, most of which are distributed, were initially designed and intended to represent the physical processes closely enough to enable the use of measurable parameters only. Inadequacy of data and model imperfections have, however, been found to limit the application of process models in this ‘ideal’ manner and process model applications invariably include some form of calibration (Refsgaard and Knudsen, 1996; Refsgaard, 1997; Western et al., 1997; Demetriou and Panthakey, 1997).

Calibration is the determination of a parameter set that gives a simulated hydrological or hydrochemical series that adequately matches the observed series. It is fundamentally an iterative process involving:

i) The simulation/s using (a) parameter set/s from the search space to obtain the model performance/s.
ii) The determination of (a) parameter set/s that is/are likely to perform better than that/those used in the previous simulation/s; and simulation/s using the new parameter set/s.
iii) The repetition of step (ii) until a satisfactory performance is obtained or until further improvements are negligible.

During calibration, the performance is quantified by an objective function. Some commonly used coefficients to quantify the quality of the simulated series are the coefficient of determination and the bias. Graphical plots such as hydrograph and scatter plots are also applied often. The three steps of the process could be undertaken manually or automatically using an optimisation method. Effective automatic methods are preferable to manual methods as they give a better chance of obtaining superior parameter sets. However, where a modeller is adequately experienced with a given model, manual calibration could suffice. This publication deals with automatic calibration methods.

While research on model calibration has been active for decades, most of the studies have focused on the location of the global optimum and/or the efficiency at which this is achieved (Johnston and Pilgrim, 1976; Duan et al., 1992; Bates, 1994; Tanakamaru and Burges, 1996; Kuczera, 1997). Gan and Biftu (1996) included the simulation performance in validation providing a notable exception to this trend.

* To whom all correspondence should be addressed.
☎(031) 204-4749; fax (031) 204-4291; e-mail jndiritu@dixie.udw.ac.za
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