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An approach using distributed data for the calibration of MIKESHE model

S.-T. Khu (1), and H. Madsen (2)

1. Centre for Water Systems, School of Engineering, Computer Science and Mathematics, University of Exeter, North Park Road, UK EX4 4QF. s.t.khu@ex.ac.uk
2. DHI Water and Environment. Denmark. hem@dhi.dk

In simple terms, hydrologic models are mathematical representations of complex hydrological behaviour within a catchment and whether the model is conceptually simple: such as the rational method, linear reservoir model or NAM model; or complex: such as the MIKE-SHE fully distributed model; is no exception. Thus, it must be realised that parameter estimation is an essential step for the hydrologic model to simulate the catchment response. Within the context of parameter estimation, methods such as field observations and a priori estimation through literature survey may be used, and calibration through optimisation is employed especially when field measurements are available.

Madsen (2003) proposed a multi-objective framework for the automatic calibration of a distributed hydrologic catchment model, MIKE-SHE. The automatic calibration scheme involves optimisation of numerical measures (objective functions) that compare observations of the state of the system with corresponding simulated values. In a multi-objective context, model calibration can, in general, be performed on the basis of:

- Multi-variable measurements, i.e. groundwater level, river runoff and water content in the unsaturated zone;
- Multi-site measurements, i.e. several measurement sites distributed within the catchment;

- Multi-response modes, i.e. objective functions that measure various responses of the hydrological processes such as e.g. the general water balance, peak flows, and low flows.

A further justification of adopting the multi-objective approach is that it allows the model results to be incorporated into a multi-criteria decision making framework. The resultant output of the multi-objective calibration is some form of Pareto trade-off curve between different objective functions, and each combination of objective functions is a possible choice for the modeler or decision maker.

This paper proposed an approach to incorporate both multi-variable and multi-site measurements within a fully multi-objective calibration framework: each set of measurements should be considered independently when performing calibration and different objective functions can be formulated for each set of measurements. The proposed method thus consists of 2 steps:

1. Classification of multi-site measurements into groups according to temporal dynamics using an artificial neural networks (ANN); and

2. Multi-objective calibration using an optimization technique known as multi-objective genetic algorithm (MOGA) which can handle more than three objective functions without the need to resort to aggregation.

Grouping of measurement sets is both crucial and pragmatic: there may be instants where the number of observation sites far exceeds the length of observation records, and considering each set of measurements separately makes the problem intractable; and some of these observations may be closely related to each other (such as groundwater observations from different wells) and this dependency will reduce the amount of information available for calibration. However, this dependency is a useful characteristic that can be exploited for grouping.

The proposed calibration approach was used to calibrate the MIKE-SHE model and applied to a Danish Karup catchment. The available measurements consist of groundwater level data sampled every two weeks from 35 locations in the catchment and daily discharge data from four stations in the river system, including the runoff at the catchment outlet. For calibration, groundwater level data from 17 wells as well as runoff data from the catchment outlet are used. An artificial neural network was used to divide the 17 wells into 5 distinctive groups according to the observed water level fluctuations. Therefore, six objective functions, one for each group of wells and the 6^{th} for discharge measurements, were formulated. The objective functions were defined as standard deviations between the observed and the simulated quantities for each time-step. All the 6 objective functions were optimized simultaneously using a multi-objective genetic algorithm known as preference ordered genetic algorithm (POGA) (di Pierro, et al., 2004)

The results obtained were very encouraging in that both the dynamics and bias in the ground water level observations can be modeled better compared to Madsen (2003). This is due to the successful classification of the groundwater dynamics using ANN without which it would not be possible to perform optimization for all distributed data. At the same time, the multi-objective approach provides the modeler a choice of calibrated parameter sets that the modeler can select based on other considerations.

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Reference:

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