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Genetic algorithm applied to a Soil-Vegetation-Atmosphere system: Calibration and model abstraction

Sébastien Schneider, Diederik Jacques, and Dirk Mallants
SCK•CEN, EHS, Mol, Belgium (sschneid@sckcen.be)

To model complex hydrological problems, realistic models and representative hydraulic properties are needed. In this study we investigate the ability of two different types of process description for water flow to quantify the water balance in a Soil-Vegetation-Atmosphere (SVA) system. A first model description is based on the Richards' equation for which the mechanistic numerical model HYDRUS-1D is used. The second model description is a compartment model assuming a bucket-type water flow process. We present calibrations of these two models performed for a SVA system developed in a podzol soil with Scots Pine vegetation. Due to a high non-linearity of the calibration problem, an efficient optimization technique is needed. Therefore a genetic algorithm, which belongs to the so-called evolutionary algorithms class, was used in this study.
Aim of this work is both (i) calibrating the SVA system and (ii) testing abstraction techniques. Examples of both parameter and model structure abstraction will be presented.
Calibrations of the soil hydraulic properties have been obtained using soil water content data collected at several depths with time domain reflectometry probes in two distinct lysimeters. All climatic data (throughfall and other meteorological data necessary for estimating the potential evaporation) and water contents at different soil depths have been recorded during one year at a daily time step in two lysimeters. The water table level, which is varying between 95 and 170 cm, has been recorded with intervals of 0.5 hour. The leaf area index was measured as well in order to evaluate the energy which reaches the soil and to deduce the potential evaporation.
Ten scenarios have been elaborated and applied on the two lysimeters in order to investigate the impact of both the water balance process description (mechanistic or compartmental) and the number of horizons used for the profile description, on the calibration accuracy. Main results are that: (i) both model process descriptions are able to describe accurately the measured water contents at all depths when a high number of soil horizon was used, (ii) the mechanistic model performs better than the compartment model, (iii) the considered number of soil horizons is the major factor that controls the accuracy of the calibration.
Finally, the compartment model is considered as an abstracted model from the reference model based on the mechanistic model. For instance, yearly drainage values predicted by both models are used to evaluate the performance of the abstracted model. It appears that drainages values simulated by the abstracted model were close to those of the reference model, provided that drainage values were averaged over a sufficiently large period (about 9 months). Therefore, this result suggests that values of drainage obtained with an abstracted model could be reliably simulated for sufficiently long time periods, with a significant gain in computational time compared to the mechanistic approach, and without an important loss of accuracy.