Geophysical Research Abstracts
Vol. 21, EGU2019-12715, 2019
EGU General Assembly 2019

Automatic Model Structure Identification: Using Mixed-Integer Calibration for Model Development

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Choosing the right model (structure) for a given purpose, catchment, and data situation is a critical task in the modeling chain. However, despite model intercomparison studies, hypothesis testing approaches with flexible modelling frameworks, and continuous efforts in model development/improvement, there are still no clear guidelines for choosing an optimal model structure.

We introduce a framework for Automatic Model Structure Identification (AMSI) based on the combination of the flexible hydrological model Raven and the heuristic global optimization algorithm DDS. It is the first demonstration of mixed-integer optimization algorithms to simultaneously optimize model structure choices (integer decision variables) and parameter values (continuous decision variables) in hydrologic modelling. Thus, AMSI is able to sift through a vast number of combinations for a given model and parameter space in order to identify the most suitable model structure for representing the rainfall runoff behavior of a catchment.
We demonstrate the feasibility of the approach by re-identifying model structures that produced a certain discharge time series and show the limits of the current setup via two real world examples. A first version of AMSI allows two coupled soil storages and 10 different processes (e.g. Infiltration, Percolation, etc.) with variable process descriptions (e.g. three alternatives for describing infiltration). Thus AMSI currently contains 3200 different model structure combinations with the number of parameters varying from 2 to 8. Calibrating against observed discharge identifies not only the most appropriate structure but also infers parameter values for the given structure.

Results show that the AMSI framework is feasible to infer a correct model structure. However, it is a complex optimization problem to identify model structure and parameters simultaneously. The variance in the identified structures is high due to near equivalent diagnostic measures for multiple model structures, reflecting substantial model equifinality. Future work with AMSI should consider revised calibration formulations utilizing hydrologic signatures, case studies with multiple types of system response data and thus, mixed integer multiobjective optimization algorithms.