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Development of an integrated modelling framework: comparing client-server and demand-driven control flow for model execution

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The construction of hydrological models at the catchment or global scale depends on the integration of component models representing various environmental processes, often operating at different spatial and temporal discretisations. A flexible construction of spatio-temporal model components, a means to specify aggregation or disaggregation to bridge discretisation discrepancies, ease of coupling these into complex integrated models, and support for stochastic modelling and the assessment of model outputs are the desired functionalities for the development of integrated models. These functionalities are preferably combined into one modelling framework such that domain specialists can perform exploratory model development without the need to change their working environment.

We implemented an integrated modelling framework in the Python programming language, providing support for 1) model construction and 2) model execution. The framework enables modellers to represent spatio-temporal processes or to specify spatio-temporal (dis)aggregation with map algebra operations provided by the PCRaster library. Model algebra operations can be used by the modeller to specify the exchange of data and therefore the coupling of components. The framework determines the control flow for the ordered execution based on the time steps and couplings of the model components given by the modeller. We implemented two different control flow mechanisms. First, a client-server approach is used with a central entity controlling the execution of the component models and steering the data exchange. Second, a demand-driven approach is used that triggers the execution of a component model when data is requested by a coupled component model.

We show that both control flow mechanisms allow for the execution of stochastic, multi-scale integrated models. We examine the implications of each control flow mechanism on the terminology used by the modeller to specify integrated models, and illustrate the applicability of both approaches by constructing integrated models from components simulating hydrological processes, land use change or biomass growth.

The PCRaster software runs on Microsoft Windows, Linux and OS X. More information about the integrated modelling prototypes and download of the PCRaster software collection is available at http://www.pcraster.eu/.