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Computationally efficient and flexible modular modelling approach for river and urban drainage systems based on surrogate conceptual models

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Water managers rely increasingly on mathematical simulation models that represent individual parts of the water system, such as the river, sewer system or waste water treatment plant. The current evolution towards integral water management requires the integration of these distinct components, leading to an increased model scale and scope. Besides this growing model complexity, certain applications gained interest and importance, such as uncertainty and sensitivity analyses, auto-calibration of models and real time control. All these applications share the need for models with a very limited calculation time, either for performing a large number of simulations, or a long term simulation followed by a statistical post-processing of the results.

The use of the commonly applied detailed models that solve (part of) the de Saint-Venant equations is infeasible for these applications or such integrated modelling due to several reasons, of which a too long simulation time and the inability to couple submodels made in different software environments are the main ones. Instead, practitioners must use simplified models for these purposes. These models are characterized by empirical relationships and sacrifice model detail and accuracy for increased computational efficiency. The presented research discusses the development of a flexible integral modelling platform that complies with the following three key requirements:

(1) Include a modelling approach for water quantity predictions for rivers, floodplains, sewer systems and rainfall runoff routing that require a minimal calculation time;
(2) A fast and semi-automatic model configuration, thereby making maximum use of data of existing detailed models and measurements;
(3) Have a calculation scheme based on open source code to allow for future extensions or the coupling with other models.

First, a novel and flexible modular modelling approach based on the storage cell concept was developed. This approach divides each subcomponent, such as the river, sewer of floodplain, in an arrangement of interconnected cells, thereby lumping processes in space and time. Depending on the behaviour of the system that needs to be emulated and the desired level of accuracy, variables of interest can be predicted by adopting and calibrating one of the predefined model structures, such as weir equations, transfer functions (Wolfs et al., 2013) and self-learning structures including neural networks, model trees and fuzzy systems (Wolfs and Willems, 2013, 2014). Next, a software tool was developed to facilitate and speed-up model configuration. A close integration is foreseen with the MIKE (DHI) and InfoWorks (Innovyze) software. The created software tool also automatically sets up the calculation scheme in C programming language.

The developed modelling approach and software were tested extensively on multiple case studies, including uncertainty flood mapping along a river, real time control of hydraulic structures to prevent flooding, and the quantification of the effect on floods of retention basins in a coupled sewer-river system (De Vleeschauwer et al., 2014). Research is currently being done on the extension of the modelling approach and accompanying software tool with physicochemical water quality modules.

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