

Staggered Coupled Simulation of Urban Precipitation Events using BASEMENT, SWMM and OpenGeoSys

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Hydrological and hydraulic processes in urban areas exhibit special dynamics, especially in their joint interactions. An effective, integrative modeling of multiple processes at once is difficult, particularly due to spatiotemporally varying boundary conditions. Different disciplines, application purposes or user groups use strongly specialized tools and software to model, simulate and evaluate these processes. The hydronumerical models and simulations are often independent, but typically make use of the same boundary conditions and fundamental data (e.g. DEM, land-use, weather data). A subgoal of the “WetUrban” research project was the development of a methodology and tools for integrating multiple hydrological and hydrodynamical processes into a digital city platform. Therefore, a procedure for semi-automated model generation and a framework to execute staggered, coupled simulations were developed. A circa 35 km² study area within the city of Dresden was chosen for testing the developed tools. The study area includes a broad range of boundary conditions such as urbanization, infrastructure, vegetation, and groundwater levels.

Targeting a semi-automated model generation, we built upon free (and open) software and tools only. Requirements included publically modifiable model definitions and externally executable simulations. Therefore, this work includes a three-way coupling of the hydraulic processes surface runoff with BASEMENT, sewage system with SWMM and groundwater with OpenGeoSys, using the same unified data source as a common base. The core element is a Python based framework, consisting of the stages preprocessing, model generation, simulation loop and postprocessing. Each integrated hydraulic process is interconnected and exchanges boundary conditions via multiple means (e. g. manholes, catchments, infiltration/exfiltration, pipe leakage) at a definable interval. The staggered coupling approach thereby allows each model to run independently and isolated from each other. Field experts can adjust and fine tune their specialized models individually. In the staggered loop, models are altered and re-generated per discretized timestep, taking the current state of other coupled models into account by using common data interfaces and processing methods. After all simulations finish, the results are combined and merged into new datasets suitable for evaluation and further processed for 3D rendering. Noteworthy features of the BASEMENT support include: programmatical adjustment and manipulation the model definition file, auto-generation of unique, multi-criteria material ids (dynamic manhole sinks / source), discretization of simulations, results manipulation (infiltration / exfiltration) and mesh handling (e.g. element lookup with kd-trees, fast shape-based material intersection).

Additional further processes (e. g. water quality, pollutant transport, evaporation, wind effects, interception) may be integrated in future iterations using a plugin-like system and define their own coupling mechanisms. The developed toolset is publicly available and is continuously being worked on.