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Very high resolution flash flood simulation for urban areas based on a fully coupled modeling concept

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Flash Floods have become a significant source of hazard for our communities due to expansion of urban areas, increased sealing of the surface and increased rainfall intensity in the last 15 years. The development of a sustainable and decentralized surface water management requires a dedicated modeling effort that involves the whole catchment area of the urban regions as well as the surface and subsurface drainage such as small creeks, channels and sewage systems. Beside the surface structures, which are discretely represented in the model and where the hydrodynamic processes are fully resolved, it needs the proper representation of hydraulic structures that are not resolved within the conservation equations and rather represented by integral hydrodynamic formula.

In order to fulfill the above demands a coupled model was developed, which involves a SWE equations solver, which is fully parallelized based on domain decomposition methods and a sewage solver that solves unsteady Bernoulli and continuum equations. Both models are two way coupled allowing surface waters entering the sewage systems as well as exiting via manholes or hydraulic structures. The shallow water equations are solved using a residual distribution scheme on unstructured triangular grids. The scheme has been proved (both theoretically and in practice): second order in space and time and well balanced; to conserve both momentum and mass; to preserve the water depth non-negativity.

As a field case we chose the city of Worms, which is located at the Rhine river in central Germany. The catchment area involves an area of 110km^2. The resolution of the model is ranging from 10m down to 0.1m in the urban region. In this region we have more than 14000 man holes and 12000 walls, 50 km of drainage channels, 150 km of sewage channels, which are inter-connected by more than 100 hydraulic structures. Houses and streets are fully discretized within the model and taken from the city land register database of the municipality. In total the model is resolved using more than 14 million triangular elements, which are adaptively distributed by an iterative process based on apriori error estimates derived from bottom gradients and geometric constrains defined by the above mentioned structures.

The results obtained for the different regions of the city have been presented to the population during an audition raising in this way awareness in the population and cross validation of the results based on the historic experience in the neighborhood of the flooding regions. Based on the results decentralized measures are being derived with the aim of retention of the water masses and this way delayed run-off in order to reduce the peak of the run-off and keep the water in regions, where no hazards to the population are anticipated.

This effort resulted for the City of Worms to one of the most comprehensive surface and sub-surface models that allows now for a sustainable development and surface water management in a changing climate system.