A spatially adaptative multi-resolution generative algorithm: application for urban flood risk assessment

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Abstract

To assess urban flood hazards, flow variables may be simulated by 2D hydraulic models that solve the so-called shallow-water equations on high-resolution meshes. Hazard indicators such as water depth and unit discharge norm can be derived from these simulated flow variables. However, the computation times of these simulations are such that these models cannot be included into operational prevention and alert systems.

To speed up the simulation times and cover operational demands, we propose a novel and extended version of an adaptive multi-resolution wavelet decomposition arising from the lifting scheme. The decomposition proceeds with stages of decreasing resolution. At each stage, the data is split into two groups. The first group contains elements that are kept for the subsequent stage and represent a smoother version of the initial signal (low-pass filter). The second group contains elements that are put aside in the following stages and represent the details of the signal or wavelet coefficients (high-pass filter). As the lifting scheme has been developed for 1D or 2D signals, we propose an extension to the spatio-temporal framework suitable for the flow variables mentioned above. Each element is a time series associated with a given location instead of a single pixel in the case of images. In addition, we introduce a clustering step that helps reducing the magnitude of the wavelet coefficients. We derive a representation of the high-resolution field based on the retained elements of the last stage and the wavelet coefficients at all the stages as these can be used to reconstruct the original high-resolution field by reversing the steps of the lifting scheme. Then, we propose a downscaling algorithm that seeks to estimate the representation of the high-resolution field derived from the lifting scheme based on upscaled simulations. These upscaled simulations can be obtained from 2D hydraulic models that run on coarser meshes and whose computation times are reduced by several order of magnitudes with respect to the high-resolution models. The downscaling algorithm seeks to recover the important non-linear spatial features of the flow variables that cannot be represented adequately on the coarser meshes.

The spatio-temporal lifting scheme representation and the associated downscaling algorithm are illustrated and evaluated on flow simulations for a synthetic urban configuration and a field-test case for various flow scenarios. A comparison is carried out with two other downscaling algorithms used in previous studies.