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Flood plain inundation modeling with explicit description of land surface macrotopography

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Land surface topography plays an essential role in flood plain inundation modeling. High-resolution digital surface models (DSMs) based on LiDAR surveys have become increasingly accessible in various geographical areas. Nevertheless, common practice involves filtering out land surface macrostructures, such as trees and buildings, by using obtained digital terrain models (DTMs) to represent the land surface hydraulic geometry. This is done by letting resistance coefficients represent the effects of both micro and macrostructures on surface flow propagation. In addition, significant information loss is observed when digital terrain models are coarsened for computational efficiency.

In the present study, physically meaningful unstructured meshes are automatically extracted from high-resolution digital surface models to explicitly describe land surface macrostructures. This is achieved by extracting relevant ridges at a selected level of representation without applying any coarsening or depression filling pre-processing. The effects of these macrostructures on floodwater propagation are evaluated by comparing simulations obtained by using digital terrain models and related Manning coefficients, simulations obtained by using digital surface models representing land surface macrostructures and related Manning coefficients, and observations for a real flood inundation event occurred after a levee failure in the lowlands adjoining the Panaro River in Northern Italy in 2020.

The explicit description of land surface macrostructures based on a 1-m digital surface model is found to yield a 42% improvement in the prediction of flooded area extent, a 36% improvement in the prediction of flooded areal position, and a 24% improvement in the prediction of flood plain inundation travel time with respect to the case in which resistance coefficients representing both land surface micro and macrostructures are used. Unstructured meshing of land surface macrostructures based on extracted ridge networks is essential for achieving a detailed description of land surface hydraulic geometry without altering the original topographic data, while also preserving computational efficiency. The obtained results highlight the role of natural and human-made macrotopographic structures in delineating flood plain inundation models and generating flood hazard mapping. These tools represent valuable assets in the context of Emergency Action Planning (EAP) and prevention strategies.