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Numerical porosity as an alternative to roughness parameterization for urban inundation modeling

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The dominant approach to modeling inundation of complex urbanized floodplains remains one and two-dimensional models, coupled to the parameterization of the inundation process using a roughness parameter. The progressive development of two-dimensional inundation models over the last 15 years has started to question this approach, and this has been reinforced by the development of high resolution remote sensing technologies, notably Lidar, which allows the explicit measurement of walls, buildings, trees etc at very high resolution. In this paper, we show that the parameterization or the effects of complex urban attributes using roughness parameters is fundamentally flawed and instead demonstrate that fusing data sources like Lidar with advanced numerical algorithms can reduce our dependence upon roughness parameters, many of which have a very poor physical basis for the situations to which they are being applied. The primary objection to representing objects on floodplains, like buildings, using a roughness parameter is that roughness parameters only impact upon the momentum equations. However, such objects also have an effect upon the mass equations through blockage. With a very high resolution numerical grid, it is easy to represent such effects explicitly, providing numerical meshes are developed that are stable and not prone to numerical diffusion. However, as the numerical grid is coarsened, which may be necessary to model very large river-floodplain systems, we show that roughness parameters cannot capture the effects of objects like buildings. Here, we present an alternative, based upon numerical porosity. For a finite volume discretisation, we specify each grid face as having: a porosity of zero when fully blocked; of one when fully flow; and between zero and one when partially blocked. We introduce associated drag terms to the momentum equations. Taken together, these changes allow: (1) us to capture the effects of sub grid scale topography as a blockage rather than require us to arbitrarily upscale the roughness parameter; and (2) a much more realistic handling of vegetation. We demonstrate the importance of this approach by modelling flood inundation for the City of York, northern England. Numerical sensitivity analyses demonstrate the extent to which a model based upon roughness parameterisation does not represent the wetting and drying process correctly. Introduction of the porosity method results in the expected wetting and drying response. Comparison of model predictions with inundation observations for a major flood event in November 2000 showed that the porosity-approach resulted in significantly improved predictions, especially form coarser grid resolutions, as compared with one based upon roughness parameterisation.