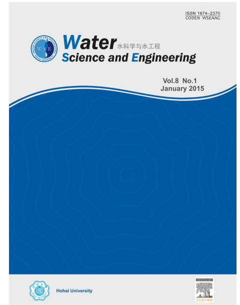

An efficient dynamic uniform Cartesian grid system for inundation modeling

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An efficient dynamic uniform Cartesian grid system for inundation modeling

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Abstract

A dynamic uniform Cartesian grid system was developed in order to reduce the computational time in inundation simulation using a Godunov-type finite volume scheme. The reduction is achieved by excluding redundant dry cells, which cannot be effectively avoided with a conventional Cartesian uniform grid system, as the wet area is unknown before computation. The new grid system expands dynamically with wetting, through addition of new cells according to moving wet-dry fronts. The new grid system is straightforward in implementation. Its application in a field-scale flood simulation shows that the new grid system is able to produce the same results as the conventional grid, but the computational efficiency is fairly improved.

Key words: Uniform Cartesian grid system; Flood simulation; Wetting and drying; Shallow water equation; Godunov-type finite volume scheme

1. Introduction

Flooding is a type of natural disaster that raises an enormous threat to lives and property. This threat is likely to escalate as a result of global warming and climate change. For example, southern England has seen the wettest winter for more than 200 years from 2013 to 2014, leading to severe and long-lasting flooding in Somerset. According to data provided by the Flood Protection Association (FPA) in the UK, of the 28 million homes in the UK, over 5 million are currently at risk, as well as over 300000 business premises and many more public and utility services buildings. Moreover, flooding is likely to cause other environmental problems. For instance, it is linked closely to water quality (Hrdinka et al., 2012). Flood prediction, which can be achieved using numerical models, can help guide people toward protection measures for the upcoming floods so that the damage can be significantly alleviated. In recent years, Godunov-type finite volume schemes have gained more attention in flood simulation, for example in Delis et al. (2008), Liang (2010), Jeong et al. (2012), Hou et al. (2013b), Ata et al. (2013), and Guan et al. (2014), as they are capable of capturing shocks, and preserving accuracy and robustness.

Simulation results have also been proven to be very sensitive to grid resolution (Wilson and Atkinson, 2003; Ozdemir et al., 2013). With finer grids, more realistic terrain features can be reflected. However, high-resolution modeling of real-world flooding may sometimes require millions of computational nodes or cells to accurately represent the domain topography of a floodplain, making such simulations computationally prohibitive on most existing computers. This signals a need to make computations faster. There are several approaches to improving the computational efficiency of a flood model. Liu and Pender (2013) used a cellular automata-based rapid flood spreading model to generate an estimated inundation map. Despite the fast computation, this approach fails to compute flow velocities. Another approach solves the simplified governing equations derived by neglecting the dynamic terms in the two-dimensional (2D) shallow water equations (SWEs) (Bates et al., 2010; Wang et al., 2011a). However, the neglected dynamic terms can affect the accuracy of the evaluated velocities, especially for flows with transient flow features. Some researchers have adopted adaptive grids to improve the computation efficiency, for instance George and Leveque (2008), Popinet (2011), Popinet

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