RAINFALL-RUNOFF MODELLING USING A SUB-GRID BASED METHOD

MSc THESIS REPORT

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May 2014
SUMMARY

In the distributed modelling framework of hydrological models where the surface flow processes are described, they generally consist of the overland flow across the terrain downslope, and along the reach of the one-dimensional channel elements. However, the assumptions made to solve the non-linear partial differential equations that result from the physical description of the above processes reduce them to similar cross-sectional averaged one-dimensional flow under a specified averaged slope. As the shallow water equations are reduced using the kinematic and diffusive wave approximations, the solutions are unable to represent the realistic variation of the Hortonian overland flow, the component of runoff not channelized. Although the kinematic or diffusive wave approximations may be adequate for relatively homogenous topography, land surfaces with significant spatial variations require more detailed approaches. To describe the processes with more details the full shallow water equations (SWE) are better equipped. However, with the rectangular grid based approach generally used in most models for the full SWE the resolution of those grid would have to be very fine to account for the bathymetric variation that very fine Digital Elevation Models (DEM) provide. For large scale catchments, this method would be computational extremely expensive, unfeasible for practical applications.

In this study, a subgrid based finite volume method using quadtrees based on the descriptions of Stelling (2012) are employed to solve the shallow water equations in the surface flow domain. This method is considered suitable to provide a realistic flow pattern over a heterogeneous topography subjected to the availability of a detailed (DEM) in a very fast and conservative way. The model has been previously used for flood simulation purposes. Presently, the model has been modified to account for the spatially varying rainfall input. One-dimensional channels as vector elements which are fully coupled with the two-dimensional model to represent networks in catchment to complement the information unavailable to the sub-grids. To quantify the effect of the permeable soil on the surface runoff, the use of a porous sub-layer with simple formulation is integrated with the surface model is assessed. The model is applied on synthetic DEMs and on the Kent Ridge catchment in Singapore, to explore the model efficiency in this regard. The use of slope limiters is also explored to tackle the drying and wetting problem for discontinuous or critical flow regimes.

The performance of the present model for the test cases is comparable to the other modelling schemes. The present model allows coarser grid definitions and testing of different critical conditions for the test cases. The model application on the test cases illustrate the importance of slope limiters and locally linear frictions as useful parameters for stable solutions and relevant calibration tools. The Kent Ridge catchment proves to be a modelling challenge with the present model. The 2D model approximates the runoff characteristics of the catchment quite accurately at the outlet and other locations and the flow paths across the catchment. The inaccuracy is observed in the peak runoff calculations, and could possibly be attributed to uncertainties in boundary conditions or suspected measurement errors in some cases.