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Hydrodynamic Simulation of Seasonal Fluvial Process over a Large Catchment

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Fluvial flooding induced by intense or prolonged rainfall poses a regular threat to people's lives and properties in almost every part of the world. Modelling provides an essential tool for simulating and predicting the hydrological processes from rainfall-runoff to flooding driven by rainfall. Prediction of seasonal or longer-term fluvial processes over large catchments has traditionally been carried out using lumped/distributed hydrological models. However, these traditional hydrological models do not consider strict momentum conservation and they are not suited for accurate simulation of highly transient and dynamic rainfall-runoff and flooding process. On the other hand, sophisticated hydraulic/ hydrodynamic models have been widely used for modelling of flood inundation including those violent flash floods from intense rainfall. But due to their inhibitive computational cost and incapability in representing certain hydrological processes, no attempt has been reported to use a fully 2D hydrodynamic model to simulate long-term fluvial processes to provide more detailed information for the analysis of flood dynamics and subsequent impact on the environment.

Therefore, this work aims to further develop and test a hydrodynamic model to simulate seasonal fluvial processes in a large catchment. The proposed long-term fluvial processes modelling system is based on the High-Performance Integrated hydrodynamic Modelling System (HiPIMS). HiPIMS solves the full 2D nonlinear shallow water equations using a finite volume shock-capturing numerical method, which is further accelerated by modern GPUs for large-scale and long-term simulations. Surface storage, overland flow and flow dynamics are automatically captured by running simulations on high-resolution topographic data. New model components are developed and coupled to HiPIMS to account for infiltration and evaporation. For infiltration, the Green-Ampt method and curve number method are implemented and compared. The enhanced HiPIMS is applied to reproduce, at 20m resolution, the seasonal fluvial processes including flooding and recovery periods in the 2500km^2 Eden Catchment, England for three months.

The simulation results are compared with gauge measurements of water level and discharge across the catchment to demonstrate the model's capability in supporting long-term simulations. More simulations have been also carried out to investigate the model sensitivity to key model parameters, e.g. grid resolution, friction, infiltration and evaporation parameters.