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Two-dimensional hydrodynamic robust numerical model of soil erosion based on slopes and river basins

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Erosion is an important issue in soil science and is related to many environmental problems, such as soil erosion and sediment transport. Establishing a simulation model suitable for soil erosion prediction is of great significance not only to accurately predict the process of soil separation by runoff, but also improve the physical model of soil erosion. In this study, we develop a graphic processing unit (GPU)-based numerical model that combines two-dimensional (2D) hydrodynamic and Green-Ampt (G-A) infiltration modelling to simulate soil erosion. A Godunov-type scheme on a uniform and structured square grid is then generated to solve the relevant shallow water equations (SWEs). The highlight of this study is the use of GPU-based acceleration technology to enable numerical models to simulate slope and watershed erosion in an efficient and high-resolution manner. The results show that the hydrodynamic model performs well in simulating soil erosion process. Soil erosion is studied by conducting calculation verification at the slope and basin scales. The first case involves simulating soil erosion process of a slope surface under indoor artificial rainfall conditions from 0 to 1000 s, and there is a good agreement between the simulated values and the measured values for the runoff velocity. The second case is a river basin experiment (Coquet River Basin) that involves watershed erosion. Simulations of the erosion depth change and erosion cumulative amount of the basin during a period of 1–40 h show an elevation difference of erosion at 0.5–3.0 m, especially during the period of 20–30 h. Nine cross sections in the basin are selected for simulation and the results reveal that the depth of erosion change value ranges from –0.86 to –2.79 m and the depth of deposition change value varies from 0.38 to 1.02 m. The findings indicate that the developed GPU-based hydrogeomorphological model can reproduce soil erosion processes. These results are valuable for rainfall runoff and soil erosion predictions on rilled hillslopes and river basins.