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A simple modelling framework for shallow subsurface water storage and flow

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In regions of extreme precipitation variability, such as the monsoonal climate of the tropics, the modelling of soil water storage and flow in the top few centimetres of soil is extremely challenging. This presents a major gap when exploring spatio-temporal processes in the soil-water continuum, hindering the capacity to predict major threats such as run-off, erosion, vegetation water use and nutrient cycling. Physically-based equations (e.g. Richards' equation) are too computationally intensive to solve at the catchment scale. Empirical, conceptual equations typically rely on steady state assumptions and include many fitted parameters that are not physically-based. In this study, we propose a simple modelling framework that incorporates shallow subsurface water storage and flow. It is based on physical soil-water relationships that can represent both upward and downward vertical fluxes. We evaluate its performance against the solution of Richards' equation, and illustrate its behaviour for a small agricultural catchment in South-east China. This subtropical region has intense monsoon rains that follow long, dry periods, so structure dynamics are intense. Results show that the proposed modelling framework can represent daily water fluxes and storage from a relatively shallow soil depth without relying on steady-state and gravity-driven flow assumptions. It performed better than and as fast as simpler approaches that do not implement a varying computing time step as a function of the soil saturation, while being significantly faster than solution of Richards' equation, allowing its implementation at catchment scales.