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Exploring dynamic (dis)connectivity of surface runoff on multiple catchments through a shallow water model

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Runoff generation and the consequent overland flow result from the interactions between gravity-driven flow over complex topography, Earth's roughness, and infiltration. These processes mostly occur at small spatio-temporal scales, but aggregate throughout the landscape to produce a hydrodynamic response at catchment and stream scales during a rainfall event. While this response is highly transient and spatially heterogeneous, it is mostly studied through aggregated signatures, such as hydrographs. It is therefore of importance to understand how the hydrodynamic response builds up across scales in the landscape into such signatures. Arguably, hydrological (dis)connectivity, which describes how different parts of a hydro-system (dis)connect through fluxes, is a useful concept to describe this multiscale behaviour. In this contribution, we explore the dynamic connectivity behaviour of surface runoff in first order catchments (ranging between 0.06 and 15 km^2) in response to singular rainfall events. We further analyse the connectivity response, mainly in terms of the number of disconnected clusters and the flooded areas, together with hydrological signatures. To do this, we use the GPU-enabled shallow water solver SERGHEI-SWE, which allows us to solve the shallow water equations at below-metre resolution (with tens of millions of grid cells per catchment). The extremely high spatial resolution of the model accurately captures spatial heterogeneity of topography and surface properties and thus, correctly represents the structural connectivity of the system. In the same manner, the hydrodynamics obtained on these high-resolution grids accurately capture the dynamic connectivity. Based on the simulated water depths, we assess dynamic connectivity at different spatial scales, and at different stages of runoff development, and study how the connectivity properties vary in different catchments. Furthermore, we perform a first analysis of how connectivity changes with scale and its relation to hydrological signatures and catchment features. Additionally, we explore the effects of coarser resolution simulations on dynamic connectivity on the same catchments.