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Numerical simulation of flood inundation using a well-balanced kinetic scheme for the shallow water equations with bulk recharge and discharge

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The flow of water in rivers and oceans can, under general assumptions, be efficiently modelled using Saint-Venant's shallow water system of equations (SWE). SWE is a hyperbolic system of conservation laws (HSCL) which can be derived from a starting point of incompressible Navier-Stokes. A common difficulty in the numerical simulation of HSCLs is the conservation of physical entropy. Work by Audusse, Bristeau, Perthame (2000) and Perthame, Simeoni (2001), proposed numerical SWE solvers known as kinetic schemes (KSs), which can be shown to have desirable entropy-consistent properties, and are thus called well-balanced schemes. A KS is derived from kinetic equations that can be integrated into the SWE.

In flood risk assessment models the SWE must be coupled with other equations describing interacting meteorological and hydrogeological phenomena such as rain and groundwater flows. The SWE must therefore be appropriately modified to accommodate source and sink terms, so kinetic schemes are no longer valid. While modifications of SWE in this direction have been recently proposed, e.g., Delestre (2010), we depart from the extant literature by proposing a novel model that is "entropy-consistent" and naturally extends the SWE by respecting its kinetic formulation connections.

This allows us to derive a system of partial differential equations modelling flow of a one-dimensional river with both a precipitation term and a groundwater flow model to account for potential infiltration and recharge. We exhibit numerical simulations of the corresponding kinetic schemes. These simulations can be applied to both real world flood prediction and the tackling of wider issues on how climate and societal change are affecting flood risk.