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Simulation of infiltration and redistribution of intense rainfall using Land Surface Models

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Flooding from intense rainfall (FFIR) can cause widespread damage and disruption. Numerical Weather Prediction (NWP) models provide distributed information about atmospheric conditions, such as precipitation, that can lead to a flooding event. Short duration, high intensity rainfall events are generally poorly predicted by NWP models, because of the high spatiotemporal resolution required and because of the way the convective rainfall is described in the model. The resolution of NWP models is ever increasing. Better understanding of complex hydrological processes and the effect of scale is important in order to improve the prediction of magnitude and duration of such events, in the context of disaster management.

Working as part of the NERC SINATRA project, we evaluated how the Land Surface Model (LSM) components of NWP models cope with high intensity rainfall input and subsequent infiltration problems. Both in terms of the amount of water infiltrated in the soil store, as well as the timing and the amount of surface and subsurface runoff generated. The models investigated are SWAP (Soil Water Air Plant, Alterra, the Netherlands, van Dam 1997), JULES (Joint UK Land Environment Simulator a component of Unified Model in UK Met Office, Best et al. 2011) and CHTESSEL (Carbon and Hydrology- Tiled ECMWF Scheme for Surface Exchanges over Land, Balsamo et al. 2009)

We analysed the numerical aspects arising from discontinuities (or sharp gradients) in forcing and/or the model solution.

These types of infiltration configurations were tested in the laboratory (Vachaud 1971), for some there are semi-analytical solutions (Philip 1957, Parlange 1972, Vanderborght 2005) or reference numerical solutions (Haverkamp 1977, van Dam 2000, Vanderborght 2005).

The maximum infiltration by the surface, I_{max}, is in general dependent on atmospheric conditions, surface type, soil type, soil moisture content θ, and surface orographic factor σ. The models used differ in their approach to describe and deal with this top boundary condition definition.

All three LSMs discretise the spatial derivative in the Richards equation ($\partial/\partial z$) using central finite differences, which is a 2nd order method, that according to Godunov's theorem is non-monotone. It is prone to producing non-physical oscillations in the solution. We performed a mesh and timestep dependence study for hypothetical soil columns and showed the presence of the oscillations in Jules and SWAP solutions. We also investigated the rainfall/runoff partition and redistribution in case of intense rainfall using these three models.