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A new model for studying the impacts of land cover change on flood hydrographs in upland peatland catchments

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There is global concern about headwater management and associated impacts on river flow. In many wet temperate zones peatlands can be found in headwater catchments. In the UK there is major concern about how environmental change, driven by human interventions, has altered the surface cover of headwater blanket peatlands. However, the impact of such cover changes on river flow is poorly understood. In particular, there is poor understanding of the how different spatial configurations of vegetation impact on the management of river flow peaks in upland catchments. This paper employs a numerical modelling approach to explore such impacts.

TOPMODEL, due to its process representation which is very suitable for blanket peat catchments, was utilized as a prototype acting as the basis for a new distributed catchment hydrological model. The new model is totally distributed with a computational unit of a grid cell. The core equations representing subsurface flow in the original TOPMODEL were inherited by the distributed version of TOPMODEL and downscaled from the catchment level to the cell level for the transformation to the distributed model. The downscaled equations constitute the main part of the subsurface flow module and the runoff produced by each cell is obtained by partitioning rainfall between evapotranspiration, subsurface flow and saturation-excess overland flow in the extended model.

A new overland flow module with a set of stochastic algorithms for overland flow transport was created to simulate overland flow movement, in which the overland flow produced in each cell is treated as many parcels (e.g. 100 parcels) of water. The flow velocity is calculated by the local slope, the overland flow depth, and the land surface roughness (associated with land cover types) based on empirical data. For each parcel the direction and distance of its movement in a single time step is obtained as a stochastic process, based on the partition of flow between downslope directions and the average flow velocity, interpreted as a probability of stopping in each cell traversed. This module also include a re-infiltration mechanism in which the overland flow yielded in upslope cells can infiltrate into the unsaturated soil in downslope cells to contribute to subsurface flow produced in these cells. This rarely considered mechanism in hydrological models shows one important way in which the real process of overland flow generation on hillslopes may be influenced by land cover. This significant new advance may have wide applicability, and there is only one new key parameter (overland flow velocity parameter) which replaces the constant overland flow velocity in the original TOPMODEL, limiting the possibilities of over-parameterization.

The new model was tested in three upland peat catchments in different parts of the UK: Trout Beck in the North Pennines, the Wye in mid-Wales and the East Dart in southwest England. The model was found to work well in all three cases, and could be employed in future land cover scenario studies concerning impacts of land cover change on river flow in upland peatlands.