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Dynamic channel networks and non-linear runoff response

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One of the commonly reported aspects of distributed, physically-based hydrological modeling is the difficulty of determining parameter sets that can simultaneously reproduce the magnitude of the flood wave peak and the form of the recession limb. For instance, globally raising the saturated hydraulic conductivity may lead to better reproduction of the shape of the recession limb, but this is commonly at the expense of lower hydrograph peaks as a result of the generation of less rapid overland flow. Likewise, a global reduction may allow reproduction of the peak, but fail to reproduce the shape of the recession limb. In this paper, we test the possible contribution made by dynamic changes in the channel network in response to the associated overland flow rate. The division between diffusive hillslope flow and concentrated channel flow is critical in mediating rapid runoff response as a result of the lower relative roughness of the channel systems as well as, in the majority of flow laws, non-linear dependence of surface velocity upon channel depth. In most distributed models, the division between hillslopes and channels is fixed, commonly using an accumulated upslope area threshold. On the hillslopes, surface routing algorithms can allow for more diffusive flow (e.g. the FD8 algorithm). In the channels, routing is almost invariably along the line of steepest slope, at least until the channel becomes unconfined by hillslopes. However, the fixed transition used in many models does not match field observations during extreme rainfall events, when there can be headward expansion of channel flow, with hillslopes becoming channels, and leading to the more rapid transfer of overland flow to the channel network. Here, we represent this dynamically by allowing the transition between hillslope and channelised flow to evolve as a function of runoff depth. Application to extreme rainfall events in a catchment in the North Yorkshire Moors

National Park, northern England, results in a marked change in hydrograph response for critical rainfall intensities, to produce markedly non-linear behaviour.