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Adjoint distributed catchment modelling for flood impact of rural land use and management change

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It is a significant research challenge to understand the impact that changes in land use and management (LUM) can have on downstream flooding and the potential for land management control to mitigate impacts. A key issue in this regard is how to understand the role of the network in propagating the effects of changes in runoff generation downstream. The effects of LUM changes can be analysed as if they are perturbations in properties or rates that cause perturbations in flow to propagate through the river drainage network. A novel approach has been developed that computes the sensitivity of an impact (for example the impact on a flood level) to upstream perturbations. This is achieved using an adjoint hydraulic model of the channel network that computes sensitivities using algorithmic differentiation. The hydraulic model provides a detailed representation of the drainage network, based on field surveys of channel cross sections and channel roughness, and is embedded into a grid-based model that represents runoff generation. Various sensitivities can be calculated, including: (a) sensitivities to perturbations in runoff generation parameters; and (b) sensitivities to perturbations in the rate of lateral inflow to the network, as could be calculated using expert knowledge on the effects that changes in LUM can have on the runoff rate from agricultural fields and hillslopes. The resulting sensitivities are decomposed and presented as maps that show the relationship between perturbations and impacts, giving valuable insight into the link between cause and effect.

Results will be shown for the Hodder catchment, NW England (260 sq. km), which has been instrumented to assess the impact of recent large-scale changes in LUM on downstream flooding. The focus is on the role of hydrodynamic and geomorphologic dispersion in attenuating perturbations in network flow, particularly for the types of perturbations expected if there are flashy changes to runoff as a result of changes in LUM. The results are in the form of maps that have the potential to provide guidance when selecting appropriate locations for applying adaptation and mitigation measures designed to reduce the flood hazard downstream.