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The United Kingdom experienced severe storm 'clusters' during the winter of 2015/6. Whilst the associated flood Return Periods (RP) of each individual storm were significant, it was the very high frequency of these repeat inundation events which further magnified the flood risk to devastate properties, economies and communities. This evidenced the inter-dependency and influence of storm sequencing, antecedent conditions and river morphology over a channel's capability to convey subsequent flow events. Thus, the aim of the present paper is to examine the sensitivity of river flood hazard to 'clusters' of flow events.

Using river flow gauge data, stochastic modelling combined a hidden Markov Model (HMM) with generalised Pareto distribution (GP) to derive 100 synthetic flow sequences (50 year duration) of comparable probability densities to the observed record. HMM-GP reorders the magnitude, spacing and frequency of events to produce different flow 'clusters' within each sequence. The full flow sequences form the inflow boundary conditions for a traditional quasi-unsteady 1D sediment transport model, effective for long-term prediction of adjustment to channel geometry and conveyance capacity. Using updated geometries, 1D or 1D-2D hydraulic modelling can then assess the sensitivity of flood hazard to flow sequence and be interpreted for 'cluster' influence.

Herein, 'clusters' are defined as a temporal grouping of multiple peak flows above a selected sediment transport threshold discharge. Using the case study location of the River Caldew (Carlisle, England) a discrete high flow 'event' was specified as a discharge above the 10% of 1 year RP. Two temporal grouping approaches were employed to cluster these events: a fixed window (up to 30 days) after a defined event; or, a defined number of antecedent dry days (ADD ≤ 30) between consecutive events. This yielded approximately 3500 above-threshold events and up to 200 clusters for each 50 year flow sequence. For all 100 simulated sequences, each cluster was characterised in terms of antecedent duration, intra-cluster event spacing, event peak discharge, cluster cumulative discharge, skewness, number of events.

The associated model outputs (flood hazard, sediment transport and channel conveyance capacity) were then analysed and cross-correlated to cluster characteristics. Results clearly show that: (i) clusters generate sediment transport loads an order of magnitude higher than that of isolated events of equivalent cumulative flow discharge; (ii) strong correlations are found between morphodynamics and the number of events within a cluster; (iii) flood hazard shows high sensitivity to morphodynamic response to clusters and flow sequence.