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Importance of sub-catchments peak flow relative timing on downstream flood risk

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Flood risk is an increasingly important issue in the UK, with both flood magnitude and frequency thought to be increasing in recent decades. Climate change and land use change have been hypothesised to have caused this trend. Both climate and land use are rarely homogeneous across the whole catchment and therefore the response of each sub-catchment is different in terms of the magnitude and timing of the peak flow.

It is probable that the relative timing of sub-catchment response is a critical control upon downstream flood risk. Indeed, both climate change (e.g. a systematic shift in the dominant direction of rain-bearing cyclones) and land management change (e.g. adoption of land use practices that lead to more rapid hydrological response) could lead to changes in the relative timing of response of sub-catchments and hence downstream flood risk. The importance of the sequencing and timing of flows from each sub-catchment has often been downplayed in past flooding investigations.

Here, we quantify the importance of both flow magnitude and timing from each sub-catchment through an innovative statistical methodology. The example used is the Eden catchment, Cumbria, UK, where 165 floods, over a threshold of 335m3/s, since 1977 were included in the analysis. Both flow magnitudes and relative timing variables were extracted from discharge data for these floods. The relative timing was calculated by subtracting each sub-catchments peak flow time from the time of the peak flow at Carlisle. The approach consists of multivariate principal components analysis combined with stepwise regression, used to predict downstream flood risk from the magnitudes and timing of the flows from contributing sub-catchments.

The results indicate that about 90% of downstream flood risk magnitude can be predicted from these variables, indicating that these are the dominant controls on high flows at catchment outlets. Of this about 50% is explained by the flow magnitudes from each of the contributing sub-catchments. However, about a third of downstream flood risk can be explained by the relative timing of the peak flows from each tributary with respect to the downstream gauge. This indicates that the timing and phasing of flows from sub-catchments is more important than initially thought in leading to high flows downstream.