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How important is the spatiotemporal structure of a rainfall field when generating a streamflow hydrograph? An investigation using Reverse Hydrology

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Flooding is the most widely occurring natural disaster affecting thousands of lives and businesses worldwide each year, and the size and frequency of flood-events are predicted to increase with climate change. The main input-variable for models used in flood prediction is rainfall. Estimating the rainfall input is often based on a sparse network of raingauges, which may or may not be representative of the salient rainfall characteristics responsible for generating of storm-hydrographs. A method based on Reverse Hydrology (Kretzschmar et al 2014 Environ Modell Softw) has been developed and is being tested using the intensively-instrumented Brue catchment (Southwest England) to explore the spatiotemporal structure of the rainfall-field (using 23 rain gauges over the 135.2 km2 basin). We compare how well the rainfall measured at individual gauges, or averaged over the basin, represent the rainfall inferred from the streamflow signal.

How important is it to get the detail of the spatiotemporal rainfall structure right? Rainfall is transformed by catchment processes as it moves to streams, so exact duplication of the structure may not be necessary. ‘True’ rainfall estimated using 23 gauges / 135.2 km2 is likely to be a good estimate of the overall-catchment-rainfall, however, the integration process ‘smears’ the rainfall patterns in time, i.e. reduces the number of and lengthens rain-events as they travel across the catchment. This may have little impact on the simulation of stream-hydrographs when events are extensive across the catchment (e.g., frontal rainfall events) but may be significant for high-intensity, localised convective events.

The Reverse Hydrology approach uses the streamflow record to infer a rainfall sequence with a lower time-resolution than the original input time-series. The inferred rainfall series is, however, able simulate streamflow as well as the observed, high resolution rainfall (Kretzschmar et al 2015 Hydrol Res).

Most gauged catchments in the UK of a similar size would only have data available for 1 to 3 raingauges. The high density of the Brue raingauge network allows a good estimate of the ‘True’ catchment rainfall to be made and compared with data from an individual raingauge as if that was the only data available. In addition the rainfall from each raingauge is compared with rainfall inferred from streamflow using data from the selected individual raingauge, and also inferred from the full catchment network. The stochastic structure of the rainfall from all of these datasets is compared using a combination of traditional statistical measures, i.e. the first 4 moments of rainfall totals and its residuals; plus the number, length and distribution of wet and dry periods; rainfall intensity characteristics; and their ability to generate the observed stream hydrograph.

Reverse Hydrology, which utilises information present in both the input rainfall and the output hydrograph, has provided a method of investigating the quality of the information each gauge adds to the catchment-average (Kretzschmar et al 2016 Procedia Eng.). Further, it has been used to ascertain how important reproducing the detailed rainfall structure really is, when used for flow prediction.