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Flood response regionalization based on functional clustering of hydrographs

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Design hydrographs for a specific recurrence interval typically represent a flood event in terms of peak discharge, hydrograph volume, and shape. In reality, combinations of different precipitation events and antecedent moisture conditions lead to various flood responses in terms of hydrograph shapes and magnitudes. This hydrograph shape variability within a catchment is insufficiently represented by assuming only one shape. Here, we thus propose a two-step clustering procedure that allows for a better representation of the hydrograph shape in design hydrograph construction. First, a representative set of hydrograph shapes is identified that describes the hydrograph shape variability within a catchment. Second, regions with similar flood responses are identified based on these hydrograph shape sets.

The clustering procedure is based on a functional representation of hydrograph shapes, i.e. each flood hydrograph observed in a catchment is represented as a function of time. This approach takes much more information into account than the classical approach of describing the hydrograph by a few characteristics. A functional data representation can be obtained by a projection of the normalized hydrograph shapes on a set of basis functions. We use B-spline basis functions because they are able to describe the main hydrograph characteristics well. The set of coefficients corresponding to the individual B-splines is used to cluster the hydrographs within a catchment into groups of similar shapes via a k-means clustering algorithm. We found that three shape clusters are sufficient to represent the flood hydrograph shape variability within a catchment: 1) fast events with both a steep rising and recession limb, 2) intermediate events with a rather steep rising but slower recession limb, 3) slow events with slow rising and recession limbs. In a second step, we describe each catchment by a set of three representative hydrograph shapes formed by the median shapes within its shape clusters, which differ across catchments. The basis coefficients of these representative hydrograph sets over all catchments are again used in clustering to identify catchments that have similar sets of representative hydrograph shapes. As a result, we identify three groups of catchments with a similar flood behavior in terms of flood hydrograph shapes: 1) catchments with a generally quick flood reaction, 2) catchments with a rather slow reaction, 3) catchments with a uniform reaction, where the variability of hydrograph shapes is neglectable. We found that these regions are not only similar in terms of their hydrograph shapes but also their hydrograph magnitudes. Such regions with similar flood behaviors are useful for regional flood frequency analysis by allowing the construction of typical design hydrographs for a specific recurrence interval instead of only one design hydrograph. A set of design hydrographs describes the variability of floods within a catchment and can be used for flood risk management tasks where storage is involved such as the construction of hydraulic structures.