Geophysical Research Abstracts
Vol. 18, EGU2016-15940, 2016
EGU General Assembly 2016

Fuzzifying historical peak water levels: case study of the river Rhine at Basel

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Hydrological information comes from a variety of sources, which in some cases might be non-precise. In particular, this is an important issue for the available information on water stages during historical floods. An accurate estimation of the water level profile, together with an elevation model of the riverbed and floodplain areas is fundamental for the hydraulic reconstruction of historical flood events, allowing the back calculation of flood peak discharges, velocity and erosion fields, damages, among others.

For the greatest floods during the last 1700 years, Wetter et al. (2011) reconstructed the water levels and historical discharges at different locations in the old city centre from a variety of historical sources (stone marks, official documents, paintings, etc). This work presents a model for the inherent unpreciseness of these historical water levels. This is, with the arithmetics of fuzzy numbers, described by their membership functions, in a similar fashion as the probability density function describes the uncertainty of a random variable. Additional to the in-site collected water stages from floodmarks and other documentary evidence (e.g. preserved in narratives and newspaper flood reports) are prone to be modeled in a fuzzy way. This study presents the use of fuzzy logic to transform historical information from different sources, in this case of flood water stages, into membership functions.

This values might then introduced in the mathematical framework of Fuzzy Bayesian Inference to perform the statistical analyses with the rules of fuzzy numbers algebra. The results of this flood frequency analysis, as in the traditional non-fuzzy way, link discharges with exceedance probabilities or return periods. The main difference is, that the modeled discharge quantiles are not precise values, but fuzzy numbers instead, represented by their membership functions explicitly including the unpreciseness of the historical information used.

Wetter, O., Pfister, C., Weingartner, R., Luterbacher, J., Reist, T., & Trösch, J. (2011) The largest floods in the High Rhine basin since 1268 assessed from documentary and instrumental evidence. Hydrol. Sci. J. 56(5), 733–758.