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Natural Hazards and Earth System Sciences
Discussions

Interactive comment on "Decreasing uncertainty in flood frequency analyses by including historic flood events in an efficient bootstrap approach" *by* Anouk Bomers et al.

Anonymous Referee #2

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This paper discuss the extension of a flood series, based on hydraulic modelling and the utilisation of extend hydrological time series to estimate the frequency of extreme floods at the Rhine gauge Lobith. The authors expect a reduced sampling effect. It is widely known that for extreme events the empirical exceedance probabilities in short observation series are often overestimated. To solve this problem the authors suggest to extend the observed time series. In their case study they propose to extent the existing series of observations between 1901-2018 by a linear regression of water levels with neighbouring gauges for the period 1772 to 1900 based on a previous study from Toonen (Toonen, 2015) and the translation of these water levels into discharges using a stage-discharge relationship, which is not specified in detail. The resulting series

(1772-2018) is named as the "systematic" time period. The other and even more uncertain step consists in an estimation of the peaks of historic floods at Lobith. Here a series of 12 historic flood events in Cologne since 1342, provided by Meures and Herget is used. As these events were estimated more than 150 km upstreams, a (1D-2D) coupled hydraulic model is used to transfer these peaks to Lobith: "The reconstructed maximum discharges at Cologne (Meurs, 2006), which are not normalized for anthropogenic interventions upstream of Cologne, are used to predict maximum discharges at Lobith with the use of a hydraulic model to normalize the data set." The meaning of "normalization" in this context stays unclear. It seems to be the adaptation of these peaks (which were roughly estimated by Meures) on to today's conditions. There are extreme uncertainties connected with this approach: the river reach changed in its hydraulic characteristics over 700 years, the water levels in Cologne dating back several hundreds of years are uncertain, the discharges as well and so on. It is a big surprise that the authors are able to specify in Fig. 3 95% confidence intervals for the maximum discharges in Cologne and Lobith for these 12 events. It stays unclear how these intervals were estimated. The authors propose a bootstrap sampling method to fill the gaps between the historic floods with annual flood peaks from the systematic data set, that have an expected value lower than the sampled perception threshold which is set as the smallest flood among the historic peaks. This is approach seems to be critical as it does not add any information to the statistical analysis. The todays conditions are modified by the first extension to the part of the series until 1772. With the sampling the authors accept that the flood series consist of independent and identically distributed random variables, which is not certain. By definition bootstrapping is any test or metric that relies on random sampling with replacement. Here the wording "resampling of the non-systematic time series below the perception threshold" would be more appropriated. This has been done 5000 times and also the historical floods are varied within their 95% confidence intervals (however these were estimated!). The systematic series were not changed. The GEV was estimated for each of these samples, the distributions were averaged (!) and their 95% percent confidence bounds were estimated.

Table 1 specifies these 95% bounds with the 2-sigma-reach, this would be only justified if the quantiles would be normal distributed. I suppose that this is not the case. In total the value of this resampling study stays unclear for me as it does not extend the information content. The information, derived from the systematic series are used in a simulation study, but the basic assumption that the floods between 1772 and 1900 are reconstructed correctly adds uncertainty to it. There are at least two other options to consider historic floods in statistics:

REIS D. S., JR.; STEDINGER J. R. (2005): Bayesian MCMC flood frequency analysis with historical information. In: Journal of Hydrology, 313, pp. 97–116 (cited by the authors)

Wang, Q. J. (1990): Unbiased estimation of probability weighted moments and partial probability weighted moments from systematic and historical flood information and their application to estimating the GEV distribution. In: Journal of Hydrology 120 (1-4), S. 115–124

Both methods combine the information from the systematic data with istoric floods without assumption that these observations are representative for the historic series. In both methods, it is assumed that the historic floods are representative for today's conditions. These events are used to improve the estimation of the upper tail only. The systematic part of the series stays untouched. In this way the uncertainty of assumptions of a large part of the time series is avoided. The statement of the authors: "Most studies found that the confidence intervals of design discharges were reduced significantly by extending the systematic data set with historic events." does not mean that an artificially extended systematic dataset would be beneficial if it was expanded with uncertain assumptions about past flood conditions and their adaptation to the current situation.

My summary: The manuscript has some weakness with regard to uncertainty assessments (confidence intervals) where the methodology is not sufficient described. The

assumption of a symmetrical interval seems to be arbitrarily. Nevertheless the topic is interesting, the manuscript should be consider the existing state of the art in this field and compare its results with well-established existing methods.

I suggest to reject the manuscript for major revisions.

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