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Hydrology and Earth System Sciences
Discussions

Interactive comment on "Compound flood potential in Europe" *by* Dominik Paprotny et al.

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We would like to thank the reviewer for taking the time to comment on our manuscript. We list the comments (C) and our responses (R) below.

C: In my opinion, the main drawback is concerning the data selection. Copula inference requires that variables would be i.i.d. that is, in practice, marginals values should be independent. This condition is not addressed in the manuscript since authors decide (as also mentioned in the discussion) to use all the available data and not to select the maximum annual values (or peak over threshold values). This is an important issue that affects results and so it is important to solve.

R:. We tested the autocorrelation of the observed time series. The lowest is for precipitation, in which case the Spearman's rank correlation for a 1-day lag is 0.42 on average, dropping below 0.1 by the sixth day. For wave height the average for all buoys for a

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1-day lag is 0.65, dropping and stabilizing around 0.3 by the seventh day. Autocorrelation for storm surge starts at 0.81 and drops to 0.34 by day 7, while for river discharges it remains above 0.5 even after several weeks. Therefore, the i.i.d. condition is less of a concern for precipitation, but more significant for river discharges. However, historical cases of compound floods show that those were often caused by storm surges happening during period of protracted (even months-long) high discharge.

Yet, as the reviewer points out, "multivariate analyses are effective with large sample dimension and usually compound events are lacking of information." Compound floods are indeed very rare as we point out in the introduction and Table 3. Using peak-over-threshold or annual maxima in particular would have generated very short time series (especially since many tide gauges have only a few years of data). But even the 95th percentile threshold analysed in the discussion reveals to change significantly the results. The joint probability is much lower when using the threshold of 95th percentile, and there is no spatial pattern in its distribution, in contrast to using the full margin, where clear geographical differences in the joint return period are visible. Further, those patterns are consistent with historical cases of compound floods only when using full margins, and not when using only the 95th percentile. The results further vary a lot depending on which margin the 95th percentile threshold is put. Finally, the joint distributions vary much more between modelled and observed datasets when the 95th percentile threshold is used. For all those reasons we opted to use the full margins, because despite not satisfying the i.i.d. condition, it gives much more consistent results matching historical compound events.

In the revision we would like to expand the discussion on this aspect, analysing the influence of the choice of a threshold (e.g. 50th, 80th, 95th, 99th percentile) on the results and adding the autocorrelation analysis mentioned in the first paragraph of this response.

C: The second point is related to the comparison among observations and model data and in general to the spatial characterization of dependence structures. Presently, it

is addressed using dependence measure and copula functions (that is affected by the i.i.d. condition). In my opinion it could be more affective and representative the non-parametric approach using the empirical copulas or the pseudo-observations. This allow to compare directly the shapes of the dependence structure without introducing the intrinsic error present in the parametric inference. An example of this approach is provided in Grimaldi, S., Petroselli, A., Salvadori, G., De Michele, C. (2016) Catchment compatibility via copulas: A non-parametric study of the dependence structures of hydrological responses. Advances in Water Resources, 90, pp. 116-133.

R: In the context of the previous point, using an empirical copula would complicate further the computation of a joint return period of compound floods given how rarely those occur. This would be particularly unfeasible if combined with shortened data series. We believe that, extrapolation using parametric copulas is a better choice to compute the joint probability of even a moderate compound event of 10-year return period on both margins. Moreover it was also of interest to investigate possible acceptable statistical models for further use in similar applications. The non-parametric approach could also be used to compare data structures from modelled and observed time series, however given that a parametric approach is used in the paper, we simplify the analysis by comparing only the rank correlations and copula types, rather than analyse the differences in detail for each station.

C: As minor point, compared to the other ones, is related to the joint return period, indeed is not clear which formulation was adopted in the paper (i.e. Gräler B., M. J. van den Berg, S. Vandenberghe, A. Petroselli, Grimaldi S, B. De Baets, and N. E. C. Verhoest (2013). Multivariate return periods in hydrology: a critical and practical review focusing on synthetic design hydrograph estimation. Hydrology and Earth System Sciences, vol. 17, p. 1281-1296, ISSN: 1027-5606.). I do not think that it would change the results however it is necessary to clarify it.

R: Using the formulation in the cited paper, the joint return period in our manuscript is equivalent to T_AND, i.e. the situation when values at both margins have to exceed the

given thresholds simultaneously. We will clarify this in the paper.

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