REVIEW REPORT

Journal: Hydrology and Earth System Sciences
Paper: hess-2018-291
Title: Multivariate hydrologic design methods under nonstationary conditions and application to engineering practice
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GENERAL COMMENTS.
The paper deals with an issue of interest for the readers of HESS. In my opinion, a few critical issues must be fixed. Below, please find some indications: the objections should be read in a constructive way, since they may help the Authors improve the paper. Some useful bibliography is given at the end of this review.

SPECIFIC COMMENTS.

Page(s) 3, Line(s) 48–49.

Author(s). ... while the exceedance probability of a multivariate flood event could have multiple definitions (Salvadori et al., 2011; Vandenberghe et al., 2011).

Referee. Here, an additional reference is Salvadori and De Michele (2004), where the non-uniqueness of return periods in a multivariate setting was first pointed out.

Page(s) 3, Line(s) 54.

Referee. The citation to Salvadori and De Michele (2004) should be added here. Actually, there are (at least) four types of approaches, as recently outlined and discussed in Salvadori et al. (2016). The Authors are missing the Survival Kendall approach, first introduced in Salvadori et al. (2013): this latter avoids possible problems of divergence of the marginals on the boundaries of the domain.

Page(s) 3, Line(s) 55.

Author(s). Due to changing climatic conditions, as well as some anthropogenic driving force...

Referee. Here, the Authors should cite the paper by Milly et al. (2008).

Page(s) 3, Line(s) 59–60.

Author(s). The multivariate flood distribution could exhibit more complex nonstationarity behaviors than the univariate distribution...

Referee. Here, the Authors should cite the multivariate distributional approach outlined in Vezzoli et al. (2017)—where Sklar's Theorem representation is used to test nonstationarity—as well as the guidelines for multivariate change-point detection illustrated in Salvadori et al. (2018).

Page(s) 4, Line(s) 87–88.

Author(s). These design criteria assess the risk or reliability of hydraulic structures...

Referee. As a further approach involving Failure Probabilities, and design under nonstationarity and extreme value marginals, the Authors should cite the seminal paper by Salvadori et al. (2018).

Page(s) 5, Line(s) 95–96.

Author(s). ... these design events are generally not equivalent because their joint probability density values (i.e. likelihood) are usually different...

Referee. This fact was first pointed out in Salvadori et al. (2011).

Page(s) 6, Line(s) 106–108.

Author(s). ... the cases for higher-dimensional hydrologic designs as well as under nonstationary conditions have not yet been covered in current studies.

Referee. In Salvadori et al. (2018) appropriate confidence intervals are computed in a nonstationary case via suitable Monte Carlo techniques (the case study is a bivariate one, but the procedures can be generalized to any dimension).

Page(s) 6–ff., Section(s) 2.1.

In my opinion, the Authors should check for possible nonstationarity by using the functions provided by the R package "npcp" (Kojadinovic, 2017), which works both for the marginals and the copula, and provides approximate p-values concerning distributional changes.

Page(s) 7, Eq(s) 1.

The Authors should explain here the meaning of the undefined variable/parameter t in Eq. (1). In addition, the mathematical notation used is wrong. Usually, in Probability, upper-case letters (e.g., $Q_{1,t}$) denote random variables, but here the arguments of the distribution functions F's are real variables (i.e., lower-case letters). Please fix the notation throughout the manuscript.

Page(s) 8, Line(s) 169.

The covariates $(x_1, \ldots, x_k)$ should be specified here.

Page(s) 8, Line(s) 172–174.

Author(s). The higher-order distribution parameters such as scale and shape parameters are assumed to be kept constant to avoid possible larger uncertainty in parameter estimation, although they could also be nonstationary.

Referee. This assumption can make the work rather weak. In fact, here maxima are investigated, and the shape parameter plays a fundamental role in distributions like GEV or GPD, in order to rule the strength of the extremes: keeping these parameters constant could be unrealistic, and may yield strongly biased estimates. As shown in Salvadori et al. (2018), the uncertainties could really be large, but "constraining" the model by fixing the most relevant parameters is not a proper way to solve the problem. Please duly comment this point.

Page(s) 8, Line(s) 178–180.

Author(s). The goodness of fit (GOF) of the probability distributions is examined by using the Kolmogorov-Smirnov (KS) test (Frank and Massey, 1951).

Referee. This is a critical statistical point: how was the p-value computed? Just comparing the values of the KS test statistics with the ones reported in some table? This would be wrong. In fact, as is well known (e.g., simply read the help of Matlab), the KS test requires that the theoretical distribution be known a priori, it cannot be the fitted one. In the latter case, suitable (but simple) Monte Carlo techniques can be used to estimate an approximate p-value. Please fix the issue.

Page(s) 9, Line(s) 191–192.

Author(s). In this study the dependence structure of (Q_1, V_3, V_7, V_{15}) is constructed by the pair copula method.

Referee. To the best of my knowledge, the current software for vine-copulas does not provide reliable p-values of GoF tests: this may represent a statistical weakness of this approach. A comment is required here.

Page(s) 11, Line(s) 227.

The covariates $(x_1, \ldots, x_l)$ should be specified here.

Page(s) 12, Line(s) 252–253.

Author(s). ... the exceedance probability p_t of (q_1, v_3, v_7, v_{15})...

Referee. What is the exceedance probability of a multivariate event? It should be properly defined here, or, at least, the Authors should put a reference to the next Section 2.2.2.

Page(s) 12, Line(s) 262.

Author(s). ... OR case, AND case and Kendall case...

Referee. Here, the best reference is Salvadori et al. (2016), where these cases are, for the first time, properly and rigorously defined in terms of suitable Hazard Scenarios based on the notions of Copulas and Lower/Upper Sets.

Page(s) 13, Eq(s) 11.

The U's notation in Eq. (11) should be upper-case: the U's used as arguments of the copula must be random variables, otherwise it make no sense to calculate a probability. Please fix this point.

Page(s) 17, Line(s) 373–374.

Author(s). The four candidate models of the time-varying margins are formulated as follows...

Referee. Please provide due comments/justifications about these choices.

Page(s) 18, Line(s) 376–ff.

Author(s). In terms of the fitting quality assessed by AIC...

Referee. The fitting procedure should work in the reverse sense. Viz., first the admissible distributions (among the ones of interest) are identified (if any) via a GoF test—e.g., KS, typically via a Monte Carlo algorithm, not by using values from statistical tables, as already mentioned above. Then, a "best" distribution is chosen (e.g., via AIC) only among the admissible ones. It makes no sense to compute the AIC of a non-admissible distribution. Please fix this point.

Page(s) 18, Line(s) 380–382.

Author(s). According to the regression functions of the location parameters μ, the means of the flood series are generally positively related to the urban population *Pop* , while negatively related to the reservoir index *RI*.

Referee. This point is not clear. If a regression has been performed, the corresponding p-value should be shown, in order to decide whether the regression is statistically significant. In general, this work lacks of a solid statistical base. Please fix this point.

Page(s) 19, Eq(s) 25.

The formulas given in Eq.s (25) look different from the one shown in Eq. (7): is this correct?

Page(s) 21, Line(s) 457–458.

Author(s). These differences among the OR, AND and Kendall exceedance probabilities induce the different design strategies.

Referee. As discussed in Serinaldi (2015); Salvadori et al. (2016), comparing results induced by the usage of different Hazard Scenarios could be misleading, if not meaningless. The Hazard Scenario should be chosen a priori, not as a result of the consequences that the choice of a given scenario might entail. This looks like a methodological flaw. Please comment this point.

Page(s) 23, Line(s) 511.

Author(s). In this paper, we present the methods addressing the multivariate hydrologic design...

Referee. The claim "the methods" is incorrect, and too strong: you present "some possible methods". Please fix the sentence.

References

Kojadinovic, I., 2017. npcp: Some Nonparametric CUSUM Tests for Change-Point Detection in Possibly Multivariate Observations. R package version 0.1-9.
URL `https://CRAN.R-project.org/package=npcp`

Milly, P., Betancourt, J., Falkenmark, M., Hirsch, R., Kundzewicz, Z., Lettenmaier, D., Stouffer, R., 2008. Climate change - Stationarity is dead: Whither water management? Science 319 (5863), 573–574.

Salvadori, G., De Michele, C., 2004. Frequency analysis via copulas: theoretical aspects and applications to hydrological events. Water Resour. Res. 40, W12511, doi: 10.1029/2004WR003133.

Salvadori, G., De Michele, C., Durante, F., 2011. On the return period and design in a multivariate framework. Hydrol. Earth Syst. Sci. 15, 3293—3305.

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Salvadori, G., Durante, F., Michele, C. D., Bernardi, M., 2018. Hazard assessment under multivariate distributional change-points: Guidelines and a flood case study. Water 10 (6), 751–765.

Serinaldi, F., 2015. Dismissing return periods! Stochastic Environmental Research and Risk Assessment 29 (4), 1179–1189, doi: 10.1007/s00477-014-0916-1.

Vezzoli, R., Salvadori, G., De Michele, C., 2017. A distributional multivariate approach for assessing performance of climate-hydrology models. Scientific Reports 7:12071, doi: 10.1038/s41598-017-12343-1.
URL `www.nature.com/scientificreports`