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Hydrology and Earth System Sciences
Discussions

Interactive comment on “Copulas for hydroclimatic applications – A practical note on common misconceptions and pitfalls” *by* Faranak Tootoonchi et al.

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Introduction

In their manuscript, Tootoonchi et al. (2020) discuss common pitfalls when applying copulas in hydroclimatic research. As this mathematical tool is only gaining in popularity, this is an interesting perspective and a subject worth discussing. However, some concepts could be more finetuned, and I hope my comments will help the authors to do so.

Specific comments

L. 41 Here you use evapotranspiration, but you used evaporation earlier. Is the use of both terms a conscious choice? If not, the recent preprint by Miralles et al. (2020), gives some insight in the discussion on the word choice.

L. 47-62: Although you mention this slightly (Hao et al. (2018), ‘compound context’), I think this paragraph could benefit from a better overview of the growing compound extremes literature, by referring to e.g. Leonard et al. (2014), Zscheischler et al. (2018) or Zscheischler et al. (2020)

L. 86: I think it would be better to cite the textbook by Nelsen (2006) instead of Schweizer (1991), as the first version of that textbook certainly invigorated the study and application of copulas, especially as you do not cite it anywhere else.

L. 89: Instead of Salvadori and De Michele (2010), I think it would be more relevant to cite e.g. Salvadori and De Michele (2004), although there are even earlier papers on the use of copulas in hydrometeorology

L. 98: Given that more and more papers use the term ‘bias adjustment’, it could be interesting to consider this term as well, as it more clearly states that the biases are and cannot fully be corrected. See e.g. Vrac (2018), Räty (2018), Zscheischler et al. (2019).

L. 101: Only referring to Räty et al. (2018) understates, in my opinion, the discussion on the use of multivariate bias-adjusting methods. For example, Meyer et al. (2019) and Zscheischler et al. (2019) have different conclusions than Räty et al. (2018), and François et al. (2020) clearly show where multivariate bias adjustment methods work and do not work.

L. 104: Schölzel and Friederichs (2008) also serves as a thorough introduction to copulas for hydroclimatic research and is worth citing as well

L. 125: For the copula density definition, it seems more logical to cite a textbook. For example, I easily found this definition in Joe (2014)

L. 136: Although Genest and Favre (2007) certainly clearly proposed how the empirical copula could be practically used, I think you should also cite Deheuvels (1979), as the empirical copula was originally proposed in this paper.

L. 143-148: It surprises me that it is not discussed how often the same few copulas are chosen in studies. This could be a potential pitfall as well. Although it is probably less of a problem for the combination of precipitation and temperature, it could be worth touching upon, especially as you cite Sadegh et al. (2017), wherein this was also discussed (hence the use of many more than the standard copulas in the toolbox presented in that paper).

L. 144: This is a mistake often made, but Archimedean and Elliptical copulas refer to classes instead of families. Gumbel, Clayton... are copula families. See e.g. Nelsen (2006).

L. 163: It would be interesting to see some references on the use of Archimedean copulas for the modeling of extreme events.

L. 168: This sentence seems to imply that there are only three different types of Archimedean copulas, although there are many more (see e.g. Nelsen (2006)).

L. 181: It would be interesting to see some examples of where exactly elliptical copulas are used.

L. 225- 247: On what is this selection based? As you intend to give a good overview of the pitfalls, I would also expect a good overview on the fitting and goodness-of-fit. See e.g. Genest and Favre (2007) (which you already cite).

L. 230: If a statistics is 'widely used', I'm interested in more than one reference, so I can compare the use in different sources. However, your opinion on this may differ.

L. 305-327: I think you could expand this discussion in some regards. First, you only speak about the (non)stationarity of the correlation. However, what about the stationarity of the marginals? These could (and are changing) as well, what could influence the

copula choice. Although this is linked with the correlation strength, I think it deserves a separate discussion. Second, although you already cite a few papers, stationarity is a heavily discussed subject. Some other interesting articles are e.g. Milly et al. (2008), Koutsoyiannis and Montanari (2015) and Serinaldi and Kilsby (2015). Third, part of this discussion is based on the statistical definition of stationarity, which you do not mention. Yet, this could be interesting, and the arguments in Koutsoyiannis and Montanari (2015) are based on this definition. Fourth, it would be interesting to discuss how, if problems with stationarity would arise, this could be dealt with. See e.g. the textbook by AghaKouchak et al. (2012).

L. 348-370. Some older papers also deal with the ranking problem, see e.g. Salvadori and De Michele (2006, 2007) and Vandenberghe et al. (2010). Besides, it is also important to consider that ties do not only occur because of dry days, but also because of measurement imprecision. Depending on the measurement error/discretization and time series length, time series can also contain several ties on wet days.

L. 423-440. Although I admit it is not the essence of the paper, I would be interested in a short discussion/acknowledgement of two aspects. First, would some of the pitfalls become more important when considering other hydroclimatic variables? Second, how would these pitfalls propagate when considering multivariate copula constructions? You for example cite Allen et al. (2017), in which vine copulas are used, which is an important tool for multivariate copula construction.

Technical comments

L. 161: I could not retrieve Hofert (2008) in the references

L. 166: 'is defined on (0 1]'. Is this correct?

L. 209: Should this instead be 'given a specific value of a second variable'

References

AghaKouchak et al. (2012): Extremes in a changing climate

Deheuvels (1979): La fonction de dépendance empirique et ses propriétés. Un test non parametrique d'indépendance. Bulletin de la classe des sciences, Academie Royale de Belgique

François et al. (2020): Multivariate bias corrections of climate simulations: Which benefits for which losses? Earth System Dynamics, https://doi.org /10.5194/esd-11-537-2020

Joe (2014): Dependence modelling with copulas

Koutsoyiannis and Montanari (2015): Negligent killing of scientific concepts: the stationarity case. Hydrological Sciences Journal, https://doi.org/10.1080/02626667.2014.959959

Leonard et al. (2014): A compound event framework for understanding extreme impacts. Wiley Interdisciplinary Reviews: Climate Change, https://doi.org/10.1002/wcc.252

Meyer et al. (2019): Effects of univariate and multivariate bias correction on hydrological impact projections in alpine catchments. Hydrology and Earth System Sciences, https://doi.org/10.5194/hess-23-1339-2019

Milly et al. (2008): Stationarity is dead: Whither water management? Science, https://doi.org/10.1126/science.1151915

Miralles et al. (2020): On the use of the term 'Evapotranspiration'. Earth and Space Science Open Archive, https://doi.org/10.1002/essoar.10503229.1

Nelsen (2006): An introduction to Copulas, 2nd edition.

Salvadori and De Michele (2004): Frequency analysis via copula: theoretical aspects and applications to hydrological events. Water Resources Research, https://doi.org/10.1029/2004WR003133

Salvadori and De Michele (2006): Statistical characterization of temporal structure of

storms, https://doi.org/10.1016/j.advwatres.2005.07.013

Salvadori and De Michele (2007): On the use of copulas in hydrology: theory and practice. Journal of Hydrologic Engineering, https://doi.org/10.1061/(ASCE)1084-0699(2007)12:4(369)

Schölzel and Friederichs (2008): Multivariate non-normally distributed random variables in climate research-introduction to the copula approach. Nonlinear Processes in Geophysics, https://doi.org/10.5194/npg-15-761-2008

Serinaldi and Kilsby (2015): Stationarity is undead: Uncertainty dominates the distribution of extremes. Advances in Water Resources, https://doi.org/10.1016/j.advwatres.2014.12.013

Vandenberghe et al. (2010): Fitting bivariate copulas to the dependence structure between storm characteristics: A detailed analysis based on 105 year 10 min rainfall. Water Resources Research, https://doi.org/10.1029/2009WR007857

Vrac (2018): Multivariate bias adjustment of high-dimensional climate simulations: the Rank Resampling for Distributions and Dependences (R2D2) bias correction. Hydrology and Earth System Sciences, https:// doi.org/10.5194/hess-22-3175-2018

Zscheischler et al. (2018): Future climate risk from compound events. Nature Climate Change, https://doi.org/10.1038/s41558-018-0156-3

Zscheischler et al. (2019): The effect of univariate bias adjustment on multivariate hazard estimates. Earth System Dynamics, https://doi.org/ 10.5194/esd-10-31-2019

Zscheischler et al. (2020): A typology of compound weather and climate events, Nature Reviews Earth & Environment, https://doi.org/10.1038/s43017-020-0060-z

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