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Natural Hazards and Earth System Sciences
Discussions

Interactive comment on "Evaluating the efficacy of bivariate extreme modelling approaches for multi-hazard scenarios" *by* Aloïs Tilloy et al.

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[R2 Introduction] This study evaluates the efficacy of various bivariate models for a variety of correlation structures in a large set of synthetic data. While I am not a fan of synthetic data, the rigorous and comprehensive evaluation of various models justify the publication of this paper in NHESS. However, there are some issues that remain to be resolved before final publication:

[AR to General Comments] We thank the Anonymous Reviewer 2 (R1) for this summary. Below, we provide detailed replies to the Reviewer comments (Author RepliesâĂŤAR).

[R2 Comment 1] 1. There is a large focus on multi-hazard analysis in this paper.

However, I cannot see the sector that is impacted by the presented case studies. For a multi-hazard coastal flood analysis, for example, it is intuitive how higher water levels and larger river flows lead to a larger risk of flooding. However, who is impacted by rainfall and wind? What is the final impact that is worsen by concurrence and subsequence of multiple hazards? Even more confusing is the wildfire case study. Wildfire is the impact of high-temperature, hence I am not clear whether it is justified to consider the wildfire and temperature as two drivers of one impact. What is going to be that impact? How is it worsen by the combination of these two hazards? The manuscript should justify the presented multi-hazard analyses.

[AR 1] Thank you for these thoughtful comments, which we respond to here including how we have modified our manuscript in response.

âĂć To put this into context, two authors of the manuscript work for an energy company and the original framework of carrying out this research was within problems that might be of interest for the energy sector. We therefore better highlight the potential impact to society and energy infrastructure in our revised manuscript (P3 L76-84). âĂć We agree with the reviewer that while compound flooding is measurable in water height (and thus the potential impacts this might have on various types of infrastructure), the potential impact of compound extreme wind and extreme rainfall is harder to quantify. In the context of energy infrastructure, the combination of extreme rainfall and extreme wind can lead, for example, to power cuts, wind destroying roof leading to greater damages, damage to energy production infrastructure (due to wind) with difficulties to repair the network arising from high surface runoff/flood due to extreme rainfall. For this point (and the next one), a paragraph is added at the end of the introduction to justify the presented multi-hazard analysis and provide better context (P3 L76-84). âĂć In the case of wildfire and extreme air temperature, we consider both of these hazards (UNISDR, 2009). Extreme hot temperature can lead to damage on infrastructure (e.g., rail track deformation) and cause death of people (e.g., 2003 heatwave in France). In term of impact of wildfire and extreme temperature, we argue that their interrelation

has the potential to put overwhelming pressure on critical infrastructure (e.g., health service, firefighters). That being said, this article is focusing on natural hazards and their interrelations and not on the measure of a combined impact, which can differ depending on the infrastructure/society considered. We hope that these explanations clarify the aims of the study. Again, to provide further clarification in the manuscript, we have added a paragraph at the end of the introduction to justify the presented multi-hazard analysis and provide better context (P3 L76-84).

[R2 Comment 2] 2. Wildfire burned area is related to temperature not the number of fires. A fire of size 0.1 ha can occur all year around, specially for human started fires (see Balch, J. K., et al. (2017). Human-started wildfires expand the fire niche across the United States. Proceedings of the National Academy of Sciences, 114(11), 2946-2951.). But more importantly, what is the impact? If it is the wildfire, is it justified to have fire as the impact and as the hazard? Is high-temperature necessarily a hazard?

[AR 2] We believe that extreme high temperatures can be considered a hazard based on sources such as UNISDR (2009). It is true that small fire occurs all year round, and our data also support that statement (see manuscript Figure 12). Burned area and number of wildfires depends on many other drivers such as wind, type of fuel and soil moisture. The aim of this study is not to decipher the mechanism leading to a wildfire but rather as an exemplar of looking at two hazards and quantifying their interrelation between two hazards. We have now made this point clearer in our manuscript. Regarding impact, both extreme high temperatures and wildfire as single hazards can potentially impact society. We also consider that extreme temperature increases the probability of wildfire occurring (AghaKouchak et al., 2018). We then try to address both of the following: (i) How much does an increase in tempearature impacts wildfire likelilhood; (ii) Estimating return periods for events of extreme heat and fire. A paragraph has been added at the beginning of Section 4.2 to justify our choices (P26 L452-457).

[R2 Comment 3] 3. Abstract needs some improvement. I struggled to understand how

the case studies are related to synthetic data.

[AR 3] This point has also been noted by Reviewer 1 (R1) and that part of the abstract has been modified (L10-11) and (L12-13)

[R2 Comment 4] 4. An important missing element in the evaluation of models is p-value. It would be interesting to see what the p-values are and determine whether the models fail/pass to represent the data! This is actually very important. The metrics used in the paper are subjective - although valuable - and a more widely accepted metric could help the general audience relate the study to other modelling practices.

[AR 4] We are unsure that p-value is applicable in the framework of this study as we are comparing curves and not the distributions themselves. However, we agree on the fact that a robust comparison point to assess the efficacity of model might be needed. We think that comparing model fitting capabilities to an empirical curve (obtained through point counting) would give valuable insight We therefore created empirical level curves and computed their wd to the reference curve following the same steps as for the 6 models. For each of the 60 synthetic datasets, models having a smaller wd to the reference curve than the empirical estimate are considered to be “passing” to represent the data with more accuracy than a naïve approach. Figure 7 has therefore been updated to incorporate this new information and a new paragraph has been added in Section 3.3 (P18 L484-489).

[R2 Comment 5] 5. There are many typos in the text. I highlighted some of them in the attached manuscript, but there are more.

[AR 5] Thank you for this noting of the typos. We have taken these into account in our revised manuscript by catching many of these, and will ensure that for any final proof reading we do a careful reading for typos.

[R2 Comment 6] 6. There are some specific comments that are provided in the attached manuscript. Hope the authors find the comments useful to improve their paper

[AR 6] Thank you for these comments. We have gone through these in detail and the major ones not addressed in R2 Comments 1 to 5 are the following, along with our replies:

[R2 Specific comments (from supplement)] L49-L51 P2 provide names not acronyms Change done

L 72 P3 joint extreme can be AND or OR scenario, Figure 1 shows AND scenario. please clarify It has been clarified

L108 P 4 Notations in equation 1&2 don't seem to be correctly presented Change done
L112 P4 u merges to 1 not infinity (if u is marginal) Change done. Thank you!

L114 P4 respectively is not needed. It is confusing actually Change done

L142 P5 this "u" is never defined before It was a mistake. U has been replaced by z and z has been defined.

L170 P6 "and" not "or" Change done

L257 P6 Summary section not needed Section has been removed

L270 P6 is this the same "u" used before? if not, it will be confusing No, but the meaning of u is specified on the following line

Figure 7 P19 while the presented metrics are nice, it would be more desirable to show the p-value for each case, to examine whether the copula/any model is representative of the data, or not. Then the distances would help select the best model The figure has been redone and the "tiles" in which models have a lower wd than a naïve empirical approach (See AR4) is highlighted. We consider that if the model represents the data better than an empirical approach in one of the cases, then the model is suitable for that case.

L472 P20 How can you say that. How is wd<0.1 selected as the criterion for goodness-of-fit, why not 0.05 or 0.2? We modified this part and also use the fact that the wd of

the model is lower than the empirical wd as a criterion for goodness of fit (See AR4).

L488 P20 needs a comma here In general commas are missing throughout the manuscript. before "respectively" you need a comma, etc We have changed some of these in our revised manuscript, along with doing a more thorough proofreading.

L510 P20 comma after "here" Change done

L599 P25 not the right reference for wildfire. Suggestion: Littell, J. S., McKenzie, D., Peterson, D. L., & Westerling, A. L. (2009). Climate and wildfire area burned in western US ecoprovinces, 1916–2003. Ecological Applications, 19(4), 1003-1021. We added the reference, thank you.

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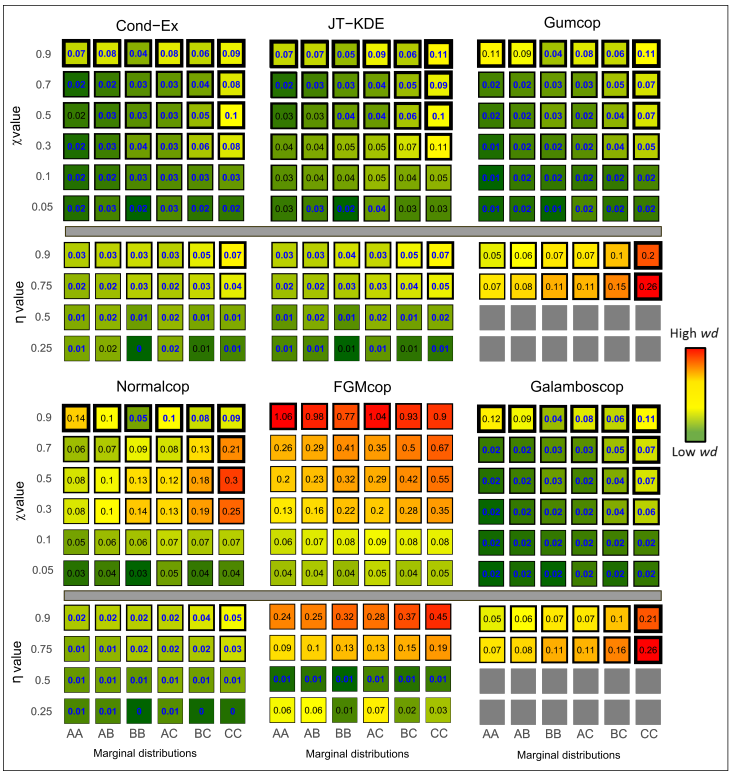

Fig. 1. Weighted Normalized Euclidean Distance (wd) to the reference curve for all 60 different synthetic datasets. Fitting capacities of each model are represented. Values in cells and colours represent the