

Interactive comment on “Changes in flood damage with global warming in the east coast of Spain” by Maria Cortès et al.

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Reviewer #1. GENERAL COMMENTS: In this article the authors carry out an assessment of the probability of future damaging events in two Western Mediterranean regions in Spain, considering both climate change and changes in exposure according to different socioeconomic scenarios. Although the results show a promising methodology for predicting flood damage, several suggestions should take into account before the work will be published.

Response: We would like to thank the reviewer for his very constructive comments.

Reviewer #1. A) Introduction: “In Spain, the findings of Barredo et al. (2012) align with these results; they find no significant trend in adjusted insured flood losses between

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1971 and 2008. These studies show the need to include exposure and vulnerability changes in future risk projections, which clearly contribute substantially to changing risks.” I think that relevance given to social variables (exposure and vulnerability) in this work is very correct. In recent years, they have acquired as much or more importance than the physical ones within the risk formula. However, from my point of view, according to the results and the significance of these social variables in the models obtained, these social variables should be better explained. Therefore, I would like to see a paragraph in the introduction of the new version of the work that deepens in this regard.

Response: We found the bibliography provided by the reviewer very interesting, and we agree on including a paragraph in the introduction section that goes deeper in the role of exposure and vulnerability factors in flood risk. We have added this paragraph (line 26, page 2): “Other studies such as López-Martínez et al. (2017) and Pérez-Morales et al. (2018) also mention the vulnerability and exposure components as possible drivers responsible for the increasing flood risk in Mediterranean regions of Spain. Specifically, these studies mention the institutional vulnerability (Raschky et al. 2008), which represents the sensitivity of public administrations to deal with hazards, as one of the main causes. Also, Pérez-Morales et al. (2018) demonstrated that the exposure in flood-prone areas in the south-east of Spain (part of the region of study) has increased in the last decades, due to a poor management of these areas by government institutions and the regulation adopted by them.”

Reviewer #1. B) Limitations and future research: “Future research should focus on incorporating further variables into the model to reproduce the complexity of flood risk. flood damage caused by other types of flood events, such as those caused by heavy precipitation episodes (surface water floods), and also taking into account the changes in the population in the analysis”. On the other hand, I suggest to the authors that, for the improvement of the models in future works, take into account those variables more related to building. Cadastre offers high-resolution temporal space data very

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useful in this regard. Although variables such as the number of inhabitants, population density per square kilometre, etc. can be significant, they are frankly improvable due to their level of temporal space aggregation. This implies an important generalization that does not correctly represent the exposure, much less vulnerability. In the case of flooding hazard, cadastre and the variable "number of buildings per census tract" of the INE are much more precise. In fact, Cadastre is much more related to the database of damages registered by the insurance consortium, since these indemnities are associated with insurance policies connected to buildings or homes with cadastral references.

Response: We wish to thank the reviewer for this constructive comment and for the information provided. We agree on the improvement of the future works by considering more variables related to the exposure and vulnerability when analysing flood risk. In this work, we have chosen representative exposure variable to obtain in future projections in order to use the same model developed in the present climate for predicting future flood damage. In order to emphasise this, we have changed the following sentence in the manuscript (line 13, page 23): "Future research should focus on incorporating further variables into the model to reproduce the complexity of flood risk, not only regarding hazard drivers but also considering more variables related to the exposure and vulnerability, as for example those related to the buildings present in the study region."

Reviewer #1. C) Data. Line 21: "The population data corresponds to the year when the flood event took place". According to this, the availability and source consulted year by year must be indicated. Municipal Register of inhabitants or Population Census.

Response: We agree with the reviewer and we have added this information in the manuscript. In addition, the reviewer's comment has helped us to realise that there was an error in the population data source of Catalonia. Population data of both regions (Catalonia and the Valencian Community) have been obtained from the same source (Spanish National Statistics Institute). We have changed the sentence as following

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(line 19, page 6): "Population data for both regions were obtained from the municipal register of inhabitants provided by the Spanish National Statistics Institute. . ."

Reviewer #1. D) Generalized Linear Mixed Model: As far as my knowledge on the subject goes, it would be convenient to carry out a spatial autocorrelation test (Moran's I) to rule out the assumptions discussed in the text of the paper.

Response: The spatial autocorrelation is almost negligible in this case. The model includes a random effect associated with the geographical basin to reflect the autocorrelation for observations coming from the same basin, and the estimates for this component have a standard deviation that can be considered zero. This means that when considering the observations from the same basin, these observations can be considered independent. For analysing the case of spatial correlation as a function of the distance between basins, we have applied the suggested test (Moran's I) for three variables: Number of events, sum of damages and mean damage. The p-values for the test in each variable confirm that there is no need to consider spatial correlation in this case. In order to clarify this point and to not create misunderstanding, we have changed the following sentence in the manuscript (page 8, line 16): "This implies high correlations within the observations, not guaranteeing the independence requirement of the Generalized Linear Models (GLM)."

For: "This implies that the observations are grouped by random factors, not guaranteeing the independence requirement of the Generalized Linear Models (GLM)."

Reviewer #1. D) Generalized Linear Mixed Model: Likewise, it would be convenient to compare the accuracy of the results with other models such as Geographically Weighted Logistic Regression (LGWR) since, as indicated in the work, there is very strong spatial autocorrelation that could reduce the accuracy of the results. The LGWR models are effective to solve spatial autocorrelation and non-stationarity, or regional variation, of some variables. Thus, the results of the GLMM models could be improved since it is possible to differentiate the local spatial variations of the parameters

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estimated by means of the implementation of a kernel function, that allows to make estimations adjusted to each observation giving greater influence on the closer observations.

Response: We agree with the reviewer that if there would have been significant the spatial autocorrelation, these kind of models could have been useful. But in this case, there are two random factors that are crossed: basin (spatial effect) and flood events (time effect). The model estimation indicates that the first is not significant but the second is. We have fitted the proposed models (LGWR) to evaluate the impact of spatial autocorrelation in the parameter estimation, but, to our knowledge, the implementation (<https://github.com/pysal/mgwr>) does not include the existence of random effects, so the time effect is not included in this model, which is clearly significant in our case. The results of the model obtained with LGWR are the same as the GLMM when the flood event effect is not considered.

Reviewer #1. E) Future probability of damaging events. Regional rivalry (SSP3): Population scenarios and, specifically SSP3, which represents a decrease in damage should be explained in greater detail by relating the comment within the context of the study area. In fact, this aspect is crucial, since it is a good find from which to establish these adaptation measures or strategies to climate change impacts.

Response: We agree with the reviewer's comment and we have included a paragraph in the results section (line 11, page 19): "This scenario refers to a fragmented world with an emphasis on security at the expense of international development. In rich-OECD countries (defined by OECD membership and the World Bank category of high-income country), to which both regions of our study belong, the SSP3 scenario depicts a low fertility rate, high mortality and low immigration (Samir and Lutz, 2017). Therefore, population is assumed to decrease in these countries (see Figure 8). On the other hand, the largest increases in probability are found under SSP5, since this has the largest increase in population (see Figure 8). As mentioned before, this scenario refers to a world that emphasizes technological progress and where economic growth

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is fostered by the rapid development of human capital. In rich-OECD countries a low mortality rate, high immigration and a relatively high fertility rate are expected, due to a high technology and a very high standard of living that allows for easier combination of work and family (Samir and Lutz, 2017)."

Reviewer #1. SPECIFIC ASPECTS: A) Figure 2. Map of both regions of study (put white lines of the provinces)

Response: We have followed the reviewer's suggestion and tried to include provinces lines in the map but for visual criteria we have decided to consider only basin borders.

B) "The solid line indicates the best estimate while the shaded blue bands indicate the 95 % confidence interval". This phrase is repeated both in the body text and in the figures caption. Consider removing from the body text.

Response: We have removed from the body text following the reviewer's suggestion.

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