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Interactive comment on "Modelling the socio-economic impact of river floods in Europe" *by* L. Alfieri et al.

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General If possible, the authors should explain some key methods used, by adding explicative equations and/or one or more sentences. Moreover, discussion should be expanded and the abstract needs to be rearranged, since it lacks to include methodology novelties and some key results.

Reply: We thank the reviewer for his critical evaluation and his useful comments on the submitted article. We will modify the manuscript accordingly, and point by point corrections are listed below. We do not disagree with the vast majority of the comments, hence most of those will result in some change, edit and addition to the original submitted version. In the revised version we will expand significantly the discussion section, by separating it from the conclusions and by adding a specific subsection on

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the sources of model uncertainty. The results will be complemented with additional text to help the readers understand the differences between the two proposed methods. In addition, we have modified two figures to make them more intuitive, clarified their captions and added a new figure to the article to give a better insight on the components of the risk assessment. Those will be included in the revised version. Also, the abstract will be modified and made it more consistent with the work presented in the main body of the article. Some additional material was produced on the Lisflood model calibration, on the simulated flood hazard maps over Europe and an explanatory table for the ISO country codes. This material consists of two further figures and two tables and it will be included in the Supplement material. We hope that the reviewer finds these modifications helpful for the readers to better follow the methods, results and conclusions of the presented research. In the following each comment is answered after the label "Reply:".

Introduction Page 1; L 22: The work is based on the great relevance that the three factors of risk (hazard, exposure and vulnerability) have in regard to river floods. I think that a further explanation of this should be included in the introduction section in order to contextualize the results presented. In addition the authors need to emphasize more the gap of knowledge and the importance of this study.

Reply: Following the reviewer's comment we will expand the introduction section to better put the research work in the context of flood risk assessment. This will include some clarification on the three factors of risk and their potential effect in risk reduction through adaptation measures. Also, we will emphasize better how the proposed work brings some novelties in comparison to existing studies. All changes and additions will be adequately supported by references to literature works.

Data and methods Page 2; L 6: "Extreme value" does not need "EV" abbreviation since it is never used in the text and could confuse the reader.

Reply: Removed as suggested

Page 2; L 9: As the Lisflood distributed model is a milestone for the supported analysis, I recommend a more detailed explanation about its efficiency, use and validation.

Reply: In the revised version we will add a considerable amount of information on the hydrological model, its calibration strategy, and some quantitative performance skill of the calibration in different river sections, including one additional figure and one table in the Supplement material. In Section 2.1 we will add: "Processes simulated by Lisflood include snowmelt, soil freezing, surface runoff, infiltration, preferential flow, redistribution of soil moisture within the soil profile, drainage of water to the groundwater system, groundwater storage, and base flow. Runoff produced for every grid cell is routed through the river network using a kinematic wave approach." Also: "The calibration work was performed using the R package "hydroPSO", which implements a state-of-the art version of the Standard Particle Swarm Optimization 2011 (Zambrano-Bigiarini and Rojas, 2013). Some performance of the calibrated stations are shown in the Supplement (Fig. S1 and Table S1)."

Page 2; L 21: T returned period considered are described in line 34. I suggest moving this information in line 20. Moreover, the consideration of 500 years of return time for 24 years analysis sounds odd.

Reply: Here, the idea is to separate the fitting of analytical distributions on annual maximum discharges, from the choice of specific return periods, which is only done at the stage of producing synthetic flood hydrographs and the corresponding flood depth maps. With regard to the use of 500 year return period estimated from a 24 year sample, we will add that it is done following similar literature examples (e.g., Sampson et al., 2015; Winsemius et al., 2015), which clearly lead to an increase in uncertainty, but it is necessary to produce estimates of the impact of flood events in the range of magnitude commonly above that of the return period of flood protections.

Page 2; L 24: Why L-moment estimators are particularly useful for short samples? Are there any references in support? I would substitute short samples with short time

series.

Reply: Amended as suggested. With regard to the author's comment on L-moments, those are more robust than conventional moments, as they are based on linear combinations of order statistics. While conventional moments of higher order (2nd, 3rd) can be estimated accurately only with a large sample of data representing adequately the dispersion, skewness, etc of the distribution, L-moments are less affected by data scarcity, as they are based on linear combinations. For such considerations and other details on L-moments we refer in the text to the work by Hosking (1990).

Page 3; L 6. Please explain further the depth-damage functions defined by Huizinga 2007.

Reply: In the revised version, more details on those functions will be included. In particular, we will add that "Depth-damage functions per each country and land use class comprise two damage indicators (Huizinga, 2007): an absolute damage value, in €m2, which is attributed to all flood depths equal or larger than 6 meters; and a damage factor relative to the maximum damage (i.e. between 0 and 1), which is defined by piece-wise linear functions. Those two indicators are derived through analysis of written documentation and data on the internet from 31 countries in Europe."

Page 3; L 11-12 "For regions in countries where no damage function was available. . ."Please list them.

Reply: The sentence will be removed in the revised version as the information was already included in the sentence before. For clarification, damage functions were available for all countries, while the regional (NUTS2) disaggregation is carried out by rescaling by the regional GDP per capita.

Page 3; L 16 For the flood risk assessment the authors proposed two approaches that I think could be merged in the chapter without the subdivision. The article is quite short and it is divided in a lot of very small chapters. As a consequence, the reading

becomes quite difficult.

Reply: As suggested by the reviewer the section will be merged by removing the 3rd level of subdivision. In the revised version the two methods will be part of Sect. 2.5.

Results Page 3; L 34-on: Flood risk assessment is an assessment of the various risks in relation to residential, industrial and commercial land uses. It is a requirement as part of any planning application especially flood-prone areas. The results proposed by the authors do not stress the implication at the European level of such novel modelling proposed assessing the social and the economic impacts. The authors evidenced some of the main results and poorly contextualized them. The same results are difficult to see in Figure 2 proposed, that lacks of a meaningful caption and a visual observation of the most and least economic damaged countries or population affected ones. ISO country codes need to be explicated (by adding a table or a figure).

Reply: In the Results section we will reshape and add some text to stress how different components of the risk formula (namely hazard, exposure and vulnerability) contribute to the overall flood risk. A new dedicated figure will also be included to give the spatial variations of the three components. The discussion and conclusion sections will be considerably reshaped and more details will be added on the strengths and limitations of the proposed methodology. Further, in the revised version of Figure 2, countries will be sorted according to decreasing values of relative damage and population affected obtained with the integral method, for easier readability. This follows the description in Sect. 3. In addition, we will add in the Supplement material a table with ISO country codes and related full country name, to make results of easier reading.

Page 5; L 2-on: The case study comes a bit unexpected to the reader. The performance test of the event based method is not included in the objectives of the present work. In addition a further explanation of the 2013-catastrophic flood is needed.

Reply: Upon the reviewer's comment we will add in the last part of the Introduction section a comment about the case study. The text will clarify that "the event based

method is used to assess the impact of the severe flood hitting a vast portion of the central Europe in June 2013, and results are evaluated against reported figures from re-insurance companies and post-event reports." Also, we will add in Sect. 3.2.1 some details on the flood event and its causes: "This was a severe, large scale event which affected several countries and led to the loss of lives as well as considerable damage in the Danube and Elbe river basins. The event was associated with a quasi-stationary upper level low located northeast of the Alps and by a significant contribution of orographic lifting (Pappenberger et al., 2013). Also, in the weeks leading up the event, rainfall totals were significantly above normal in large parts of central Europe, exacerbating the runoff process. The return period of the discharge peaks was estimated to equal or exceed 100 years in various rivers including the Isar, Inn, Salzach, Danube, Elbe, Mulde, Saale, Rhine and Neckar (Zurich, 2014)"

Discussion and Conclusions Page 5- L25-on: Discussion and conclusions need to be separated. The discussion part lack to include a very broad discussion of the results presented and the implications they have in flood risk assessment. Fig. 2 needs further discussion since it seems that for some countries there are controversially results obtained from the two methods. In addition, it should discuss the different between the two approaches. In addition, please move some paragraphs in the discussion part: L 20 to 25 and L 29 to 38. Page 6, L 9-on: Chapter 4.1 "The influence of flood protection" needs to be included in the discussion session, since it presents some important considerations linked to the results of the presented work.

Reply: In the revised version, Discussion and Conclusions will be separated into different sections as suggested, and each of them integrated with additional text. The revised Discussion section will include three subsections: 1) the event based method, 2) The influence of flood protections and 3) Sources of uncertainty. The Conclusions will be separated and will include some key messages of the presented research. Further, some additional text will be included in the results section to clarify the differences between the flood impacts obtained with the two methods in Figure 2.

Page 6, L 29-30 Please rephrase.

Reply: The sentence will be rephrased as follow: “If the adaptation effect is not considered in the impact assessment, flood risk is likely to be overestimated in those areas hit by a series of floods within a relatively short time range, as seen in Sect. 3.2.1.”

Figures Figure 1 “Schematic view. . . risk assessment” is difficult to read. There are a lot of abbreviations that are not explained in the text.

Reply: In the revised version we will modify the figure by removing most acronyms and replace those with more self-explanatory labels of the methods and of the input/output data. Also, the figure caption will be expanded.

Figure 5 “Estimates.. in Central Europe” is difficult to read. The meanings of the grey dots are explained only in the text. Please add more information in the caption.

Reply: The caption of the figure will be expanded to include more details: “Estimates of damage and population affected (event based method) in Central Europe from 25 May to 10 June 2013. Grey circles indicate hotspots of simulated damage larger than 100 M€ and population affected in excess of 5,000. Areas outside the simulation domain are masked in grey”.

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