Reply to Referee #1

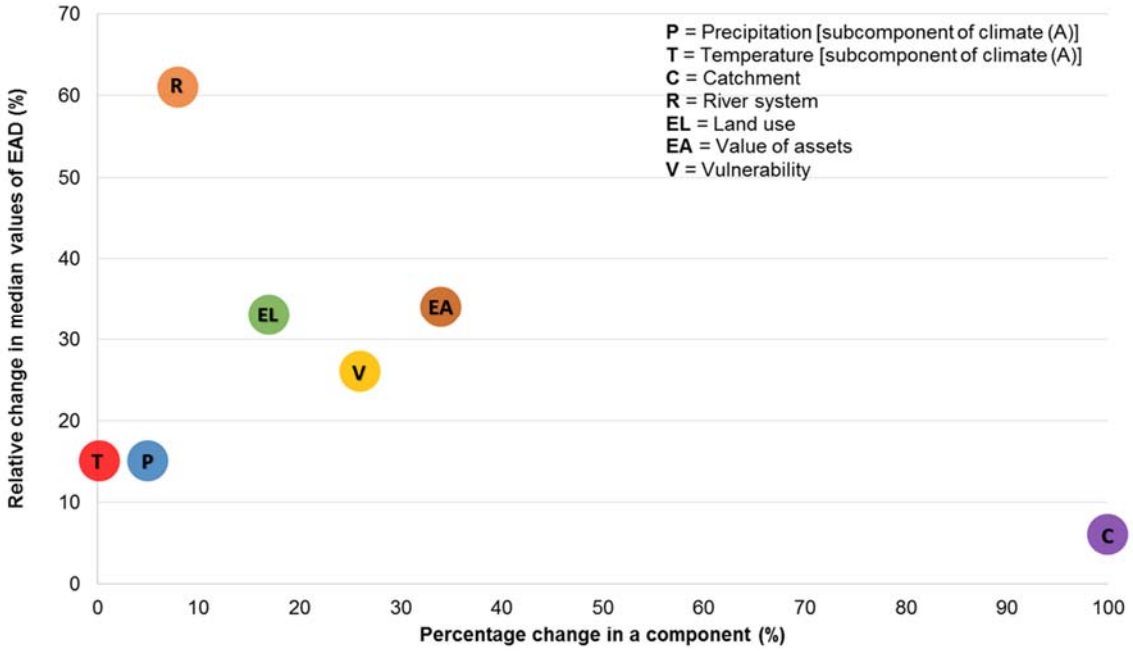
First of all, we would like to thank the referee for the time and effort put into reviewing the manuscript. In the following, we provide our responses to the individual questions posed by the referee.

The paper studies the sensitivity of flood risk to various factors: Changes in precipitation and temperature, reservoir size, dike height, distribution of residential areas, the value of affected buildings and private household precautions. Thus, the factors consider changes in climate, catchment, river system, land use, assets and vulnerability. Changes in the likelihood of monetary losses are determined by changing the aforementioned factors. To achieve this, a model chain consisting of a weather generator, a rainfall-runoff model, a river-network routing model, a hinterland inundation model as well as a flood-loss model is set up. For each of the 729 selected scenario combinations 4000 years of continuous model simulations are produced and analysed.
The study is within the scope of NHESS. It is important to the scientific community as it shows that it is possible to consider the entire flood risk chain and identify the most influential factors for flood risk. It is the first/one of the first studies attempting this comprehensive approach. The most important result is that, not-surprisingly, increases in flood risk due to climate change can be compensated by appropriate protection and precautionary measures.

We would like to thank the reviewer for his/her positive feedback. We are pleased that the reviewer finds the research important for scientific community.

Major comment:
The changes imposed on the different risk components are very different in magnitude (e.g. small atmospheric changes but huge changes in reservoir size (+100%)). To get a better idea of the sensitivity of losses to these components it would be good to add a graph which displays the influence of normalized changes on the losses. I am aware of the fact that there will be some subjectivity when deciding on a suitable way to normalise the imposed changes.

We thank the reviewer for this comment. Although the changes imposed on the different risk components are very different, we would like to highlight that the imposed changes are plausible. In response to this comment, we add a graph which shows percentage changes in the different components versus percentage changes in the median expected annual damage (EAD). It is visible that river system has a big impact on loss despite the fact that the imposed change is one of the lowest. However, the normalization to obtain percentage change would be very subjective and may mislead the readers. For example, adding 0,5 °C during the winter season would mean a large change of 100%, whereas adding the same delta during the summer would be a small change of 3%. Summing up these different changes for the years does not provide a sensible piece of information. Further, the imposed changes depend on the spatial characteristics of the component which is changed in the sensitivity analysis. For instance, for atmosphere the change is imposed on all sub-basins across the catchments, whereas for the catchment component, it depends on the existence and the size of the reservoirs. Therefore, we prefer not to add this figure to the manuscript as it could easily mislead the reader and we do not see that it provides additional, useful information.



Minor comments:

p.1 l.38 Is Kreibich et al. the first/only publication that states this? Otherwise please add. "e.g." to the reference. Please also check this for all other references.

It is not the first/only publication. We will add ‘e.g.’ to the reference and checked for the all other references.

p.2 l.78 Did you search for all keywords separately or only in combination?

We searched all keywords both in combination and separately, not to miss any relevant study.

p.9 l.231 "More importantly, with the new setup, the SWIM model seems to be able to represent the cut-off process more accurately." Where do I see this?

We thank the reviewer for this comment (which has been addressed by the reviewer #2 as well). Because the reservoir component is only present in the new setup of the SWIM model, we will remove the irrelevant text “more accurately” from the sentence. Additionally, we will also modify the paragraph to make it clearer.

p.10 l.258-266 For which size of area is the model acceptable (what is meant by "largescale")?

The model has been developed for the risk assessment in large-scale catchments, but the quality of model is adequate for the Mulde catchment, which is a meso-scale catchment.

p.11 l.271-272 Please specify: Less damage if people are regularly affected.

We will include this statement to support that’s why advanced version of FLEMO considers the return period of the inundation.

p.11 l.280-281 How do modelled return periods compare to observed return periods?

We did not compare modelled return periods with observed return periods directly. However as stated in the manuscript, the SWIM model has been validated against daily stream flows with a focus on high flow at selected gage stations. This implies that the model is supposed to be adequate for modelling flood (extreme) events and hence the return periods should be reasonably modelled by the hydrological model. The FLEMO damage model uses three classes of flood return period as descriptive variable (<10 year, 10-99 years, >100 years) (Elmer et al., 2010). Therefore, we believe that the final risk estimates are not too sensitive to small deviations in the estimated

return periods. Moreover, in the sensitivity analysis presented here, relative changes in risk are in focus rather than accurate estimates of the actual risk.

p.11 l. 283-287 Are these values better when reservoirs are considered? (You show before that discharge was improved.)

Actually, the mismatch is larger when the reservoirs are added into the model. The calculated damage amounts to approximately €61 million and is slightly reduced due to retention effect. The major problem is the mismatch between observed and simulated inundation areas due to dike breaches. Dike failures are insufficiently implemented and captured in the model (only dike overflow is considered). We will mention the change in loss estimation due to reservoir implementation.

p. 11 l.298 It would be interesting to learn something about the computational demand of the different modules of the model chain, relative to each other (e.g. 10% weather generator, 30% SWIM ....)

Approximately computational demand: 8% RWG (coverage: Germany+), 10% SWIM, 80% RIM, 2% FLEMOps. Please note that RIM runs on a mixed infrastructure CPU + GPU. The other components run on CPU only.

p.12 Fig. 4 In my opinion this figure is not needed.

Figure 4 shows the combinations of three plausible change scenarios for each of the six components. We added this figure to show the complexity in the design of the scenarios and to help readers to capture the idea. By considering Referee #2's comment on this figure as well, we propose to change capture of the figure. We shall use "conceptual scheme" instead of "logic tree".

p.12 l.336-339 Please give the numbers or refer to table 2.

We will refer to Table 2 in the revised version.

p.13 sec. 3.23 Please move the explanation on the operation of reservoirs from page 15 to this section.

We thank the reviewer for this comment. In the page 8, l.215-220, we have explained the operation of reservoirs. Therefore, we would prefer not to repeat it here. Instead, we will move the explanation on the operation of reservoirs in the page 15, 'Reservoirs operated in this way are very effective in reducing the peaks of extreme flood events' to p.8 l.220.

p.14 l.402-403 In the discussion section you clarify that anthropogenic climate change may be associated with very different temperature and precipitation values (patterns, duration, clustering ....) in the future, which are not captured by your approach. Here you seem to suggest that the other studies overrate the effect of climate change. Please rephrase.

We thank the reviewer and we will rephrase this sentence as in the following. "Another remarkable result is the rather small increase in the median loss values for changes in the atmosphere (A) from scenarios 0 to 2 (from €0.6 million to €0.8 million), despite the realistic assumptions on average changes in climate variables. Although our model does not capture complex change patterns such as changes in duration of wet spells or clustering of events, this result indicates that changes in climate might be not the dominant ones along the risk chain contrary to the prevailing perception."

Figs 9+11 I find it impossible to follow the path of the thin lines towards the right of the plot. I assume that this could be improved if you consider to refrain from changing the colours along the graph. In case you want to keep the colour change you need to explain it in the text. It took me a long time to figure out what the colour change (probably) wants to tell me. I would also suggest to add a black default-scenario line.

We will improve these figures by using same colour along the graphs.

Technical remarks:
p.2. l.69 Something is missing in this sentence

We will rearrange this sentence as following. “Hence, conclusions from normalization studies, such as there is no evidence for the effect of human-induced climate change on the loss trend (e.g. Barredo, 2009), need to be taken with care.”

p.4 l.137 "but they also have storage capacity"

This will be corrected.

p.4 l.144 "the Mulde catchment has been hit by large floods associated with high damages before"

This will be corrected.

Fig. 10: EAD values on y-axis are missing

This will be added.

p.21 l.592 "our scenarios are reasonable to represent"

This will be corrected.