Point-by point response to Referee comments on:
"Understanding flood regime changes in Europe: a state of the art assessment"

Below we will respond to the comments of the two referees as on HESSD and the third referee that could not deliver her/his report on time and indicate how we have incorporated the changes into the revised manuscript (*in italics*). The major changes will be listed at the end of this file.

Responses to referee comments and changes made - Anonymous Referee #1 (RC1)

RC1-1: The main attempt of the work presented in this manuscript is to improve the understanding of flood regime changes in Europe. The authors selected a state of the art review as the presentation format. The manuscript is organized in four main sections, starting with the introduction, followed by the review of data base and model base approaches, an idea how to improve the understanding and future research. The presentation includes a detailed review of available literature.

Unfortunately, this paper failed to provide an improvement in understanding the change of flood regimes in Europe – therefore the title may be misleading. This contribution looks much more like a proposal for the research project that should result in an improved understanding of flood regime changes than the presentation of the completed work. The main benefits of the paper include (a) a clear indication that floods are changing in Europe and (b) an indication that many authors are dealing with this questions at different locations across Europe using different methodological approaches.

Response: We would like to thank the reviewer for providing his/her opinion on the review article.

Unfortunately, the basic premise on which the reviewer's comments hinge is inaccurate.

The first sentence of the reviewer's comment states "The main attempt of the work presented in this manuscript is to improve the understanding of flood regime changes in Europe."

Actually, that is not the case. Rather, the original manuscript clearly states "The purpose of this paper is to review the current understanding of flood regime changes of European rivers, in particular whether changes have been observed in the past, the drivers of change, what changes are likely to be expected in the future and the current methods used." (p. 15529).

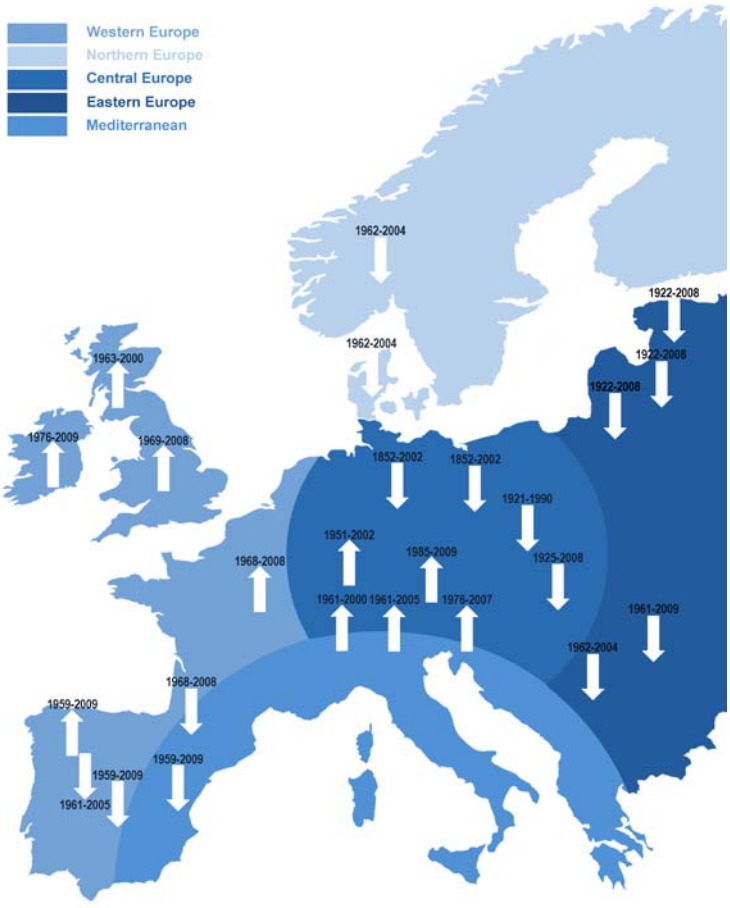
In other words, the aim of the paper is to REVIEW the current understanding, rather than "to IMPROVE the understanding", as implied by the reviewer (p. C7757).

The HESS submission guidelines state "Review Articles summarise the status of knowledge and outline future directions of research within the journal scope." (http://www.hydrology-and-earth-systemsciences.net/submission/manuscript_types.html). This is indeed what the paper attempts to achieve.

The identification of the paper type as a review has been stressed in the initial submission in the following manners: 1) by choosing the wording "state of the art assessment" in the title; 2) by indicating the category "review" in the paper type on submission; 3) by clearly stating in the aim of the paper ("The purpose of this paper is to REVIEW the current understanding ..." (p. 15529).

RC1-2: In order to become a significant contribution a synthesis work should be completed before the final acceptance of this publication. There are some difficulties in trying to synthesize the work of many authors and results obtained using various methodological approaches. However, comparison of results for three larger geographic regions and specially their presentation in aggregated form for the whole Europe would be a very useful outcome of this publication. It is very hard to see what is the value of an analysis that simple states what is available in the literature. For example, just a quick look at the Western Europe and Northern Europe presents decreasing and increasing (on some stations) trends in Spain, no change, increase and decrease in France, increase and no change in UK, no conclusion in the Scandinavian countries – so what can be inferred about the change in flood regime?

Response: All referees suggest to summarise observed flood regime changes. F*or ease of interpretation of the review of studies results we present the complex picture of observed changes in a schematic (see the new Figure 4 (below) showing observed flood regime changes from the literature reported in the text. We have also added a paragraph that further describes how to interpret the new schematic (see page 14 of the revised manuscript).*



New Figure 4: *Schematic summarising the observed flood changes in Europe derived from cited studies using different not directly comparable change analysis methods and time periods. Note: Arrows in the schematic indicate the majority of trends including regions with weak and/or mixed change patterns. Areas with no/inconclusive studies due to insufficient data (e.g. Italy) and inconclusive change signal (e.g. Sweden) are not shown.*

RC1-3: Large portion of section 2 provides the review of methods that are commonly used in hydrological practice and there is no need for extending the length of the manuscript by their presentation.

Response: Indeed, this is the purpose of a review paper. The nature of a review paper is that it does not go beyond what has been published in the literature (rather it provides order to the existing literature), yet this seems to be the main criticism of this reviewer.
The reviewer seems to evaluate our manuscript as if it were a "research article". However, this is not a research article and never claimed to be one, as noted above.

RC1-4: The discussion of scenario analysis in section 3 is not necessary. Use of scenarios in water resources management is very common and comparison with origins of scenario analysis as it applies to management science (especially use of Shell example) do not provides any additional value for the reader of the manuscript. Scenario analysis has direct links to our understanding of decision making under uncertainty. Flood risk management today and the understanding of future change of flood regimes will depend on the use of quantitative assessments of associated uncertainties. Presentation of sources of uncertainty, their regional differences, and their impact on the understanding of flood regime changes, as well as integrated presentation for the whole Europe will be necessity before final acceptance of the manuscript.

The prediction of future changes in flood regimes is appropriately linked to land use change, climate change, and physical change of river characteristics (hydraulic structures and morphology). It will be essential for proper understanding of future changes to clearly identify the key drivers of change and start the analysis of causal relationships (feedbacks) from change in population (results in change of land use, urbanization, river characteristics) and climate.

Response: For section 3, it has been suggested by both anonymous referees to omit the general discussion on scenario analysis in the revised version of this manuscript. *Instead of discussing the origin of the term scenario (i.e. the Shell example), we focus on the usefulness of being explicit about the different futures and associated uncertainties that are made when scenarios are being used (see page 22 in the revised manuscript).*

While we agree with the referee, that a quantitative assessment and 'presentation of sources of uncertainty, their regional differences, and their impact on the understanding of flood regime changes, as well as integrated presentation for the whole Europe' are important and desirable at a future stage, we are not including such an assessment as this is clearly out of scope for a review paper. The same applies to the identification of key drivers of change and analysis of causal relationships as proposed by the referee.

RC1-5: Section 4 of the manuscript is clearly indicating that the material presented in the manuscript is much closer to a research proposal than the journal article.

Response: We would like to refer the reviewer to the HESS submission guidelines for reviews. These are very clear in that review articles are to "outline future directions of research within the journal scope". This is exactly what section 4 does.
In case the reviewer believes that the readers will struggle to understand that this is a review paper rather than a research article, we would be happy to make a clearer statement in the manuscript that this is a review paper to avoid misunderstandings, and would appreciate any guidance on how to do this.

In summary, while we appreciate the reviewer's concerns in the review, we are afraid that the point that this is a review paper has been missed. We therefore would appreciate further comments and insights bearing in mind that this is a review paper.

Responses to referee comments and changes made - Anonymous Referee #2 (RC2)

RC2: <u>General comments:</u>

The authors present a review about flood regime changes in Europe. The review includes methods for detection and prediction as well as the results regarding flood regime changes in Europe. For the changes the three driver's: river hydraulics, land use and climate are considered. Based on the review of methods for detection and prediction the authors discuss challenges and opportunities. The paper finishes with a synthesis of approaches and recommendations for future research.

This is a very long and comprehensive article. On one hand, this gives a rough but almost complete overview about the topic. On the other hand, the paper is missing focus and somewhat tedious to read. From my point of view, the main problem is that the authors try to cover simultaneously both a review of methods and a review of results regarding flood regime changes. Especially the long listing of papers about flood changes in Europe is confusing and not giving any clear picture or message about the change signal.

I think the paper can become a good review contribution to the hydrological sciences for HESS. However, it needs major revisions. I see two options: a) either make the paper even a bit longer and try to better summarize quantitatively flood changes in Europe using more figures/tables or b) make two papers from it separately addressing a review of methods and a review of flood regime changes. Considering shorter and more focussed papers, I personally would favour option b) but would not be insistent.

Response: Regarding the general comment on the length of the paper, we would like to keep the paper in the current format and avoid splitting it. We believe that a key strength of this review paper is that it combines the methods used to detect flood regime changes and also the detected changes together with the challenges and opportunities. *To illustrate the detected changes we will add a figure that shows where and when the changes have been observed* (see also response to **RC1-2** and the new Figure 4)

RC2: <u>Detailed comments:</u>

RC2-1. Page 15538: The significance of change is discussed extensively but how to address the magnitude of change is somewhat neglected.

Response: We agree that the information on the magnitude of change is an important part of the change signature. However, as mentioned in the manuscript, the studies used different methods and time periods to detect flood changes which results in a complex picture of

change. Therefore, less attention is given to the actual magnitude of change. Additionally, most studies only test for significant change (e.g. using the Mann-Kendall test) and do not report on the magnitude. *We add an additional sentence to clarify to the reader why the magnitude is not available or not comparable for most of the studies (see p 14 of the revised manuscript).*

RC2-2. Section 2.2.1: This section contains a huge listing of reported changes. This is hard to read and a general picture of changes cannot be seen. The authors should try to sort this out and summarize the different results using figures and tables.

Response: *As mentioned above we have included an additional figure to summarise the complex pattern of changes into a general picture (see response to **RC1-2** and the new Figure 4). Additionally some minor edits have been made to this section to increase clarity.*

RC2-3. Page 15548: The suggestion to focus on flood -poor and flood -rich periods is interesting. The authors should briefly discuss possible implications for prediction and design here.

Response: The focus on flood -poor and flood -rich periods is indeed an important point. *Therefore, as suggested, we included a discussion on the possibilities for prediction and design associated with flood-poor and flood-rich periods (see page 19 in the revised manuscript).*

RC2-4. Pages 15551/52: The general discussion on the term scenario is not constructive here. Better, make definitions in the sense the term "scenario" is used throughout the paper.

Response: *The discussion on the term scenario has been shortened and (see page 22 in the revised manuscript and also response to **RC1-4**)*

RC2-5. Page 15553: There is quite a bit of textbook knowledge about river hydraulics. Consider shortening. This applies also to some other sections.

Response: We agree that for some part of the readership the points listed here might not be new, however for the broader audience in Earth Sciences we consider this kind of information beneficial. This also applies to the other sections, which the referee suggested to shorten. Reducing this or other sections would change the consistency with the other drivers of change (i.e. sections).

RC2-6. Section header 3.3 is same as 3.2. I would assume 3.3 should be extended by "- challenges and opportunities".

Response: Section header 3.3 should indeed have the suffix "- challenges and opportunities". This part of the caption got lost in the typesetting process. Thank you for pointing this out. *This has been changed on p 36 in the revised manuscript.*

RC2-7. Figure 7: How is the magnitude of the trend calculated here? See also comment #1.

Response: Trend magnitudes are calculated using linear regression applied to time series with a minimum length of 30 years up to a maximum length of 180 years for all possible start and end years between 1828 and 2008.
To clarify this, the caption of Figure 7 (now Figure 8 in the revised version) has been changed accordingly (see p 90 revised manuscript).

Responses to referee non public comments and changes made - Anonymous Referee #3 (RC3)

RC3-1: I would put 1.3 before 1.2 (or even integrate in introduction) as it is a logical continuation of the introduction.

Response: Indeed, section 1.3 could go before section 1.2. However, we prefer to leave section 1.3 in the position as it is, as this allows to explain better the entire structure of the following paper.

RC3-2: The authors talk about 'flood peaks', but it is not clear if they mean peaks in discharge, or peaks in water level. Given the paper concerns river training, floodplain remove and such this is an important distinction.

Response: *In several instances in the revised manuscript the text was amended so it becomes clear that discharges are considered*.

RC3-3: 2.1.3: maybe 'Methods of change detection' instead of trend detection. It looks like both trends and regime shifts are looked at.

Response: Section 2.1 has already the heading 'Methods of change detection' whereas in section 2.1.3 the main focus is on trends.
T*he first sentence of this section has been amended to clarify this.*

RC3-4: 2.2: this section I found rather tedious as it stands now and entails my main comment. The text claims that the review suggests 'some broader patterns' (page 15539, line 3). However, that does not become clear at all as the following is mainly a listing of studies and what they found. I would suggest to make a table grouped by region, showing for the different studies/catchments (rows) during which times (columns) they found increases/decreases (in table itself). If this is ordered in a good way, some of the broader patterns may emerge, or at least the heterogeneity will become clear. This table can then be discussed with text.

Response: *As mentioned above we have included an additional figure to summarise the complex pattern of changes into a general picture (see response **RC1-2, RC2-2** and new Figure 4).*

List of all relevant changes made in the manuscript

1) F*or ease of interpretation of the review of studies of observed flood changes we present the complex picture n a schematic (see the new Figure 4 (p 86 in the revised manuscript) showing observed flood regime changes from the literature reported in the text. We have also added a paragraph that further describes how to interpret the new schematic (see last section p. 14 (line 20-31) in the revised manuscript) and made the entire section more concise.*

2) Instead of discussing the origin of the term scenario (i.e. the Shell example as in the original manuscript which was removed), we added a sentence to explain the usefulness of being explicit about the different futures and associated uncertainties that are made when scenarios are being used (see p. 22 line 28-30 in the revised manuscript).

3) plus some smaller changed detailed above