Reply to Reviewer 2

Review of paper:

Stucki et al.: Reconstruction and simulation of an extreme flood event in the Lago Maggiore catchment in 1868

General Comments:

The paper aims at the reconstruction of an extreme hydro-meteorological event causing great damages in the Lago Maggiore region and parts of the Swiss Alps, which took place in 1868. The authors combine historical information with a meteorological and hydrological modelling. Their modelling approach makes use of the 20th Century Reanalysis (20CR).

The paper is well written and covers an interesting approach. The authors manage to paint a plausible picture regarding the reconstruction of an at least centennial scale extreme event more than 100 years ago. In principle, this paper fits well in the scope of this journal.

My major concern is that it is not fully clear how specifically the 20CR data are used in their analysis or to derive their high-resolution downscaling simulations. The expected uncertainty of the 20CR data to reproduce a series of mesoscale events is not well addressed. I would guess that the 20CR ensemble is poorly constraint by the few available surface pressure information available at that period. Therefore, I would expect a large ensemble spread and a too smooth ensemble mean over 56 members. The figure they present (section 3.3) show sharp mesoscale feature with respect to streamers, wave breaking or hydrological variables.

In addition, it is not clear to me, how an appropriate forcing for the downscaling is derived from an ensemble mean, since the averaging could induce imbalances in the dynamical fields or at least cause too smooth fields to allow the development of very extreme events. What are the consequences for the high-resolution quantitative results presented? Similar topics are discussed for the representation of windstorms in Welker et al. (2015) paper, which also hints at the smoothing effect of using the ensemble mean.

Both aspects should be more extensively addressed in the paper.

Thank you for the appreciation of language, style and content, and are pleased to read that you judge the manuscript worth publishing after revision.

We understand the concerns of both reviewers about inherent uncertainty in 20CR, which might be passed on to the regional model, and the limited predictability of parameters like precipitation. Similarly, we understand the concern about a large spread and smoothing effects. In the following, we respond to both reviewers regarding these concerns.

In an ideal world, we would assess all uncertainties and include an 'uncertainty bar' for each step, as it would be desirable for a risk assessment study. Unfortunately, this is far beyond the possibilities of this study. Yet, we clearly see the need for describing the limitations and uncertainties of the used tools and the obtained results. In the revised version of the manuscript, we do this for each step of the modeling chain in the respective results sections.

Most prominently, we have added an extended quantitative assessment regarding the 20CR ensemble mean and members in Sect. 3.3. First, we address the spread of the 20CR SLP fields over Central Europe, which is mostly below 1 hPa. We show that the isobars remain within a narrow band, and that the ensemble mean represents a middle scenario; it runs always within the bulk of the members. To further assess the uncertainty of 20CR in the region and time of interest, we analyze specific diagnostics for each observation that went into the assimilation. Specifically, we analyze the ensemble spread of the first guess and of the analysis, and we analyze the background departure (obs-bck). Our analysis shows that the observations reduce the ensemble spread by a factor of 0.5 to 0.75. Observation departures are relatively small and no clear pattern appears. In addition, we analyze the smoothing effect by comparing minimum pressure in the ensemble mean to the minimum pressure values from the full ensemble. The minimum pressure values in the ensemble mean lie between the 54th and 57th percentile of the ensemble members. This illustrates that there is hardly any smoothing effect in the pressure fields of the ensemble mean for our region of interest. The corresponding analyses are shown in Fig. A2 in the Appendix. The analyses support the choice of the ensemble mean as a plausible and realistic depiction of the meteorological situation in 1868.
We also include descriptions of limitations in the subsequent steps of the model chain. Please refer to the specific comments for more detailed information. In summary, the limitations of the weather and hydrological model setups are described in a semi-quantitative or qualitative way. The choice of the WRF setup is now justified at the top of Sect. 3.4. Uncertainties regarding the hydrological modeling are addressed in a separate paragraph in Sect. 3.5. Specifically, the description of uncertainties regarding E-OBS are included in the data section.

Your general comments had us also think about what the choices of tools and model setups mean and what the simulation outcomes represent under these circumstances. Following Compo et al., (2011), we regard the ensemble mean as a ‘minimum-error estimate’, and the results from the hydro-meteorological simulations can be regarded as a well-reasoned proposal of how the weather evolved during the 1868 event. These notions are elaborated in the article, and also appear in the conclusions.

We hope that we meet the expectations of the reviewers with these revisions and adaptations.

Specific
points:

Section 1

I agree with the other reviewer that the introduction is too long and includes aspects which would better fit in the results sections.

According to your suggestion (and the same by reviewer 1), we have moved some specific content to the results sections, i.e. concerning the Swiss legislation after the 1868 event, the mesoscale flow modulation on the south side of the Central Alps, and the hydrological response. Because this is an interdisciplinary study, we think we should shortly introduce some important concepts, e.g., political responses, or the role of IVT, PV-streamers, or the zero-degree line.

Section 2.2 lines 9ff:

How is the initial state of the soil moisture derived? The downscaling period might be too short to derive a reasonably balanced soil.

The soil moisture in the WRF simulations is initialized from the reanalysis soil moisture data, and indeed, the soil moisture is a long-memory variable that reaches its equilibrium later than the atmospheric variables. However, the relatively short spin-up time used here (6-12 hours) allows for a good reproduction of the event (see Messmer et al., 2017, using a spin-up of 6 hours for a comparable experiment). Overall, the model spin-up time has been determined in a trade-off between avoiding model adjustment and remaining faithful to the reanalysis data. We have inserted an according sentence in the article.

Section 3.3:

Please state also here which data are used within the chapter – presumably the 20CR ensemble mean.

Yes, this is an essential information. We have also added an extended explanation of why we chose the 20CR ensemble mean; see our reply to the general comments.

Figure 6: Not all the variables shown are explained in the caption but discussed later.

Thank you for the hint. We have inserted the missing information about geopotential height.

Figure 9: There seems to be a typo in the figure caption

Yes, the caption is adapted. Thank you for pointing this out.

Figure 12 right: There is a white curve, which is not explained in the caption

Thank you for the hint; the figure has been revised and replaced.