Response to the comments on the manuscript (HESSD-2019-415) " New flood frequency estimates for the largest river in Norway based on the combination of short and long time series" by Kolbjørn Engeland, Anna Aano, Ida Steffensen, Eivind Støren, Øyvind Paasche

This is the authors' answer to the interactive comment posted by Anonymous Referee #1.

We are very grateful for the excellent review afforded by the anonymous reviewer which we believe will improve our paper.

Length of the paleoflood record.

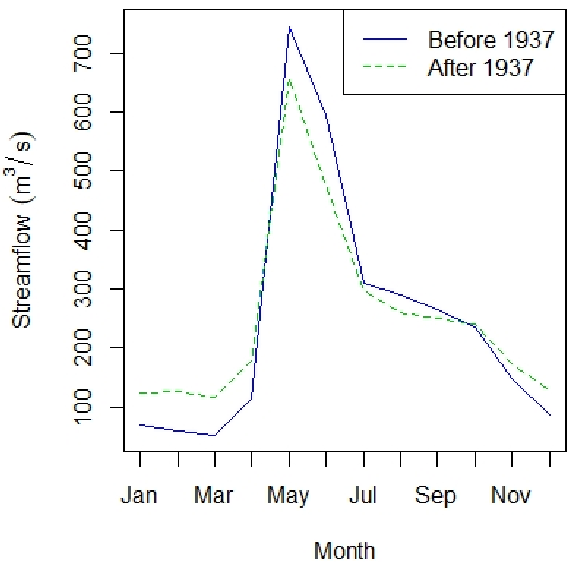
The value of 10 300 comes from Table 5 where the calibrated age based on 14C-dating of the lowest sample is 10259 – 10403 BP (68 % C.I.). We therefore think that 10 300 is a reasonable and robust assessment of the age of the lowest part of the sediment core based on the data used in this study. The paper by Høgås & Longva (2016) does not contradict our age assessment but suggest that the lowest part is not older than 10 400 years. Do note that the age estimate provided by Høgås & Longva (2016) comes with considerable uncertainty as well.

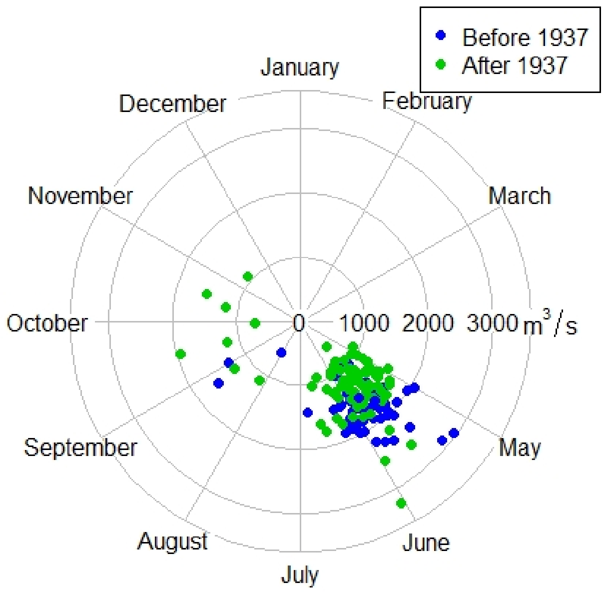
Section 1

We agree that a main reason for the increasing of flood damages is the corresponding increase of economic values within the flood plains. We will add this important clarification in the first paragraph of section 1.

Section 2

In the figure on the left hand side of Fig. 2, we follow the suggestion by the reviewer and add dashed lines. We will also use different colors in order to increase the contrast between the two. This modification is shown below.





Specification of the Holocene period:
The beginning of the Holocene period is in most literature referred by 11 700 years B.P. See e.g Walker et al (2009).

Section 3 and 4.3

Data and periods used for flood frequency analysis:

The different periods of data used in the flood frequency analysis are as follows

- Systematic data used for flood frequency analysis is 1872 – 1936
- Historical flood data is 1653 – 1871, a length of 219 years
- Paleo-period lasted from 1300 – 1652, i.e. a length of 352 years with 110 flood events in total when we combined paleo- historical and systematic data.
- The paleo record lasted from 1300 – 1871, a period of 571 years with 208 floods when we combined paleo and systematic data.

The period with systematic streamflow data started in 1872. We used data for the period 1872 - 1936 to avoid effects of river regulations on the flood peaks. We did not use the floods from 1966, 1967 and 1995 in the flood frequency analysis. These floods are, however, listed in Table 1 since they are documented on the flood stone. It could be an option, but would require a detailed hydraulic model, to recreate the catchment dynamics with no river regulations. This is beyond the scope for our study. The mean annual flood for the period 1872 – 1936 is 1700 m^3/s. For the period 1937-2019 it is 1362 m^3/s. A Wilcoxon test indicates that this difference in mean value is significant with a p-value of $2*10^{-8}$ for the zero-hypothesis (i.e. no difference in mean values between the two periods).

The oldest historical flood was observed in 1675. The average waiting time between the historical floods are 22 years. The start of the historical period was therefore set to 1675-22 = 1653 as recommended by Prosdocimi (2018) and Engeland et al. (2018).

We decided to let the paleo-periods start in year 1300, since we have a quasi-stationary period from 1300 until today. Before 1300 the flood frequency is small. We will slightly change the length of the paleo-periods so that they both start in year 1300 and ends the year before the systematic record starts or the start of the historical period.

We will clarify this in both the manuscript and in the figure legends for Figs. 14 and 15.

Plotting positions:
The plotting positions in Figure 14 and 15 are based on Hirsch and Stedinger (1987) that is based on the Cunnane plotting position (Cunnane 1978) the exceedance probability p_i of x_i

with rank i from a data set with t historical floods representing the historic period h, and s systematic floods with e extraordinary floods is given as:

$$p_i = \frac{i - 0.4}{l + 0.2} \cdot \frac{l}{n} \qquad i = 1, .., l$$

$$p_i = \frac{l}{n} + \frac{n - l}{n} \cdot \frac{i - l - 0.4}{s - e + 0.2} \quad i = l + 1, \dots, t + s$$

where i is the rank, l is the number of extraordinary floods ($l = t + e$) and n is the length of the period for which we have information about floods (note that $n = h + s$)

Since we used the systematic streamflow data from 1872-1936, we have 2 systematic floods exceeding the threshold (1916 and 1934) (i.e. $e = 2$) and 9 historical floods (i.e. $t = 9$ and $l = 11$) for the period 1653 - 1871. The length of the systematic record $s = 65$. The length of the historical period $h = 219$ years, thus $n = 284$ years. We did not include the floods from 1966, 1967 and 1995.

The plotting position for the highest flood is 292 years and agrees well with the Figs. 14 and 15.

We will add information about how the plotting positions were calculated.

Stability of river profile at Elverum:
The stability of the river profile at Elverum is an important assumption when we assess the discharges of the historical floods. The gauging station was moved around 660 meters in 1969. For the period 1872 – 1968 only one rating curve is used. For the period 1969-2020, the rating curve changed following the flood in 1995. In our study, it was assumed that the river profile at Elverum was stable for the historical period and that the flood in 1789 did not make any substantial changes. This seems to be a reasonable assumption since four large floods occurred during the period 1872 - 1968. We will ad a small discussion on this topic to the revised paper.

Section 5.2
The two sub-periods with increased flood peaks during the LIA are indeed interesting, and we thank the reviewer for pointing this out. During this period the average summer temperature for the northern hemisphere did not change substantially. To interpret the dip in flood frequency around year 400 BP remains challenging. Firstly, the temperature anomaly represents an average for the northern hemisphere and not for south-eastern Norway in particular. Secondly, the combination of winter temperature and precipitation might be even more useful for interpreting the flood frequency. Such proxy information is not yet available and therefore limits the possibilities to fully what we observe.
In the revised paper we will add more discussion on flood generating processes and how the available proxy-data can assist us in interpretation of the non-stationarity observed in the paleo-record. See also our answers to Reviewer #2.

Section 5.3

We agree that this part of the text explaining how the period for the paleo-data was chosen is a little confusing and we will make an effort to improve the clarity as explained in an earlier comment.

Small Typos

All typos will be corrected accordingly. Thanks.

References

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