NEW FLOOD FREQUENCY ESTIMATES FOR THE LARGEST RIVER IN NORWAY BASED ON A NOVEL COMBINATION OF STREAMFLOW-, HISTORICAL- AND PALEO-DATA

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Photo: NVE/Arne T. Hamarsland
Flood in Glomma

Background

The Glomma river is the largest in Norway and repeated destructive floods continue to represent a major climate hazard.

Photo: NVE/Arne T. Hamarsland
Flood in Glomma

Motivation

- Floods patterns are changing
  - We need to interlink different types of data and flood information on different time scales
- Design flood estimates are based on extrapolation
  - Reduce uncertainty in design flood estimates for long return periods

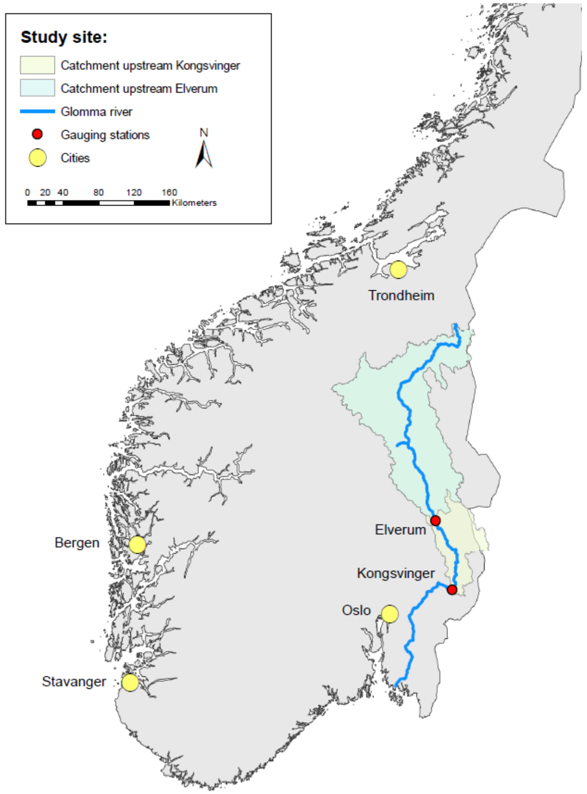
Photo: NVE/Aldo Dyvik
Flood in Viksvatn

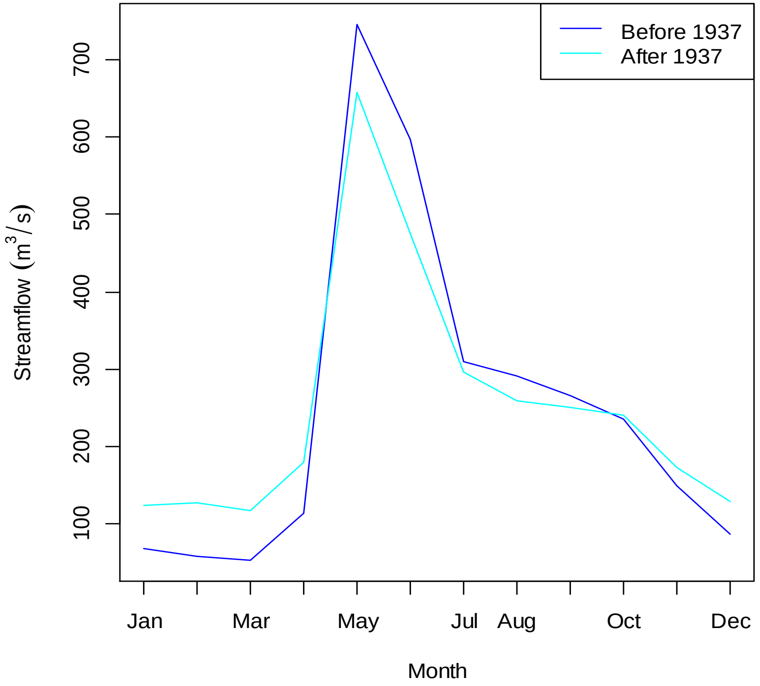
Aims

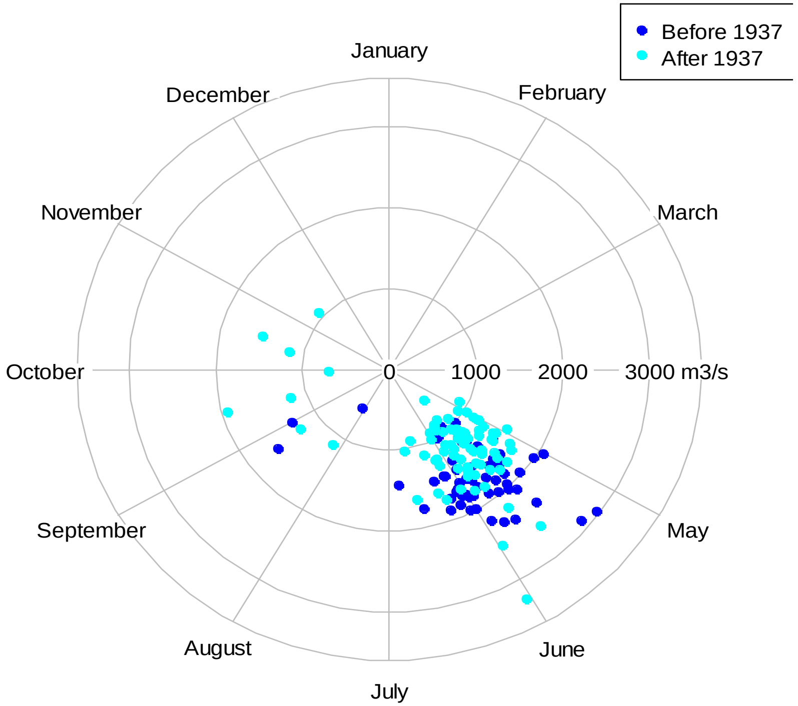
Combine systematic- historical and paleo-information in a flood frequency analysis in order to better understand and predict changes in flood frequency and magnitude for Norway's largest river, Glomma. In particular we want to explore:

- Past variability in floods as reconstructed from lake sediment cores.
- Potential non-stationarity in our new paleoflood record and its potential connection to regional climate change.
- The added value of combining systematic-, historical-, and paleo-flood data when estimating flood quantiles

Study catchment at Elverum



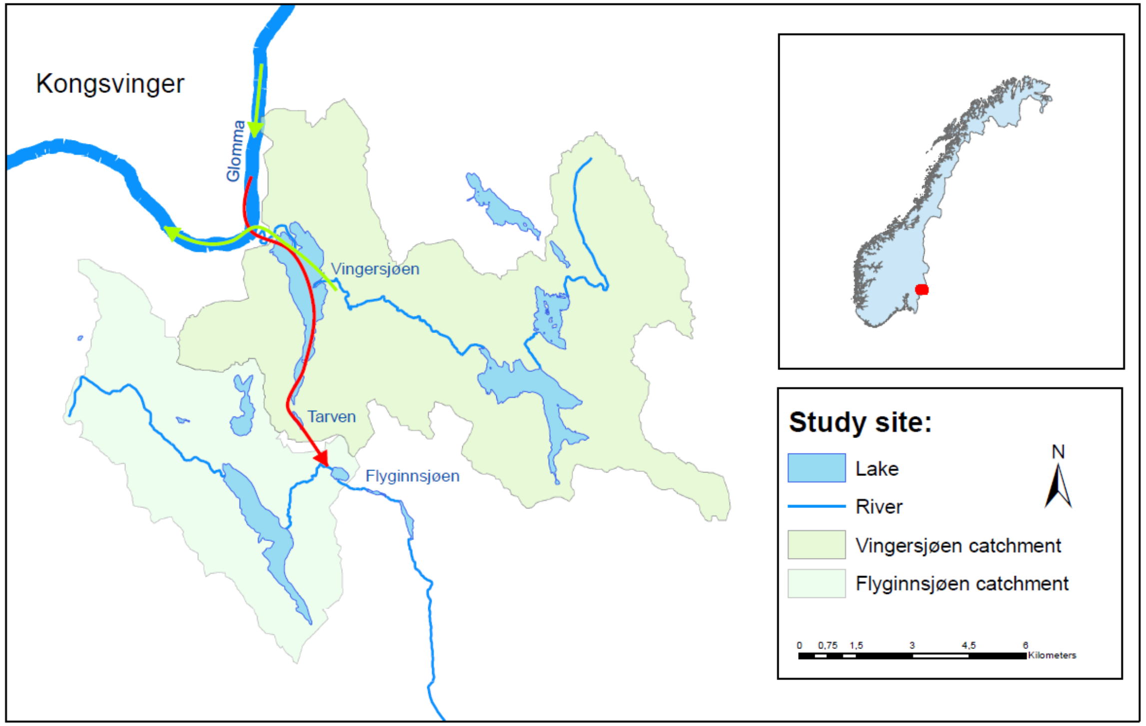




The location of the streamflow gauging station at Elverum used for flood frequency analysis, and the site for paleodata collection close to Kongsvinger.

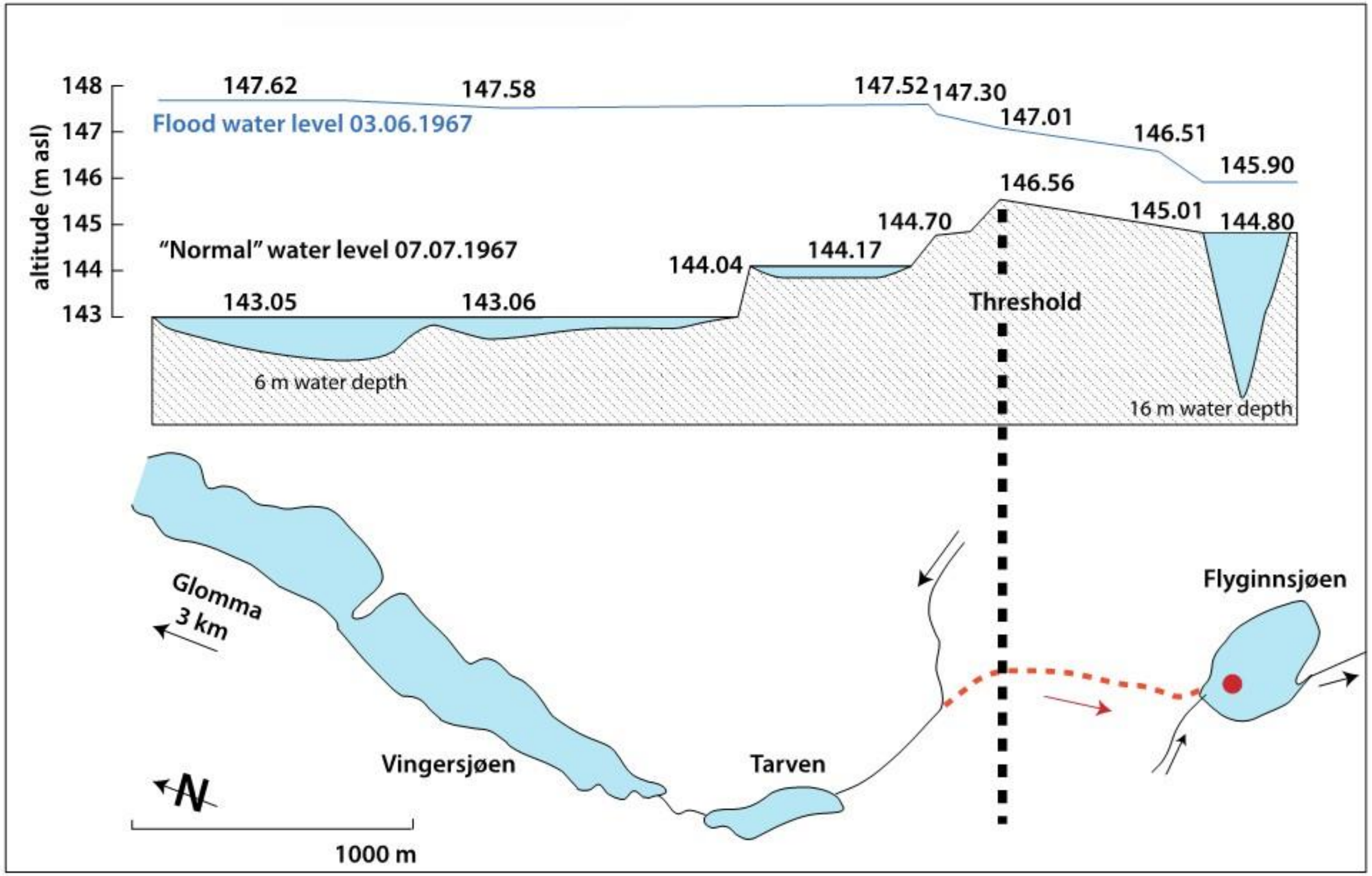
Seasonality of Glomma's monthly streamflow (left) and annual maximum floods (right) at Elverum. The dampening of floods after 1937 is explained by up-stream dam-building.

Study site for paleo-data



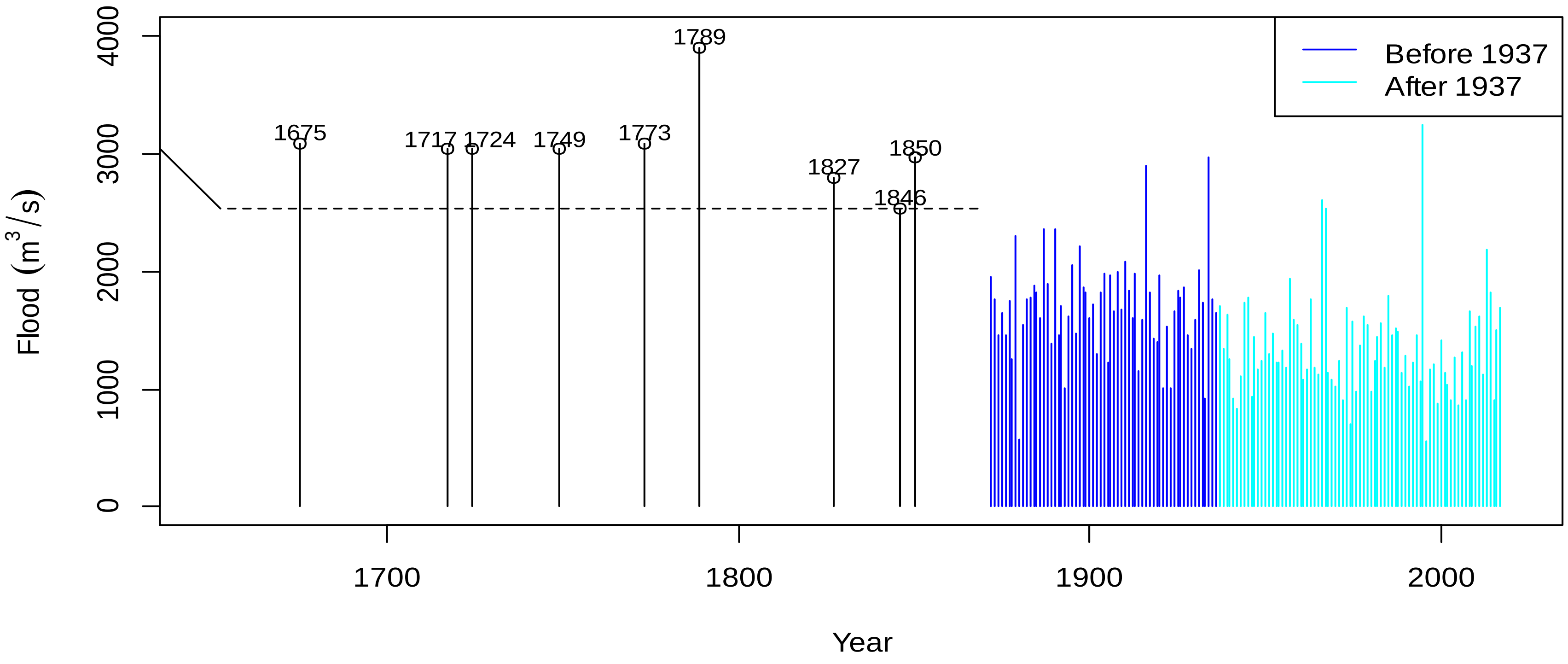
Study site for the paleodata. The sediment cores were extracted from lake Flyginnsjøen. The green arrows indicate the flow direction under normal conditions, whereas the red arrow shows the flow direction whenever there is a flood that exceeds 1500 m3/s.

Study site for paleo-data



Conceptual model of the lakes involved, flood water levels, thresholds and flood pathways

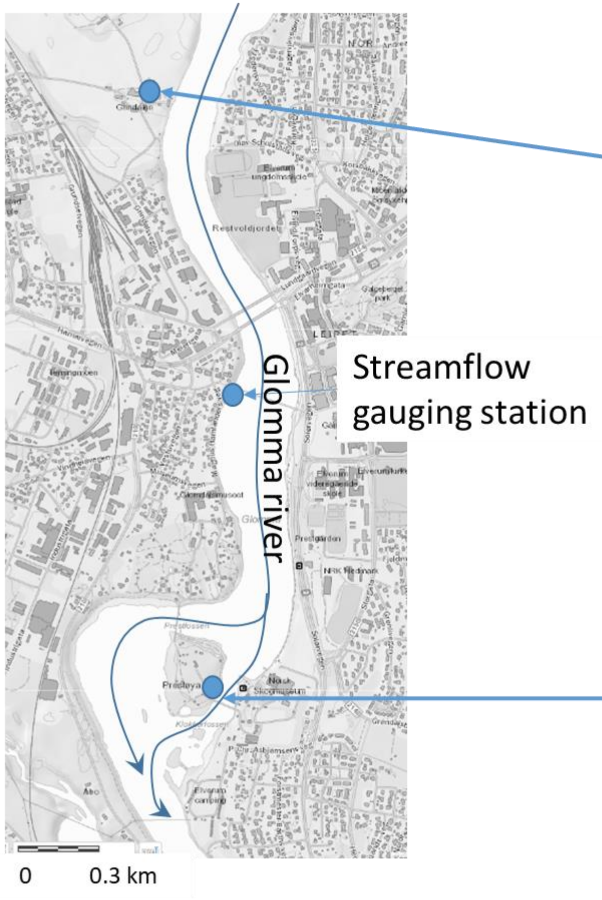
Systematic and historical flood data



Historical floods at Elverum

Flood monuments at Elverum

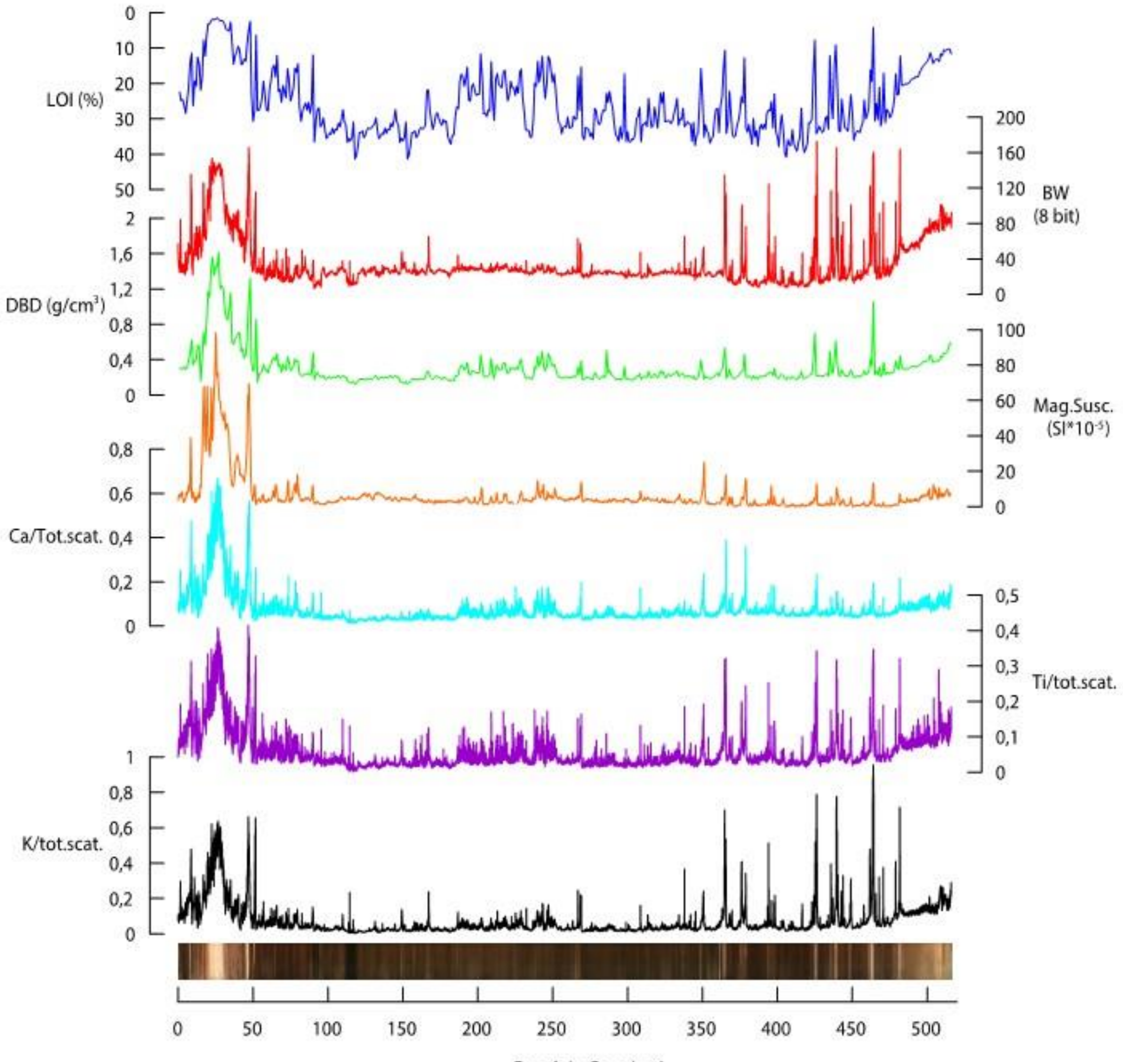
Largest flood in July 1789, same year as the French revolution



Flood stone at Grindalen

Flood stone at the Norwegian forest museum

Results of XRF-scan and CT scan of a sedimentcore

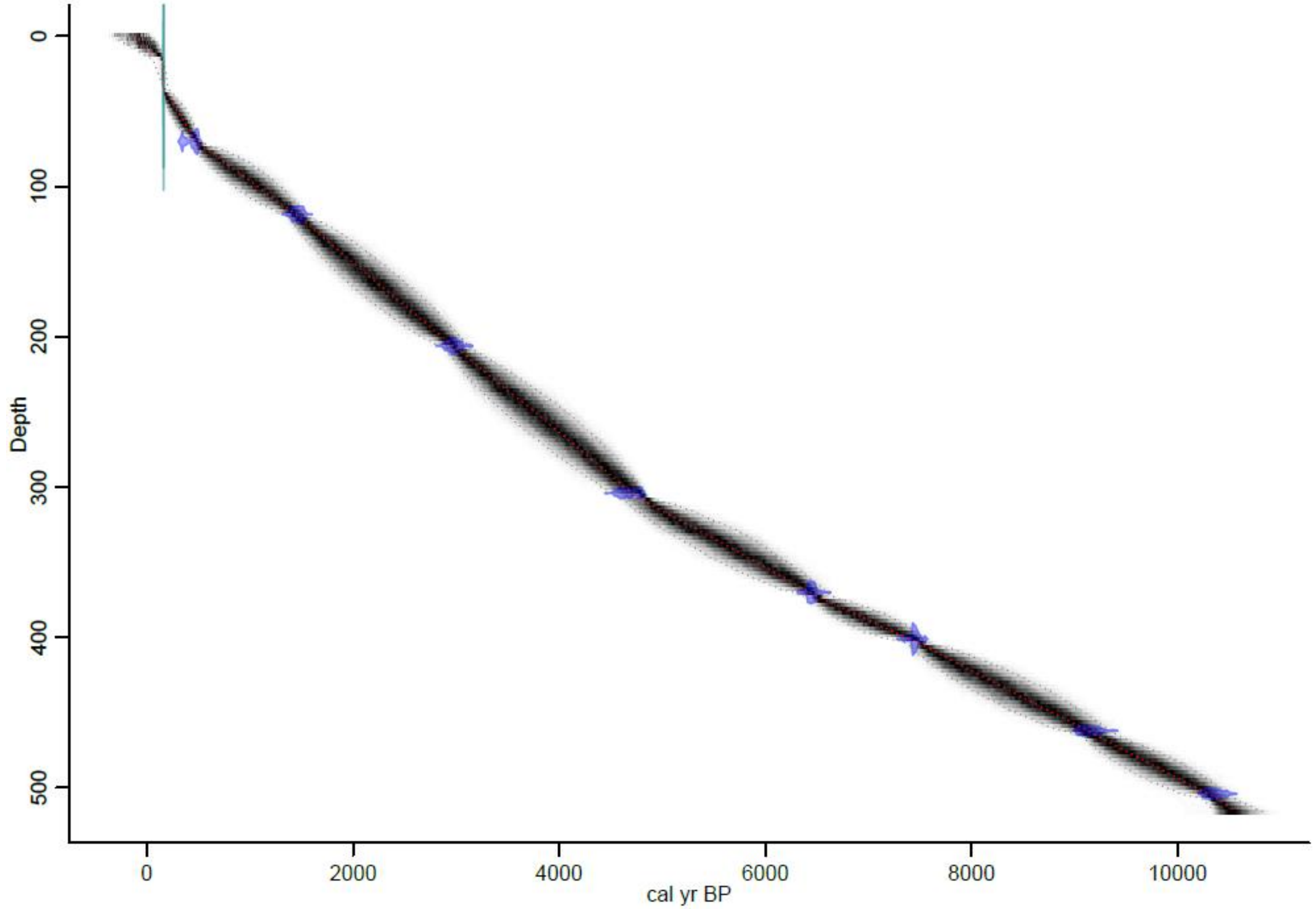


Results from measured parameters in FLP213. Loss-on-ignition (LOI %) indicated content of organic matter in the core, and are plotted on an inverse scale (blue). BW (red) shows the 8-bit (0-255) black-white values extracted from a photo of the core surface where 0 is black. Dry bulk density (DBD) is plotted in unit gram per cm3 (green). Magnetic susceptibility (orange) is plotted as SI*10-5 as magnetic susceptibility is a dimensionless parameter. XRF-data (K, Ca and Ti) are normalized against total scatter to reduce effect of water content.

Depth-age model

Age-depth model based on 14C datings.

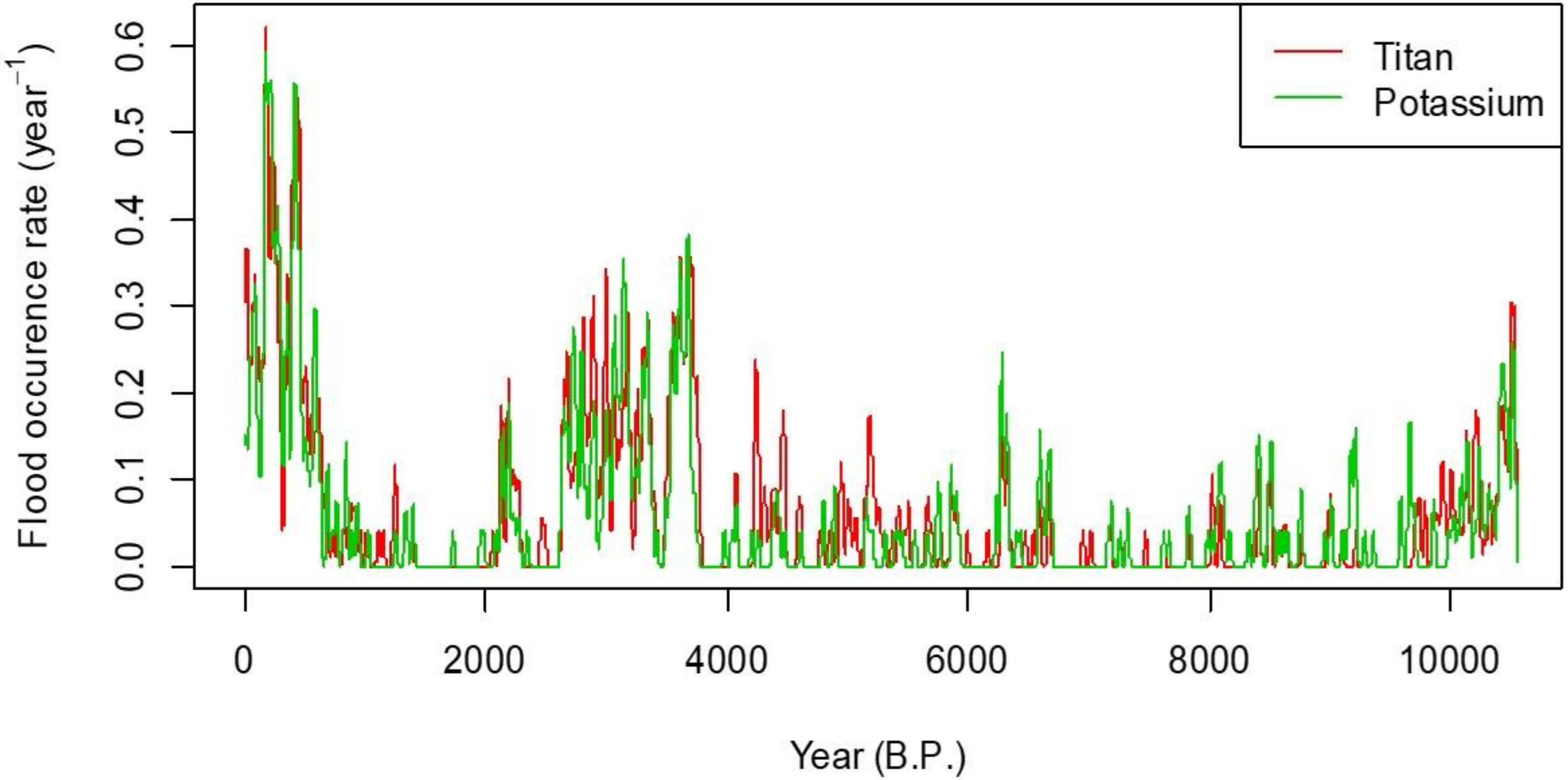
Used R-package Bacon



Counting floods last 10 000 years

Flood rate counted in a sliding time window of 50 years.

Extracted local peaks in measured kps for Titan and potassium



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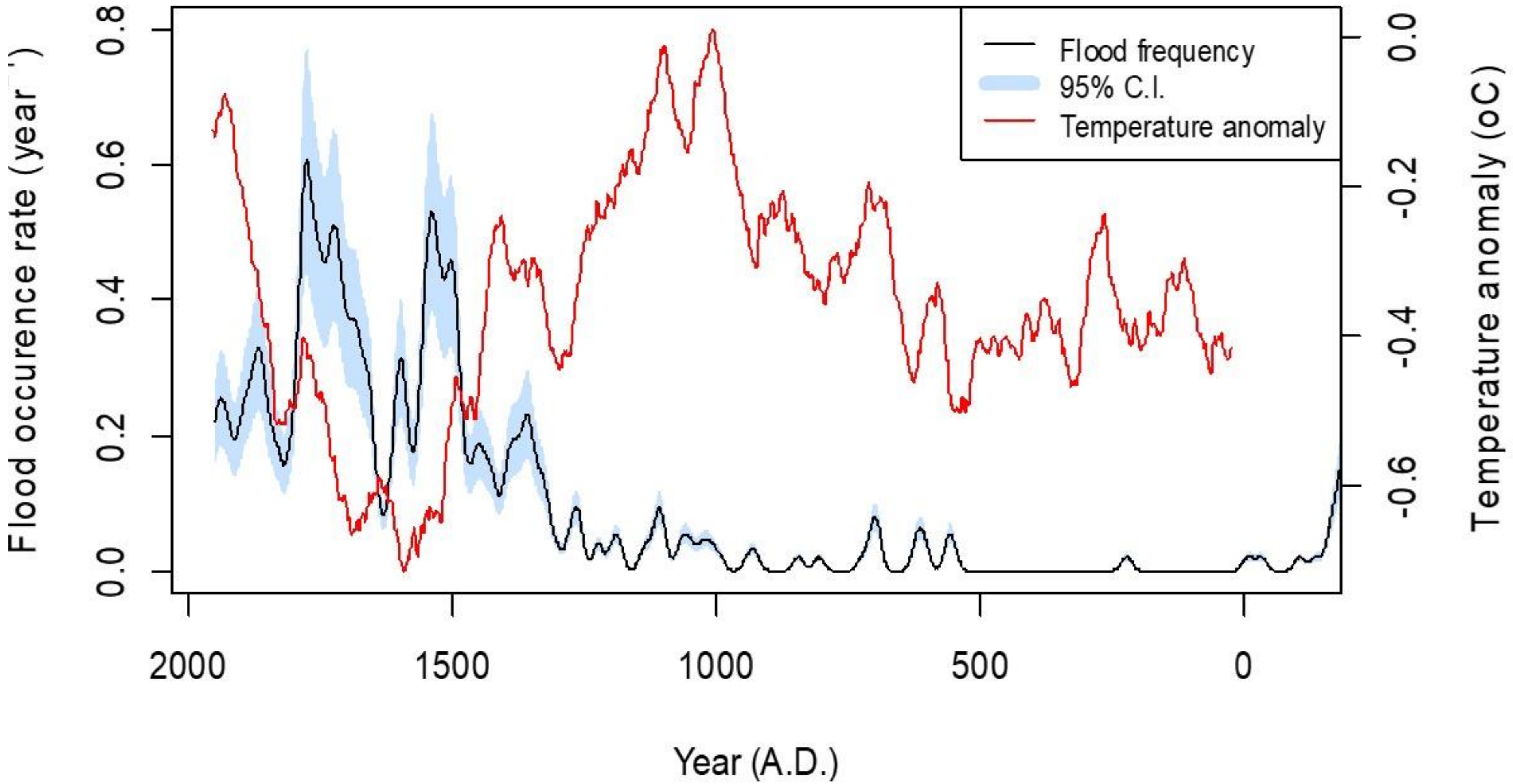
Counting floods last 2000 years

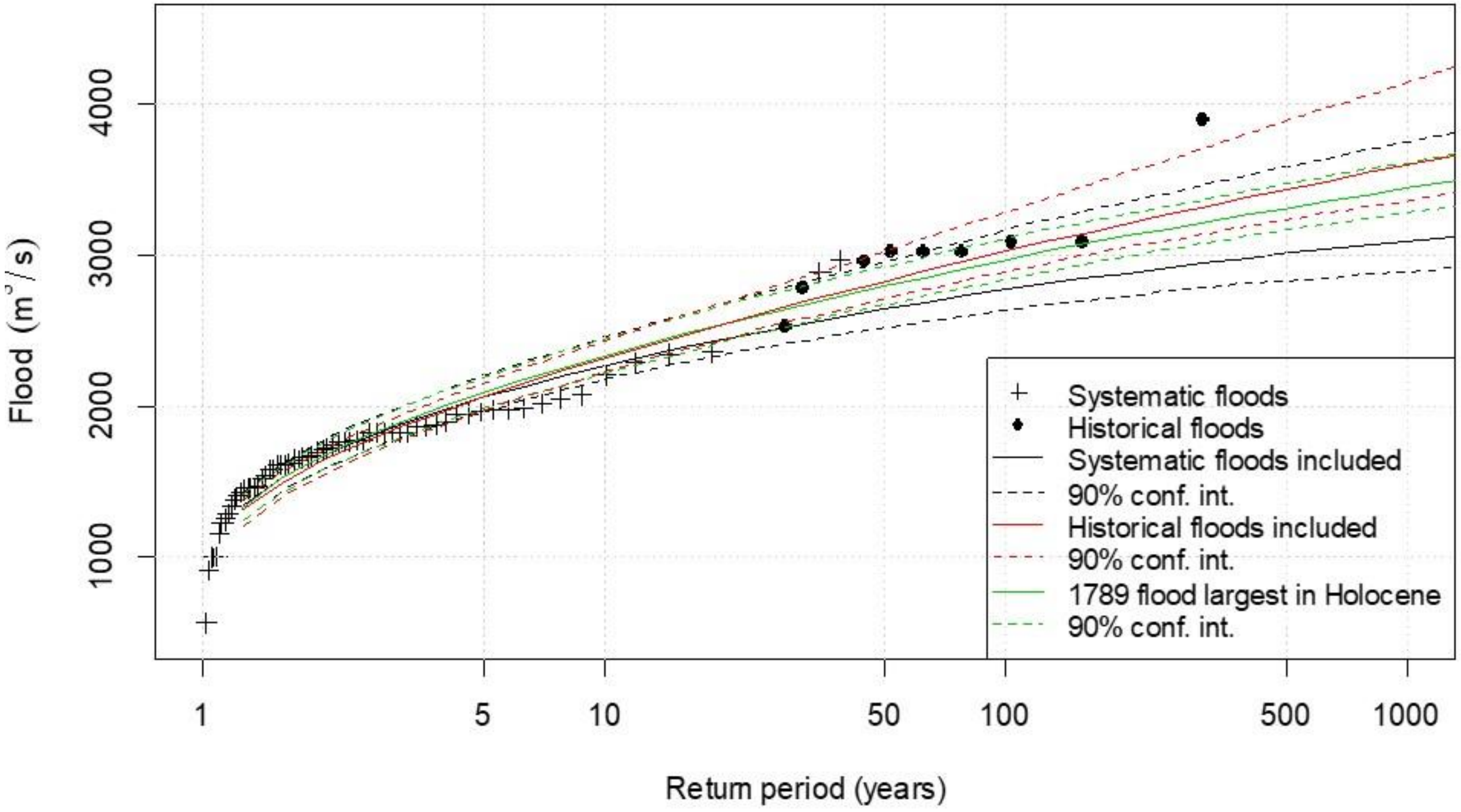


Flood frequency in Glomma (blue bars) and 30 years moving average Northern Hemisphere summer temperature anomaly from Moberg et al (2015).

Moberg, A., D.M. Sonechkin, K. Holmgren, N.M. Datsenko and W. Karlén. 2005. Highly variable Northern Hemisphere temperatures reconstructed from low- and- and high-resolution proxy data. Nature, Vol. 433, No. 7026, pp. 613-617, 10 February 2005

Flood frequency distribution

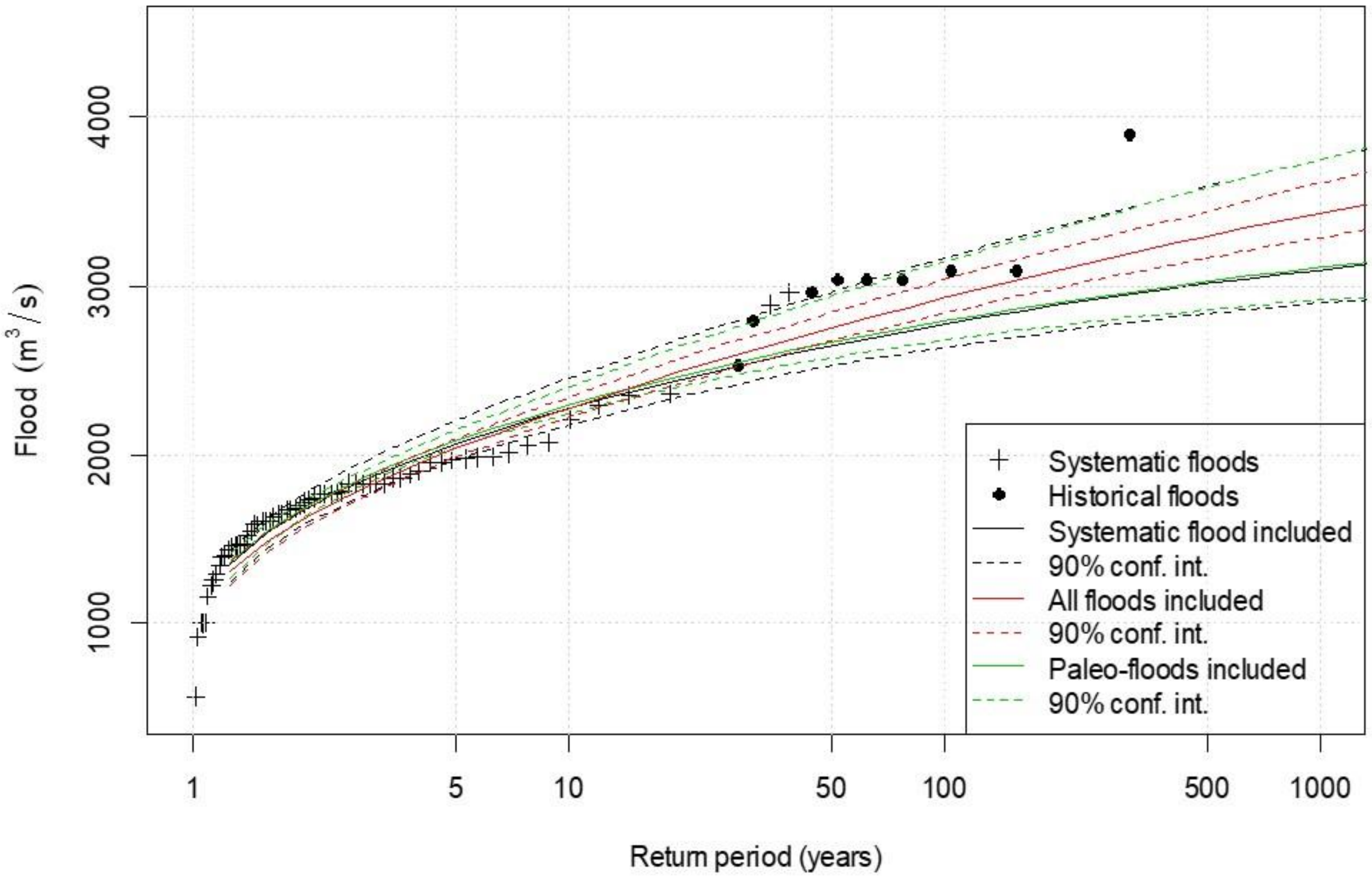
The sensitivity of flood frequency analysis to historical floods.
Hypothesis: the flood in 1789 was the largest one during Holocene



Flood frequency distribution

The sensitivity of flood frequency analysis to paleo-floods.

We see only small changes.



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Summary

- Based on the lake sediments, we could estimate flood frequency in a moving window of 50 years. It is challenging to nail specific sediment layers to flood events, and we were not able to provide information about flood sizes.
- The paleodata shows that the flood frequency is non-stationarity on several time scales. Flood rich periods has been identified, and these periods corresponds well to similar data in eastern Norway and also in the Alps. The flood frequency can show significant non-stationarities within a flood rich period. The most recent period with a high flood frequency was the 18th century, and the 1789 flood is probably the largest flood during Holocene.
- The estimation of flood quantiles benefits from the use of historical and paleo data. The paleodata were in particular useful for evaluating the historical data. We identified that the 1789 flood was the largest one for the recent 10 00 years and that the 18th century was a flood rich period as compared to the 20th and 19th centuries. Using the frequency of floods obtained from the paleo-flood record resulted in minor changes in design flood estimates.

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Outlooks

This study has demonstrated the usefulness of paleo-flood data and we suggest that paleodata has a high potential for detecting links between climate and flood frequency. The data presented in this study could be used alone, or in combination with paleo-flood data from other locations in Norway and Europe, to analyze the links between changes in climate and its variability and flood frequency.