I appreciate the opportunity to review this insightful manuscript, which examines the impact of climate-induced flood variability on the morphological changes of a sub-arctic river. The study addresses a critical issue in river geomorphology, offering valuable insights into how climate change affects sediment transport and river morphology in cold regions. The 32-year dataset and morpho dynamic modeling are significant strengths, providing both observational and computational perspectives on climate-induced changes in river systems.

From my point of view, the manuscript offers valuable and very timely contributions to the field. However, there are areas that could benefit from further refinement. Incorporating recent studies on warming-driven erosion and sediment transport, particularly in permafrost areas, would broaden the context. Additionally, the manuscript would be strengthened by more empirical evidence, such as observable morphological shifts, to support claims regarding sediment transport dynamics during multi-peaking floods. A clearer explanation of the methodology and its limitations would improve the transparency of the analysis. Finally, a deeper discussion on the role of permafrost thaw and riverbank erosion would enhance the manuscript's relevance to current hydrological and geomorphological research.

Overall, I would recommend a moderate revision.

Response to reviewer:

Thanks for the review, we have modified the manuscript based on your comments and suggestions. We have added recent findings on cold climate sediment transport in seasonally frozen ground to the introduction. We don’t want to go too deep in permafrost dynamics since this river studied is not a permafrost river. Unfortunately, we don’t have long time-series of empirical evidence on migration rates, but we have added stronger justification based on previous studies done in the same region with findings which support our claims. In addition, we have modified the methodology section based on your comments and suggestions to make it more see-through. We have added discussion about seasonally frozen ground and freeze-thaw dynamics on the discussion section. We discuss shortly about permafrost in global scale, however, we do not want to address permafrost thaw too much in this section since it is not relevant for this study site. Hopefully our modifications made based on your comments have improved the manuscript.

Major Comments:

Lines 40-47:

The introduction and discussion provide a solid overview of the impact of climate change on river morphology. However, I believe it would enhance the manuscript to compare with recent studies addressing warming-driven erosion and sediment transport in wider cold regions in a more detailed way. This could place the study in a broader context, providing a more comprehensive framework and thus potentially broadening its appeal to a wider audience. Many sub-arctic rivers drain through frozen landscapes. I also wonder whether the catchment is a catchment with permafrost and seasonally frozen ground and this aspect should be better introduced in the introduction. Please check the permafrost map (https://www.sciencedirect.com/science/article/pii/S0012825218305907)

and add such information in the study area Figure 1. Also, some new progress for permafrost river dynamics under climate change are:
https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2024GL112752;
https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2024GL111536;

Response: Thanks for the comment. We have added more details on warming-driven erosion impacts on river morphology, sediment transport and migration rates to the introduction section, rows 50-74. In the northernmost Finland, we have very limited amount of sporadic permafrost. Small patches can be found, mostly in a form of Palsa mires, and from fell summits above the treeline (~400m amsl) where in some cases the bedrock is permanently below 0 degrees. This catchment/river network studied in this paper does not have permafrost to our knowledge based on the research conducted in the area during the past 20-years. However, we added a map of the potential permafrost areas (10-50 % probability) and Palsa mires to figure 1, based on the Nordic permafrost map of Gisnås et al. (2017) (https://doi.org/10.1002/ppp.1922). The lack of permafrost in Finland is due to the warming effect of the Gulf Stream and North Atlantic Drift, limited high elevation areas, thick snow insulating the ground during winter, and abundance of wetlands with warm waterlogged soil and groundwater flow. In Gisnås et al., (2017) the figure 12 shows the modelled distribution of sporadic and discontinuous permafrost between 1980-2010, and indicates that in the region studied in this current study, there is no discontinuous permafrost, and hardly any sporadic permafrost (with very low probability) left this day. There are no permafrost findings from the field either.Therefore, we do not consider this catchment/river network as permafrost river, even though it is located in subarctic region. The ground/soil, however is seasonally frozen during winters which affects the erodibility of river banks during spring flood (https://doi.org/10.1002/esp.4796 and https://doi.org/10.5194/egusphere-egu24-10175 and https://doi.org/10.1002/2013WR014106). We now mention this on introduction and study area description as well (rows 104 and 130).

Lines 440-450:

In the " 5.2. Flood event types and morphological response" section, I believe it could benefit from an explicit reference to permafrost dynamics. The thawing of permafrost significantly impacts riverbank stability, which in turn can alter sediment availability and transport processes. This factor is absent from the manuscript. Additionally, the discussion of future morphological changes mainly emphasizes increased sediment loads due to hydroclimatic shifts, but it would be important to also consider potential changes in riverbank erosion and meander migration rates, which are highly relevant in the context of permafrost thaw and sediment transport dynamics.

Response: Thanks for the comment, we do not consider this river network as permafrost river and therefore we have not addressed permafrost dynamics. However, based on your comment we have added reference to freeze-thaw dynamics of seasonally frozen ground, and how that impacts bank erosion/sediment transport volumes. In addition, we added wider discussion about bank erosion, migration rates and sediment transport dynamics in context of freeze-thaw dynamics related to seasonally frozen ground to this section. Rows: 475-485.

Lines 452-462:

The study suggests that the increasing frequency of multi-peaking floods could lead to long-term shifts in sediment transport regimes, potentially destabilizing the channel. While this is a valuable observation, the evidence provided seems to be inferred rather than directly demonstrated. It would greatly strengthen the argument to present evidence of observable morphological shifts in the study reach over the 32-year period. For instance, a comparison of historical channel adjustments (e.g., planform changes, bank erosion rates from in-situ or remote sensing observations) would provide empirical support for the claim of long-term changes in river morphology due to the increasing frequency of multi-peaking floods.

Response: Thanks for the comment, this river is relatively narrow and accessing migration time-series from remote-sensing observations (satellite images) is basically impossible, since you can't spot the river from the images. National Land Survey of Finland has aerial images from the area taken in years 1961, 1993, 2004 and 2015 (https://kartta.paikkatietoikkuna.fi/?zoomLevel=9&coord=539507.7631314445_7757882.135039186&mapLayers=801+100+default,3400+100+&timeseries=1961&uuid=90246d84-3958-fd8c-cb2c-2510cccca1d3&noSavedState=true&showIntro=false) but this time-series is too sparse to analyse trends in meander migration or bank erosion rates. From that time-series of historical aerial images, it is however possible to notice that the migration rates of this river channel are very low (~10-15 metres in ~60 years). No notable changes in planform types can be detected from the historical aerial images. We are currently working on studies focusing on laser scanned bank erosion time-series of ~20-year biannual measurements of this river reach as well as time-series of the morphological planform adjustment, but it is too early to say about the results, whether or not it is possible to identify increase/decrease in morphological activity during that relatively short time period. Therefore, we based our claim that increase in multi -peaking floods could lead to increased geomorphic activity over time, to the findings of this study, findings from previous studies, and findings of morphological and hydroclimatic factors at the same river system, and in other rivers around the subarctic/Arctic region. Previous studies show that this river reach experiences mostly vertical erosion and the lateral changes are of low magnitude (Kasvi et al., 2012 & 2017; Lotsari et al. 2014; Salmela et al., 2020). Annual bank erosion is measured to be from no change at all to max of 0.6m at certain locations, mostly between 0-0.2m (Lotsari et al., 2019). In the same study, it is found that most frequent changes in river banks happen during spring flood peak, where as changes with the greatest magnitude happen during falling limb of the spring flood. Rainfall induces frequent small-scale bank erosion in other seasons. The bank material (cohesion) and whether the bank is frozen or not has significant impact on the erodibility of the bank during spring flood. In addition, observations of melting ground in Siberia have indicated increased bank and valley slumping in a large arctic river (Séjourné et al., 2015). Therefore, bank erosion processes are expected to become even more important for sediment supply, leading to higher annual sediment yields in (presently) subarctic areas. Therefore, we based our claims of likely increasing geomorphic activity leading to significant changes in sediment transport rates and morphological adjustment over time on previous climatic, hydrological and morphological research findings from the same region and similar river systems, as well as our own results which are pointing to that direction. We address this issue in row 530-561.

Minor Comments:

Lines 167-171:

In the "3.2. Hydrograph classification" section, the study classifies flood hydrographs into four distinct categories, but I feel that the rationale for selecting the 75th percentile (p75) as the threshold for flood discharge could be further explained. Why was this specific quantile chosen? It would be valuable to explore whether other quantiles (e.g., the median or the 90th percentile) might result in different classifications and what implications such variations could have on the analysis. Providing a clearer justification for the chosen threshold would enhance the transparency of the methodology.

Response: Thanks for the comment, we selected the 75^{th} percentile because the use of 90^{th} percentile confined the hydrograph data too much. With p90 only the highest peaks of the hydrographs were detected leaving out the important rising and falling phases when evaluating sediment transport dynamics. In addition, with p90, some years no spring flood could be detected at all as moderate or low spring flood peaks did not reach the p90 value. Therefore, we decided to use p75 to include the rising and falling phases of the flood hydrographs, and to detect flood hydrographs also in years with low and moderate spring flood peaks. This issue is now addressed in rows 190-196.

Lines 178-184:

While the study classifies flood events based on peak sequencing, it does not address whether these sequences are driven by intrinsic hydrological processes (e.g., soil moisture memory, antecedent conditions) or external climatic factors. A more detailed discussion of the underlying drivers of peak sequencing would add depth to the analysis and potentially strengthen the study's conclusions by clarifying the factors that influence flood event sequences.

Response: Thanks for the comment. The classified events are spring flood events. In this region spring floods are driven by external climatic factors, e.g. temperature rise and rainfall, which cause the snow to melt and river ice-cover to break, leading to high discharge peak. This issue and the affect of adjacent conditions are now addressed in rows 211-219.

Lines 327-335:

The analysis suggests that sediment transport rates during the second peak of multi-peaking events are lower than during the first peak, which is consistent with previous findings on sediment depletion. Nevertheless, it would be valuable to consider whether there is any evidence of hysteresis reversal due to finer sediment contributions. If possible, separating the suspended sediment and bedload data in the analysis could provide a more comprehensive understanding of the sediment transport dynamics during multi-peaking events.

Response: Thanks for the comment, unfortunately separating the suspended load from the total transported sediments (TTS) does not provide the information of hysteresis reversal, possibly caused by finer sediment in this case, as the modelled sediment fractions were generally too large to be transported as suspended load. This river system has very low 0-

180mg/l suspended load during flooding, thus we did not value modelling the smallest sediment fractions even though the van Rijn's equations considers both, bedload and suspended load. Thus, the amount of suspended load in the model is low, and we cannot separate the different grain sizes from the bedload. However, previous studies have found that hysteresis reversal can be due to bank erosion, which the model did consider. Previous studies (Lotsari et al., 2014; 2024; Yang et al., 2024) found that bank erosion intensifies during the falling limb of the flood hydrograph, thus this could explain the hysteresis reversal. Reversal could be therefore explained by bank erosion contributing to the sediment flux between the peaks and during the rising limb of second peak in event D. We have now addressed this issue in rows 478-492.

Figures 1-9:

Some of the figures would benefit from clearer labeling, particularly in the distribution of climate data and the identification of flood event types. Additionally, ensuring that the legends and axis labels are consistent across the figures would enhance clarity and facilitate easier comparison of the results.

Response: Thanks for the comment, we have modified legends, labels/axis's from figure 1, 4, 6, and 8 to make them clear and consistent.