Reviewer 1

We sincerely appreciate your efforts to improve our submission to "*Earth Surface Dynamics*". We have responded to all review comments in the following paragraphs. The blue-highlighted sentences are the review comments; sentences in black represent our responses to these review comments. Labels and line numbers after our response correspond to those in the revised manuscript with tracked changes.

The manuscript has substantially improved and I was glad to see the added analyses on rainfall seasonality and uncertainty. I look forward to seeing this study published and think that it will draw some attention to this underrepresented topic of runoff formation in cold regions and it's relation to hazards. However, before publishing in Esurf I have one general comment and more specific ones are listed further down.

Thank you for your comment. We think our manuscripts has been improved by your review comments.

The authors repeatedly point to the importance of their findings with regard to climate change (e.g. L.39., L522, L. 541). However, I am missing a discussion on possible implications of the findings for the future debris flow hazard. I realize that is complex, as it depends on changes in temperature, precipitation, sediment recharge, etc. and not all processes will consistently change towards more or less debris flows. Nevertheless, it is important because as it is now, one could conclude that a warmer climate increases debris flow rainfall thresholds (Fig. 10) and additional sediments due to e.g. permafrost thawing would stabilize the debris flow material (Fig. 12).
Based on the review comment, we have added discussion on the impact of future climate change on debris flow hazards (Rev.1-1, lines 539-545). Climate change has both positive and negative effects on debris flow hazards. Our study implied that debris flow risk decreases by the climate change by shortening the periods with seasonal frozen ground. We have added a statement on climate change in conclusion (Rev.1-1, lines 555-556).

Specific comments

L.20: I would consider leaving out the sentence in the abstract on higher thresholds with more sediment storage. First, it is counter-intuitive and would need an explanation. Second, it is based on quite few events.
We have removed the sentence based on the suggestion by the reviewer (Rev.1-2, line 20).

L.27: Consider citing Hirschberg et al. (2021) https://doi.org/10.1029/2020JF005739

We have cited Hirschberg et al. (2021) as suggested by the reviewer (Rev.1-3, line 28). We also cited this paper in discussion (Rev.1-3, line 544)

L.67-73: This paragraph jumps from aims to methods and then to aims again and may not be clear to the reader. I would start with the goals and then explain how you get there. For example, the focus is on "...understand the hydrological processes triggering debris flows..." so I would put this first and then say something like "We do this by analyzing temporal changes in rainfall thresholds. To this end we estimated seasonal ground freezing ground freezing and use it for...".

We have revised structure of the last paragraph in Introduction. We started with aim of the study and then explained methods used to achieve the aim (Rev.1-4; lines 67-77).

L.125: Which “problems” do you mean?

The problems include electric troubles and destruction of devices. We have described in the sentence (Rev.1-5, lines 129-130).

L.167-169: it would be helpful if you could provide units for all variables and parameters. If possible, also typical values for cf and cm.

We have clarified units of variables and parameters (Rev.1-6, lines 172-176). The value cf generally ranges from 0.02 to 0.06. However, it is difficult to show typical value for cm. Therefore, we did not describe typical values.

L.213: How did you bootstrap? did you resample to have the same number of triggering and non-triggering events as the original observations?

Total number of resamplings was set to the same number of rainfall events as the original observations under each condition of debris flow initiation zone. Number of debris flow events is not consistent among bootstrapings. We have clarified it in the text (Rev.1-7, lines 119-224).

L.221: please explain why this decay factor is necessary

We used decay factor ($K<1$), because a considerable amount of groundwater gradually infiltrates into deeper part of the mountain body in high elevation on Mt. Fuji. We have explained in text (Rev.1-8, lines 235-237).

L.235: I'm not sure how to interpret this. Does that mean there is a bias? I think providing the standard error would correspond better to other studies.

This is standard errors between control points along horizontal and vertical directions. We have clarified that these are standard errors (Rev.1-9, line 247). There was a bias between horizontal and vertical directions in some periods. Because we could not access original data, it was not possible to calculate the simple standard error.

Figure 3: Could you please make the major ticks of the x-axis larger? Otherwise it is hard to see the exact years.

As suggested by the reviewer, we have made the major scales longer (Fig. 3).

Figure 3: I am a bit confused because the threshold for small/large channel deposit is 350000 m3 but here the storage is only up to 160 m3. Could it be 160*10^4? You could also consider plotting a horizontal line at the small/large threshold

As the reviewer points out, maximum value is $160*10^4$ m^3. We have revised the figure (Fig. 3).

Figure 4: please state in the caption what "GS" is. I don't think I see it in the plot.

GS indicates ground surface. We have revised the figure legend (Fig. 4).

L. 291: why minimum standard error and not mean error?

According to calculation formulas, the cf, which minimizes standard error, also gives minimum mean square error and root mean square error. Therefore, we can also say root mean square error instead of standard error. For the time being, we did not revise the term.

Figure 6: I would add that antecedent rainfall was determined using eq. 5. Also consider adding ticks outside the figure so the month can be identified.

We have added a statement that the antecedent rainfall was determined using Eq. 5 (Rev.1-10, lines 339-340). We have changed direction of sales on x-axis (Fig. 6).

L.326: delete "in the figure"

We have deleted “in the figure” (Rev.1-11, line 339).

L.337: threshold is missing an s in the end

We have added “s” after the “threshold” (Rev.1-12, line 350).

L.360: it is not clear to me how you exactly conducted the bootstrapping (see L. 213).

We have improved explanation of the bootstrapping (Rev.1-13, lines 219-224). We obtained appropriate rainfall thresholds in each resamplings.

L. 503: This is a good hypothesis for your findings. However, to avoid any misunderstandings I would also say that in case of threshold exceedance, which happens sooner or later, debris flow volumes will also be larger. As it reads now one could infer that more loose sediments mitigate debris flows. In addition, this specific finding could also result from the fact that there are relatively few triggering events.

Based on the suggestion by the reviewer, we have described that the debris flow volumes are likely larger when a large volume of channel deposits is stored in the channel. We also discussed possibility that relatively small number of debris flow events affected the specific characteristics of rainfall threshold in unfrozen periods (Rev.1-14, lines 517-520).

L.521: Please then describe how future seasonal ground freezing will affect debris flows.

We have added discussion on impact of climate change on occurrence of debris flow (Rev.1-15, lines 537-545). Because rainfall thresholds in unfrozen periods were higher than that in frozen periods (Figs. 9, 10), global warming possibly decreases debris flow risks by shortening the period with seasonal frozen ground, which decreases rainfall threshold for the occurrence of debris flow. Increases in the amount sediment delivered to channels by thawing of permafrost possibly increases volume of sediment storage in debris flow initiation zone, resulting in the higher rainfall threshold for the occurrence of debris flow in unfrozen periods. However, climate change also has effects that increases debris flow risks.

L.531-536: Again, the way it is written one could think that e.g. increased amounts of sediment form instable slopes due to permafrost thaw would increase the threshold and mitigate debris flows. But climate change will also provide loose sediments where there was none before.

As described above, we have added the discussion on the climate change (Rev.1-15, lines 537-545). In addition, we have added a sentence on the climate change in conclusion (Rev.1-16, lines 555-556)

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