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## **Comment on esurf-2021-23**

Anonymous Referee #1

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Referee comment on "A 4000-year debris flow record based on amphibious investigations of fan delta activity in Plansee (Austria, Eastern Alps)" by Carolin Kiefer et al., Earth Surf. Dynam. Discuss., <https://doi.org/10.5194/esurf-2021-23-RC1>, 2021

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The manuscript "A 4,000 year debris-flow record based on amphibious investigations of fan delta activity in Plansee (Austria, Eastern Alps)" (esurf-2021-23) presents an exceptional record of debris flow events in Lake Plansee and its catchment in the Eastern Alps. Kiefer et al. combine a detailed geomorphological analysis of fan deltas using LiDAR data and swath bathymetry to a sedimentological analysis of lacustrine deposits to analyze sediment delivery by debris flows to the depo center of the Lake. By analysing the occurrence rate of debris flows as recorded in sediment cores, the authors propose a sharp increase in the occurrence of debris flows in the 20<sup>th</sup> and 21<sup>st</sup> century linked to an increase in rainstorm frequency.

The manuscript is generally well written and structured with the exception of a lengthy and at times contradictory discussion at the end of the manuscript (see minor remarks). The only major shortcoming of the manuscript in its present form is the analysis of occurrence rates (see major remark), which cannot account for changes on sub-millennial time scale. Parts of the results and conclusion (including the 7-fold increase at the beginning of the 20<sup>st</sup> century) might be artefacts of the sampling strategy. Therefore, I recommend reconsidering the manuscript once a viable methodology has been adapted and the manuscript has been updated accordingly. I hope my comments to be helpful during the revision of the manuscript.

### **Major remark**

The temporal analysis of occurrence rates is neither robust nor valid in the present form of the manuscript. Any analysis of the frequency spectrum of events in lake archives is essentially an analysis of the underlying age-depth function. As I understand it, you are using the mean (or median) scenario from Bacon, which is constrained by seven age estimates for the last 4000 years (see Figure S2). The corresponding sampling rate of one age estimate per 500 years cannot resolve potential rapid sedimentation changes in this record. This sampling rate restricts the analysis to the millennial frequency band (see

Nyquist-Shannon sampling theorem). Changes in higher frequency bands (as analyzed in the 21-yr window, see line 255) cannot be resolved. As a result, the inferred changes in occurrence rates during period 1 to 4 might be pure artefacts of the sampling strategy.

Obviously, an analysis of debris flows in the millennial frequency band is not satisfying, especially considering the detailed record at hand. From my point of view, there are two viable options for increasing the resolution of your analysis:

- Increase the sampling rate for the mean age-depth function. An analysis in decadal resolution requires at least two age estimates per decade. Varve counting could be a viable option if the finely laminated sediments in your record represent annual laminae.
- Making use of age uncertainty. Blaauw et al. (2018) showed, that a sample rate of two samples per millennia (as in this case) stabilizes the precision of Bayesian age-depth models. This suggests that individual simulations of Bacon can mimic higher-frequency changes in sedimentation patterns. Repeating the frequency analysis for different Bacon model simulations in a Monte-Carlo approach could therefore be used to decrease the bandwidth and construct confidence limits on the occurrence rates. Individual model simulations of Bacon are readily accessible in the output of the algorithm (with accumulation rates (years per spacing) usually stored as .out file in the default folder). I am not sure how much this approach would allow to decrease the bandwidth, so I suggest coupling your analysis with a suitable bandwidth selection test (see e.g. Muddelsee, 2014 or Merz et al., 2016 and references therein).

There might be other approaches, but the design of the frequency analysis in its current form requires major revisions to make inferences on debris flow occurrence robust and bring it in line with the excellent set up of this study.

### **Minor comments**

Line 255 to 257: Please add a detailed description of the occurrence rate estimation once the approach has been adapted.

Line 489-490: I can't detect any changes in the mean thickness of layers during phase 3. The cumulative function stays linear in my opinion. Can you quantify the change?

Line 574: Consider replacing "prove" with "suggest".

Line 618-624: Has the vegetation cover stayed constant during the last 4,000 years? Are there pollen records from Lake Plansee or different archives in the Eastern Alps which

back up your line of argument?

Line 647: How can you be sure, that both layers correspond to the heavy rainstorms in 1999 and 2005, especially considering age uncertainty and that not every df turbidite has a corresponding rainstorm event (see lines 652-653)?

649-651 You stated in line 540-541, that you would refrain from detailed comparisons to other flood deposits.

Line 661-664 This passage is difficult to relate to passage iv (line 625-634), in which you argue that human influence enhanced coastal erosion and subsequently the volume (not the frequency) of debris flows. If it is only influencing the volume of debris flows, how can human influence affect the frequency of debris flows recorded in the core?

Line 666-667: Does "we" refer to this study or to the results of Diedrich and Krautblatter, 2017?

Line 673-676: The absence of other increases in occurrence rates might be an artefact of the applied methodology (see major remark).

Figure 4: The main channel in August is difficult to distinguish from the red background on the map.

Figure S2: Age units correspond to BP in this figure, in contrast to BCE/CE notation in the rest of the manuscript.

Table S2: This table only contains five <sup>14</sup>C measurements, contrary to six radiocarbon dates shown in Figure S2.

## References

Blaauw, M., Christen, J.A., Bennett, K.D. and Reimer, P.J., 2018. Double the dates and go

for Bayes—Impacts of model choice, dating density and quality on chronologies. *Quaternary Science Reviews*, 188, pp.58-66.

Mudelsee, M., 2014. *Climate Time Series Analysis*. Springer International Publishing.

Merz, B., Nguyen, V. D. and Vorogushyn, S., 2016: Temporal clustering of floods in Germany: Do flood-rich and flood-poor periods exist? *Journal of Hydrology* 541, pp. 824–838.