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# Reply on RC2

Patrick Oswald et al.

Author comment on "Magnitude and source area estimations of severe prehistoric earthquakes in the western Austrian Alps" by Patrick Oswald et al., Nat. Hazards Earth Syst. Sci. Discuss., https://doi.org/10.5194/nhess-2021-281-AC2, 2022

**Point to Point Response to the comments by Christian Beck**

The manuscript submitted by P. Oswald and co-author is very well written and organized, and, thus, easy to understand and analyze. It represents a comprehensive investigation regarding a discipline which strongly developed during the last decades: paleoseismology based on sedimentary records (here intra-mountane lakes). The here-presented work is an actual paleoseismology one, including all necessary tools from sedomentological observations, to pure geophysica:/ seismological approaches, all parameters discussed with up-to-date statistical approaches. Illustrations are of good quality and referencing is totally relevant to the subject. I hereafter just underline few difficulties faced in the presented investigations.

**We thank Christian Beck for this overall positive feedback on our study.**

The concerned area belongs to a complex collision zone with different units themselves having undergone polyphasic tectonics, metamorphism, and granitic magmatism. Thus it represents a set of active faults, often representing re-activation of older ruptures, and of different lithologies. This leads to a difficulty to assess seismic wave attenuation, and size and geometry of an epicentral area (and subsequently the use of the later one in a direct or reverse sense).

**We fully agree with the reviewer that the geological structure of the Eastern Alps is complex which may contain many difficulties or uncertainties in the investigation of (neo-)tectonic activity. So far, only one of these numerous faults (the Pertisau-Sulzgraben fault at the lake Achensee; Oswald et al 2021) could be assigned to be ‘active’ with supporting geological data. The status of the other faults remains speculative. Moreover, the causative faults of the few devastating historical earthquakes are as well unknown. We are fully aware that a complex geological architecture, the geometry of the rupture area as well as the faulting mechanism affect the propagation and attenuation of seismic waves. However,**

**given the complex setting with only one out of probably numerous known active faults and none of this first-order earthquake parameters recorded, the application of these parameters for further calculations of paleo earthquakes might contain more uncertainties than actual benefit and the introduction of such parameters would be very user-dependent. Therefore, we apply the state-of-the-art method for the paleo-earthquake scenarios of reversely using an empirical intensity prediction equation in a grid-search algorithm with established intensity threshold values as input parameter and without any further geological or seismological presumptions. Moreover, also the shakemaps are state-of-the-art and corrected for site effects and topographic amplification. In any case, we hope that this work will contribute to stimulate future research to improve our knowledge in the above-mentioned unknown earthquake parameter and to improve future scenario modelling of paleo-earthquakes.**

Extrapolating the sedimentary records back in time, down to Late Glacial, is off course, precious to extend the paleoseismic archive. Nevertheless, in several alpine lakes where complete coring (down to morainic or pro-glacial complex) could be achieved, a specific pile of very high sedimentation rate ( true "varves") has been detected, representing specific depositional process. Thus, a time-equivalence different from the Holocen one, and different behaviour with respect to neighbouring seismicity ?

**The reviewer is correct that sedimentation rates are increased in the Late Glacial compared to the Holocene sediments, which is also shown by the age-depth models of Plansee and Achensee (sedimentary facies change indicated by the lowermost horizontal dashed line in Figures 3 and 4). Although this change in sedimentary facies might increase the sensitivity of the lake in recording earthquakes as discussed in section 5.1, the high sedimentation rates in the Late Glacial do not really affect our results. First of all, there are only a few events (one out of nine and three out of eleven events) derived from the calculated sediment depth at Plansee (1 out of 9 events) and Achensee (3 out of 11 events). We are aware that within the Late Glacial sediment pile there might be periods with varying sedimentation rates, which we do not capture in the calculated sediment depth. However, we account for this potentially varying sedimentation rates with the large error in the lower parts of the age depth models (newFigures 3 and 4).**

**We fully agree with the reviewer that the different sedimentary facies of the Late Glacial likely has a different behavior i.e. higher sensitivity to seismic shaking (see also our response to reviewer 1). This would require in-situ geotechnical measurements and stability analyses of subaqueous slopes (e.g. Strasser et al. 2007, Strupler et al. 2017). In any case, the different behaviors of Holocene and Late Glacial sediments to seismic shaking makes it difficult to assess whether there was an increased seismicity in the Late Glacial related to deglaciation (e.g. Beck et al. 1996).**

**References:**

**Beck, C., Manalt, F., Chapron, E., Rensbergen, P. Van, and Batist, M. De (1996). Enhanced seismicity in the early post-glacial period: Evidence from the post-würm sediments of lake annecy, northwestern Alps. J. Geodyn. 22, 155–171. doi:10.1016/0264-3707(96)00001-4.**

**Strasser, M., Stegmann, S., Bussmann, F., Anselmetti, F. S., Rick, B., and Kopf, A. (2007). Quantifying subaqueous slope stability during seismic shaking: Lake Lucerne as model for ocean margins. Mar. Geol. 240, 77–97. doi:10.1016/j.margeo.2007.02.016.**

**Strupler, M., Hilbe, M., Anselmetti, F. S., Kopf, A. J., Fleischmann, T., & Strasser, M. (2017). Probabilistic stability evaluation and seismic triggering scenarios of submerged slopes in Lake Zurich (Switzerland). Geo-Marine Letters, 37(3), 241-258.**

The defined Scenario B (about 4.1 ky BP) appears as rather strong. Could it be correlated with the stronguest reworking event observed in farther lakes (like Annecy ?); thus a very large vent ?

**The scenario B seems to have had already only an intensity of V (EMS-98 intensity scale) at the western Austrian border (to Switzerland) and only negative evidence was found at the nearby lake paleoseismic records (Lake Constance, Walensee, Silvaplanasee, Achensee). The calculated intensity at lake Annecy for a Mw 6.1 event near Garmisch would be even much lower. Therefore, a single very large event is not conceivable, but periods of enhanced seismicity over larger regions are likely, as was proposed based on the paleo-earthquake record of Switzerland (Kremer et al. 2020).**

**Kremer, K., Gassner-Stamm, G., Grolimund, R., Wirth, S. B., Strasser, M., and Fäh, D. (2020). A database of potential paleoseismic evidence in Switzerland. J. Seismol. 24, 247–262. doi:10.1007/s10950-020-09908-5.**