

## Comment on cp-2021-54

Anonymous Referee #1

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Referee comment on "Early Holocene cold snaps and their expression in the moraine record of the eastern European Alps" by Sandra M. Braumann et al., Clim. Past Discuss., <https://doi.org/10.5194/cp-2021-54-RC1>, 2021

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This manuscript reports new  $^{10}\text{Be}$  exposure ages from Holocene moraines in the Silvretta Mountains in the Eastern European Alps and puts them into the regional and hemispheric paleoclimatic context. The data is very useful, as Holocene chronologies in the Eastern part of the Alps are still scarce, especially such robust, consistent data sets that allow for meaningful paleoclimatic interpretation. The multi-boulder ages are indeed remarkably consistent for each landform and belong thus to the most valuable data sets from the Alps, which are still relatively rare among the many existing Alpine chronologies.

The manuscript is very well written and illustrated. Also, a new and very promising method is presented that allows low-quartz or low- $^{10}\text{Be}$  samples to be analyzed with high precision.

The manuscript is thus worth to be published in Climate of the Past. Before acceptance, a few minor issues should be addressed though.

My main comment relates to the  $^{10}\text{Be}$  mean ages of the Early Holocene (EH) moraine sets that are reversed with regard to the stratigraphic order of the landforms. Two EH ice margins were dated in each of the studied valleys. The multiple ages from each ice margin are strikingly consistent with each other, and their mean ages are in perfect agreement between both valleys. But the  $^{10}\text{Be}$  ages from the outer (thus older) ice margin are systematically younger, thus leading to a nominal mean age that is younger by  $\sim 500$  years, in both valleys. This is not discussed nor even mentioned in the manuscript. While from a dating perspective this can be handled relatively easily (see my suggestions below), the major challenge consists in the correlation of the moraine depositions with the independent high-resolution proxies (Discussion). This is particularly notable in section 5.3.2, where the cold spells during the EH warming are discussed, and the timing of the outer moraine formation (MIF 4) is correlated with both the DCP1 (+PBO;  $\sim 11.6$ – $11.2$  ka) and DCP2 (+related cold spell;  $\sim 10.6$ – $10.5$  ka). See line 531 for the first ("...evidenced by moraines J4 and L4 dated in this study...", i.e. MIF 4), and lines 536–537 for the second

("Moraine formation..., concurrent with DCP2, is observed in the Silvretta Massif (MIF 4)..."). Maybe there's a typo and the authors meant MIF 3 for the first, as the 10Be ages MIF 3 agree with DCP1. But that would of course make no sense, because a stratigraphically older moraine cannot be correlated with a younger paleoclimatic event (also see below my comment on lines 439-440, where this correlation was actually done).

I suggest that the reversed moraine mean ages should be acknowledged and possible reasons discussed. Are there any field observations that might explain a systematic age underestimation, like enhanced exhumation, erosion, cover on the outer moraines? Exhumation seems unlikely, given the big boulder sizes on the supplement pictures. Could the systematic offset just be a coincidence? It can easily be tested, e.g. by using an MSWD, if the dispersion of all MIF 3 and 4 ages is only due to analytical errors. It could be argued that the moraine formation at the two ice margins occurred within such a short interval that their ages are not distinguishable with the 10Be dating method. Logically, the average of all ages from the MIF 3 and 4 ice margins would then provide the best estimate of the two glacier stabilizations. Parts of the discussion will need to be adjusted to this.

Minor comments per line:

20-21: According to my above comments, better change by saying that two Early Holocene moraine formation intervals occurred around ~11 ka and that they were close both in space and time.

44: revise grammar

79-80: make two sentences

84: Yes, that's indeed important, also for the Late Glacial in the rest of the Alps (just a comment).

Legend of Fig. 1: For the light blue shading that's the ice extent rather than the ice margin. For the national border it might be interesting to indicate to which countries it belongs.

130: something is wrong at the end of this line: "they form" instead of "or"?

176-179: I recommend to at least indicate the potential impact of a possible snow pack scenario, as snow has a higher impact than erosion. The effects of erosion are tested

(supplements), but one could argue here as well that it might lead to a higher age dispersion given the various geometries of the boulders. So, testing one but not the other doesn't seem straightforward.

192-193: J1 is dated to the 18<sup>th</sup>, that's not the end of the LIA. Shouldn't it therefore say that J0's age falls between the LIA maximum and the turn of the 20<sup>th</sup> century? Or if you just cite Fischer et al. (2019), then phrase the sentence differently ("...is thought to fall..." or similar). The same comment applies to the first line of Fig. 2's caption.

Fig. 3: Make sure the same language is used in the text and figures (hut/Hütte)

Table 1 and 2: The third to last column has a wrong header in each table. The blanks could be added to the tables, notably for easier comparison of the numbers of atoms <sup>10</sup>Be.

308 and 345: Given that there's just one sample, I would phrase this more cautiously: "might capture" or similar

313-315: Grouping the L3L moraine segments with the other MIF 3 moraine segments seems arbitrary, because the ages of MIF 3 and 4 are statistically the same. Unless you have more convincing arguments, I would attribute these Left-lateral ridges to both MIF 3 and 4.

Fig. 7: According to my main comment above, it would make more sense to compare the kernel plots for MIF 3 and 4 in each valley to show that they are indistinguishable from each other, and show their mean ages and insist that they are the same in both valleys.

364: glacier advance

Fig. 8: It would be convenient to have one of the scales in years before present.

345 + 362 + 395-396 etc: Are the earlier-LIA and pre-LIA boulders in a stratigraphically different (outer) position compared to the ~18<sup>th</sup> century boulder? And do you have field evidence that the "LIA" moraines are composite moraines? If yes, it would be good to mention this in the Results – Geomorphology section. Just to interpret this from a few isolated boulder ages is very speculative and should be handled more cautiously.

396: "in the following sections..."

396-398: This sentence probably needs to be revised, it's unclear. I guess you mean that J1 and L1 mark the MAXIMUM glacier advances and temperature minima SINCE the YD-EH transition?

Revise the title of section 5.2, as it's the same as for section 5.1

407: Nothing is mentioned about the fact that the nominal ages are systematically reversed, see my main comment above.

410: Concerning the statement about the climate variability in the studied valleys, is this based on specific observations and does it refer to a specific time period? Can you provide a source?

411: "Also, catchments are comparable..."?

413: It's not clear to which "variations in the timing of moraine formation" is referred here. The same applies to "age variability among moraines dated in the region". These variations have not been discussed and cited so far. I guess the statements refer to the Verwall and Ochsental chronologies, but this needs to be clarified.

422: FIG. 9c-f

432 and 435: Were the ELAs in both valleys determined with the same methods? It would be good to give a few more explicit arguments that support the concept that the dated Kartell moraine is not the equivalent of the MIF 3 and 4 moraines and that the age difference is not due to dating uncertainties.

439-440: How can MIF 4, being stratigraphically older than MIF 3, be related to a younger paleoclimatic event??? This needs to be corrected. See my main comment.

446-337: remove "on the one hand" and "on the other hand"

523 and 525: Fig. 9 not 8

531: Fig. 9g-h

535: "which in turn led..."

595: Again, a glacier stabilization that is recorded in the most external position cannot have occurred a few centuries later. Please correct this.

573: this needs to be phrased more cautiously.