

Clim. Past Discuss., author comment AC2  
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## Reply on CC2

Irene Schimmelpfennig et al.

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Author comment on "Glacier response to Holocene warmth inferred from in situ  $^{10}\text{Be}$  and  $^{14}\text{C}$  bedrock analyses in Steingletscher's forefield (central Swiss Alps)" by Irene Schimmelpfennig et al., Clim. Past Discuss., <https://doi.org/10.5194/cp-2021-110-AC2>, 2021

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**Thank you very much for your constructive and relevant comments. We agree that taking into account your three comments will further strengthen the paper and place the findings correctly in the context of the accelerating current glacier and climate change.**

- Please add in Fig. 6 b the global temperature for the reference period 1991 – 2020 which is significantly above 1961-1990; This is relevant to specify what 'today' means; 'today' should refer to 1991-2020 (recommendation WMO).

**We agree that the most up-to-date reference period should be used, given the rapid temperature rise. We added this information in the revised Fig. 7b. According to data available at the NASA website, the global mean surface temperatures in 1991-2020 was  $\sim 0.5^\circ\text{C}$  above that in 1961-1990. We also added the mean July temperatures in the Alps for the reference periods 1981-2010 and 1991-2020 in Fig. 7c.**

- it would be helpful to show in Fig 6 g the extent of Mer de Glace and Great Aletsch in 2019/2020 (e.g. <https://www.glamos.ch/en/factsheet#/B36-26> or WGMS data).

**Illustrating the strongly accelerating current glacier retreat is indeed relevant when studying glacier recession during the Holocene. The information has been added in the case of the graph depicting the length changes of Great Aletsch (now Fig. 7 h). However, in the case of Mer de Glace, the graph taken from Le Roy et al. (2015) (now Fig. 7g) illustrates elevation changes and are thus not directly comparable to the available recent length measurements.**

- Seconding the Comment by Heinz Wanner: please add in the Discussion (Section 5.3) a short paragraph about the orbital forcing during the Holocene (particularly for summer) and how this influences summer TT and glacier lengths (based on the argument that glaciers are sensitive to summer temperature).

**We agree and added the following paragraph at the end of the discussion (lines 571-579): "Various drivers are relevant for Holocene climate change, i.e. external forcings at low (orbital summer insolation) and high frequency (volcanism and solar irradiance), feedback of the carbon cycle (greenhouse gases) and different climate boundary conditions linked to residual Northern**

**Hemisphere ice-sheets (Mayewski et al., 2004; Wanner et al., 2008). Our findings of Alpine glacier retreats and advances are in line with the current understanding of Holocene climate change. Orbital summer insolation modulates the long-term summer temperature evolution, thus driving millennial scale glacier evolution in the Northern mid and high latitudes (e.g. Solomina et al., 2015). Insolation is strongest in the Early Holocene followed by progressive decrease, consistent with glacier retreat during the Early and mid-Holocene and glacier re-expansion in the Late Holocene. Volcanic eruptions and changes in solar irradiance, superimpose centennial to decadal glacier fluctuations on the long-term trend during the Late Holocene (e.g. Büntgen et al., 2016; Jomelli et al., 2016)."**

- I would also like to see a crystal clear statement (maybe in the Conclusions) that the main findings of this paper (small glaciers in the Early and Mid Holocene) is fully in line with the theory and current comprehensive understanding of Holocene climate change (including glacier variations) in the mid latitudes of the NH, and that recent glacier retreats (in the Alps and worldwide) and warming temperatures are undoubtedly attributable to anthropogenic forcing (e.g., Roe et al. 2021 *The Cryosphere*, 15, 1889–1905 and references therein; IPCC AR4, 5 and 6). The causes for (Early) Holocene glacier retreats were very different from those of today.

In light of recent glacier retreats under anthropogenic climate forcing (in the Alps, but also globally), it is most relevant to place Holocene glacier variations (this paper) and their causes in the appropriate, unambiguous and scientifically sound context.

**We agree. We added the following lines (579-584) at the end of the discussion: "Finally, while greenhouse gas concentrations were relatively stable over the Holocene, the accelerating anthropogenic greenhouse gas forcing has caused glaciers in the Alps and worldwide to retreat over the last century, with drastically increasing speed over the past few decades (Figs. 3b, 7g,h; e.g. Maurer et al., 2020; Roe et al., 2021; IPCC, 2007, 2013, in press). The high sensitivity of Steingletscher to the moderate summer temperature amplitudes during the Holocene implies that the glacier will continue to melt and shrink dramatically, and will most likely disappear if the human-induced warming is not reversed."**