Response to the comments by M. Le Roy (CC1)

Dear,

First, congrats to the authors for this long-awaited and well conducted work!

Thank you very much!

I have two comments on the manuscript:

1) Regarding Western Alps outlines

The Figure 2 shows Ecrins massif with 'new' outlines in 'blue'.

However, these LIA glacier outlines were already available (please see the figure attached here) in Marie Gardent's 2014 PhD thesis (where the 'yellow' outlines you use originate I suppose)

So why have you redigitized them and presented them as new here (Fig. 2)?

By the way, the two Gardent's references listed at the end are not actually quoted anywhere in the main text/figures of the manuscript.

So, why not quoting them in the caption of Figure 2, as it seems yellow outlines come from them?

If not, please provide a reference here for previously available outlines.

Thank you very much for pointing out to the datasets created as part of Marie Gardent's PhD thesis. The yellow outlines in Figure 2 were actually downloaded through the Glariskalp database, but the link is not working anymore (http://www.glariskalp.eu/?it_inventario-delle-estensioni-attuali-e-passate-dei-ghiacciai,9). For these outlines, we have cited the Gardent and Deline (2011) study (with a spelling error), as this appeared to be the contribution of France to the Glariskalp project. Back then, we missed to check if the datasets presented in the PhD thesis of Marie Gardent (2014) were also digitally available and decided to map the missing regions ourself. We now asked and got access to the full dataset and used it instead of our outlines as it is more complete. We will thus recalculate area and volume changes for this region using the LIA outlines of Marie Gardent, cite her in the analyst field of the attribute table in the merged alpine-wide dataset and will also cite the PhD thesis in the main text.

Regarding the two references, in L34 we have cited Garent and Deline (2011) with a spelling error (missing d) which we will change to Gardent (2014). We will also acknowledge Antoine Rabatel, who has kindly provided the complete dataset to us.

2) Regarding the timing of LIA maximum extent

It sounds to me somehow misleading and too simplistic to present differences in the timing of LIA maxima as depending only on the geographical location (e.g Western Alps/Italy in 1820 CE vs Austria in 1850 CE) as it was done here in the Introduction of the manuscript.

There might be a misunderstanding here. We do actually not make a difference in the LIA maximum timing and have used 1850 to calculate change rates for all glaciers (see L118). The values presented in the introduction should just give an overview of selected studies presenting results on LIA maximum timing. Additionally, in Section 4.2 we describe the effects of the LIA timing on change rates. We will also add the references mentioned below for a clearer presentation of the large regional variability.

Better, the response time of glaciers should be mentioned as one of the (most likely) explanations for the differences in the chronology of LIA glacial maxima.

Indeed, we showed recently in two review papers dealing with the early LIA period (https://journals.sagepub.com/doi/full/10.1177/09596836221088247) and the Holocene (https://www.sciencedirect.com/science/article/abs/pii/B9780323997126000180?via%3Dihu) in the Alps, that (small) glaciers reached LIA maximum extent during any periods of LIA glacier maxima. For instance, many small glaciers, located from the Ecrins massif (to the west) up to the Tirol (to the east), reached absolute LIA maxima during the early 14th century.

We agree that the timing of the maximum extent might have a relation to glacier response times, but (in contrast to some other regions) all earlier LIA moraines can be found very close to the 1850 outlines (see Figure 20.10 in Chapter 20 of the cited book). Using an earlier date would thus result in a misleading calculation of area and volume change rates. However, to not confuse it in the text with the real maximum extent, we will refer to it as the late LIA maximum extent instead of the LIA maximum position.

The LIA chronology is therefore biased towards large (and most slowly reacting) glaciers because majority of available dates come from these sites, where most work has been carrying out in the past.

Yes, we agree that this could be the case. However. there are also exceptions from the rule. With a view on the study by Nussbaumer and Zumbühl (2011), the quickly responding Oberer Grindelwald Glacier had its final maximum extent also after 1850, the position just a bit shorter than in 1820 and 1600. And the slowly reacting Mer de Glace has the same number of maximum extent peaks since 1600 (about 8) as the fastly reacting Glacier de Bossons. So response times are likely only one possible factor for differences in the chronology.

Related comment for Line 42:

'in contrast to other regions in the world, extent differences (e.g. between 1850, 1820 or 1600) are small in the Alps'

Please provide references to support your point here. This affirmation does not seem straightforward to me at all.

We will add some references for this statement. For example, the comparison shown in Fig. 2 of the PAGES news (Vol. 19, No 2, Page 69) from 2011 and the study by Nussbaumer and Zumbühl mentioned above should make the point clear: Glacier maxima for the Alps all reach about the same extent between 1600 and 1860 (cf. also Fig. 20.10 in the book chapter), whereas

for some outlet glaciers of the Jostedalsbreen Ice Cap in Norway there is a steady decrease after they reached their maximum extent around 1750. Similarly for many glaciers in the Andes with their multiple and progressively younger moraine walls (e.g. Rabatel et al., 2008). Even if not precisely dated everywhere, these well-separated moraine sequences indicate rather different response characteristic compared to the Alps where the 1850 extents where about as large as those before. Hence, for the Andes change rate calculations have to consider the longer period when using the outermost moraine wall for the extent (see also Reinthaler and Paul, 2023).

Mainly because:

Even if it's relatively true at large Alpine glaciers, it is less at small glaciers.

But foremost, dates with temporal resolution high enough to assert this (archives, tree rings) are barely available outside the Alps

Yes, the sample of properly dated LIA moraines is indeed still small, but we think in the meantime we have some good data from many regions in the world. However, for the statement above one might not even need the dating. There are typical regional differences in moraine deposition which allow us using the '1850' extent as a proxy for the LIA maximum extent in the Alps, but this is not possible for certain glaciers in southern Norway or many glaciers the Andes.

Using 1850 as an averaged reference date to calculate glacier area and volume change rates for glaciers in the Alps is certainly a simplification, but we think sufficient for a first estimtion at regional scales. As in similar regional-scale LIA studies (e.g. Carrivick et al. 2023 https://doi.org/10.1029/2023GL103950), we provide lower and upper bounds to consider the uncertainty (and variability) of the timing.

We are looking forward to the many studies that will further refine and improve the LIA glacier outline dataset presented here.