Response to Dr. Renato R. Colucci (Reviewer #1) to manuscript TC-2020-82

Italic: Referee comments

Bold: Authors comments

Red: Selected changes in the manuscript (note, not all changes are shown here, but will be submitted as revised manuscript with track-changes)

SPECIFIC COMMENTS

Referee:

L26-27 When referring to the definition of glacieret a good reference is also the Unesco glossary of glacier mass balance and related terms by Cogley et al. available at this link https://unesdoc.unesco.org/ark:/48223/pf0000192525 Nevertheless, Serrano et al. 2011 gave a very interesting view of such minor ice bodies discussing their evolution from a disintegrating glacier or in areas where nival processes are dominant. To me, it would be important to add also this view in the introduction.

Authors:

The terminology is indeed vague when it comes to exact definition of the glacieret, so the definitions and discussions of Cogley et al. and Serrano et al. are now added in the text, and readers are referred to these two references for further reading.

…glacierets are defined as a type of miniature (typically less than 0.25 km^2) glaciers or ice masses of any shape persisting for at least two consecutive years (Cogley et al., 2011; Kumar, 2011). Serrano et al. (2011) differ them from ice patches in terms that glacierets are "the product of larger ancient glaciers, still showing motion or ice deformation, although both very low. They have a glacial origin, glacial ice and are never generated by new snow accumulation", whilst ice patches are "ice bodies without movement by flow or internal motion". Despite their small size, glacierets occupy a significant volume fraction at regional scales (Bahr and Radić, 2012), and can therefore be considered as an important target for palaeoclimate studies. Accordingly, many present-day glacierets are closely monitored and studied (Gądek and Kotyrba, 2003; Grunewald and Scheithauer, 2010; Gabrovec et al., 2014; Colucci and Žebre, 2016), but the peculiarity of current global climate change requires more evidence from different proxies and from further in the past when current ice patches and glacierets were still glaciers…

Referee:

L 29-30 Pay attention, reference Bahr and Radi´c, 2012 should be highlighted after the sentence "occupy a significant volume fraction at regional scales" and not after "and are thus an important target for palaeoclimate studies". . . they never stated this. Anyway, the sentence is overall questionable because the maximum size of the Triglav glacier during the Holocene was much larger than the size of a glacieret. I suggest rewriting the sentence in order to clarify this important aspect.

Authors:

We corrected the citation order, and also made it clearer that Triglav Glacier (Glacier with the capital as it is its official name) is now ice patch, but used to be glacier (and glacieret) in the past.

Referee:

Line 39-43 Subglacial carbonate crusts are also reported in the European Julian Alps by Colucci, 2016 (ESPL page 1232, Geomorphic influence on small glacier response to post-Little Ice Age climate warming: Julian Alps, Europe).

Authors:

The reference was added to the text.

Referee:

Line 51 You should be consistent with the given definition of glacieret, representing the actual state of this ice body. Honestly, as mentioned above, I would prefer the definition given by Serrano et al., 2011 and classify this ice body as a "glacial ice patch", meaning that it is actually an ice patch (no more than 2-3 m thick), residual ice body of a recently flowing glacier.

Authors:

We largely reworked the whole introduction chapter so it is clearly stated that Triglav Glacier is at present a "glacial ice patch" (and was also recently a "glacieret", and less recently a "glacier").

Referee:

Lines 84 and 94 Add space after "(sub)"

Authors:

Corrected.

Referee:

Line 127-133 I would suggest replacing here the term "glacieret" with "glacier" especially because when referring to the further chapter at line 135-138 is correctly stated that carbonate deposition resemble flow direction of the glacier and precipitation was strongly influenced by the mechanical force of the ice movement. Please, give clues about the location and number/name of such younger dated samples and of all the cited samples. It is important for the reader to understand where each dated sample is located in the surrounding s of the present ice patch which is a non-moving ice/firn mass. Nevertheless, after reading all the manuscript, I think this sub-chapter is rather unuseful and might be deleted because they are better presented and discussed in chapter 4.

Authors:

The term "glacieret" was replaced with "glacier". We also made it clearer in the Methodology chapter how many samples were collected and referred a reader to the location figures (Five subglacial carbonates were collected 50 m to 100 m from the current ice patch (Fig. 2).**). Since this chapter is strictly representing the results only (as the chapters before this), followed by a discussion chapter, we still left the chapter included in the manuscript.**

Referee:

Line 174-175 In that paper Resfinder et al. stressed the fact that carbonate crusts were preserved by very cold and dry Arctic climate, which is really not the case of the Triglav cirque in the last century or during any possible period of absence or almostcomplete- absence of an ice body. This is particularly true when looking at Mean Annual Precipitation (MAP) of 2600 mm w.e. recorded at Kredarica.

Authors:

This is a helpful additional argument for the continuously existing Triglav Glacier during the Holocene, and we added this part to the chapter 5.

…whilst Refsnider et al. (2012) discussed the preservation of the subglacial carbonates by very cold and dry Arctic climate, this cannot be the case of the cirque of Triglav Glacier in the last century or during any possible period of absence of an ice body, evident by mean annual precipitation at Kredarica hut (2515 m a.s.l.) (Slovenian Environment Agency, 2020) (see Fig. 2 for location)….

Referee:

Line 182 I'm wondering if this could be entirely correct. At the LGM peak, Kuhleman et al2008 suggested a lowering of summer temperature of about 9-11°C in the southeastern Alps. This roughly means that at Kredarica (2514 m), where the present summer temperature (1981â˘A˘ T2010) is around +6.0 ° C (http://meteo.arso.gov.si/uploads/probase/www/climate/table/sl/by_location/kredarica/climatenormals_81-10_Kredarica.pdf) and considering the recent warming in the area calculated in the southeastern Alps in +1.7 C since the end of the Little Ice Age by Colucci & Guglielmin 2015, should have been roughly between -4.7 and -6.7. These characteristics lead to the existence at that location of a cold base glacier, instead of a temperate glacier. Nevertheless, given dates at 23.62 ka, 18.45 ka, and 12.72 ka suggest some interesting speculation. As stated by Monegato et al., 2017 in the paper "The Alpine LGM in the boreal ice-sheets game" published in Scientific Reports (https://www.nature.com/articles/s41598-017-02148-7), the LGM seems to be characterized by 2 main peaks with a withdrawal phase between 23.9 and 23.0 ka when tha Garda glacier retreated, which fit rather well with the 23-62 ka date given in this work. The final collapse of the Garda glacier occurred around 17.7-17.3 ka but soon before there was a progressive stacking of moraines related to the retreat and lowering of the ice surface which seems to fit well with the 18.45 ka dating. Both events could represent the occurrence of "some" subglacial water at the glacier-bed. Finally, I have no problem considering that during the Younger Dryas phase there was certainly a large amount of free water flowing at the glacier-bed. Small scale Detailed paleoclimate conditions in the Alps are still an open question, and uncertainties are evident especially in the eastern Alps when looking at bias between the modeled MIS2 stage ice extent (Seguinot et al., 2018) and geomorphological reconstruction (Ehlers et al., 2011), but the discussion could be expanded in such a way.

Authors:

This discussion was avoided in the first draft due to the greater focus into preservation of subglacial carbonates and the lack of high-number/resolution dates to constrain the individual withdrawal periods during the LGM. Nevertheless, the retreat of the Garda Glacier indeed points out rather interesting correlations to the single ages of the subglacial carbonates of the Triglav Glacier, so we added the proposed discussion in the text.

…the cold Alpine environment during the glacial period with low biological respiration rates could be indicated in the relatively high δ13C signal, also reported by others (Lemmens et al., 1982; Fairchild and Spiro, 1990; Lyons et al., in press), but the (re)freezing of the subglacial water causes supersaturation with respect to carbonate and the non-equilibrium conditions produced by this process can affect the stable isotopic composition of the subglacial carbonate, usually leading to isotopic enrichment in the carbonate minerals (Clark and Lauriol, 1992; Courty et al., 1994; Lacelle, 2007). In any case, the climate during the precipitation of subglacial carbonate had to be "warm" enough to produce subglacial water at the glacier-bed. Kuhlemann et al. (2008) suggested a lowering of summer temperature of about 9-11°C at the LGM peak, meaning that the summer temperatures at Triglav Glacier should have been around -4.7 to -6.7°C (based on the present summer temperatures at around +6°C (Slovenian Environment Agency, 2020) and additional considering the recent warming of +1.7°C in the area calculated in the southeastern Alps since the end of the Little Ice Age by Colucci and Guglielmin (2015)), which would have been conditions for the cold base glacier and the absence of subglacial water flow. Whilst small scale detailed palaeoclimate conditions in the southeastern Alps are still uncertain, the current U-Th ages of subglacial carbonates within this research fit with the temporary Garda Glacier withdrawal phases reported by Monegato et al. (2017); 23.62 ka age of subglacial carbonate relates to the withdrawal phase between 23.9 and 23.0 ka, and 18.45 ka could relate to the glacier retreat from around 19.7 to 18.6 ka or even the final collapse of the glacier around 17.7 to 17.3 ka; both time periods could relate to commencement of subglacial water flow also at the Triglav Glacier and consequently the precipitation of subglacial carbonates. In addition, the 12.72 ka age of Younger Dryas would predate the period of maximum cooling between ca. 11-10 ka (Mathewes, 1993; Renssen and Isarin, 1997)…

Referee:

Lines 195-200 this is too speculative in my opinion. There is no evidence at present of cave ice older than roughly 10 ka at least in Europe, on my best knowledge. I would be more cautious in this manuscript deleting "perhaps even Last Glacial Maximum times".

Authors:

We deleted this part.

Referee:

Line 236 I would prefer "ablation" instead of "melting".

Authors:

We changed the words accordingly.

Referee:

Line 241 I might agree with what it is here stated, but as a possible cause I would also cite the important work of Painter et al., 2013 (https://www.pnas.org/content/110/38/15216).

Authors:

We included this work (and also added it in the chapter 7).

Referee:

Line 242-248 This part is too hasty, although crucial in the discussion, and should be more deeply investigated and discussed. For instance, has been shown as the retreat of Triglav glacier since the LIA in the last century has been more evident than in other sectors of the Julian Alps where other glaciers existed. This is the case of Canin-Kanin or Montasio West glaciers which are lower in elevation than the Triglav glacier. The Montasio West is still classified as a moving glacier with dynamics due to internal deformation. The reason why Canin-Kanin and Zeleni Sneg (the largest LIA glaciers in the Julian Alps) had different fates in terms of shrinking velocity and a 200 m difference in the Equilibrium Line Altitude (ELA) has been justified by Colucci 2016 to a large difference in Mean Annual Precipitation (in the Triglav area precipitation are roughly 60% of that in Canin-Kanin) and potential annual solar radiation for the glaciers differed by about 7%. In this view Triglav glacier generally has higher sensitivity to summer temperature while Canin-Kanin lies in a more "maritime" environment and is more sensitive in changes of winter precipitation. I guess a discussion in terms of variability of these two parameters during the Holocene and/or in the Lateglacial period would improve this part of the manuscript. The literature is quite abundant on this topic.

Authors:

We emphasised now the geomorphological peculiarity of small glaciers which influence their dynamics and included the Canin example. Nevertheless, the aim of the paper is to demonstrate the value of subglacial carbonates which offer possible indications of on-going persistence of the Triglav Glacier since the LGM, which based on geomorphological predispositions would be

amongst the first ones to disappear, despite its higher altitude, and therefore the most appropriate one to relate this to other small glaciers. However, as stated in the paper, high-resolution analyses of subglacial carbonates need to follow to justify further environmental discussions.

…on the other hand, further comparable research on various small glaciers is needed to generalise the palaeoclimatic data due to geomorphological peculiarity of glacier regions; for example, even though the resilience of the Triglav Glacier until present can be emphasised due to the above described regional components, the retreat of the Triglav Glacier has been more evident than the retreat of the Canin Glacier (Italy), Montasio West Glacier (Italy) and Skuta Glacier (Slovenia) (all in southeastern Alps), which are all lower in elevation than the Triglav Glacier, but large difference in mean annual precipitation (e.g., in the Triglav area water equivalent precipitation (2071 mm) is 62% of that in Canin area (3335 mm)) and potential annual solar radiation play a major role for differences in glaciers' dynamics (Colucci, 2016)…

FIGURES

Referee:

Figure 3 Is not adding anything crucial to the study area or the manuscript itself. It Maybe could be deleted and glacier outlines drawn in figure 2. Instead, Figure S2 could be added in the main article as Figure 3, maybe highlighting with arrows and numbers the location of the samples because in the main manuscript a picture of the study area with a view of the present state of the ice patch is missing.

Authors:

Figure 3 was deleted. We added the locations of samples in Figure 1 B, which is showing the area of the present state of the ice patch. Figure S2 and S3 are therefore also not needed as they are similar to Figure 1 B and were therefore deleted. The ice outline from previous Figure 3 was added (only 1946 year) to the Figure 2, whilst additional outlines can still be traced in supplementary material. All of the figures have now text changed into Times New Roman and in places enlarged to be more visible.

Fig. 1

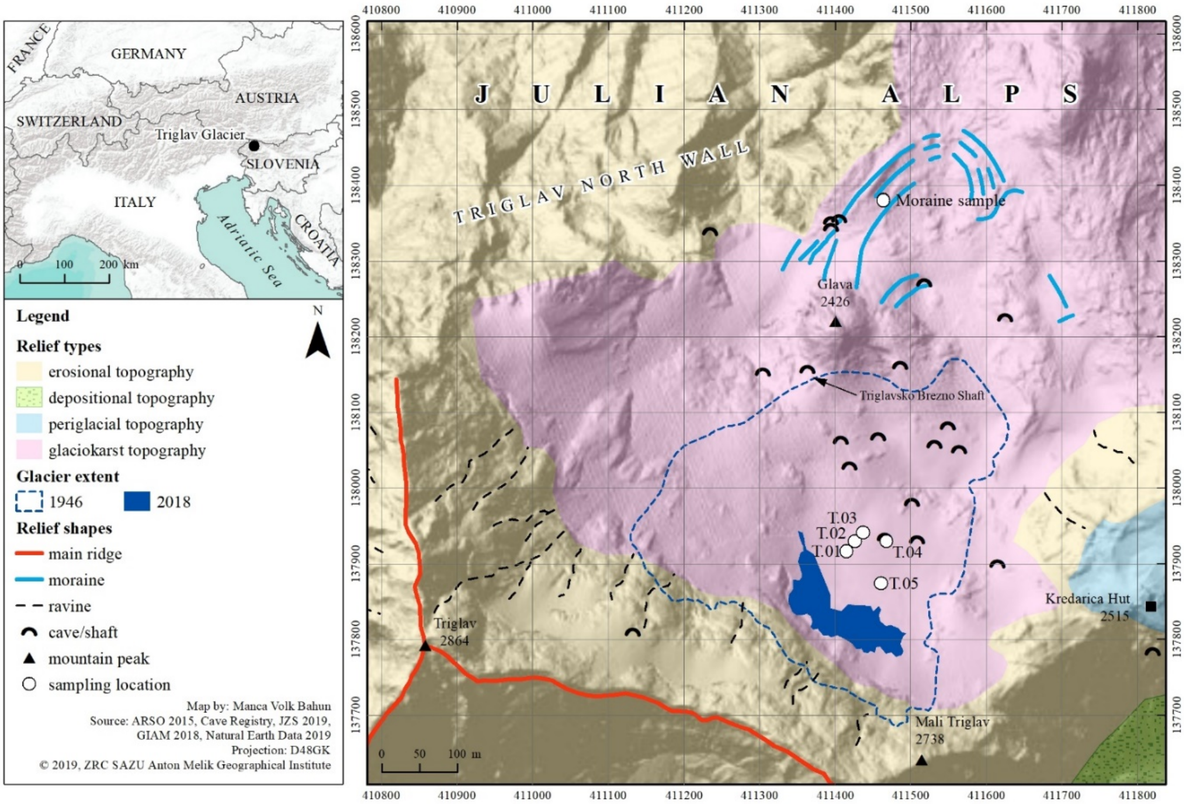


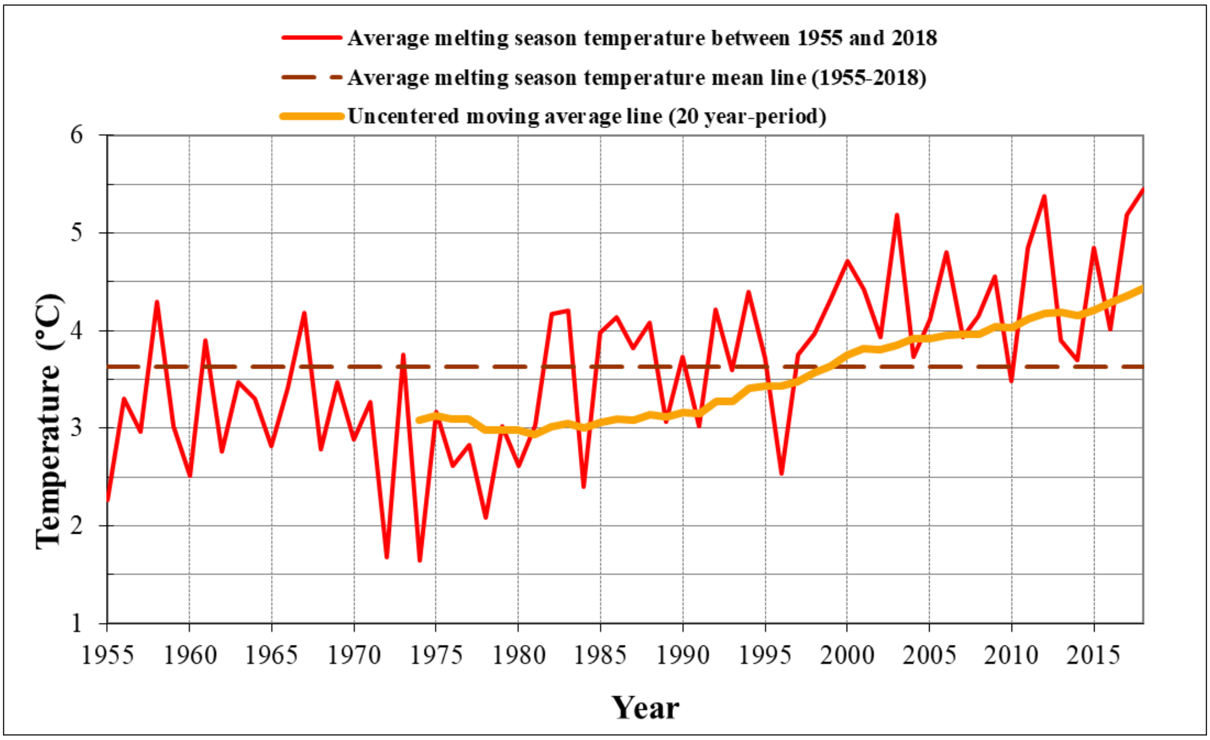
Fig. 2

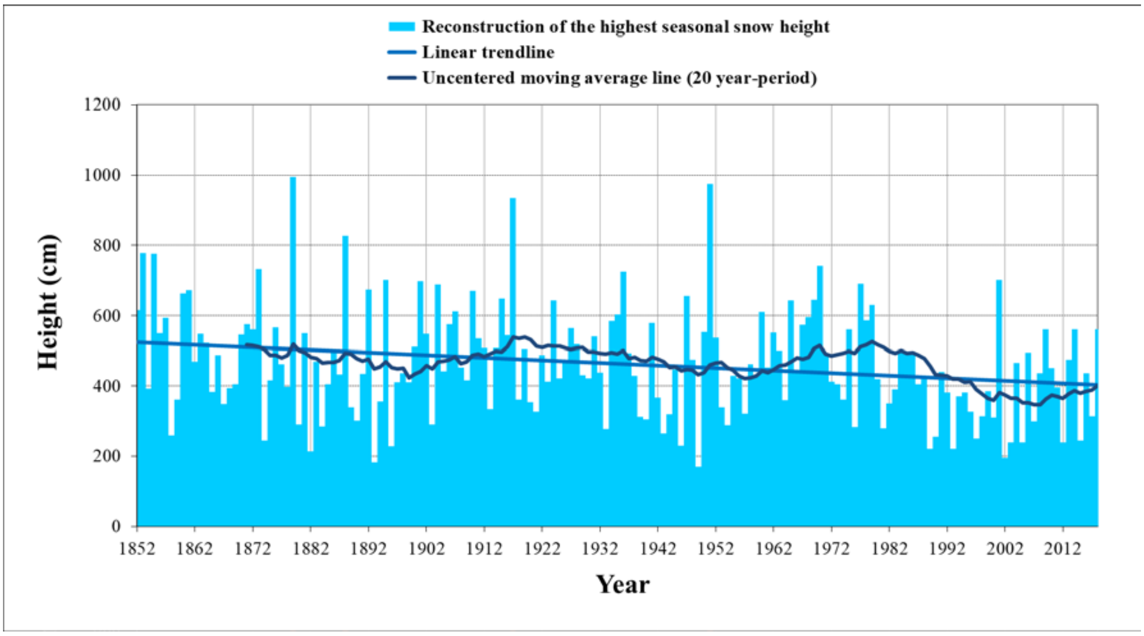
Referee:

Suppl. Material Figure S3 . . . it would be useful to add a number of samples together with arrows Figure S5 . . . not clear which of the 3 caves is the Tiglavski Brezno Shaft. . . Fonts and size are not the best, please improve the size and the visibility of the text Figure S6 . . . I would change "melting season" with "ablation season". More, please give clues about the moving average used (how many years ?! It is centered ?) Figure S7 . . . Besides linear regression, I would also add a moving average which probably better highlights variability along about the last 170 years. These are indeed very interesting data, I'm asking my self if they are available in some repository to the scientific community.

Authors:

We made on all the figure maps clear now which is the Triglavski Brezno Shaft, and also improved fonts and size. Figure S6 is updated, also Figure S7; we included now the 20-year uncentered moving average for both graphs. The raw data of Figure S6 is available through Slovenian Environment Agency site (https://www.arso.gov.si/en/), and a number of additional raw data of the Triglav Glacier are accessible on the dedicated page of the Slovenian Environment Agency (http://kazalci.arso.gov.si/en/content/triglav-glacier). The original reconstruction data of Figure S7 was primarily published in Gabrovec et al. (2014) and the reader is referred to this reference (as the caption states as well); the reconstruction of the highest seasonal snow height is not the main topic of the manuscript, however, due to its recognition as a valuable data, the process has been started to build a repository upon the referenced (Gabrovec et al., 2014) work.





Again, we thank dr. Colucci for the fair and constructive review.

Authors.