

The Cryosphere Discuss., author comment AC2  
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## Reply on RC2

Loris Compagno et al.

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Author comment on "Brief communication: Do 1.0, 1.5, or 2.0 °C matter for the future evolution of Alpine glaciers?" by Loris Compagno et al., The Cryosphere Discuss., <https://doi.org/10.5194/tc-2021-31-AC2>, 2021

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The following pages contain a point-by-point reply to the comments provided by the two referees that reviewed our first submission (TC-2021-31)

Each of the referee's comment (**RC**) is numbered. If a comment contained several points, we numbered them, and address them individually in our author replies (**AR**).

**[RC 2.01]** The paper is clearly written, and the conclusions are clear, some minor comments for improvements are suggested below.

**[AR 2.01]** We thank the reviewer for the very positive feedback.

Specific comments:

**[RC 2.02]** The abstract is very brief and only hints at the results and conclusions. Suggest to include the quantification presented in the conclusion also in the abstract and clarify what 'glaciers might start recovering' actually mean, when does the recovery start (same for all scenarios)? What does recovery mean (full, partial)? Why do they recover? The abstract should really entice the reader to read on so in my opinion more information already here would be useful.

**[AR 2.02]** We thank the reviewer for these important questions but note the 100-words limit imposed by the Brief Communication format only leaves us with marginal room for answering. In the hope that the journal will allow for some flexibility, we propose the following amendment (ll.4-7):

'Our results show that even half-degree differences in global temperature targets have important implications for the changes predicted until 2100, and that – for the most optimistic scenarios – glaciers might start to partially recover owing to possibly decreasing temperatures after the end of the 21st century.'

Technical corrections:

**[RC 2.03]** Page 1, Abstract, Line 5, suggest to edit 'temperature targets' with 'scenario' or 'projections resulting in different temperature change'. Suggest also to clarify what 'implications' and what 'changes' are meant, by adding a little more text this sentence would be more informative.

**[AR 2.03]** We changed the sentence following reviewer's suggestion (see AR 2.02)

**[RC 2.04]** Page 1, line 8, suggest to delete 'need to'

**[AR 2.04]** Done

**[RC 2.05]** Page 1, line 12, sentence is not clear, what is ambitious about the targets? What important environmental change is to occur? My suggestion would be to write out what specifically is meant hear.

**[AR 2.05]** We rewored the sentence (Il.12-13) into:

'Even under these ambitious climate targets, important environmental changes, such as changes in water availability, migration of species, or glacier loss, are expected to occur'.

**[RC 2.06]** Page 1, line 21-22, suggest to clarify what 'integrated response of climate forcing over decades to centuries' means here. Why is it integrated? What is the time scale? Why decades to centuries?

**[AR 2.06]** We rewored the sentence into:

'Across the world, glaciers are amongst the most prominent indicators for climatic change, providing visual evidence for climatic changes occurring over decades'

**[RC 2.07]** Page 2, line 26, suggest to clarify what 'tease out' means and how the authors 'do so'

**[AR 2.07]** We rewored the sentence into:

Il. 26-29: ' Whilst future projections for the glacier evolution of the European Alps already exist under different representative concentrations pathways (RCPs) (e.g. Zekollari et al.,

2019, Marzeion et al., 2020), targeted information on policy-relevant climate targets (like the difference between 1.5 and 2.0°C IPCC, 2018) is difficult to identify. [...]'

**[RC 2.08]** Page 2, line 53, would be helpful to state what the 0.1° resolution is in km. It is further not clear how the climate is downscaled to the glacier scale, some explanation or statement of how the mass balance (at one point or several) for each glacier is computed.

**[AR 2.08]** We added in the text that 0.1° resolution is 11 km. We acknowledge that the limited space provided within a Brief Communication does not leave room for detailed questions related to the methodology. We have now clarified more explicitly that the methodological steps addressed by the reviewer are described in Huss and Hock (2015).

ll. 62-65: 'In a nutshell, the procedure uses a set of additive and multiplicative correction factors to adjust both the long-term mean and the long-term variability of the coarse-resolution GCMs (100 km) to the level of the high-resolution E-OBS data (see Huss and Hock, 2015, for more details). '

**[RC 2.09]** Page 3 line 1, here would also be useful to state that the 'coarse' resolution is in km

**[AR 2.09]** We added in the text that it is 100 km.

**[RC 2.10]** Page 3, line 65-66 suggest to turn sentence around, it would be the modelled loss that is close to the observations, rather than the other way

**[AR 2.10]** We turn the sentence around, as suggested by the reviewer.

ll. 72-73: '[...] our modelled loss is of 24.9 km<sup>3</sup>, which is very close to the observation-based estimate of 23.6 km<sup>3</sup>(Grab et al., under review). '

**[RC 2.11]** Page 3, line 68, suggest to add 'global' between 'century' and 'warming', also would be useful to tell which scenarios those are (it is given a few lines below, my suggestion is to move that information to this location)

**[AR 2.11]** Done

**[RC 2.12]** Page 3 line 75, is it also averaged? How are the grid cells used to produce SMB for each glacier?

**[AR 2.12]** We are not sure to fully understand the reviewer's question. The values of temperature and precipitation change that we report in Figure 1, for example, are indeed averaged over the considered domain (as acknowledged by the figure's caption). For

forcing, GloGEMflow's surface mass balance module, instead, the climate information of every grid-cell is considered individually and 'downscaled' for each individual glacier following the procedures described in Huss and Hock (2015). Since this information is now passed at Lines 62-65 in reply to RC 2.08, we do not repeat it here.

**[RC 2.13]** Page 3, line 80 it is not stronger for all three, only for the higher two, the first is decreasing from 0.98 to 0.96, suggest to edit the sentence

**[AR 2.13]** we changed the sentence into:

'During the summer months (JJA), the temperature increase in the Alps for the two warmer climate targets is even stronger [...]'

**[RC 2.14]** Page 5, line 107, suggest to edit/replace 'results anticipate' with 'simulations project'

**[AR 2.14]** Done.

**[RC 2.15]** Page 5, line 109, suggest to edit 'is well documented' with something like 'projected in other studies' or 'established'

**[AR 2.15]** We changed 'is well documented' into 'projected in other studies'.

**[RC 2.15]** Page 6, line 115, not clear whether the three GCM members are same as in the previous simulations, 're-run' indicates that, but it could be clarified. If the are same then 'extend' would be clearer. Maybe this information could be added?

**[AR 2.15]** One GCM member (MRI-ESM2-0) is the same, the other two (IPSL-CM6A-LR and CanESM5) were not used for the previous simulations.

We added this information in the manuscript:

ll.127-129: 'To gain insights into glacier evolution beyond this horizon, we run GloGEMflow with three GCM members (one of which was already considered in the 2100 simulations, see Fig. S3) that provide climate data until 2300.'

**[RC 2.16]** Page 6, line 120 suggest to edit 're-gain a total volume that is between 47% and 72% of the 2020 level', the regained volume is the other part of the 2020 level (53% and 28%), so the sentence is not clear, can it be made clearer? How much is regained?

**[AR 2.16]** We agree the sentence was not clear, and we now reformulated it into:

'While glacier volume losses of 80-85% are calculated for 2100, the experiment projects Alpine glaciers to re-gain part of the lost volume, reaching a total volume between 28% and 53 % of the 2020 level by 2300. '

In other words: by 2300, the glaciers are projected to re-gain a volume that is between 1.5 and 3.5 times larger than the one projected for 2100.

**[RC 2.17]** Page 6, line 122, it is not clear what 'perception of an irreversible trend' is, maybe that could be stated, is the perception that the mass loss is irreversible? Where would that perception come from?

**[AR 2.17]** We addressed this already in AR 1.13.

Here we provide a copy of the new paragraph:

'These results show that, owing to slow lowering of air temperatures and enhanced precipitation implied by this particular scenario after 2100, slow glacier recovery might happen (Fig. S3). While glacier volume losses of 80-85% are calculated for 2100, the experiment projects Alpine glaciers to re-gain a total volume that is between 28% and 53% of the 2020 level by 2300. Although this result is only based on three GCM members and is thus very uncertain, it suggests that considering projections beyond 2100 might change the current perception of a possibly irreversible glacier loss. From the physical point of view, the result that glaciers might re-grow after a potential cooling global temperatures is not surprising. Still, increasing the number of GCM members that consider such longer-term horizons and having different research groups performing similar analyses would help verifying the robustness of this preliminary finding. We also stress that decisive climate action would be required for steering global temperatures towards such an evolution (i.e. SSP126).'

**[RC 2.18]** Page 6, line 123, suggest to replace 'verifying' with 'verify'

**[AR 2.18]** Done

**[RC 2.19]** Page 7 line 125, this sentence is not clear, what is 'decisive acting'? what are 'unwanted consequences'? where is the 'overwhelming consensus'? suggest to turn sentence around the temperature target (rather than 'climate target')

**[AR 2.19]** The wording 'decisive acting' was unfortunate, and we now make reference to some of the most important reports for clarifying the other two questions. The wording 'temperature target' was adopted as suggested. The revised sentence reads:

ll.142-145: ' Whilst there is overwhelming consensus that decisive action has to be taken to limit unwanted consequences of ongoing climatic change (UN, 2015; IPCC, 2018; IPBES, 2019; IPCC, 2019; WEF, 2020) , the debate around which temperature targets to

pursue is all but settled'

**[RC 2.20]** Page 7, line 128, suggest to replace 'showed' with 'show'

**[AR 2.20]** Done

**[RC 2.21]** Page 7 line 131, suggest to replace 'would' with 'will'

**[AR 2.21]** Done

**[RC 2.22]** Page 7, line 135, edit sentence, it is not the changes, but rather the peak runoff that occurs 1 to 2 months earlier. Suggest also to replace 'anticipated' with 'projected'

**[AR 2.22]** We edited the sentence into:

II.154-155: 'Changes in monthly runoff – with a runoff peak projected to occur 1 to 2 months earlier by the end of the century -- will be even more pronounced '

**[RC 2.23]** Page 7 line 136, suggest to add 'peak' between 'August' and 'runoff'

**[AR 2.23]** Done

**[RC 2.24]** Figure 2. Why is there a bed upwards (kink) for +2°C (red line) at 2020?, less for the +1.5°C (light blue line) and downward dip that goes up for the +1°C (blue line) is this due to the transition from the E-OBS to CMIP6 models? This could be discussed in text. Caption, line 3, replace 'or' with 'of' and suggest to add that the (n) is given in panel (a).

**[AR 2.24]** The upwards kink for the +2°C was an artifact introduced by the running mean. This is now corrected, also in response to request RC 1.16. The caption was amended as suggested and now reads:

'Figure 2. Modelled evolution of total glacier (a) volume, (b) area, (c) annual glacier runoff, and (d) monthly glacier runoff of the European Alps. Time series in c are smoothed with a 30-year running mean. In all panels, the thick line represents the mean and the

transparent band corresponds to one standard deviation of the results obtained by forcing GloGEMflow with the selected GCM members. The numbers of GCM members is given (n) in panel (a).`

### **Supplementary material**

**[RC 2.25]** Figure S2, Delete 'annual' in figure title after 'winter'

**[AR 2.25]** Done

**[RC 2.26]** In figure captions of S1 and S2 suggest to replace 'of 72 glaciers' with 'from 72 glaciers'

**[AR 2.26]** Done

**[RC 2.27]** Suggest to edit figure caption S3 it is not only Modelled glacier evolution until 2300 but also temperature and precipitation evolution.

**[AR 2.27]** We changed it into 'Evolution until 2300'

**[RC 2.28]** Table S2.1 replace 'and' with 'an' before 'area'

something strange in the parenthesis what does (given as 'Area??) refer to?

**[AR 2.28]** We reformulated the caption into: 'Table S1: Overview of glacier volume change between 2020 and 2100 for glaciers with an area >10 km<sup>2</sup>. The provided glacier area is from the RGI v6.0.'

### REFERENCES:

Bliss, A., Hock, R., and Radić, V. (2014), Global response of glacier runoff to twenty-first century climate change, *J. Geophys. Res. Earth Surf.*, 119, 717– 730, doi:10.1002/2013JF002931.

Compagno, L., Zekollari, H., Huss, M., & Farinotti, D. (2021). Limited impact of climate forcing products on future glacier evolution in Scandinavia and Iceland. *Journal of Glaciology*, 1-17. doi:10.1017/jog.2021.24

Huss, M., Farinotti D., Bauder, A. and Funk, M. (2008). Modelling runoff from highly glacierized alpine drainage basins in a changing climate. *Hydrological Processes*, 22(19), 3888-3902, doi:10.1002/hyp.7055