Dear Dr Ian S. Evans

(corresponding to https://doi.org/10.5194/tc-2021-182-RC2)

We thank you for your valuable comments. Here we address how we will revise the manuscript corresponding to your specific comments. The comments are in black words, which are followed by our responses in red words.

Comment

The authors report very interesting observations on five Japanese glaciers, over several years. These are clearly exceptional compared with other glaciers, which is attributed to avalanching and perhaps wind drifting, combined with very heavy snowfall. They are narrow and linear. All the Tables and Figures are clear and informative. The writing is concise and the structure is acceptable. The expression is readable but occasionally imprecise, with a strange use of 'between', and there are a few careless errors.

More context would be welcome, both on other possible glaciers among the "More than 100 perennial snow patches "in this region, and on comparison with other avalanche-fed glaciers and other glacierets / very small glaciers elsewhere. Can the feeding avalanche tracks be mapped? Are there cornices in winter, suggestive of wind drifting? Many aspects of the literature are well covered, but a number of other papers on glacierets or very small glaciers could be considered:

Some of these state that mass balances tend to vary from year to year, positive throughout or negative throughout, rather than between accumulation and ablation areas.

On the 'Inventory of perennial snow patches…', the Higuchi et al. GeoJournal paper is only 8 pages. Might it be worth citing the fuller (81-page) Atlas? –

Higuchi, K., Iozawa, T.: Atlas of perennial snow patches in Central Japan. Water Res. Lab., Faculty of Science, Nagoya U., 81 pp., 1971.

Apart from the detailed corrections, and extending comparisons with avalanche-fed glacierets elsewhere, my main suggestion is to compare the (1.92 to 4.34) ratio of winter mass balance to local weq snowfall, with similar ratios for the other nine glaciers smaller than 0.11 km^2 in the Appendix (or consider similar ratios for balance amplitude).

Response

The following is a split response to the above comments.

i. More context would be welcome, both on other possible glaciers among the "More than 100 perennial snow patches” in this region, and on comparison with other avalanche-fed glaciers and other glacierets / very small glaciers elsewhere.

Response

Other possible glaciers:

There are no references about other possible glaciers. The references related to glaciers are only Fukui and Iida (2012), Fukui et al. (2018), and Arie et al. (2019). These are cited in this paper. As you referred to comparison with other snow patches, we progress to investigate the influence of topographic conditions are investigated. In addition, we have researched three perennial snow patches in fieldwork. In this paper, we add some sentences about the topographic condition, because we focused on glacier mass balance in this paper.

The comparison of other topographic-controlled VSGs:

Topographic-controlled VSGs have been reported mainly in the European Alps but also Rocky, Urals, Andes. Results of comparing Topographic-controlled VSGs in this paper, we show that (1) the Japanese VSGs have the annual mass balance greatly affected by the winter balance, and (2) the mass balance amplitude of the Japanese VSGs is larger than that of any other VSGs in the world including glaciers located in a warmer and wetter region. As you pointed out, we did not mention that the mass balance of some VSGs becomes positive or negative throughout large annual fluctuations. In our revised paper, we include Colucci et al. (2021), a recent study of VSGs in the European Alps, and Fukui et al. (2018), which describes the same characteristics as VSGs in the European Alps.

ii. Can the feeding avalanche tracks be mapped? Are there cornices in winter, suggestive of wind drifting?

Response

In aerial images, fresh avalanche tracks can be observed on the glacier. However, it is impossible to determine where all avalanches occurred during winter. Conies also can be observed on the upper ridge of the glacier. The previous study shows that avalanches and snowdrifts have effects on the formation of perennial snow ravines (Higuchi, 1968). In our revised paper, we add Higuchi (1968) and the effect of snowdrift on the east slope of the main mountain ridge and observation by aerial images.

iii. On the ‘Inventory of perennial snow patches…’, the Higuchi et al. GeoJournal paper is only 8 pages. Might it be worth citing the fuller (81-page) Atlas?

Response

As your points, we add the reference of Higuchi and Iozawa (1971).

iv. my main suggestion is to compare the (1.92 to 4.34) ratio of winter mass balance to local weq snowfall, with similar ratios for the other nine glaciers smaller than 0.11 km^2 in the Appendix (or consider similar ratios for balance amplitude).

Response

This is a very interesting proposal, but it is difficult to compare it with other VSGs, because we do not have the snowfall amount data at the observation of winter balance.

The following is an answer to the DETAILS.

DETAILS:

'likely' should usually be replaced by 'probably'.

Response

We replace all 'likely' with 'probably' in the sentence.

Line 19 Why not 'very small avalanche-fed glaciers'? 'Topographically controlled' is a broader class, including effects of aspect (shade) and shadow, and shelter from wind drifting snow off a plateau (not in this rugged part of the Japanese Alps!).

Response

The VSGs in the Japanese Alps are located at the valley bottom in the eastern part of the mountain range. This means an effect of avalanche, snowdrift, and shade. Some of the VSGs in the Japanese Alps are covered by debris. In our revised paper, we add more evidence and effects to classify them as topographic-controlled VSGs.

69 presumably end-winter: best to give a date for this, here.

Response

We give a date.

73-78 'glacial erosion valleys' are usually termed

Response

We replace 'glacial erosion valleys' with 'glacial troughs'.

82 'with little debris'

Response

We change it.

Table 1 Karamatsuzawa cannot be 1.03 km^2. That contradicts the Introduction and all the maps.

Also, the average inclination is sometimes close to (altitude range)/ length, but not for Komado and Karamatsuzawa – i.e. it is not overall inclination. Perhaps define how it was calculated.

Response

We mistook the unit of measurement for Karamatsuzawa Glacier. The correct value is 0.103 km^2. This inclination angle was calculated on ArcGIS using the DSM created by aerial images and SfM software. This inclination angle is the average value. However, this method is affected by crevasses and ice holes. This may be the reason why the average slope does not match the (altitude range)/length. Therefore, as your suggestion, we calculate the average inclination of all glaciers using the altitude range and length （$\theta = \tan^{-1} b/a$）. We also improve Table 1.

95-96 'from an altitude range'

Response

We change it.

155-155 How can you be so precise, unless photos were taken daily?

Response

We used the smallest area for each glacier at the end of the snowmelt season in observation periods.

We add "for five years" to the end of the previous sentence in Line 153.

158 'between … and …' ??

Response

We change it.

Fig.4 Why does the '10 m' buffer zone extend much further, especially downglacier in c and d, and upglacier in a ?

Response

In the case that we set a buffer zone around the glacier area, the DSM comparison includes the change of snow depth, because snow cover around glacier does not disappear on positive balance year. To avoid this, we took a 10 m buffer zone from the outline of the remaining snow area around the glacier in the positive balance year of 2017. The entire area within this buffer zone is the bedrocks. We compared the DSM differences at the same location through the observation period.

Fig.5 caption Not 'Each circle represents' – delete that. Rather 'The following numbers of glaciers in each region are included: …' [thereafter, repetition of 'glaciers' is unnecessary]

Response

We change it.

179 ‘amounts’

Response

We change it.

180 ‘accumulation increases with’

Response

We change it.

Fig.7 on left: ‘slope’

Response

We change it.

186-187 The sentence seems redundant, if you just mention ‘profile and gradient’ earlier.

Response

In the first part of this chapter, we mentioned only the profile, but did not explain the mass balance gradient. We explain that the slope of the profile is a mass balance gradient. For this reason, we remain this sentence.

219 should it be ‘within’ rather than ‘between’?

Response

In this sentence, “between” is correct.

Because we calculated the altitude difference between DSM and GPS.

221 again unsure how ‘between’ is being used.

Response

We change it.

230 & 234: ‘5 to 13 m’, not 5 to 11 m. (From Table 4: winter 5.63 to 12.72, summer 7.16 to 11.64.) Per glacier, summer balances vary up to 1.6 m, so are not exactly constant, just with much smaller variation than for winter.

Response

We change it.

238 ‘nearly constant’ is an exaggeration. I would say ‘is much less variable’

Response

We change it.

243 Add ‘It is reassuring that balances are closely correlated between the five glaciers, over this time period (Figs. 9 and 10).’

Response

We add it.

Table 3: seems like ‘correction’ should read ‘corrected’. Caption should remind reader what the correction is for. (The text does not even mention correction, except for lines 111-114 on the DSM: is that relevant, or is the correction for emergence velocity?)

Response

We change it.

This correction is calculated from the mean and standard deviation of the DSM differences within the buffer zone on the bedrock. We subtract the mean value of the difference in the buffer zone from the value of the difference on the glacier. The standard deviation of the buffer zone is used as the error (±). We add this sentence to the caption.

251-252. Yes, but it is more logical to say that standard deviations increase linearly with amplitudes.

Response

We change it.

Fig.11 Not m ! Numbers on y axis are in mm, unless 000 is deleted throughout.

Response

We change it.

255-262 As emergence velocity has presumably been used above, should this section come earlier? More explanation of how it was used is needed.

Response

In the case of calculation of the profile using the geodesic method, the emergence velocity is needed to calculate. In the previous section about the mass balance of the entire area, the emergence velocities of the upstream part and downstream part are canceled out by each other. Therefore, we do not need to calculate it in the previous section. The position of this section is correct, because this calculation is necessary for the profile.

Fig. 11 provides an interesting comparison between regions, but is not the most relevant way of comparing mass balance data with the results in Japan. Clearly glacier size is important: the larger the glacier, the less important the topographic effects including avalanching and wind drifting of snow. As the Japanese glaciers are 0.11 km2 or smaller, I suggest focussing on comparison with the small number of glaciers in the Appendix which are also of such tiny areas. I think there are nine: numbers 20, 21, 27, 51, 56, 74, 139, 151 and 180. One is in New Zealand, three in the Andes, four in the Alps and one in Apennines (Calderone is not in the Alps.) As the winter balances in Japan are 1.92 to 4.34 times the average direct snowfall (2.93 m), it would be useful to calculate similar ratios for the other very small glaciers. I think that would reveal that glaciers e.g. in the Urals have similar ratios, from what has been termed 'suralimentation' ('over-feeding'). That is, the Japanese glaciers are exceptional (practically 'outliers') in absolute terms, but probably not in amplitude relative to direct snowfall. (More accurate ratios could be calculated from annual snowfall values, rather than e.g. average snowfall at Tateyama Murododaira.)

Response

Fig. 12 shows that the VSGs in the Japanese Alps have the largest mass balance amplitude among all glaciers which is recorded in WGMS, including VSGs. Fig. 11 is the same result as Fig. 12. In our revised paper, we exclude Fig. 11, and show VSGs in the Japanese Alps have the largest mass balance amplitude using Fig. 12.

We are interested in your suggestion (Comparison of the ratio of snowfall to winter balance in VSGs), but we do not have local precipitation data of the same elevation. If you have some data or know data site, please let me know.

Table 5: 'a-1'

Response

We change it.

275 'from typical glaciers,' - although I would rather say 'from valley glaciers' because many cirque glaciers also have much snow-drift and avalanche input.

Response

We change it.

293-2895 Indeed: the dependence of Ural glaciers on wind-drifting (from summit plateaus) and consequent avalanching was noted long ago by Dolgushin:

Response

We add the reference.

295 Not narrow valleys, but cirques.

Response

We change it.

298-299 delete one of the repeated 'In addition,'s.

Response

We change it.

302 delete 'likely'?

Response

We change it.

313 'vertical profiles'

Response

We change it.

315 'become negative throughout' OR 'Even if the glacier can become an ablation-area throughout'

Response

We change to 'Even if the glacier can become an ablation-area throughout'.

325 It might be good to mention (somewhere) that (from the maps in Fig.3 and photos in Fig.2), the glaciers seem to receive avalanche snow throughout – not just at their upstream ends. Also, the evidence for some wind-drifting effect (despite the lack of plateaus or even rounded summits – the ridges are rugged) comes from the eastward component of aspect of all five glaciers.

Response

In line 78, we add 'These glaciers are located at the valley bottom surrounded by steep bedrock in the east part of the mountain range. This means snow avalanches and snowdrifts contribute largely to the accumulation of the entire glacier'. In fact, most glaciers and snow patches are located on the east part.

336 ‘tend to have annual balances strongly …’

Response

We change it.

349 Yes, very probably, but by how much?

Response

Kawase et al. (2020) showed that an increase of 2 °C lead to about 10% decrease in the maximum snow cover in light snow years and about 30% decrease in heavy snow years. We could not show the value because the article did not show a specific value.

349 ‘2°K’

Response

We change it.

354 delete first ‘the’.

Response

We change it.

359 ‘very little’ - not ‘almost no’.

Response

We change it.

362 ‘of a typical’

Response

We change it.

364 ‘in Japan often had negative winter balance gradients’. Fig. 13 does not really show negative annual balance gradients, and line 281 states “the gradients vary significantly”. OK they did not have ELAs: that is because of the lack of positive annual mass balance gradients.

Response

We change to ‘they did not have ELAs: that is because of the lack of positive annual balance gradients’

375 Appendix A: Another 3-orders-of-magnitude error: clearly the amplitude for #1 cannot be 10.7 km. The 4 columns ABw – SBn must be in mm, not m!

Response

We change it.

391 ‘fee’ ??

Response

We change it.

406 ‘Ödenwinkelkees, central Austria,’

Response

We change it.

429 ‘4(4), 303-311’

Response

We change it.

439 ‘The Cryosphere’

Response

We change it.

Reference

Arie, K., Narama, C., Fukui, K., Iida, H. and Takahashi, K.: Ice thickness and flow of the Karamatsuzawa perennial snow patch in the northern Japanese Alps, Journal of the Japanese Society of Snow and Ice, 81(6), 283–295, doi:10.5331/seppyo.81.6_283, 2019.

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