## Summary

Y. Verhaegen et al. used a combined ice flow-mass balance-debris evolution model to simulate the behavior of Djankuat Glacier, North Caucasus from 1752 to 2100.
This is the first study where Djankuat Glacier was modeled for such a long-time period, as well as using a model which explicitly takes into account debris evolution.
In its current form, the study has 3 minor limitations related to the way future climate is dealt with, to missing informations regarding a mass balance perturbation factor, and the sensitivity analysis.
I think that these limitations can be improved relatively easily and, therefore, I support the publication of this manuscript after the required improvements (**minor revisions**).

## General Comments

1) **Future climate**
   The surface mass balance model was forced with climatic observations in the past, and with CMIP5 climate scenarios for the future (l. 410-419). However, some important information seems to be missing:
   (i) Which climate models did you use (model name, institute, resolution, …)?
   (ii) Did you applied a de-biasing procedure to accommodate the future climate projections with the past climatic dataset (e.g. Huss, 2015)? Such a procedure is often needed to avoid sudden changes in temperature and precipitation between the past climate dataset and the future climate projections.
   (iii) Why did you use a linear trend (l. 413-415) for the future temperature and precipitation and not the trend (and variability) proposed by the CMIP5 data? This virtually discards any CMIP5 information between now and the end of the century…

2) **Mass balance perturbation**
   In the manuscript, a mass balance perturbation is used as a tuning factor, so that model results agree with observations (l. 330, 390, 493, fig. 9 and fig. 11). However, how this perturbation factor is calculated and applied is not well explained. Here additional information are absolutely needed so that the reader can understand what this factor is and how it is meant.

3) **Model sensitivity**
   l. 330-338 show a sensitivity analysis. However, also here many important informations are missing.
   (i) Are these experiments done starting by a glacier steady state? If yes, during which time period?
   (ii) Your results show how much the glacier length changes for each degree (°C) of warming, using the unit ‘m/°C’, (line 335). Over what temperature-range can the glacier response be expected to be linear? It seems easy to imagine that the topography of the glacier and its bedrock play a role, since they are not homogeneous and thus influence the glacier response depending on the glacier’s position?

## Line-by-line comments

l. 14: better to say already in the abstract which future climate data you used.

l. 24-25: this sentence needs some references.

l. 40: change '.,' to ','.

l. 44-45: are you referring to the whole Caucasian region?

l. 65: you cannot use one glacier as representative for a whole area (Huss, 2008). However, at lines 78-79 it becomes clearer what you meant. So, please reformulate.

l. 89: give a number for 'higher elevations'

l. 101: (i) it is not clear which mean annual temperature you are referring to (mean temperature of the 1981-2010 period?). (ii) it is not clear what 'here' is referring to.

l. 106-107: (i) you mentioned two places and then you say that you used only one automatic weather station (AWS). Did you used the same AWS in the two places? (ii) 'was installed' –> can you add from when to when? This information is especially important if you used only one AWS for two places.

l. 114: maybe add 'glacier' before 'top', so that it becomes 100% clear.

l. 117-119: sorry, I cannot follow this sentence. Can you maybe reformulate it?

l. 121 (eq1) The way Eq. 1 is cast looks somewhat unusual to me. Can you maybe add a reference where the derivation can be looked up? Or add the derivation in the manuscript?

l. 134: spell out 'FTCS'

l. 141: remove 'specific', since it is the glacier wide balance here

l. 145: Is there one value of ACC for the whole glacier, is it evaluated along the central flowline, or is there some sort of spatial grid playing a role?

l.149: (Oct-Mar) add also the day, or whether the beginning or end of the month are meant.

l. 154: add link to table 1 already after 'gamma_p'

l. 144-159: not super clear to me, especially how exactly all these factors are derived.

l. 167: and alpha? Add that alpha is the albedo.

l. 180: about which 'tilt' are you speaking? Is the AWS station tilted?

l. 189: ‘more or less’ - please use a synonym.

l. 189: ‘Table 1’ - It took me quite a lot to find values that you were referring to. Can’t it simply be added to the text?

l. 192: ‘plotted’ – Is this the correct word? With ‘plotted’ I expect a Figure…

l. 200-205: Is the implicit assumption that C_debris is homogeneous within the entire glacier body? Since that’s unlikely to be true, the assumption should at least be discussed.

l. 208: ‘at 1680 m from the highest point’ – where is this point? Maybe show this location in Fig.1.

l. 209-211: the choice of stopping the debris input flux at a given glacier width sounds rather arbitrary. Also the fact that the debris input location x_debris is fixed in time (and not moving) causes some doubts. Both points seem to merit some discussion.

l. 215: (eq. 13) The variable ‘t_debris’ is not introduced.

l. 225: can you give some more details about the relationship which was found?

l. 228: how is the debris-area growth factor G_A ‘updated yearly’? One should be pointed at eq. 17 at this stage.

l. 234: you took into account the melting reduction effect of debris, but what’s about the melting enhancement effect of thin debris (e.g. Østream, 1959)? Add some discussion about this.

l. 247: ‘this time period’ – maybe re-state the time period.

l. 251, 254: use always the same unit.

l. 258: what’s the meaning of ‘between 0.18 and +/- 0.6 m’.

l. 261: ‘second a’ → ‘a second’

l. 267: can you give some numbers about the ‘snow redistribution by wind/avalanche’?

l. 270-273: Did you validate the model with the same data which were used also to calibrate the model? If not, specify which data you used. If yes, isn’t there a different, independent dataset which can be used for model validation?

l. 280: I don’t understand what t_debris exactly is (cf. l. 215).

l. 297: ‘the bed was slightly adjusted’ – how? Can you give some more details?

l. 326: is the volume change a yearly volume change? If yes correct the unit.

l. 331: please correct the unit/make it consistent with the rest of the manuscript.

l. 332: can you add a reference or some details about the ‘e-folding length response time’?

l. 334 and 335: well, I imagine that these numbers depend a lot on the topography (see general comments)?

l. 330-338: the sensitivity experiments need some more details on how they are done (see general comments).

l. 336-337: ‘an acceptable accuracy’ – please give a number.

l. 381-387: in my opinion, all these sentences can be reduced into one or two sentences.

l. 390-395: How is this mass balance perturbation obtained (see main comments)?

l. 411-413: Can you give some more details about these data? Did you use global circulation models (GCMs) or regional climate models (RCMs) ? Which model did you used (all GCMs and RCMs have specific names, realizations, institutions…)

l. 413-415: Why did you use a linear temperature and precipitation evolution? Why not using the transient evolutions of the climate models? Moreover: did you applied a de-biasing approach between past climate dataset and the future climate projections? (see main comments)

l. 417: ‘+7.1 °C’ compared to when? Is this number a temperature difference between two periods or a temperature mean? If it is a temperature mean, please report also the value of the first period, or the difference.

l. 455-456: Are these values arbitrary? That seems fine but if they are, better add a sentence explaining why these values are taken and from where.

l. 503: ‘-80%’ – of area? Of volume? Or of length?

## Comments to figures and tables

Fig.1: the scale bar is bizarre. Why not using 0, 0.25, 0.5, 1 km instead of 0.5, 0.25, 0, 0.5 km?

Fig.2: Would be nice to have a little map showing where these other glaciers are, or at least their distance to Djankutan Glacier.

Fig.4: (i) I may have missed it, but what is causing the modelled MB gradient to ‘flip’ at the highest elevations (>3550 m) in Fig. 4a?
(ii) Also here the units are different than in the main text.

Fig.5a+b: (i) Would be interesting to see longer-term evolution of these values as well. (ii) What's causing the sharp bend around 1985? Is it the switch to very negative MBs

Fig. 10: (i) add labels for temperature and precipitation, (ii) say what "w.r.t." is and (iii) say what the black line is.

Fig. 11: What is the black line?

Fig. 12: Can the volume be plotted as well? That seems an important quantity.

Fig. 13: (i) unit in the y-axis (/year?), (ii) say in the caption what 'present' is for this study (what year?).

Fig. 14: Why are the impacts visible only after ca. 2050?

General comment about figures: The 'YYYY/YY' format is pretty distracting. Better use 'YYYY'

Table 1: Can you explain what the '-' means?

# References

Huss, M., Bauder, A., Funk, M. & Hock, R. Determination of the seasonal mass balance of four Alpine glaciers since 1865. *J. Geophys. Res.* **113**, F01015 (2008).

Huss, M. & Hock, R. A new model for global glacier change and sea-level rise. *Frontiers in Earth Science* **3**, (2015).

Østrem, G. Ice Melting under a Thin Layer of Moraine, and the Existence of Ice Cores in Moraine Ridges. *Geografiska Annaler* **41**, 228–230 (1959).