Thank you for your helpful comments. In the text below, reviewer comments are indicated with colored background, our replies are in plain text and changes to the manuscript are put in italic.

Response to general comments

General comment 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:

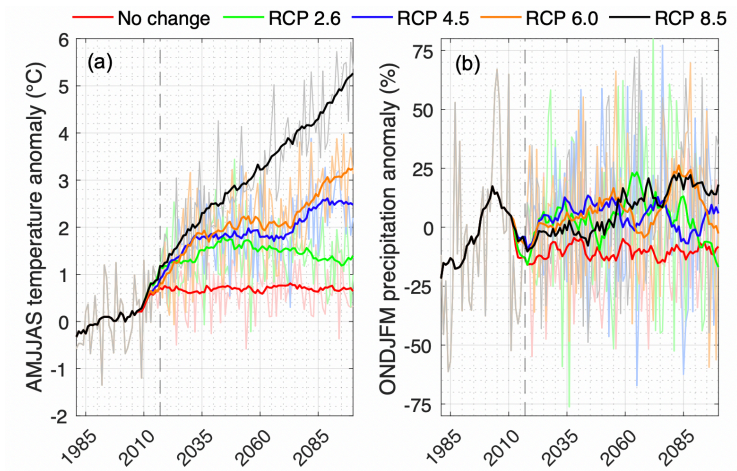
(i) Which climate models did you use (model name, institute, resolution, …)? (ii) Did you applied a de-biasing procedure to accommodate the future climate projections with the past climatic dataset (e.g. Huss & Hock, 2015)? Such a procedure is often needed to avoid sudden changes in temperature/precipitation 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…

We acknowledge that our original approach to derive future climate projections used a simplified linear approximation for the 21th century based on average CMIP5 model output. We have now recreated the future climate forcing directly from available CMIP5 models for the grid cell closest to Djankuat Glacier. In this way we encompass the variability captured by the CMIP5 models. We also applied a de-biasing procedure to match the future climate forcing with the past, both concerning the trend and the variability. The following text is now used to describe the future climate forcing and replaces lines 411-419:

"Future projections of temperature and precipitation were obtained by a multi-model approach, using output from the Coupled Model Intercomparison Project Phase 5 (CMIP5) simulations (Taylor et al., 2012) for the grid cell closest to the Djankuat Glacier. Mean temperature and total precipitation amount at monthly resolution from 21 Global Circulation Models (GCMs) for the RCP 2.6, RCP 4.5, RCP 6.0 and RCP 8.5 scenarios were used, based upon their availability (Table 2 and 3). The data were downloaded for both historical runs (from 1981 AD) and for projections (until 2100 AD). Although the choice of ensemble member can largely influence the eventual results (e.g. Huss and Hock, 2015), we solely focus on the first realization, i.e. ensemble member r1i1p1. Absolute data were at first scaled to anomalies with respect to the 1981−2010 reference values for each respective model, so that additive (temperature) and multiplicative (precipitation) biases could be removed when matching to the past forcing. For each RCP, the monthly temperature and precipitation data were then averaged over all models, resulting in a multi-model mean time series. To account for year-to-year variability, the CMIP5 data were at last rescaled with respect to the standard deviation of the overlapping period for the observed Terskol data (e.g. Huss and Hock, 2015; Zekollari et al., 2019). As with the past simulations, the observed 3-hourly Terskol data sequence was finally used to downscale the monthly data to the temporal resolution that suits the mass balance model.

All scenarios exhibit a further increase of the temperature, which is most pronounced in the summer season. Projected precipitation, on the other hand, shows slightly decreasing values at annual resolution, but shows a tendency for a drier summer half year (April to September, AMJJAS) and a wetter winter half year (October to March, ONDJFM). By 2071−2010 AD, the mean AMJJAS temperature (total ONDJFM precipitation) anomalies with respect to the 1981−2010 period are +1.4°C (+0.1 %), +2.3°C (+3.7 %), +2.7°C, (+11.2 %) and +4.5°C (+11.7 %) for the RCP 2.6, RCP 4.5, RCP 6.0 and RCP 8.5 scenarios respectively (Fig. 10a and b). Additionally, also a future projection is made under a no change scenario, in which the last observed 10-year climatic interval (2009−2018 AD) is repeated with respect to its mean *(corresponding to a AMJJAS mean temperature and a total ONDJFM precipitation amount of 9.2°C and 373.3 mm yr^{-1} w.e. respectively).”*

A figure in which these results are summarized is added as Figure 10 in the updated manuscript, and replaces Table 2 of the original manuscript:



New Figure 10 in the updated manuscript. Projected future (a) AMJJAS temperature and (b) ONDJFM precipitation changes for Terskol, as compared to the 1981−2010 reference, for different RCP scenarios until 2100 AD. Thin colored lines represent annual values, thicker lines represent 15-yr moving means. The dashed vertical line represents the present (i.e. 2017, the most recent year of glaciological observations).

A new Table 3 was added to the updated manuscript, indicating which climate models were selected to reconstruct the future forcing:

New Table 3 in the updated paper. CMIP5 climate models used to reconstruct the future forcing (2019−2100 AD).

Model	Spatial resolution	RCP 2.6	RCP 4.5	RCP 6.0	RCP 8.5
BCC-CSM1-1-M	2.81°×2.81°	X	X	X	
INMCM4	1.50°×2.00°		X		X
ACCESS1-3	1.25°×1.88°	X	X		X
CNRM-CM5	1.41°×1.41°	X	X		X
IPSL-CM5A-LR	1.90°×3.75°		X	X	X
IPSL-CM5B-LR	1.90°×3.75°	X	X		X
MPI-ESM-MR	1.88°×1.88°	X	X		X
GFDL-ESM2G	2.00°×2.00°	X	X	X	X
GISS-E2-R	2.00°×2.50°		X	X	X
HadGEM2-CC	1.25°×1.88°		X		X
ACCESS1-0	1.25°×1.88°		X		X
BCC-CSM1-1	2.81°×2.81°	X	X	X	X
BNU-ESM	2.81°×2.81°	X	X		X
IPSL-CM5A-MR	1.25°×2.50°	X	X	X	X
MPI-ESM-LR	1.88°×1.88°	X	X		X
NorESM1-M	1.88°×1.88°	X	X	X	X
CMCC-CMS	3.75°×3.75°		X		X
GFDL-CM3	2.00°×2.50°	X	X		X
GFDL-ESM2M	2.00°×2.50°	X	X	X	X
GISS-E2-R-CC	2.00°×2.50°		X		X
HadGEM2-ES	1.25°×1.88°	X	X	X	

A small section was added related to the application of the most extreme scenario (Line 449):

“The averaging of the future climatic data implies a reduction of spread. When, for example, the model was forced with the highest warming scenario of all CMIP5 models (i.e. the RCP 8.5 scenario of the GFDL-CM3 model, with mean AMJJAS temperature increase of +7.9°C by 2071−2100 AD), the glacier will cease to exist by 2086 AD.”

The resulting projections of future glacier geometry are included in the comment to “Fig. 12” below.

General comment 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.

The mass balance perturbation ΔB_a, used in the dynamic calibration procedure, was not explicitly calculated but was instead derived by a trial and error procedure. In this regard, the values for ΔB_a were iteratively adjusted to calibrate historic length variations of the glacier. These artificial mass balance perturbations were therefore superimposed on the mass balance profile that was simulated with the climatic input, until modelled and observed historic length coincided. The process is now clarified in the updated paper by explicitly stating how the procedure was applied (Lines 389-392 of the original paper):

> *"…applied by incorporating artificial mass balance perturbations (ΔB_a) into the model. This factor was not explicitly calculated but was instead derived and adjusted iteratively by a trial and error procedure. The obtained perturbations were then superimposed on the mass balance profile that was simulated with the climatic input, until the reconstructed glacier length sufficiently matched with the observed values (e.g. Oerlemans, 1997; Zekollari et al., 2014):*
>
> $$B_a = B_{a(SMB)} + \Delta B_a,$$
>
> *Here, $B_{a(SMB)}$ is the mass balance simulated with the climatic datasets and ΔB_a is the artificial mass balance perturbation that was applied in the dynamic calibration procedure."*

For more information, we refer to general comment 2 of RC 3.

General comment 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?

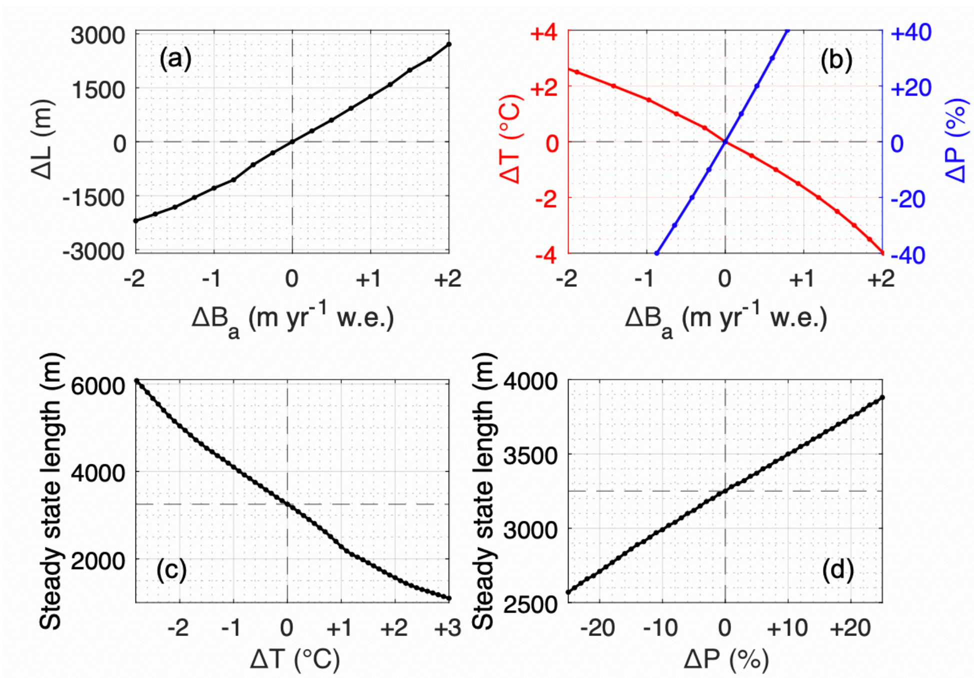
(i) All sensitivity experiments were conducted with respect to a steady state glacier with present-day length (i.e. a length of 3260 meter). We clarified this in the paper, and Lines 330-331 now read:

> *"Some basic sensitivity tests were conducted with the flow model, which all initially started from a steady state glacier with present-day geometry. Perturbed mass balance profiles (ΔB_a, in steps of 0.25 m yr^{-1} w.e.) were then used as forcing to the model, until a new steady state was reached. As such, a relationship with a slight deviation from linear was found between the steady state length and ΔB_a, exhibiting a value for $\partial L / \partial B_a$ of ca. 1100 and 1355 m (m yr^{-1} w.e.)$^{-1}$ for negative and positive perturbations respectively (Fig. 7a)."*

(ii) We acknowledge that glacier geometry plays a decisive role in determining the climate sensitivity (m/°C) of the glacier. In this regard, sensitivity to temperature changes shows a linear behavior (815 m°C^{-1}) for temperature perturbations between -1.4 and +0.7°C (with respect to the 1967/68−2006/07 reference climate). Outside this range, the climate sensitivity slightly deviates from that linear trend, see Fig. 7c below. As suggested, the bed topography is key to explain this behavior, as the glacier front is located on significantly steeper terrain for higher temperatures. Clarification has also been added to the text, as Lines 334-335 now read:

> *"To assess the climate and glacier sensitivity for equilibrium, mass balance profiles were furthermore altered by temperature and precipitation perturbations within the -3 to +3°C and -25 % to +25 % range respectively (as compared to the 1967/68−2006/07 reference values). Sensitivity of steady state length to temperature changes ($\partial L/\partial T_{air}$) shows a linear behavior (815 m°C^{-1}) for perturbations between -1.4 and +0.7°C, but is modelled to vary between 400 and 1400 m°C^{-1} when assessed over the entire range (Fig. 7c). The glacier sensitivity depends largely upon geometry and increases (decreases) for more negative (positive) mass balance perturbations, predominantly due to the flatter (steeper) terrain. The sensitivity also peaks around a temperature perturbation of +1°C, i.e. when the glacier front is positioned at the transition between the broad accumulation area and the narrower snout (ca. x = 2300 m on the flow line). Also the non-linear nature of the temperature-mass balance relationship (Fig. 7b) triggers a deviation from linear behavior. Consequently, the change in forcing needed for a retreat from 2 to 1 km is nearly twice as large as for a retreat from 4 to 3 km. For precipitation the sensitivity is more or less constant for a value of 250 m 10 %$^{-1}$ (Fig. 7d)."*

We present the new Fig. 7 as a replacement to the old Fig. 7-9 (in Sect. 4 of the original paper):



"New Figure 7 in the updated manuscript. Sensitivity of the Djankuat Glacier showing (a) sensitivity of the glacier steady state length to mass balance perturbations (ΔB_a), (b) sensitivity of the mass balance to temperature (ΔT) and precipitation (ΔP) changes for a fixed present-day glacier geometry, (c) sensitivity of the steady state glacier length to temperature changes, and (d) the same for precipitation changes. All perturbations are with respect to the 1967/68−2006/07 AD reference climate (2.5°C and 980.7 mm yr^{-1} w.e.), and with respect to a steady state glacier with present-day length (3260 meter)."

Line-by-line comments

>> Line 14: Better to say already in the abstract which future climate data you used.

Agreed. This was added:

> *"Future projections using CMIP5 temperature and precipitation data exhibit…"*

>> Line 24-25: This sentence needs some references.

We have included some references to these sentences:

"… changing climate (e.g. Shannon et al., 2019; Zekollari et al., 2019; Hock et al., 2019)."

>> Line 40: Change '.,' to ','.

Done.

>> Line 44-45: Are you referring to the whole Caucasian region?

Yes, the reference is updated, and it is stated explicitly that this encompasses the whole region:

"…debris coverage has expanded at a rate of ca. +0.22 % yr^{-1} between 1986 and 2014 when the entire Caucasus region is considered (Tielidze et al. 2020)."

>> Line 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.

To avoid confusion, it is clarified in the updated manuscript:

"… the behavior of the Djankuat Glacier as a WGMS reference glacier for the Caucasus …"

>> Line 89: Give a number for 'higher elevations'

It was added to the updated text:

"… higher elevations (> 3600 meter) and the…"

>> Line 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.

(i) We refer to average annual temperatures. (ii) The word 'here' refers to both the Terskol and Mestia meteo stations. This is now clarified in the updated manuscript:

"The average annual mean temperatures in Terskol and Mestia are 2.8°C and 6.0°C respectively during the 1981−2010 reference period. For the summer half-year from April to September (AMJJAS), the corresponding mean temperatures are 8.7°C and 12.0°C."

Likewise, for precipitation:

"At Terskol and Mestia, the average total precipitation amounts equal 1001.1 and 1035.1 mm yr^{-1} w.e. respectively for the 1981−2010 climate. During the accumulation season (October to March, ONDJFM), the corresponding precipitation values are 418.4 and 490.0 mm yr^{-1} w.e. respectively."

>> Line 106: (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.

(i) We used data from 2 AWSs (one in the Adylsu Valley near the LIA extent of the glacier, AWS 1, and one in the glacier ablation zone, AWS 2). We used data from AWS 1 for precipitation comparisons between Terskol and the Adylsu Valley, and data from AWS 2 to derive transmissivity, temperature lapse rates, albedo, and shortwave, longwave and turbulent fluxes. We now specifically refer to each AWS when data are discussed in the text. For Line 147:

"Hence, a direct comparison of measured air temperatures between AWS 2 on Djankuat and the Terskol weather station was found…"

For Line 150:

"In this study, a value for f_e of 1.5 between Terskol and the Adylsu Valley was found after a comparison of precipitation amounts from AWS 1 in the glacier valley."

For Line 179:

"Measurements of the incoming solar radiation from the AWS 2 were used to derive atmospheric transmissivity…"

For Line 185:

"The ice albedo α_{ice} can, according to raw data from the AWS 2, vary between 0.15 and 0.40 depending…"

And Line 191:

"Here, these fluxes, as derived from AWS 2, are added up and plotted analyzed against air temperature following the method…"

The location of AWS 1 and 2 were added to Figure 1 of the original manuscript. (ii) These AWSs were only operational during the summer months (June to September) between 2007 and 2017. This was clarified manuscript as follows:

"In 2007, two automatic weather stations (AWS) were additionally installed, one in the Adylsu Valley at ca. 2640 m elevation (AWS 1 in Fig. 1) and one in the ablation zone of the glacier at ca. 2960 m on a sparsely debris-covered ice surface (AWS 2 in Fig. 1). During the summer seasons (June to September) of 2007−2017, a wide range of additional meteorological variables have therefore been acquired by AWS 1 and 2 (air temperature, dew point temperature, incoming and outgoing shortwave/longwave radiation, relative humidity, wind speed and direction, air pressure and for AWS 1 also precipitation amounts) (Rets et al., 2019). The AWSs did not operate outside the JJAS period."

>> Line 114: Maybe add 'glacier' before 'top', so that it becomes 100% clear.

Done.

>> Line 117-119: Sorry, I cannot follow this sentence. Can you maybe reformulate it?

The main point here is that we want to make our 1D flow line representative for the 3D glacier to not misestimate the rate of glacier shrinkage. To make this clearer, it was reformulated as:

"To avoid creating a bias in the rate of glacier evolution, the representativeness of the glacier cross-section along the flow line was further determined..."

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

The continuity equation in this form was discussed and derived by Oerlemans (2001).

>> Line 134: Spell out 'FTCS'.

Done and added to the text:

"… FTCS (forward in time, centered in space) numerical scheme…".

>> Line 141: Remove 'specific', since it is the glacier wide balance here.

The terminology in the literature is not consistent in this aspect. We choose to leave it like this.

>> Line 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?

It was derived for every point along the flow line. This was clarified in the text:

"Accumulation for each point along the flow line is only dependent…"

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

Done. The text was updated to:

"Due to lack of AWS data outside of the JJAS period, a temperature lapse rate of -0.0049°C m^{-1} was used for the winter half-year (1 Oct – 31 Mar), in accordance..."

>> Line 154: Add link to table 1 already after 'gamma_p'

Done.

>> Line 144-159: Not super clear to me, especially how exactly all these factors are derived.

Precipitation between the Adylsu Valley and Terskol was scaled using a factor f_e. For the precipitation gradient, we did not have reliable data to extrapolate the precipitation from the Adylsu Valley over the entire glacier. We therefore used the accumulation profile to tune the precipitation gradient. The derivation of the parameters has now been described more extensively in the revised manuscript. Firstly, it is clarified where the factor f_e comes from (See also comment Line 106):

"In this study, a value for f_e of 1.5 between Terskol and the Adylsu Valley was found after a comparison of precipitation amounts with AWS 1 in the glacier valley."

Secondly, it was explicitly stated that the precipitation gradient γ_P is used as a tuning parameter:

"… by making use of a vertical precipitation gradient γ_P, of which the latter is used as a tuning parameter due to a lack of data (see Sect. 3.1)."

Thirdly, with respect to f_{red}, for which a description was already pesent in the text, some additional info was included into the revised manuscript as follows:

"Here, a topographic characteristic is used to parameterize snow addition or removal from the glacier surface. It was quantified by dividing the linear accumulation profile (without the redistribution factor) with the observed profile and correlating these anomalies to the laterally averaged surface slope s along the flow line (e.g. Huss et al., 2009). As such, a polynomial fit was found. For slopes steeper than the threshold, removal of snow can hence occur, and is assumed to be proportional to the surface slope itself."

>> Line 167: And alpha? Add that alpha is the albedo.

Done.

>> Line 180: About which 'tilt' are you speaking? Is the AWS station tilted?

The tilt of surface slope is not relevant to measure incoming solar radiation. This was adjusted:

"To derive atmospheric transmissivity, measurements of the incoming solar radiation from AWS 2 were used."

>> Line 189: 'more or less' - please use a synonym.

This is changed to:

"… are approximately equally important…"

>> Line 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?

We opted to put less values in the text to not oversaturate the text with numbers. Therefore, we synthesized most values in one single table.

>> Line 192: 'plotted' – Is this the correct word? With 'plotted' I expect a Figure…

To avoid confusion, the choice of words was adjusted. In the text, this was modified as follows:

"… fluxes, as derived from AWS 2, are added up and analyzed against air temperature…"

>> Line 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.

This assumption had to be made due to lack of abundant information for this parameter. A short section is added to the revised manuscript to discuss the assumption:

"Here, a constant value for C_{debris} in space and time is assumed. The emphasis of this work is to investigate the effect of supraglacial debris on melt patterns and glacier geometry. Encompassing englacial debris pathways or the spatial distribution of englacial debris concentration would add more detail than warranted by the lack of reliable data."

In this regard, another change was made in Sect. 7 of the original manuscript. Here, we constrained the up-glacier position of the debris input locations x_{debris} to a maximum position of x_{debris} = x_{ELA}, where ELA is the equilibrium line altitude. This was addressed as (Line 454):

"… is initiated from $x_{debris} = x_{ELA}$, at $t_{debris} = 2035$ with a magnitude of $F^{input}_{debris} = 1.5$ m yr⁻¹. For x_{ELA}, we calculated the average position of the ELA during a window of ±15 years surrounding t_{debris} in the 'no additional debris scenario' (Sect. 6.1), which hence varies for each climatic scenario. We therefore choose to not initiate debris fluxes from positions above the ELA, due to the neglect of englacial pathways in our debris model (see Sect. 2.5)."

"… the debris input location x_{debris} was changed to 80%, 60% and 40% of the distance between x_{ELA} and x_L (further downstream), …"

>> Line 208: 'at 1680 m from the highest point' where is this point? Maybe show in Fig.1.

The reader can locate this point on the map by identifying the margin of the up-glacier debris extent in Figure 1. The following text was added to the manuscript:

"… 1680 m from the highest point (just below the ELA, at 88% of the distance between the terminus x_L and the ELA x_{ELA}), since it is…"

>> Line 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.

We link connectivity issues between the topographic debris source and the main glacier body to this assumption. Hence, by that time, the glacier has shrunk too much to ensure that debris fluxes reach the glacier surface. This was added accordingly to the text (Line 212):

"Connectivity issues between the topographic source and the main glacier are forwarded as the main reason to justify this modification of the Anderson and Anderson (2016) model. Hence,

by that time, the glacier shrunk too much to ensure that debris fluxes could still reach its surface."

With regards to the debris input location, we attribute a lack of direct observations regarding past or future (static or moving) topographic debris sources to this assumption. However, an archived (rather unclear) satellite image of the Djankuat glacier in Pasthukov (2011) seems to point out that there has been only minor up-glacier migration of debris on the main glacier body since the 1970s. This led us to believe that our assumption of a static debris source could indirectly be justified. It was added the following discussion (Line 209):

"It was chosen to keep the debris input location at a fixed position due to a lack of direct observations regarding past or future (static or moving) topographic debris sources. However, a comparison of present-day satellite imagery with those from the 1970s (Pasthukov, 2011) seems to point out that the debris patches exhibit only minor up-glacier migration of debris on the main glacier tributary and the debris-covered orographically left part of the snout (when seen from the downstream direction), hence indirectly justifying the assumption."

>> Line 215 (eq 13): The variable 't_debris' is not introduced.

It is now indicated explicitly what the term means (Line 208 in the original manuscript):

"Hence, t_{debris} is the time at which the topographic debris source firstly starts to release its mass flux towards the glacier surface."

>> Line 225: Can you give some more details about the relationship which was found?

This relationship can be seen in Eq. 15 and Fig. 5d of the paper. It incorporates an exponential decay of the fractional area along the flow line. We added this to the text:

"…parameterized based upon the distance from the terminus D_T, for which an exponential relationship was found from observations…"

>> Line 228: How is the debris-area growth factor G_A 'updated yearly'? One should be pointed at eq. 17 at this stage.

Done. We added a reference to eq. 17: *"(see Eq. 17 in Sect. 3.2)."*

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

With respect to the inclusion of the melt-enhancing effect for thin debris, studies performed on Djankuat Glacier point to a low value of the critical thickness (0.03 m by Lambrecht et al., 2011 and 0.07 m by Bozhinskiy et al., 1986). The areal fraction of debris cover on the Djankuat Glacier that holds such thin thickness values is very small, so we believe that the ablation enhancement effect of debris plays a very minor role on Djankuat Glacier. Therefore, the inclusion of this factor was not included in the parameterization. The following section was added to the updated manuscript for justification (Line 224):

"The melt enhancement that may occur for a very thin debris cover was not implemented. Values in the literature of the critical debris thickness for the Djankuat Glacier vary from 0.03 m (Lambrecht et al., 2011) to 0.07 m (Bozhinskiy et al., 1986). The areal fraction of Djankuat Glacier that holds these thin thickness values is very small (Popovnin et al., 2015) and are therefore not believed to have a significant influence on the ablation of Djankuat Glacier."

>> Line 247, 251, 254: 'this time period' – maybe re-state the time period. Use same unit.

We changed *"this time period"* to *"the 1967/68−2006/07 period"*. Consistency in the units was achieved by changing them to *"m yr^{-1} w.e. m^{-1}"*.

RC 1 – Loris Compagno (rebuttal by Verhaegen et al. – tc-2019-312)

>> Line 258: What's the meaning of 'between 0.18 and +/- 0.6 m'.

The ± means *"approximately"*, and the text was adjusted accordingly'.

>> Line 261: 'second a' to 'a second'

Done.

>> Line 267: Can you give numbers about the 'snow redistribution by wind/avalanche'?

In the upper part (> 3600 meter), the local mass balance of the glacier is reduced by ca. 76%. The following was added to the text (Line 94):

> *"Moreover, the mass balance profile in these upper areas is significantly distorted (by ca. -76%) by snow redistribution processes (Pastukhov, 2011)."*

>> Line 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?

There are very few or no independent data to validate the model results. In the revised manuscript this was acknowledged by reformulating the text in several places, e.g. Line 308 (Sect. 3.3):

> *"However, as with the mass balance and debris cover model, there are no, or only few, independent data to validate our model results with a sufficient degree of certainty."*

For Line 394-395, Sect. 5.2, the word 'validation' was removed:

> *"It can thus be stated that the calibrated mass balance model performs well when forced with the observed Terskol climatic data, and that credibility can be assigned to the dynamic calibration procedure."*

The same was done for the statement in the conclusion (Line 495, Sect. 8):

> *"… no artificial mass balance perturbations were needed, ensuring proper model calibration and credibility."*

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

See comment Line 215 above.

>> Line 297: 'the bed was slightly adjusted' – how? Can you give some more details?

This was clarified in the text by adding the following:

> *"Additionally, the bed width for the assumed trapezoidal-shaped cross section was slightly adjusted to ensure that the parameterization fits the observed area-elevation distribution for a total surface area of 2.688 km²."*

>> Line 326: Is the volume change a yearly volume change? If yes correct the unit.

Yes, *"annual"* was added.

>> Line 331: Please correct the unit/make it consistent with the rest of the manuscript.

Not sure what is unclear here.

>> Line 332: Can you add a reference or details about the 'e-folding length response time'?

The following was added for clarification:

> *"The e-folding length response time (i.e. the time needed to achieve (1 - e^{-1}) or ~63% of the total length change) of Djankuat is in the order of …"*

>> Line 334-335: Well, I imagine that these numbers depend a lot on the topography (see general comments)?

See general comment 3.

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

See general comment 3.

>> Line 356-357: 'an acceptable accuracy' – please give a number.

The integrated mass balance of the glacier in steady state exhibits a value of 0 $\pm$ 0.006 m yr^{-1} w.e., which was added to the text in the following way:

> *"…integrated surface mass balance over the entire glacier approaches zero to within an acceptable accuracy of 0.006 m yr^{-1} w.e. and by…"*

>> Line 381-387: In my opinion, all these sentences can be reduced into one or two.

The subsection was shortened to:

> *"Especially during the last few decades, an accelerated warming trend has occurred, as the latest 10-year climatic interval exhibits a mean annual temperature anomaly of +0.5°C compared to the 1981−2010 mean. This makes it the warmest period in the reconstructed time series. For temperature, a clear sequence of colder and warmer intervals can be seen. Changes in precipitation show a sequence of drier and wetter periods (Fig. 8)."*

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

See general comment 2.

>> Line 411-413, 413-415, 417: 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…). 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 dataset and the future climate projections? (see main comments). '+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.

See general comment 1.

>> Line 445-456: Are these values arbitrary? That seems fine but if they are, better add a sentence explaining why these values are taken and from where.

These values are indeed arbitrary. It was added after Line 459 of the original manuscript:

> *"It must be noted that the values of these parameters are arbitrary, as the exact location, time and magnitude of future debris sources cannot be predicted. By assessing multiple possible values for each of these parameters, we encompass various potential future scenarios in order to account for the high uncertainty regarding these parameters."*

>> Line 503: '-80%' – of area? Of volume? Or of length?

The following was changed (with a slight deviation due to the new future climatic datasets):

> *"… most drastically (ca. -93 % of its current surface area) under the RCP 8.5 scenario…"*

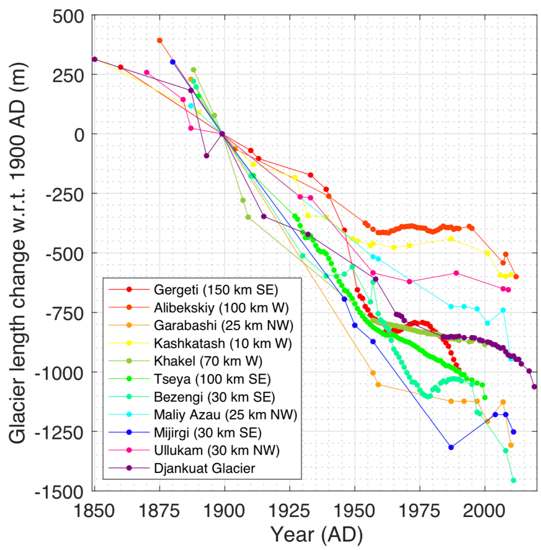
Comments to figures and tables

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

We don't think the scale bar in this form is confusing.

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

The distances and direction to Djankuat Glacier are added to the updated Figure 2. Balance years are changed to calendar years and all length changes are now relative to 1900 AD:



"New Figure 2 in the updated manuscript. Historic length variations of the Djankuat Glacier compared to other glaciers in the Caucasus (Solomina et al., 2016; WGMS, 2018). Approximate distances and direction to the Djankuat Glacier are indicated."

>> 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 the units are different than in main text.

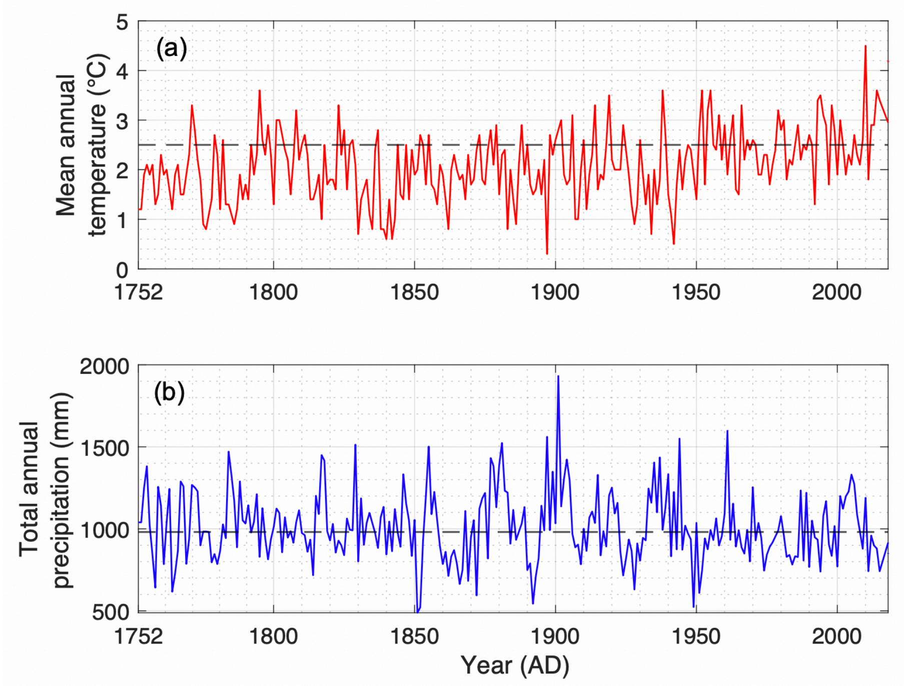
(i) This is due to snow redistribution due to avalanches/wind redistribution in the steep upper part of the glacier (Lines 154-159 in the original manuscript). See comment to Line 267 above. (ii) All mass balance terms are expressed in m w.e. yr^{-1}.

>> Fig. 5: (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

(i) An additional figure with the further evolution of the debris layer was not added to the manuscript in order to not overload the paper. The effect of additional debris sources can however be inferred from Fig. 14 in the original paper. (ii) The bend around the 1980s is when the debris that had been deposited at x_{debris} = 1680 meter since t_{debris}= 1958, has reached the glacier terminus due to advection.

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

Labels were added, "w.r.t" has been deleted and the data have been converted from balance years to calendar years:



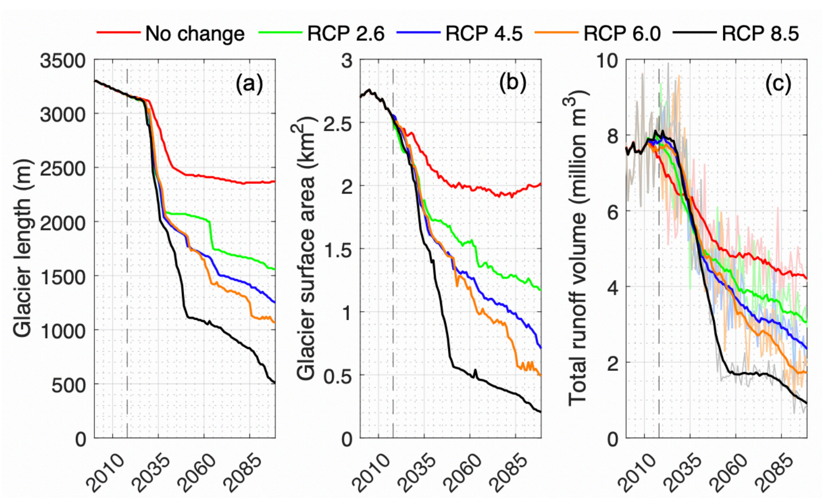
"New Figure 8 in the updated manuscript. Reconstructed and observed evolution of (a) mean annual temperature and (b) total precipitation for Terskol weather station, based upon proxy data (tree ring reconstructions) and measurements from nearby weather stations (Mestia, Pyatigorsk and Mineralnye Vody). The dashed horizontal line represents the 1981−2010 annual reference values (2.6 °C and 1001.1 mm w.e. yr⁻¹). We refer to the text and Table 2 for more details."

>> Fig. 11: What is the black line?

This is the 15-yr moving average. This is now clarified in the figure caption.

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

We have opted to not overload the picture with an additional volume projection. Rather we chose to merge total annual runoff volumes (old Fig. 13) into the figure of the future projections, in the light of future water resource management. The results of the new future projections are represented in the following updated Figure 11:



"New Figure 11 in the updated paper. Modelled (a) glacier length, (b) glacier surface area, and (c) total annual runoff volume of the Djankuat Glacier for different RCP scenarios until 2100 AD. In (c), the thin lines represent annual values, while the thicker lines represent 15-yr moving average. The dashed vertical line denotes the present (i.e. 2017, the most recent year of glaciological observations)."

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

This figure has been deleted and incorporated in the updated Figure 11 (see comment above).

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

The following statement is added to the manuscript:

"It is worth mentioning that the effects on glacier length are not immediate, as it takes some time for the debris to be advected to the terminus."

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

Done for all figures that require annual labels on the x-axis.

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

The – means that there is no constant value for this parameter. We have added this as:

"Table 1. Variables, constants and their units. The – denotes a variable or a dimensionless quantity."

New references added:

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

Hock, R., Rasul, G., Adler, C., Cáceres, B., Gruber, S., Hirabayashi, Y., Jackson, M., Kääb, A., Kang, S., Kutuzov, S., Milner, Al., Molau, U., Morin, S., Orlove, B., and Steltzer,H.: High Mountain Areas. In: IPCC Special Report on the Ocean and Cryosphere in a Changing Climate [Pörtner, H.-O., Roberts, DC., Masson-Delmotte, V., Zhai, P., Tignor, M., Poloczanska, E., Mintenbeck, K., Alegría, A., Nicolai, M., Okem, A., Petzold, J., Rama, B., Weyer, N. M. (eds.)]. In press, 2019.

Shannon, S., Smith, R., Wiltshire, A., Payne, T., Huss, M., Betts, R., Caesar, J., Koutroulis, A., Jones, D., and Harrison, S.: Global glacier volume projections under high-end climate change scenarios, The Cryosphere, 13, 325–350, doi: https://doi.org/10.5194/tc-13-325-2019, 2019.

Taylor, K. E., Stouffer, R. J., and Meehl, G. A.: An overview of CMIP5 and the experiment design, Bull. Am. Meteorol. Soc., 93, 485–498, doi: 10.1175/BAMS-D-11-00094.1, 2012.

Zekollari, H., Huss, M., and Farinotti, D.: Modelling the future evolution of glaciers in the European Alps under the EURO-CORDEX RCM ensemble, The Cryosphere, 13, 1125–1146, doi: https://doi.org/10.5194/tc-13-1125-2019, 2019.