Final author comment

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We thank the reviewers for their comments and suggestions. We have prepared a revised and extended version of the paper which adresses their concerns, including new simulations as suggested. In particular we expanded our modeling approach including also the case where the glacier width varies along the flowline and briefly discussing a simple model in which the glacier width is proportional to its length. In addition to the simple empirical model used, we added a Positive Degree Days method to estimate the relationship between the mass balance and climate variable. We explain in detail these changes and we respond point-by-point to the reviewer comments in the following.

In our work we want to obtain a first estimate for the present day and near future evolution of the large amount of small glaciers in the Western Italian Alps by means of a simple model. We chose a simple approach also because more complex models can be of difficult use for a large number of glaciers, and in fact have been rarely used in literature, due to the "under sampling problem" that imposes strong limitations on the number of model parameters and on their reliability [Marzeion et al., 2012]. As a consequence direct modeling is often avoided and simple models or extrapolations are used, i.e. [Meier et al., 2007], [Raper and Braithwaite, 2006]. In our reply and in our modified paper we have decided to remain close to this approach and we have avoided the use of much more complex models (suggested by some reviewer comments), which in our opinion are beyond the scope of this work.

We answer first general comments given by the referees (enumerated list) in the following and then we answer specific comments.

Referee 1: tcd-8-C456-2014

1. *First, the method used to simulate the mass balance is very simplified. The authors used seasonal (June-September) temperature and precipitation (October-May) data to calculate the wide glacier mass balance. It is clearly an oversimplification for the following reasons. The authors adjust three parameters a, b and c to fit reconstructed snout changes*

on observations. From Table 3, "b" can have positive or negative values. For negative values of "b", it means that a precipitation increase leads to a decrease of mass balance. Similarly, Table 2 shows a positive value for "a" (Grand Etrèt) which means that an increase of temperature would lead to an increase of mass balance. I do not believe that the observations can support these results. Consequently, I do not believe this approach can be used for projections.

While this point is also highlighted in the paper, we try to expand it for greater clarity.

The negative values of "b" in Table 3 were obtained for the glaciers Moncorvè, Mulinet Nord and Mulinet Sud which are mainly dominated by the third term, which represents the influence of external forcing different from October-May precipitation and June-September temperature changes, such as glacier shape, topography or direct radiation, as highlighted in the paper.

The case reported in Table 2, instead, was influenced by the uncertainties in the parameter values obtained with the bilinear regression, in fact negative values, as expected, are in the the uncertainty range. Moreover, in the paper we already set the "a" values equal to zero and the values obtained for the other two parameters ("b" and "c") were close to the values obtained in the initial case (see chapter 4.1). Table 2 reports also the uncertainity ranges for these parameters in order to better highlight this point.

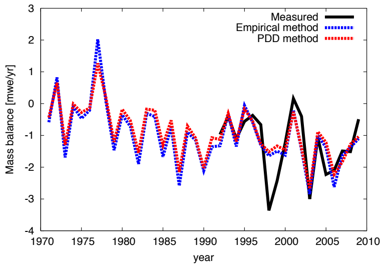
In conclusion, in our opinion, the signs of the coefficients "a" and "b" for the above mentioned cases do not disqualify the validity of the method, even if its uncertainities have to be taken into account, as we discuss in the paper.

2. *Moreover, from this paper, it is difficult to evaluate the relationships given that the authors do not provide the performance of the correlations between observed and reconstructed mass balance (for Ciardonney and Grand Etrèt glaciers).*

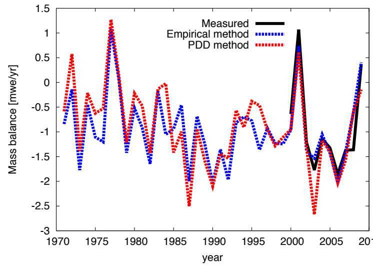
   We thank the reviewer for the suggestion. In the revised manuscript, we added a figure showing the correlations between observed and reconstructed mass balance. This new figure (see Fig 1 in this document) will be included in the paper as Fig. 2:

   The figure also reports results based on the Positive Degree Day (PDD) method, which we introduced in reply to a specific comment by Reviewer 2.

3. *More important, the parameters a, b and c have been calculated using the relationships between wide glacier mass balance and temperature and precipitation, calibrated over the last decade. Equation 5 means*



a)



b)

Figure 1: (a) Measured mass balance in the period 1992-2009, data from SMI, and the reconstructed values obtained using the empirical method and the PDD method in the period 1971-2009 for the Ciardoney Glacier. (b) Measured mass balance in the period 2000-2009, data from GPNP, and the reconstructed values obtained using the empirical method and the PDD method in the period 1971-2009 for the Grand Etrèt Glacier.

that wide glacier mass balance does not depend on the geometry of the glacier. From numerous previous studies (Elsberg et al., 2001; Harrison et al., 2005; Huss et al., 2012), it is obvious that these relationships changed with time due to the geometry changes of glaciers.

Following this comment and also a suggestions by reviewer 2, we decided to include two new minimal models in the revised paper:

(a) we discuss the case of a simple relationship between glacier width and glacier glacier length: $W = w_a L$. In this case the final equation in this case differs from the previous one by a constant multiplicative factor;

(b) we use also a width which is changing along the flowline with an equation like: $W = L/L_0(w_0 + w_1 x e^{-w_2 x})$, where the parameters w_0, w_1, and w_2 are related to the position of the maximum width along the flowline and the width at the snout of the glacier. This case give a more complex relation, even if the final solution do not change too much respect to the previous one.

The second method is presented in more detail in our answer to the first comment of the second referee, and Fig. 2 shows the results that we obtain using this more complex approach.

4. *In Conclusion, the authors recognize that "our approach is sensitive on changes in the a, b, c parameters values" but I believe that it is not sufficient. The change in the surface areas cannot be neglected whatever the approach. Consequently, these relationships obtained from observations of the last decades cannot be used for the next hundred*

years. The authors should take into account the decrease of the surface areas and thickness changes.

Secondly, in order to reconstruct the dynamic behavior of the glaciers, the authors used the very simplified approach of Oerlemans (2011) with idealized glaciers geometries. According to this approach, many large assumptions have been made. The width of each glacier is fixed and uniform over the entire surface area of the glacier. The thickness is uniform too. The width does not change with time. The slope is uniform over the entire surface area. This is obviously a crude approach.

We agree with the limitations of our approach and we discuss them in the paper. In order to overcome such limitations we would need data on surface and thickness changes of the studied glaciers, but this information is unknown for all the glaciers of the study area (except a punctual datum for Grand Etrèt). Also, as already discussed, in this paper we wish to explore a simple modeling approach which can be applied to a great number of glaciers for which only limited measurements and information are available. As discussed in the previous answer, we expanded our analysis discussing also the case of minimal models in which the width is a simple function of length or varies along the flowline.

5. *Following this oversimplified approach, the response of the glacier is related directly to mass balance. The authors recognize that "The approximation assume an ly response time to climate forcing". According to this direct relationship, the reconstructed length changes should be similar to the calculated cumulative mass balance changes. Consequently, from Figure 6, we should conclude that the mass balance changes are very different from a glacier to another glacier. This conclusion, resulting from the reconstruction of this model, is not supported by observations. Indeed, several studies based on observations show a very similar pattern of cumulative mass balance over the last century (Vincent, 2002; Huss et al., 2008).*

   Indeed the two measured glaciers (Ciardoney and Grand Etrèt) show a similar cumulative mass balance, in fact they were also selected for this reason. Anyhow, the relation obtained between climate variables and mass balance was quite different between these two glaciers. We agree with the referee on the point that each glacier in our studies, which shows a different behavior in Fig. 6, is related directly to a different cumulative mass balance reconstruction, but, as described in the paper by [Huss et al., 2008]: "the general trend (of mass balance) since 1865 is strongly negative, however, displaying large differences between neighboring glaciers". This is similar to our results, where we find a general negative trend but with large differences between neighboring glaciers.

The literature cited by the referee supports the point that the trend of the Alpine glacier is similar, but with differences between each glacier, as also found in our results. Furthermore, the paper by [Vincent, 2002] displays that the main climate variables influencing the mass balance are winter precipitation and summer temperature, the same used in our work, even if the method used to relate these variables to mass balance values which we use is simpler compared to the method presented in [Vincent, 2002].

To summarize, as already stated, in this work we use on purpose a simple relation and we test its reliability. We find that even a possibly oversimplified relation can provide a good and fast estimate of glacier length evolution.

Referee 2: tcd-8-C462-2014

1. *The use of a minimal glacier model in which (for some of the glaciers) the width and/or slope is allowed to vary along the flowline, and (for all glaciers) the width is scaled with the glacier length (Oerlemans, 2011; chapter 8).*

   We thank the referee for this suggestion. As a consequence in the revised manuscript we test also a minimal model in which the width is changing along the flowline as described in [Oerlemans, 2011] (chapter 8). The difference respect to the case reported in literature is the absence of a changing bedrock, since no information on the bedrocks of the studied glaciers is available.

   We consider the glacier width changing along the flowline by means of this relation:

$$W(x) = \frac{L}{L_0}\left(w_0 + w_1 x e^{-w_2 x}\right) \tag{1}$$

   where the maximum width of the glacier along the flow line is placed at $x = w_2^{-1}$ and w_0 and w_1 are related to the glacier width at the snout of the glacier as given in [Oerlemans, 2011]. After some calculations in which an average width given by $W_m = \frac{1}{L}\int_0^L W(x)dx$ is used, we obtain an equation for the glacier length evolution:

$$\frac{dL}{dt} = \frac{\dot{b}(w_0 L + w_1 \Lambda(L))}{\frac{\alpha_m}{1+\nu s} L^{\frac{1}{2}} \left(\frac{5}{2} w_0 + \frac{3}{2}\frac{w_1}{L}\Lambda(L) + w_1 L e^{-w_2 L}\right)} \tag{2}$$

   where $\Lambda(L) = w_2^{-2}\left(1 - w_2 L e^{-w_2 L} - e^{-w_2 L}\right)$ is used to obtain an easier-to-read final equation. This formulation requires more information which is not always available, and it adds more free parameters to our simple model.

Table 1: Best values for the parameters used for Ciardoney glacier and Grand Etrèt glacier for the basic case (method presented in the paper), and the best values for the W(x) case, presented here.

Glacier	Basic case			W(x) case					
	ν	α_m	RMS [m]	ν	α_m	w_0 [m]	w_1 []	w_2 [m^{-1}]	RMS [m]
Ciardoney	10	7.6	10.0	10	3.9	70	3	0.002	11.1
Grand Etrèt	10	11.2	4.7	10	8.5	53.5	3	0.003	4.6

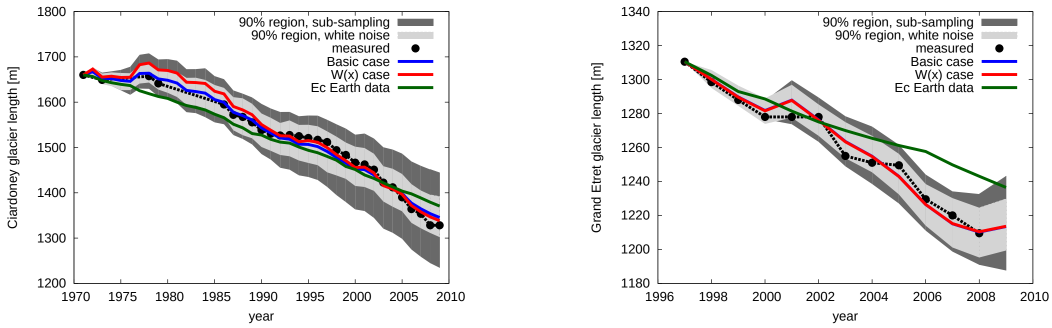
We find the best values for the application of this model for the Ciardoney Glacier and Grand Etrèt Glacier, where the value of ν, one of the two parameters used to relate climate data and mass balance (Eq.(1) in the paper), and the value of w_1 are taken from literature [Oerlemans, 2011], while w_0 and w_2 are taken from geometrical information. The values of α_m are the best values obtained after a minimization of the root mean square (RMS) difference between the measured glacier length variations and the modeled ones. The results obtained with this method are reported in Fig. 2.

Figure 2 presents the application of the model to the Ciardoney Glacier (Fig. 2a) and to the Grand Etrèt Glacier (Fig. 2b). Geometrical model parameters are found in Table 1 in the revised paper and in Table 1 here. Equation (5) in the revised paper provides the relation between climate variations and surface mass balance values, while Eq. (4) in the paper and Eq.(2) here provide the glacier dynamics. Circles indicate years with measured length variations while the straight blue line represents the model result using the Basic case (the first method presented in the paper), while the straight red line represents the model result using the W(x) case (Eq.(2) here). Finally the green line represents the results of the basic case forced with the ensemble mean of the Ec-Earth models. The dark gray area is the 90% confidence region obtained with the "sub-sampling" method, while the light gray area is obtained with the "white noise" method, both of them applied to the basic case.

Fig. 2 demonstrates that both method give a similar results in the two test cases. For this reason, in the rest of the paper we use the simpler model for all other glaciers, also in order to avoid having to set too many unknown parameters.

2. *The use of an energy balance model to relate changes in ELA to monthly precipitation and temperature anomalies.*

   Some missing data limit the complexity of the energy balance model that we can use in our approach. The ARPA dataset that we use for



a) b)

Figure 2: Application of the model presented in the original paper in Sect. 2 and the new method (with glacier width changing along the flowline) to the Ciardoney Glacier (a) and to the Grand Etrèt Glacier (b).

the present day simulation provides only temperature and precipitation fields, while an energy balance model requires more fields, such as incoming solar radiation, outcoming shortwave and longwave radiations, winds, etc., which are not available to us. In order to reply in part to the concerns of the reviewer, in the revised manuscript, we introduce also the use of a Positive Degree Day (PDD) method. The PDD method is used to estimate the ablation part of the mass balance while the accumulation part is given by the winter precipitation. It uses the average annual and summer temperature to reconstruct a sinusoidal annual temperature cycle over which a daily cycle is added by means of a probability distribution. Then, the number of days with temperature above the melting temperature are accounted and translated into effective melting through two melting factor: β_{snow} for the melting of the snow layer and β_{ice} for the melting of the ice part.

The temperatures used to reconstruct the annual cycle are first corrected for the difference in elevation between the glacier position and the orography of the optimal interpolation (OI) grid point by means of a temperature lapse rate, which is set equal to: $-6.309\ 10^{-3}\frac{K}{m}$ as used in [Fausto et al., 2009].

The comparison between what we obtained with this two methods and the observations for both Ciardoney Glacier and Grand Etrèt Glacier are reported in Fig.1. Figure 1 shows that these two simple methods reproduce quite well the observed mass balance series, and the results obtained with these two methods are comparable.

Specific comments

- *Reviewer 1: p. 1480, l. 11-12: : "High mountain regions present an heterogeneous landscape,which includes glaciers, rocks, debris, streams and lakes, and rich ecosystems": I believe this sentence is unuseful. The authors should remove it.*

  We removed this sentence as requested.

- *Reviewer 2: p. 1480, line 21: Indicating the "health" of a mountain environment by the state of glaciers is a awkward statement. Is a mountain environment healthy when the glaciers are in steady state, unhealthy when the glaciers grow ? Please remove this formulation.*

  We removed this sentence as requested.

- *Reviewer 2: p. 1480, line 26: "among the most important ones". Why not simply state that "The response of glaciers to climate forcing is determined by a glacier's geometry and the climatic setting." Then you have it all.*

  We changed the sentence as suggested.

- *Reviewer 1: p.1481, l.1-3: : "According to the combination of these and other factors, some glaciers are more sensitive to variations of winter precipitation, while others are more sensitive to summer temperatures." The authors should add a reference*

  We changed the sentence as follows:

  "According to the combination of these and other factors, some glaciers are more sensitive to variations of winter precipitation, while others are more sensitive to summer temperatures, as shown in other regions, i.e. [Letréguilly, 1988] and [Vincent et al., 2005]."

- *Reviewer 1: p. 1481, l.4-5 : "The time and mode of response to climatic oscillations vary from one glacier to another, and even between different parts of the same glacier (Calmanti 5 et al., 2007).": not clear : what are varying ? thicknesses ? ice floxw velocities ? This sentence should be removed.*

  We removed the sentence as requested.

- *Reviewer 2: p. 1481, line 14-15: replace "an order of magnitude for the glaciers expiration date" by something like 'a first picture of the future evolution for the glaciers".*

  We changed the sentence as suggested.

- *Reviewer 1: p. 1482, l. 1-5: "Most of them have been classified as small or very small: 101 (13 %) have a surface smaller than 0.05 km2, and*

591 of them (73 %) have a surface ranging between 0.05 to 1km2. The inventory identified 308 glaciers in the Western Italian Alps (38% 5 of the total), accounting for 42% of the total glacierized area in the Italian Alps.": I do not think these information are needed in this paper. The authors should remove these sentences

Reviewer 2: p. 1481, line 26: "best preserved". What do you mean by that ? Have glaciers in the Wester Alps shrinked less than in the Eastern Alps ?

We used "best preserved" in order to emphasize the importance of the Western Italian Alps, which, alone, account for 42 % of the total glacierized area in the whole Italian Alps. We changed this sentence as follows, instead of removing it as suggested by the first referee:

"We focus on the Western Italian Alps, which host some of the most important and best preserved glacierized areas of Italy, in fact this region accounts for 42% of the total glacierized area in the Italian Alps, as described in the most recent statistics on Italian glaciers [Ajassa et al., 1997], and presents some of the major Italian glaciers."

- *Reviewer 2: p. 1482, line 8-9: size and shape are physical properties!*

  Thank you for highlighting this error, we changed the sentence as follows:

  " [...] in terms of size, shape and *other* physical properties."

- *Reviewer 1: p. 1483, l. 1-3: "Series of measured length variations, ELA position and mass balance data are available from 1971 to 2009 for the Ciardoney glacier and from 1997 to 2009 for the Grand Etrét glacier, as shown in Fig. 2.": confusing: the mass balance data are available since 1992 and 2000 for Ciardonney and Grand Etrèt respectively, not since 1971 and 1997. Rephrase it.*

  We rephrased this sentence:

  "Series of measured length variations, ELA position and mass balance are available for Ciardoney glacier and Grand Etrèt glacier. The Ciardoney glacier presents length measurements for the period 1971-2009 (Fig.5a) and mass balance measurements for the period 1992-2000 (Fig.2a); while the Grand Etrèt glacier presents length measurements for the period 1997-2009 (Fig. 5b) and mass balance measurements for the period 2000-2009 (Fig.2b)"

- *Reviewer 2: p. 1483, line 1-4 How have the mass-balance measurements been converted to a net balance ? With respect to a reference hypsometry for the whole period ? If so, can you estimate the errors due to a changing glacier geometry ?*

The net balance used in our work is set equal to the values determined by the GPNP and SMI operators, so no geometry and hypsometry correction has been added. The geometry is only considered in the calculation of the surface budget (B_s), where the net balance rate $\dot{b}$ is multiplied by the glacier length and width.

- *Reviewer 1: p. 1483, l.14: the authors should give the size of the grid in kms.*

  We added also the dimension in kilometers as requested by the referee:

  "[...] regridded onto a regular grid (0.125°x0.125°, almost 14 km) [...]"

- *Reviewer 1: p. 1483, l.19-22: this sentence is confusing. The surface mass balance respond to meteorological variables but the response of snout fluctuations is more complicated. Rephrase it.*

  Reviewer 2: p. 1483, line 15-24: The study of Bonanno et al.(2013) is not readily available to me. Is this about statistics between weather data and glacier length ? So why is it relevant for assessing the relation between weather data and net balance ? Many papers have been written about the relation between mass balance and seasonal/monthly meteorological data none of this is mentioned... Why not using monthly data anyway ?

  The paper by [Bonanno et al., 2013] describes the main climate forcing influencing glacier dynamics in our study region, theWestern Italian Alps. We used the results in this paper as a starting point in defining the accumulation and ablation seasons in our work. We focus on these two seasonal period instead of considering the monthly values, since we need to evaluate annual series for the total mass balance, in order to be able to compare the measaured values with the modeled ones.

  We reformulates the sentence in the revised version of the paper: "In the analysis we consider seasonal averages of precipitation during the accumulation period (from October to May) and temperature during the ablation season (from June to September), since we want to relate the meteorological variables to mass balance values, which are on annual basis. We indicate these two seasonal averages as "October-May precipitation", and "June-September temperature" respectively, and the timing of these seasonal averages are taken based on the study by [Bonanno et al., 2013]"

- *Reviewer 1: p. 1483, l. 23-25: the seasonal averages precipitation and temperature have been standardized by removing the average and dividing the standard deviation. Is it useful to divide by the standard deviation (normalized values)? The authors should give more explanations.*

We changed the sentence to better clarify this point, as requested by the referee:

"The seasonal averages have been standardized by removing, for each grid point, the climatological mean in the period 1971-2000 and dividing by the standard deviation in the same period. This operation is done in order to better highlight the relative importance of temperature and precipitation fluctuations in determining the mass balance variations in our approach."

- *Reviewer 2: p. 1484, line 1-12: The data used for projections are, as far as I know, not explicitly given in Hazeleger et al. (2012). Additional reference to source(s) needed!*

  As we explain in the following lines the scenarios used in this work are Representative Concentration Pathway (RCP) projections RCP 4.5 and RCP 8.5 prepared with EC-Earth v. 2.3 for the Climate Model Intercomparison Project (CMIP5) archives, using the model with atmospheric resolution 1.125°and 62 levels. The data are public and available from the CMIP5 ESGF distribution nodes (http://cmip-pcmdi.llnl.gov/cmip5/). We added this link in the paper.

- *Reviewer 1: p. 1484, l. 1-12: the authors use (i) temperature and precipitation from ARPA database between 1959 and 2009 to calibrate the model and (ii) temperature and precipitation from RCP projections for the future. These data are very different (grid size. . .). The authors should provide more explanations about the connection and the overlapping of these series over the common period.*

  In fact we didn't have any figure showing the difference between ARPA and Ec-Earth forcing. For this reason, we plot in the Fig. 2 in this document also the results that we obtain by using the temperature and precipitation fields taken from the Ec Earth ensemble mean (green line). The difference in resolution between ARPA and Ec-Earth gives a difference in the final glacier length reconstruction. We can see that the simulations based on the Ec-Earth forcing fields, which have a lower resolution, are still able to capture the main trend in the glaciers length evolution.

- *Reviewer 2: p. 1484, line 16: "between glacier length and mean ice thickness"*

  We changed the sentence as suggested.

- *Reviewer 2: p. 1484, line 20-24: In Oerlemans (2011), minimal models are discussed that have varying width, varying slopes (even with an overdeepening when applicable); applications are shown in which the* *width is scaled with the length. In these models, an assumption that the ice thickness is constant is not needed and not used at all.*

We agree. In fact we missed to stress that the assumption of a constant ice thickness, which is set equal to a mean ice thickness value, is used since no information on ice thickness and bedrocks shapes are available for the studied glaciers. For this reason we rephrase the sentence at page 1484, line 20–24 as:

"Ice thickness is assumed constant along the entire glacier and set equal to a mean ice thickness, $H(t)$, which is only a function of time t, since no information on ice thickness and bedrocks shapes are available for the studied glaciers."

- *Reviewer 2: p. 1485, Eq. (1): Eq.(1) is not based on perfect plasticity, but on a large number of numerical experiments with a SIA flow-line model.*

  We corrected the manuscript accordingly.

- *Reviewer 1: p. 1486, Equation (4): the authors should rewrite Equation 4 to be clear. Equation 4 is similar to the first term of the second member of Equation 6 in Oerlemans and others (2011). The authors should explain how they simplified the minimal model given Equation 4 is a simplification of the very simplified model of Oerlemans and others.*

  In equation 6 in [Oerlemans et al., 2011] they keep into account a bedrock changing along the flow line, which is an information which is not available in our case. In our case we simplified further assuming a glacier of uniform width resting on a bed with constant slope, and with a constant mass balance gradient along the glacier, leading to our eq. 4.

- *Reviewer 2: p.1485,Eq. (2): Eq.(2): why dealing with a varying width here when you have assumed it is constant ? The obvious approach to be taken is to let W vary with x, and probably also scale it with the glacier length.*

  We agree with the referee, but we kept the width term in Eq. (2) in order to display the general equation on which we applied, in a subsequent step, the approximation of a constant W.

  In the revised manuscript we test and add another minimal model case in which the width of the glacier is changing along the flowline. This case is described in the answer to the first comment by the second referee.

- *Reviewer 1: p. 1485 and p.1486: the authors assume a constant value of width (W): no change with time. Do the observations support this assumption over the last 50 years ? and for the future ?*

We didn't deal directly with this point in our work, for this reason we tested a case in which also the width changes along the flow line depending on the glacier length. The description and results of this new case are reported in the first answer to the second referee.

- *Reviewer 1: p. 1486, l.1-18: The response of the glacier is related directly to mass balance. The approximation assume an instantaneously response time to climate forcing. According to this direct relationship, the length changes should be similar to the cumulative mass balance changes. Consequently, from Figure 6, it would mean that the mass balance changes could be very different from a glacier to another glacier. This conclusion, resulting from the reconstruction of this model, is not supported by observations. Indeed, several studies based on observations show a very similar pattern of cumulative mass balance over the last centuries (Huss et al., 2008; Vincent, 2002).*

  We answer in detail to a similar comment by the first reviewer above (point 5).

- *p. 1486, line 14-19: I do not understand the discussion on the "instantaneously response to climate forcing". Does this refer to the relation between the net balance and the meteorological variables ? But then, why is this different for smaller and larger glaciers ?*

  The "instantaneous response to climate forcing" refers to the glacier response time. The length variations of a smaller glacier depends directly to changes in mass balance of the same year. Larger glaciers require some years before the changes in accumulation and ablation are able to influence the glacier length.

  We are considering mainly small glaciers in our work, so we assume no delay in the response between climate forcing and glacier length changes.

- *Reviewer 1: p. 1487, l. 7-17: The parameters a, b and c have been calculated using the relationships between wide glacier mass balance and temperature and precipitation. These relationships obtained from observations of the last decades cannot be used for the next hundred years ((Elsberg et al., 2001; Harrison et al., 2005; Huss et al., 2012).*

  To further evaluate our empirical method we test it against a different method: the Positive Degree Day (PDD) method (see reply 2 to the second referee above for a complete description). Figure 1 in this document shows that the reconstructed mass balance, which is obtained using the empirical method, is in good agreement with the observed one. Furthermore, the empirical method is also in agreement with the results obtained with a simple PDD method. The ablation from the PDD method depends on two melting factors which, in literature, are considered to have a significant spatial variation, but a less pronounced variation in time [Zhang et al., 2006]. Since the good agreement between these two method is found in the last 40 years we can assume that this good agreement will continue also for the near future (next 50/100 years), and that both approaches will work properly for future simulations.

- *Reviewer 1: p. 1487, l. 18-26: the authors should provide the scores of these correlations for each variable and both variables. A table with correlation values is needed.*

  In the revised manuscritp we added the 95% confidence interval for the values reported in Table 2. Furthermore, we report also the RMS difference between modeled length and measured ones for the basic case (see Table 1), which presents also the best parameters combination for the basic case model and the W(x) case. This table will be added to the paper.

- *Reviewer 1: p. 1487, l.19-26: check the unity of a, b and c.*

  We thank the referee for this suggestion. The mass balance is in $mwe/year$ and, since the temperature and precipitation are normalized (no unit), "a,b,c" should have the same unity of the mass balance.

- *Reviewer 2: p. 1487-1488: The approach to model the mass balance, apart from the problems with a changing geometry, is really out of date and has too many uncertainties. Sometimes the coefficients from the regression analysis are impossible to understand and perpendicular to what we know about the processes of mass and energy exchange between glacier and atmosphere. The obvious way to relate mass balance to meteorological forcing is to run an energy balance model, and calculate sensitivities of ELA to monthly perturbations of precipitation and temperature.*

  The method suggested by the referee is more accurate, but requires more information. These extra informations are missing in the ARPA database, in fact we have only temperature and precipitation series. As already discussed, in order to improve the method used, we decide to apply also a simple PDD method, and we compare the results between this method and the previous one (empirical method) obtaining a similar mass balance reconstruction (Fig. 1 here). The description of the PDD method is given in the answer at the second point of the second referee.

- *Reviewer 2: p.1490 and further: ∗∗ Based on the methodology discussed so far, the further analysis cannot be considered reliable. ∗∗ It would be interesting to see a more-to-the-point discussion about what step(s)* *in the analysis contributes most to the uncertanties. I guess overall it is the uncertainty in the meteorological input data and the relation between meteorological data and net balance.*

In general, the shortage of information on the studied glaciers increases the uncertainties of our approach. In particular the relation between meteorological data and mass balance (Eq.(5) of the paper) represents the largest uncertain point of our model. We tested the sensitivity of our approach to the estimate of the three parameters a, b, and c by using the sub-sampling method presented in Sect. 4.1 of the paper. The error bars obtained with this method are reported in Figs. 5 a,b in the paper as dark gray regions, which show the large impact of this parameters on the final glacier length reconstruction. Furthermore, also the lack of knowledge on the ice thickness represents another source of uncertainty in our model: in fact the parameters α_m and ν in Eq.(1) in the paper are set to general values for the nine glaciers without measured mass balances, due to the absence of this specific information. While our method presents certainly several uncertainties, the aim of our study is to obtain some information and projections for a large amount of small glaciers on which only few informations are available and, as shown by our results, also very simplified models able to give a first estimate of the present and future behavior of these glaciers.

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