Reply to Referee #2 Siri Jodha Khalsa

In this document, we include the reviewer´s comment in black, and our response embedded in blue. Line numbers refer to those of the version in track changes mode off.

This is a well-conceived and executed investigation of glacier mass balance based on height differences between a pair of DEMs derived from satellite measurements. My comments are as follows.

We thanks Siri Jodha Khalsa for the favorable opinion our paper.

The seasonality correction, which the authors state is the 2nd most important source of error (section 5.1), is based on stake measurements made in 2013, 2014 and 2015 (section 3.2). I believe this assumes that all Monte Tronador glaciers lost mass at the same rate of 1 m w.e./yr between February and April in both the years 2000 and 2012, but Fig 6a shows 2000 had a large positive temperature anomaly in the region compared to the later years. Also, it seems there would be a substantial spatial variability in the seasonality adjustment. It seems that a greater effort could have been made to estimate/model this adjustment. Also, what is the rationale for using +/- 1 in the error estimation (section 3.6.3)?

The seasonality correction represents the mass loss between mid-February 2000 and April 21, 2000 and was applied in an attempt to estimate the annual, glacier-wide mass balance in an integer number of year (April 21, 2000 to April 21, 2012).

The mean temperature anomaly for the year 2000 (Figure 6A in the manuscript) is -1.8°C, one of the lowest values after 1976 (the lowermost was in 2009; -5.2°C). The temperature anomalies for the years used to assess the seasonality correction were between 1.8 and 4.7°C, so it is possible that during the summer of the year 2000 the Alerce glacier lost less mass than what we assume (this is one of the reasons why we applied a 100% error).

As we acknowledge in our manuscript, this is considered one of the main sources of error and can only be overcome with mass balance measurements in the rest of the glaciers in combination with numerical mass balance models to assess the mass change in a specific time period (if the mass balance measurements do not cover the specific time period under investigation). Until then, we believe that high uncertainties will remain when using a mass balance model to calculate the seasonality correction for individual glaciers. This is mainly due to the lack of data to constrain or assess the accuracy of the model in all of the glaciers. Currently the only glacier where we have mass balance data is Alerce glacier, so we can only assess the accuracy of the numerical model there, and we will have the uncertainty of extrapolating these results to the rest of the glaciers. To obtain mass balance measurements in the rest of the glaciers would represent a great effort and is beyond the aim of this paper. To overcome this main drawback, in Table 4 we present the glacier-wide annual mass balance ($\overline{b_a}$; which includes the seasonality correction) and the glacier-wide mass balance ($\overline{b}$), without the seasonality correction, so interested readers can compare these results and/or use a different correction, including a glacier specific seasonality correction.

We used for that the seasonality correction a conservative 100% error estimate to emphasize the poorly constrained nature of this value, in the same way as Gardelle et al. (2013) did for the mass balance estimation in the Pamir-Karakoram-Himalaya ranges. We also included a statement in the Discussion to emphasize the uncertainties associated with the seasonality corrections (p. 12, l.13-15). “Nevertheless, due the lack of mass balance measurement in the rest of the glaciers and the difference in the temperature anomalies between the year 2000 and the ones used to assess the correction (Fig. 6A) we assume a conservative 100% error in this correction. Direct measurements of mass balance on various glaciers combined with mass balance models (Huss et al., 2008) could help to improve the correction applied here and its inherent error.”

p.4,l.20 - “integer time span” - needs units (i.e. years).

We included the units “(i.e. years)”.

p.5,l.19 and l.25 - seems that screening for dh outliers is done twice, initially by the +/-100 m threshold and then again when averaging in elevation bands by rejecting dh outside of 3 sigma. Explain why, and provide % rejected by these procedures.

We applied the +/-100 m dh threshold to eliminate possible spurious values associated with artifacts in the DEMs that could pass the curvature correction and/or the masking of voids in both DEMs. However, we had not checked if there were cells that were rejected by this filter. Thanks to your comment, we now note that there are no cells inside the glacier area in 2000 with dh values higher than 100 m (the highest values are lower than 50 m) or lower than -100 m (lowest value is -94 m in the Casa Pangue debris-covered lower tongue). Thus, we decided to eliminate this sentence and have now emphasized that the excluded cells are associated with voids and with extreme curvature values. As the reviewer points out, any remaining spurious values would be rejected by the 3 sigma threshold, so the +/- 100 m threshold is not necessary. The percentage of cells rejected by each filter correction step is as follows:

Cells with voids or rejected by the curvature correction: ~25% of the ice covered area in 2000. Cells rejected by the 3 sigma threshold: ~10% of the remaining data, or ~7% of all cells covered by glaciers in 2000.

Now the sentences read as follows;

P. 5, l.18-21. "Before calculating the height and mass balance changes, we excluded all the void pixels in SRTM-X and PLEI, as well as those with extreme curvature values (Fig. 2C). The excluded cells represent ~25% of the area covered by glaciers in 2000. Here we briefly summarize the procedure to obtain the volume and glacier-wide mass balance (see Appendix A for a detailed description of the calculations)."

P.5, l. 25 "This is an efficient way to exclude outliers (less than 10% of the remaining data after eliminating the voids and the extreme curvature values),.."

In fig. 3 are the outliers included or excluded? caption says "all data".

The blue dots represent all data available after the curvature correction. We clarified this point in the caption of the figure.

The caption of Figure 3 now it reads as follows "Figure 3. Elevation changes and hypsometry of Monte Tronador glaciers. Grey area shows the hypsometry of each glacier. The blue dots show all the elevation changes data for each glacier available after the curvature correction. The green dots represent the mean elevation change for each elevation band. The error bars (in black) are smaller than the green dots. For clear comparison all plots have the same scale and are sorted in glacier size in descending order. Glacier names are shown in each plot."

p.5,l.24 - mixed tense. if "were analyzed" then must say "we averaged"

Fixed.

p.5,l.33 - isn't Pangue a more dramatic example?

Although Pangue (Fig. 3L) also shows some positive values, they are present in elevation bands were there are very negative values as well, so we interpret these values as outliers. In the case of Castaño Overa, the lower reaches of the glacier is characterized by positive values related with areas of high curvature.

p.6,l.12 - “i” should be subscripted

Fixed.

p.6,l.13 - “it” should be “its”

Done.

p.6,l.19 - “represent” should be “represents”

Fixed.

p.7,l.4 - “assumption” should be “assumed”

Done.

p.8,l.9 - unclear what comparative “more” refers to. Is “most” the intended word?

Yes, we changed it.

p.10,l.21 - “the thickening of the debris layer due to the melting of glacier ice” needs clarification. if ice melts under the debris cover it simply lowers the glacier, increasing the relative, but not absolute thickness of the debris cover. Debris cover can increase only by deposition or convergence.

The debris on the surface of Casa Pangue glacier came from rock falls and avalanches which falls from the upper slopes of the glaciers and valley sides. Debris that came from the upper slopes are mixed with snow/ice and transported within the ice, when the ice melts them concentrates on the surface of the glacier thickening the debris layer. Also, the direct accumulation of debris by a rock fall from the valley sides will thicken the debris layer. Since we do not have data to support that the cause of the slower rate is the thickening of the debris layer and the cause of that thickening we decide to shortcut the sentence, which now it reads as follows “…which could be related with the thickening of the surface debris layer.”

p.10,l.29- change “hypothesized” to “hypothesize”

Fixed.

p.11,l.1 - “ice flux is compensating the mass loss due to surface climatic mass balance” We changed the sentence, which now reads as follows (p.11, l.5) “ice flux is compensating the mass loss due to surface mass balance in this glacier”.

p.11,l.5 - “contrast” should be “contrasts”

Fixed.

p.11,l.12 - “a shift towards slightly more negative values” is not supported by the data; difference is within estimated error.

We agree with the reviewer. This sentence now reads: “In the last two decades, negative mass balances, between -0.6 ±0.4 m w.e. a-1 (1993-2003) and -0.7 ±0.2 m w.e. a-1 (2003-2012), have been observed in South America and the Sub-Antarctic islands (Mernild et al., 2015).”

p.25, Table 4. Include the error estimates for each figure in the table.

We included a sentence in the caption to point out that the error estimations are also shown in the table. The caption of Table 4 now reads as follows “Table 4. Area, volume and mass balance change of Monte Tronador glaciers (2000-2012), with their corresponding error estimation. See Appendix A for a detailed description of these calculations.”

Throughout - inconsistent capitalization and abbreviation of “Figure”

Fixed.

Throughout - change “we” and "w.e" to “w.e.” where necessary

Fixed.