

Reply to Anonymous Referee #1

In this document, we include the reviewer's comment in black t, and our response embedded in blue. Line numbers refer to those of the version in track changes mode off.

General Comments:

The submitted manuscript presents an important study of the surface mass balance of Andean glaciers on Monte Tronador, in a region where a dearth of such data exist. If anything, this manuscript delves into the lack of data in the area and the need for more measurements as outlined in the discussion and conclusions. Further, the manuscript demonstrates that DEM differencing method can be used in a region with limited available data to determine elevation change, and also, importantly, demonstrates the limitations of this method. The discussion of the methodology, particularly the discussion of the error propagation in the methods used, is very thorough, and appreciated. There are a number of minor technical errors/typos that should be addressed to improve readability.

We thanks anonymous referee #1 for the favorable opinion our paper.

Technical Comments:

Abstract, line 10: Should be, "...little is known" not "little it is known..."

Done.

Page 1, Line 27: "over at a period" should be" over a period"

Fixed.

Page 1, Line 28: "that spans from a few years...." instead of "that spans from few years..."

Done.

Page 1, Line 29, "measure the contribution of glaciers to sea-level rise..."

Done.

Page 2, Line 3: Due to difficulties sustaining...

Done.

Page 2, Line 7: Not sure if the authors are trying to say that the lack of information about small glaciers hampers complementing the larger data set that covers, the wider region?

Here we meant that the lack of mass balance data in this region hampers the possibility of fully exploiting the glacier frontal fluctuation dataset which is available for this region.

We rephrased this sentence as follows “Unfortunately, the lack of mass balance data hampers the possibility of exploiting the relatively much more complete and longer glacier fluctuation series available for this region (Davies and Glasser, 2012; Leclercq et al., 2012; Masiokas et al., 2009; Paul and Mölg, 2014; Ruiz et al., 2012).”

Page 2, Line 15: “Owing to its discontinuous spatial coverage, the X-band SRTM has not been as widely used for glacier elevation change studies as the C-band SRTM has been (Neckel et al., 2013; Rankl and Braun, 2016).” This statement begs the question of why it is ok to use in this particular study, it might be good to add a phrase to qualify that here?

We included a sentence to emphasize that, despite its discontinuous spatial coverage, the shorter wavelength of the SRTM X-band makes it more suitable to study glacier elevation changes. Now it read as follows “Due to its shorter wavelength and smaller penetration, the SRTM X-band is more suitable to estimate elevation changes in snow or ice surfaces (Rignot et al., 2001). However, it has not been as widely used for glacier elevation change studies as the SRTM C-band (Neckel et al., 2013; Rankl and Braun, 2016) because of its discontinuous spatial coverage. This is not an issue in Monte Tronador where there is a full SRTM X-band coverage.”

Page 3, Line 1: “Meanwhile, Parra and Vuriloches were designated as a unique glacier (No Name 1) by that same study.” This statement is a little confusing, do the authors mean, “Meanwhile, Parra and Vuriloches were designated as a single glacier (No Name by that same study.” ?

Yes, we rephrased this sentence as follows “Based on our most recent results, we introduced some modifications to the glaciers outlines presented by Ruiz et al. (2015). We renamed glaciers No Name 2 and No Name 3 to Mistral and Peulla, respectively, and split glacier No Name 1 (Ruiz et al. 2015) into Parra and Vuriloches.”

Page 3, Lines 3-10: Are all of these glacier dynamics outlined in Ruiz et al., 2015? If yes, I would add a statement along the lines of, “as outlined in Ruiz et al., 2015, ...” in order to properly cite these data.

Agreed, we include the sentence.

Page 3, Line 23: “ and due to a narrower ground track..” or “and due to its narrower ground track...” not “and due to his narrower ground track...” There is also something a little confusing

about this phrase, which is why I suggest adding “and” but not sure if that is the intention of the authors.

We changed the sentence as follows “The X-SAR sensor ($\lambda = 2.8$ cm) has a narrower ground track (swath width of 50 km), and covers approximately half of the area sampled by SIR-C.”

Page 3, Line 27: “scientific proposes” should be “scientific purposes”

Fixed.

Page 3, Line 29: “Penetration of the radar signal into snow and ice is related to their physical parameters” should be “Penetration of the radar signal into snow and ice is related to snow and ice physical parameters...”

Done.

Page 4, line 22, delete extra parenthesis in front of Gardelle et al. (after “e.g.”)

Fixed.

Page 5, line 5, should be “for extreme values of the curvature” instead of “extremes values”

Fixed.

Page 5, line 7, “mid-Februarys” should be “mid-February”

Fixed.

Page 5, line 17, should “voids pixels” be “void pixels”?

Fixed.

Page 6, line 2, should be, “resolves the edge of the cliff more sharply”

Done.

Page 6, line 3, not sure what “the lower reaches of the Castano Overa is quite small”

refers to? Is it that “the area of the lower reaches of the Castano Overa is quite small in comparison to the total area”?

Yes, we included “the area of the” to clarify this sentence.

Page 6, line 13, I think that “it” should be “its” in front of altitude band.

Fixed.

Page 6, line 19, should be “number of independent values”

Fixed.

Page 6, line 25, A_i should be defined.

Agreed. We now define it in the text: “Where A_i is the area of each elevation band”.

Page 7, line 4, I’m not sure what, “The assumption density error represents a 16% error.” I think it means, “The assumption of a density of 850 kg m^{-3} represents a 16%

error.” Or “The assumption of a density value represents a 16% error.”

It means that the assumed density error represent a change in the estimated mass balance of 16%.

We change the sentence as follows “The assumed $\pm 60 \text{ kg m}^{-3}$ density error represents a 16% change in the glacier mass balance.”

Page 9, line 11, suggest putting “i.e.” in front of “curvature correction”.

Added.

Page 9, line 15, Should be, “Our mass balance error...is in the same range...” not “are in the same range”.

Fixed.

Page 10, line 5, AAR should be defined.

Agreed. We defined AAR in the text.

Page 11, line 4, “their” should be “its” as it is referring to “the snout of the Verde glacier”. ”.

Fixed.

Page 11, line 25, should be “the icefield-wide mass balance is...” not “are” (or could be, probably more correctly, “the icefield-wide mass balances for the two icefields are, respectively, are...”.

Done.

Page 12, line 17, not sure what “the longest and detail length fluctuation series available in the North Patagonian Andes” means. Is it, “the longest and most detailed length fluctuation series available in the North Patagonian Andes”?

Yes. We clarified it. Now it reads as follows “(Fig. 6C; the longest and most detailed length fluctuation series available in the North Patagonian Andes)”

Figure 1: hard to see the blue lines differentiating the glaciers vs. some of the features which are also blue-ish. What is the white line? Looks like it is marking the bedrock step zones, but that should be specified in caption.

We clarified the caption. Now it reads as follows “Figure 1. False-color pan-sharpened Pléiades image of Monte Tronador from 7 March 2012 (RGB bands 3, 2 and 4, © CNES 2012, Distribution Airbus D&S). Individual glacier limits are indicated by the thin blue line. The thick white line shows the location of the bedrock cliff discussed in the text. The inset shows the location of Monte Tronador and other glaciers with long mass balance measurement series in the Southern Andes (22°S-55°S).”

Figure 3 and Figure 4: It would be clearer if the blue and green data are identified as the hypsometry data and the grey data are identified as the area data...as it is, it is not completely clear which data are which unless the reader ponders the figure for a little bit Should be written, “all plots have the same scale and are sorted in glacier size in descending order”

We clarified the caption of the figures.

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.”

The caption of Figure 4 now it reads as follows “Figure 4. $E\Delta h$ distribution with altitude, the grey area represents the number of pixels off- glaciers and off-forest in each elevation band. At very low (<500 m asl) and high (>2700 m asl) elevations the raw error increases, an artifact associated with the lower number of values available. The red line represents the $E\Delta h$ used to calculate the error of the geodetic mass balance estimation of Monte Tronador glaciers.”

Figure 4. The label “data” is not very helpful, maybe put “off- glacier and –forest pixels” Instead.

We changed the label of the figure.

Table 3.”La Almohadilla is the closest temperature records to Monte Tronador” should be ” La Almohadilla is the closest temperature record to Monte Tronador” and ” Los Alerces the closest

precipitation records to Monte Tronador.” Should be Los Alerces the closest precipitation record to Monte Tronador.

Done.

Page 25, line 9, should define B as the glacier mass balance in this line.

Done.