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Editor

Following the editorial processes established in the Journal *Climate of the Past*, we are enclosing below our responses to the reviewer's comments on our manuscript: *Fluctuations of Glaciar Esperanza Norte in the north Patagonian Andes of Argentina during the past 400 years* by L. Ruiz, M.H. Masiokas, and R. Villalba.

We thank the reviewers by their time and effort in reviewing our contribution to *Climate of the Past*. We believe that the paper has significantly been improved after incorporating their suggestions.

Reviewers' comments in black.

Authors' responses and comments in red.

Response to comments from Dr. Vanessa Winchester

Specific comments

The most crucial problem concerns dating accuracy. There is no mention of how or why the authors derived the generalized 20-year addition to ring counts in cases where a core failed to reach pith. Did they measure the circumferences of tree stems at coring heights? And how can they apply a generalized 20-year rule to species as widely different as *Nothofagus* and *Fitzroya*? What evidence have they that these species possess the same growth rates (maybe they show the same average ring widths? If so, this needs saying). How did they estimate years to pith 'based on ring curvature'? Did they fit clear acetate rings to curvature?

The ecesis estimate seems entirely reasonable in relation to the last few decades, however (page 4080, line 12) ecesis delay before colonization could have been much longer following the LIA maximum when climatic conditions were far harsher. Some references that could help:

Winchester, V. and Harrison S. 2000: *Dendrochronology and lichenometry: an investigation into colonization, growth rates and dating on the east side of the North Patagonian Icefield, Chile*. *Geomorphology*: 34 (1-2): 181-194.

Winchester, V., Harrison S., Warren, C.R. 2001. *Recent Retreat Glaciar Nef, Chilean Patagonia, Dated by Lichenometry and Dendrochronology*. *Arctic, Antarctic and Alpine Research*, 33(3): 266-273.

In the revised version of our manuscript we included a new section indicating how the minimum ages for moraines were estimated as well as on the assumptions made in the process of age estimation (see below). Although *Nothofagus* and *Fitzroya* trees were sampled, minimum ages for the moraines were based mostly on *Nothofagus* trees. Only the minimum age for Moraine 9 was estimated from a *Fitzroya* tree. However, as the core taken from this tree intercepted the pith, not error due to the estimation of pith offset was introduced in dating M9 (see Table 1). The remaining *Fitzroya* trees, which reach ages over 1000 years, were used to provide a context for minimum ages reached by forests not affected by Glaciar Esperanza Norte during the LIA event. We agree with the Reviewer's comment that the delay before colonization could have

been longer in the past. However, changes in ecesis over time are extremely difficult to figure out. We consider our 13-year estimation as an extremely conservative value consistent with minimum age estimation for the moraines. Certainly, moraines could be older but not younger than our age estimates.

“Dendro-geomorphological determinations (Luckman, 2000) allowed the dating of lateral and frontal moraines located in the glacier forefield associated with LIA and post-LIA events. Minimum dates of formation of the moraines were determined from the age of the oldest trees sampled on their surface. Three species – *Nothofagus pumilio*, *Nothofagus dombeyi*, and *Fitzroya cupressoides* – were recorded on the glacier forefield and sampled in this study. The sampling of these trees was performed with increment borers and their ages determined using standard dendrochronological procedures (Stokes and Smiley, 1996). Cores were taken as close as possible from the tree’s base but except for the youngest, smallest trees the sampling height generally ranged between 0.5 and 1 meter. Previous related studies in Patagonian glaciers (Masiokas et al. 2009, 2010) shown that the error in estimating basal dates of *Nothofagus* spp. is relatively minor (i.e. < 10 years) when sampling up to 1 meter from the tree’s base. In the absence of direct information from the study area, here we used a vertical growth rate of 10 cm/year to correct for sampling height (Table 1). Whenever possible, for samples with no pith we also estimated pith offset values based on ring curvature. However, pith offset values were difficult to determine in samples with almost parallel inner rings. We added 20 years to the dating of the innermost ring to account for missing rings in these incomplete samples. The dating accuracy from these samples (usually coming from old large trees with rotten centers) is poorer and contains larger inherent uncertainties than cores collected at the base of young trees reaching the pith. These age corrections provide a dating likely closer to the true age of the older trees. However, resulting dates should be used with caution and only as approximate minimum age estimates for the moraines. Although the examination of the different sampling sites suggests that the selected trees constitute the first generation colonizing the deposits, additional evidence that could ideally provide maximum age estimates (e.g. from trees tilted, scarred or overridden by the glacier) is needed to better define the date of formation of these moraines (see e.g. Luckman, 2000; Luckman and Villalba, 2001).

Concerning dating accuracy: Table 1 needs extending and reorganizing. It is not ‘user friendly’. The word ‘trees’ in 2 of the columns needs to be placed above in the titles row. It is not clear (without tiresome calculations) what extra years have been added to each date (only two dates have 20+13 years added, other variations suggest a good deal of estimating was required). An extra column could help. Additionally, which of the 3 species you selected relates to which date (unless they are all the same species, in which case this should be mentioned (or add symbol beside each date?). Maybe it would be better to give only the oldest dates for each moraine?

Table 1 was re-organized to show the adjustment made to each core to estimate the moraine minimum age. Information on the species used for dating each moraine is also included.

A critical section on dating accuracy in the Discussion is needed.

A detail discussion on the accuracy of tree-ring based dates was added to the discussion section (see below).

“Nineteen subsequent readvances evidenced by moraine crests were identified inside M1 (Fig. 3A). In most cases we were able to estimate minimum ages for the formation of these deposits based on tree-ring counts from trees growing on their surfaces (Table 1, Fig. 5). It is important to note that the accuracy of these estimations is determined by inherent limitations of this particular dating technique and the tree-ring material available. In general, at GEN the dating of older deposits is less accurate than the dating of younger moraines where trees are smaller and it is easier to reach the pith at their base (see Data and Methods above). The various corrections applied to the samples (sampling height, pith offset and ecesis; Table 1) are intended to minimize the errors in the estimation of the true age of the moraines but obviously these minimum age estimates should be treated with caution as it is not currently possible to provide a well verified, calendar date of formation for any of the moraines at GEN.”

Fig 1 labelling almost invisible: needs to be in black. Volcano names in text should be included. The elevation key is not really helpful. The high mountain/volcano tops don't show up well in white and the dark-shaded valley-sides are more of a visual aid than an elevation guide. The word “cities” in the caption = towns (unless they have a cathedral).

In Figure 1, we changed labels, inserted volcano names, and changed the grey-scale.

Fig. 2A Change font to black where it is superimposed on yellow/pink background. Giving scale of ‘boulder’ is not helpful among all the detail. Caption error “(see also Fig 2)” = Fig 3?

Figure 2, we changed the color font and took care of the caption error, the distance between the glacier tongue and moraine M1 is indicated for scale.

Fig. 5. Consider changing solid lines showing icefall to another type of line (they look like moraines). Black font for dates instead of grey which is hard to read – especially the oldest dates.

Figure 5, we changed the font and the solid lines according to the reviewer's comments.

Fig. 7. Remove “two” from caption insert ‘adjacent’ data points.

Corrected.

Technical Details

We took in account all your English grammar and style corrections.

Pag 4082 line 13 Group A ... Group B – what/where is this? Suggest removal
Pag4082 line 24 Group B suggest removal – as suggested line 12;
Pag 4083 line 1 Group C If you keep these groups show them on a figure

Moraines were grouped based on geomorphological and sedimentological characteristics of the moraine crests in combination with dendrochronological dating. For clarification they are now shown in figure 4 and discussed in the Discussion section.

References to check: “Jarvis et al 2008” “Luckman 2000” and “Villalba et al. 1998”. I couldn’t find these in the text. Neumeyer 1949 needs to be referenced properly in text. Page 4081 line 26.

All references were checked and properly corrected.

Response to comments from Reviewer # 2

Overall, an interesting contribution and competently done. Two major comments:

1)It is quite long and there is some repetition; it could be gone through and cut down by several pages.

We went carefully through the whole manuscript and delete repetitive sentences and paragraphs.

2)Errors associated with the tree-ring dating of the moraines could be made more explicit. For example, in Figure 5 and Text, I wonder if it would be better to round the ages of the moraines based on tree rings, given the errors and assumptions you needed to make. The figure seems to imply one year accuracy. For example, the outermost moraine could be 1650 (+/- ?), the 1691 could be 1690 or even 1700, etc. Or even better, a range could be given, based on the age range of trees and estimates of the potential errors of the assumptions. Similarly, Figure 6 could be drawn with some estimation of the errors – a wider band rather than a line.

As it was indicated above, in the Methods and Discussion sections of the new version, we have included new paragraphs specifically dealing with the limitations of the tree-ring dating, indicating the assumptions that we made for age estimation. In the caption of figure 5, we state that: Tree-rings dates have inherent assumption and corrections. In addition, in Figure 6, we added error bars to variations in glacier extents and dating estimates.

A few comments:

We took in account all English grammar and style corrections made by Reviewer # 2.

Line 110: “During the warm season the westerlies are stronger: :” Don’t you mean “weaker”? I would think the westerlies are stronger in winter, when the pole-equator temperature gradient is greater. Or am I missing something?

Certainly, at the lower levels of the atmosphere (925 Hpa) the Westerlies are stronger in summer showing a mean intensity larger than 10 m/s between 45 °S and 55 °S latitude. In contrast, the mean intensity at 925 Hpa in winter is lower than 10 m/s and centered at 40-45 °S. At higher levels (300 Hpa) in the atmosphere, the intensity is larger than 25 m/s in both summer and winter, but centered at 42-52 °S in summer and 20-42 °S in winter. The original text was rephrased as follow to be more precise on this particular issue.

During the warm season the Westerlies at surface (925 hPa) are stronger but concentrated further south between ca. 45° and 55°S, whereas during the cold season they expand to the north thus bringing most of the precipitation to northern Patagonia during the winter months (Villalba et al., 2003; Garreaud et al., 2009).

Line 160-161: do you mean “the size distribution and shape of the clasts”? The sentence is not entirely clear.

The sentence was rephrased as follows:

Whenever possible, the size distribution and shape of the clasts was measured or estimated in these morainic deposits.

Lines 170-173: It is not clear to me how accurate this estimation would be or why 20 yrs was chosen as the default. Perhaps a comment on the assumed precision, or else a note stating that it really doesn’t matter at the scale of the analysis. And a statement of how many samples were estimated this way.

Please, see our response to Reviewer #1 on the same issue.

Line 312ff: This is an interesting observation, but the discussion of it would be better in the Discussion rather than Results.

We moved this sentence to the Discussion section.

Line 361-2: reword – not clear. Alternatively, lines 361-372 could be simply dropped, they are out of place and repetitive. Same with the first sentence of the next paragraph.

We dropped this sentence.

Line 400: : :”is interesting for a number of reasons:” drop this phrase and get right to the results – if it were not interesting you wouldn’t be discussing it, so not needed.

We dropped this sentence.

Line 413: “The available evidence: : :”

We dropped this sentence.

Discussion and Conclusions: This is quite long, and there is a fair bit of repetition and some speculation. I would suggest going through and cutting it back to just summarize the history of the site, with a brief discussion of the relation to others and the climate causes.

We dropped repetitive and speculative sentences and paragraphs in the Discussion section.

Figure 2 caption: you mean “see Figure 3”? But I don’t quite understand what this figure is. Is it a retouched photo? The green debris fans look odd. The colors on the bottom legend don’t resemble that on the photo in my version. Also, I assume it is taken with a wide-angle lens, and greatly distorts the picture. To say the boulder is 5 m is not very helpful; I assume the photo covers several km from west to east, but using this as a scale suggests it is a few hundreds of meters. I think we need some explanation.

Following the reviewer’s advice, we indicated that Figure 2 is a panoramic view of the glacier and the bottom valley including the moraines since the LIA. To provide a more realistic scale we indicated that distance between the glacier tongue and the M1 moraine.