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Climate of the Past Discussions

Interactive comment on "Climatic interpretation of the length fluctuations of Glaciar Frías, North Patagonia, Argentina" *by* P. W. Leclercq et al.

R. Neukom (Referee)

neukom@giub.unibe.ch

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This manuscript represents the first attempt to combine a multi-centennial record of glacier fluctuations from the southern Andes with a mass-balance model. As the knowledge of past glacial fluctuations from South America as well as the dominant causes for these fluctuations is still very limited, this paper is a very welcome contribution to this field of research. I think the approach of comparing model-driven fluctuations with independent glacier length records is adequate and interesting. As I am not an expert in glacier reconstructions and modeling, I cannot comment on the methods used herein and have to assume that they were used correctly and were adequately adapted to the special situation of Glaciar Frías. My comments will be restricted on structure and content of the manuscript in general as well as the comparison with the reconstructions

and climatological interpretations. From this perspective, I think this paper is worth to be published in CP after correction and adaptation the points listed below. In particular, I have one major concern regarding the interpretation of the model and resulting suggestion of errors in the reconstructions. This point concerns one of the main conclusions of the paper and needs to be carefully re-assessed before the manuscript can be accepted.

MAJOR POINT

1. P3675 line 10 – P3676 line 1

Is it really possible to make statements about the temperature amplitude of a warm phase between two dated advances such as around 1800? The dynamical calibration cannot reproduce any warming before ca. 1900 as the dated lengths only increase back in time. The authors claim that the reconstructed temperatures are ca. 0.7°C too high around 1800 to reproduce the 1843 moraine. But for example a closer look at the black curves (Villalba et al. data) shows that this is not the only possible explanation. After the minimum around 1810, the black curve in Fig. 9a starts to increase rapidly. If the curve would continue to increase with the same slope until 1843, it would hit the dated glacier length of this year very closely. However, this does not happen, because there is another short warming phase in the Villalba et al. reconstruction around 1820 or so (Fig. 9c), causing the glacier length to increase more slowly. Without this short warming period, the modeled curve would probably have matched the 1843 record even with the warm phase around 1800. In short, it also possible that the maximum warming around 1800 was correct in the reconstructions but, for example, the subsequent cooling occurred to slowly. The modeled glacier length does not depend only on the amplitudes of climate maxima/minima but also on the length of the cold/warm periods and the velocity of the changes. Hence, the overestimation of temperature of 0.7°C is not the only possible conclusion. The same criticism is also valid at other periods. The authors should re-evaluate, what kind of interpretations are possible with the model and dated glacier lengths available. From my understanding statements

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about the absolute error of extreme phases in the reconstructions can, if at all, only be made for cold extremes/glacial advances, at least in the period, where the glacier length record does not contain information about minima (actually the first dated minimum is 1970). From a climate reconstruction perspective it is more probable, that the reconstructions have issues with the variance back in time in general, not only in particular short periods (e.g. the warm years around 1800). Statements about the general under- or overestimation of variance back in time (for cold AND warm periods) would therefore be more plausible (i.e. would the match with the dated advances be better for reconstructions with more/less variability?). As the manuscript title focuses on "climatic interpretation", this issue must be really clear and statements as on page 3675 and 3676 need to be re-assessed and explained in more detail, especially as they are included in the abstract (last sentence). Numbers such as the suggested 0.7°C overestimation of temperatures around 1800 should either be removed and instead be explained in a more qualitative way or they need to be verified by analysis such as alternative model runs. It could also be a stated a bit more clearly that the very large uncertainties in the model parameters or even the concept of the model may also be responsible for miss-matches between the modeled and documented advances.

OTHER POINTS

2. Title

Maybe include an information about the temporal coverage of the paper e.g. by adding "1639-2009" at the end.

3. Abstract

The abstract does not contain much information about "climatic interpretation" as promised in the title. I suggest to either include more of the climatological findings into the abstract (e.g. the fact that the glacier seems to be more driven by temperature variability rather than precipitation) or adapt the title in a way that the focus is more on the modeling. To save some space, I suggest removing the naming of all the archives

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that were used in the reconstruction and just say "...with independent tree-ring and multi-proxy reconstructions of..." at lines 11-12.

4. General comment

Although Glaciar Frias is the best documented glacier from the area, there are dates of advances of other glaciers from the larger area as well. A short note on how well they compare to the variability of Glaciar Frias would be helpful to understand, whether the results can be interpreted as representative for a larger region or only for the location of the study area.

5. Page 3655, line 10

This statement could be a bit stronger e.g. "...has not yet been addressed in a quantitative way" instead of "... fully exploited".

6. P3655 line 29

I don't think that the "interaction between glaciers and climate is well understood", otherwise the influence of temperature and precipitation in the glacier model would not be a point of discussion later in the paper. I suggest rephrasing in a way saying that the general concept of climatic variables influencing glacier variability is well established, but relative importance of these variables is unknown in most cases.

7. P3656 line 10

Remove "the southern part of", as the availability of historical evidence of glacier fluctuations is much less than in Europe in all Andean regions.

8. Section 2.3

I think it would be helpful to clarify somewhere that the gridded reconstructions available for South America were designed for analyses on sub-continental to continental scales and may therefore not be ideal for analyses on local to regional scales. This may help to explain some of the discrepancies with the glacier evidence.

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9. P3670 line 9

Maybe provide the number for (1−e−1) i.e. 0.63 so that someone who is not familiar with the variable “response time” can get an immediate idea of what it means. I think this is crucial as many readers may intuitively understand this measure as the time until the final changes is nearly or fully met, which according to Fig. 7 is much larger than 14 years.

10. P3671 line 26

These numbers are interesting and should be elaborated on a bit more. How does the change between the early 17th century (or the LIA maximum) and present look like in the reconstructions. Are the numbers for temperature (+1.16K) and rainfall (-34%) similar? If not, what may be the explanations? This would allow making some better estimates of LIA-present temperature amplitudes, which is of high interest regarding climate sensitivity issues etc. Is it possible to get some probability for the temperature and rainfall changes? For example further below it is concluded that “fluctuation in precipitation are in general of minor importance” for Glaciar Frias, so one would estimate that the true temperature amplitude is very close to 1.16K. Or maybe the amplitudes from the climate reconstructions can help refine the model parameters?

11. P3673 line 12-14

This sentence is in contradiction to P3672 lines 9-10 “Rivera et al. (2002) attribute the retreat of glaciers in Southern Chile for a large part to a decrease in precipitation”. So the authors should either change the argumentation on P3672 or provide an explanation for the difference of Glaciar Frias to the other glaciers.

12. P3674 lines 13-16

I think it would be good to show the dotted line (not including the reconstructed winter temperatures in the model) for the full period. If it performs better than the winter-forced model in general, I recommend using this version as the “best guess”. There are two

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good reasons to do so: first, summer temperatures are of less importance for the mass balance (especially JJA which are used in the reconstruction; Fig. 6). And second, the winter temperature reconstruction is less reliable than the summer temperature reconstruction (Neukom et al. 2011).

13. P3675 lines 15-19 and P3676 lines 1-5, difference in the early 20th century

The large difference between the reconstructions in this period is indeed “remarkable” and as it falls into the calibration periods it is most probably caused by the differences in the instrumental calibration data used. This should be mentioned. Whereas Nekom et al. (2011) used grid cells from the CRU TS3 cru grid; Villalba et al. (2003) used PCs of instrumental stations. This issue emphasizes the problem of getting adequate instrumental data for the region. As the “ideal” temperature during this time would be somewhere between the two reconstructions, this may help to identify the most representative meteorological data from the area. Does one of the stations Bariloche or Puerto Montt data show temperatures that are in between the two reconstructions during this period? If so, can a shorter version of the model be run using this station? This would provide helpful imformation about the climate at Glaciar Frias as well as the model dynamics.

14. P3677 lines12-14

Are there comparable projections from other continents to compare with? Is this projected retreat more than expected in the Alps, for example? Some more context would be very helpful here. A short discussion of the economic and ecological consequences would be interesting. Is the melt water of this glacier crucial for irrigation or hydropower generation?

TECHNICAL COMMENT

Please be consistent with temperature units, use either °C or Kelvin in all instances.

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