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The Cryosphere Discussions

Interactive comment on "Glacier changes on Sierra Velluda massif, Chile (37° S): mountain glaciers of an intensively-used mid-latitude landscape" *by* A. Fernández et al.

Anonymous Referee #1

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General comments

This paper presents a detailed analysis of recent glacier variations in the Sierra Velluda Massif (SV), an area that has received significantly less attention than other glaciated areas in Chile. For this I think that the paper constitutes an important contribution for the better understanding of the general situation and recent behaviour of glaciers in this region. It is clear from the manuscript that the authors have put great effort in documenting and presenting a well organized set of analyses.

However, in my opinion the manuscript still needs significant improvements before it can be published in The Cryosphere. One of the main issues I found is that in many

cases the authors pay too much attention to some aspects of the study (that in my opinion are not really very relevant, or that could be shortened substantially without affecting the quality of the work) but do not describe with enough detail some crucial aspects of the study area, or the glaciers studied within this area. For example, the paper provides a rather massive amount of information about sources of data and images, uncertainty estimations, and DEM comparisons, but lacks a table with basic information about the glaciers under study (individual surface area, altitudinal range, etc) and a nice, well labelled, close up view of the SV where one can clearly identify the glaciers that are being analyzed and discussed in this manuscript.

I also think that at present the paper is too wide in scope. Although it is intended to describe the recent glacier changes at SV, a great portion of the manuscript is dedicated to the methodological issues involved in the calculation of uncertainties, DEM comparisons, compilation of satellite images, selection of band ratios, description of sources of historical information, etc. I understand this is important information and demonstrates the great amount of work that the authors have invested in this study. But in my opinion the paper would be much more effective if it went right to the point without describing in so much detail the intermediate analyses that were necessary to reach the main results. At present, and given the great amount of detail paid to these methodological issues, the main focus of this study (the current situation and recent changes of these glaciers) is somewhat diluted and some other important points are missed in the process.

In fact I believe the methodological discussions presented in the paper about uncertainty calculations and DEM comparisons, for example, could make another, very interesting methodological study where these issues are described and assessed in detail (perhaps using the example of the SV glaciers vs. other contrasting region).

Another detail that got my attention is the discussion of the relationship between glacier changes and climate variations. Although I agree with the authors that these relatively small glaciers are likely highly sensitive to climatic variations, I think that most of the

hypotheses proposed in the Discussion and Conclusions section are highly speculative without specific analyses involving meteorological, hydrological and mass balance data from this area.

Below I include the manuscript evaluation criteria proposed by The Cryosphere and try to address most of the questions. Other more specific, complementary suggestions and comments are discussed in the Specific comments section below.

1. Does the paper address relevant scientific questions within the scope of TC?

Yes

2. Does the paper present novel concepts, ideas, tools, or data?

The paper presents new data on recent glacier changes in the Sierra Velluda Massif in south-central Chile.

3. Are substantial conclusions reached?

Yes, but at present the discussion could be improved significantly.

4. Are the scientific methods and assumptions valid and clearly outlined?

Yes, but too much attention has been paid to the finest details which makes the methodology section too long.

5. Are the results sufficient to support the interpretations and conclusions?

To some extent yes, but the authors go too far in my opinion linking the observed glacier changes with climate changes, ENSO-PDO, the behavior of other glaciers in Chile, and proxy climate evidence from the region.

6. Is the description of experiments and calculations sufficiently complete and precise to allow their reproduction by fellow scientists (traceability of results)?

Yes

7. Do the authors give proper credit to related work and clearly indicate their own new/original contribution?

Yes and no. Important previous glacier inventories in the area should have a more prominent place within the manuscript.

8. Does the title clearly reflect the contents of the paper?

Not really. The title does not indicate the time frame under investigation (last decades? Last millennium? The Holocene?) and introduce the land use changes in this region which are only marginally relevant for the purposes of this study.

9. Does the abstract provide a concise and complete summary?

In my opinion should be improved substantially.

10. Is the overall presentation well structured and clear?

See general comments above. I believe the paper should be significantly shorter and focus specifically on the analysis of glacier changes at Sierra Velluda, leaving the methodological discussion for an accompanying study perhaps.

11. Is the language fluent and precise?

In some section. The Discussion and Conclusions section should be improved significantly.

12. Are mathematical formulae, symbols, abbreviations, and units correctly defined and used?

Yes.

13. Should any parts of the paper (text, formulae, figures, tables) be clarified, reduced, combined, or eliminated?

See question 10.

14. Are the number and quality of references appropriate?

Yes.

15. Is the amount and quality of supplementary material appropriate?

Not applicable.

Specific comments Page Line Comment

685 1-5 It is my understanding that central Chile is known as a “hot spot” not because the reasons proposed by the authors but because of its very rich and greatly endangered biodiversity (a very high number of endemic species under great stress from human activities). Please check and clarify if necessary. In addition, I think that putting the retreat of glaciers and their impact on this region′s water resources as the introductory sentence of the paper is a bit misleading. I am not saying here that glaciers in the area are not important as water resources, but regionally their impact seems to be quite small compared to rainfall and snow. Mean monthly streamflow data for the Bio-Bio river at Rucalhue (data available at http://www.dga.cl/productosyservicios/informacionhidrologica/), indicate this river is a major river in terms of monthly and annual discharges and can reach (on average!) up to 700 m3/second during peak discharges in June and July. The March 2011 report shows that the river has, on average, a bimodal hydrograph with a peak in mid winter (Jun-Jul) and a second peak in spring (Oct-Nov). Thus to me it is highly unlikely that the small glaciers at SV (ca. 25 km2 in area) and the other relatively small glaciated areas within the basin contribute significantly to the runoff of the Bio-Bio river, which is clearly fed mostly by rainfall in winter and by snowmelt at the beginning of the warm season.

685 6-8 In one sentence it says the focus are volumetric changes and in the following sentence it says frontal, areal and volumetric changes. Please rephrase as the 2nd sentence is more accurate.

685 6 Please provide geographic coordinates for the study area. It would be important to mention somewhere in the abstract the total area covered by glaciers in the SV massif at the beginning and/or at the end of the period under investigation.

685 9 This sentence in the abstract is not clear, please rephrase. To me it is not clear the need to perform an analysis of significance in relation to the measures of accuracy of glacier changes. If I understood correctly from the text (page 690, lines 15-21; page 702, lines 13-19), the authors assess only those frontal and areal changes that are significantly different over a certain period of time. If that is correct, I don′t understand why changes that are NOT statistically significantly different in two different dates should be discarded, as they are also providing important information, i.e. They indicate that glaciers have not changed much in size during the period under study (they have remained of approximately the same size), and that in itself is an important finding!

685 12-14 I think the discussion of the 1828 “maximum” position of the glacier front is somewhat confusing. The evidence available is not related to a glacier advance or to the maximum position reached by the glacier during the Little Ice Age, for example, and therefore it is quite complicated to try and relate this data point with the evidence provided by other proxies. The information is just an indication that in the past (1828) the glacier was more extensive than at present, but there is no way to find out (or at least it was not clear to me from the text) if the glacier was advancing, retreating or stationary at that time. Therefore I think it is too complex extrapolate this single date to what other climate proxies might be telling from this region.

685 17 It is not clear here if the general shrinkage is related to ENSO or the PDO? Please be specific as these are quite different ocean-atmospheric features acting on different time scales (inter-annual vs. multi-decadal) along the Pacific basin.

685 23-25 I understand this is a highly altered region in south-central Chile but in order to support this claim I think it is necessary to show (at least as approximate figures)

what is the actual contribution of glaciers to the surface runoff of the Bio Bio basin. As I said earlier I am not convinced that glacier melt is nearly as important hydrologically as snowmelt or winter rainfall in this region, and therefore the claim that this region is of concern due to the impact of glacier retreat on water resources is difficult to support with the streamflow data available.

686 1-3 It is not clear here why is it more important to develop studies of climate change where climate has a transitional character than in other regions of the planet (where climate is better defined maybe?)? Please explain better.

686 8 replace “extant” by existing?

686 7 I think it is absolutely necessary to discuss in much more detail the work by Valdivia (1984) and Rivera (1989) in this area. Are the glaciers in these earlier studies the same glaciers discussed in this paper? If they have already developed glacier inventories for this region, please provide total areas, location and other relevant details from these studies. Is there a way to incorporate this previous information that would allow a visual comparison of glacier sizes that could be shown in addition to the figures provided here?

686 12 In the abstract (line 8) you say “frontal, areal and volumetric changes”. Please be specific.

686 to 695 All these pages have in my opinion too much detail and could be trimmed quite substantially. I would strongly suggest focusing only on the main points necessary to understand the methodology and the key aspects of your analyses without getting into much detail on less relevant aspects of the study (e.g. instead of describing the websites where the images were obtained, I would just mention which images and dates were used; instead of discussing the many options of band ratios available for identifying glacier ice in the literature, just focus on the band ratio that worked best for your area). Please also indicate which threshold you selected for the band ratio you applied for mapping your glaciers (currently not mentioned in the text).

Please also see my comment above regarding the scope of the paper. I would suggest removing most of the methodological discussion on the uncertainty calculations and DEM comparisons and leaving only what is absolutely necessary to understand the main results presented here. Although these tests appear to be an interesting set of analyses for this area, I think that, as presented, the detailed description in these 10 pages does not help the manuscript as it makes it too long and arid before the reader gets to the main point which is the discussion of glacier changes in the SV.

696 4 Please indicate which year you are talking about here.

696-697 I think it is important to indicate here some basic but crucial facts such as how many glaciers are considered, their total area, range of sizes, altitudinal range, etc.

Given the coding adopted to identify SV glaciers, I think it is also very important to also provide a well labelled, clear and good size figure indicating where the glaciers are located, their relative position within the SV, etc. This is not easy to discern in the figures provided with the manuscript.

696 9 Please indicate which glaciers you are referring to here.

697 15-17 The reasoning followed in the sentence about the dynamics of the glaciers /7 and /8 is confusing. Please explain better.

698 9 Replace “glaciered” by glaciated?

699 11 From Fig. 5 it is not apparent that a “significant reduction” has taken place in the SV. The figure shows some retreating fronts but also several advances and by looking at the figure it is hard to assess which is the net result of these changes. Maybe a better way of portraying these changes would be to present cumulative changes over time? That would probably show the end result in more clearly.

699 18 Please see comment above regarding the 1828 position of the glacier. The evidence presented here points to a more extended frontal position of the glacier in the past but cannot be related specifically to a glacier advance (as seems to be implied

here in the comparison with the Cipreses glacier). This data just indicates a point in time of the glacier front which was ca. 676 m more extensive that today, but I think it is risky to refer it to a “maximum” position as we have no clues if this was in fact a maximum position during a certain period of time or not.

699 25 What evidence???

700 2-5 It is quite hard to follow this reasoning. Please explain better.

701 8 ENSO or PDO? Which one are you referring to here? See above, ENSO and PDO are not the same thing, please be specific.

700-703 Most of the information provided in these final pages is quite interesting but in many cases it is difficult to follow the reasoning used to relate this complementary information with the changes observed on SV glaciers. I find there is too much information and that it is used to make highly speculative inferences that are very difficult to support without proper testing or additional data. In particular, I find the discussion about the relationship between SV glaciers and climate changes not very strong, and would suggest not extending the conclusions beyond what can be demonstrated empirically by the results of this study.

Finally, I would also suggest revision of the English language used in the text (especially in these last pages with the discussion of results and the assessment of additional evidence from the region).

Tables 4-6 In order to save space, maybe these three tables could be merged together and the results for frontal, areal, and volume changes presented in just one table?

Figure 5 Maybe presenting the cumulative changes over time would show a clearer picture and support better the claim for a significant reduction of glacier area in this region.

Interactive comment on The Cryosphere Discuss., 5, 685, 2011.