

Interactive comment on “Glacier changes and climate trends derived from multiple sources in the data scarce Cordillera Vilcanota region, Southern Peruvian Andes” by N. Salzmann et al.

N. Salzmann et al.

nadine.salzmann@geo.uzh.ch

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Many thanks for the constructive review, which helps us to improve the manuscript considerably. Please find the replies to each point of your comments below.

Major points

1) Scales: - Representiveness: This is certainly an important issue. We will give more attention to this topic in the manuscript, particularly regarding the differences between ice cap type glacier and mountain type glaciers. The representativeness is finally assessed based on glacier response times.

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- radar: Of course, one radar profile is not valid for all glaciers of the Cordillera. Nevertheless, in view that this is the only available measurement for ice thickness in the CV, it is an important source of data to analyze the model results.

- types of glacierized areas: As mentioned above, we include in the manuscript some more discussion on the difference between ice cap type glaciers and mountain type glaciers.

- glacier response: Although in principle the processes are of course the same, differences in local topography and microclimate can lead to different response time (see also above). Based on the available data for CV and regarding the related scale of our study, we can, however, assume relatively similar response times.

- How many glaciers are in the Cordillera Vilcanota: We can provide a number based on the Peruvian glacier inventory from 1962.

- What are the distribution of the altitudes of the glaciers: Again, we can provide a number based on the Peruvian glacier inventory from 1962.

2) Glacier volume: - Presentation of methodology: In our view we do not present the methodology in three different chapters. In Chapter 4.1.2 we describe the method that we used in the current study to estimate glacier volume. In chapter 5.1 (Result section) we only validate the results achieved by the method described in 4.1.2 with a radar profile. In chapter 6.1 (Discussion section), finally, we put our results for CV in a regional context by comparing our results with results from studies in the tropical Andes. Therefore, we prefer to keep this structure of the article.

- calculation: as indicated on page 396, we use values for shear stress that are plausible based on available literature. We are fully aware that some uncertainty is related to the estimate of shear stress, which has an effect on volume calculation. Shear stress estimates are, to our knowledge, not available for the tropical Andes glaciers. We therefore make several physically plausible assumptions that we will document in more

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detail. Eventually, it is important that we take uncertainties into account by defining a range of shear stress values, rather than just one unique value. We will therefore explain the runs based on Eq 1 more clearly in the manuscript. - five glaciers only: Estimate of glacier volume reduction from 1962 to 2006 depends on the reduction in glacier area and ice thickness. We have a satellite based assessment of 2006 glacier areas but no similar estimate or measurement for ice thickness (except the radar profile). Our approach therefore is to select several (5 in this case) glaciers that represent different glacier types across CV. We calculate ice thickness for 2006 based on these selected glaciers, using the same method as for 1962. These calculations indicate a general thickness reduction of 10-20%, which we then take into account for the ice volume estimate for the whole CV. We believe this is a transparent method that does not try to introduce any precision that is not supported by the uncertainties necessarily related to ice volume estimates.

- Bahr's method: Currently available methods for glacier and ice volume estimate imply an uncertainty of about 20-30%. This is also true for Bahr's method. However, it could in fact be an interesting added value to compare the method we used with results of the application of the Bahr method. The reviewer furthermore doubts the necessity of any volume estimate in our study. Based on our knowledge and experience in the region, we can state that ice volumes in fact are of major importance in relation with water resources. While we are able to present data on glacier area changes with much higher precision than for ice volumes, we are convinced that both, scientifically and in view of impacts of glacier retreat on water resources, our ice volume estimates are of interest. Therefore, we would like to keep the volume estimates in the article.

3) Glacier area: Many thanks for pointing to these additional references. They will be included in the article. We have been discussing already at an earlier stage the possibility of a table showing all results from different studies. However, due to the many difficulties associated with comparability of different studies (area, methods, etc.), such an effort goes beyond the scope of this paper, and would rather be a separate

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paper.

4) Santa Rosa: - correlation coefficients: We will provide the correlation coefficients.

- arithmetic mean: We believe there is a misunderstanding. We have calculated the value for Santa Rosa by using linear correlation estimates from several nearby stations. From these estimates we have then taken the arithmetic mean. We believe this approach is sound and in fact what you are proposing. However, we will rewrite this part in the manuscript in order to describe the approach and make it better understandable.

- lapse rate: We did not use lapse-rates for reconstruction, but used the linear correlation estimates from nearby stations (see above).

- liquid-solid: We will provide some estimates about the seasonality of the liquid-solid limit.

Specific comments: - abstract: We will skip specific humidity in the abstract and emphasize on glacier change.

- change 'precipitation sum' to 'precipitation': We don't see the argument here. Since we used precipitation sums (and not frequency or an other precipitation parameter) the term p precipitation sums is correct.

- Map: We can provide an overview map.

- 391-6-7: will be skipped.

- area estimation: Well, we would of course be very happy to present 'good' estimates, but to our knowledge, the study of Morales-Arno is the only one for the specific area, and in our view should nevertheless be mentioned to be as complete as possible. We will also further outline the 'differently defined spatial domain of the CV' (i.e. the definition of glaciers that are included in the assessment), which is related to the general difficulties that apply when it comes to the definition of borders and comparisons of results from different studies in general (see also comment regarding a Table under

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point 'Glacier area' above).

- ENSO: Without annual mass balance measurements, the influence of ENSO is difficult to quantify. In general, the CV area is not heavily influenced by ENSO, at least not in terms of temperature and precipitation. Nevertheless, we will enhance somewhat the discuss the possible influence of ENSO on glacier changes.

Interactive comment on The Cryosphere Discuss., 6, 387, 2012.