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The Cryosphere Discussions

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.

Anonymous Referee #2

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GENERAL COMMENTS

The authors address relevant questions on glacier changes and climate trends in the data scarce area of Cordillera Vilcanota, Peru. Such information is much needed because glacier retreat is rapid in this region and impacts the role of glacier as water reservoirs. It is a good idea to assimilate a collection of data from multiple sources (satellite, meteorology, Climate Reanalysis, ground penetrating radar). I have read this paper with great interest. Nevertheless I recommend asking for major revisions because, in its present state, its value for other researchers is quite limited. The study area and the data are not enough described; the climate study must be improved; the

methodology to estimate the volume must be revised.

The paper must better underline the different scales of the study, from the specific Qori Kalis glacier to the Quelccaya Ice Cap and the whole Cordillera. What is the representativeness of this specific glacier at the level of the Cordillera? Is one radar profile valid for the whole Cordillera? What are the different types of glacierized areas in the CV? Do the glaciers around the highest peak at 6384m react similarly to the ones around the Quelccaya ice cap? How many glaciers are in the Cordillera Vilcanota? What are the distribution of the altitudes of the glaciers?

The glacier volume estimation is not clear. It is not understandable to present the methodology in three different paragraphs (presently 4.1.2, 5.1, 6.1). The calculation runs must be explained to determine the shear stress value around 1.2 bar. Is the thickness in Equation (1) only linked to the surface slope, because the values are constant for f, ro, tau and g. Is this slope variable on the ice cap profile of Fig. 2? Why do the ice thickness estimates based on only five glaciers. What were the criteria to consider the glaciers as representative? The methodology for volume estimation sounds too much empirical with huge uncertainties! At least, scaling laws between area and volume (Bahr's method) will give values to compare. Moreover, I am not convinced that the volume estimation is necessary in this paper.

Glacier areal changes of Qori Kalis have been analysed by Brecher and Thompson (1993) and by Thompson et al. (2006). These references must be added. The present results are important to illustrate the evolution in the region. The changes must be compared to all the results on glacier changes in the part of the Andes. Due to the location of the Cordillera Vilcanota closed to the Cordillera Real (Bolivia), the comparison is then important with the data from Soruco et al. (2009). A Table could be useful with all the areal glacier changes from the bibliography concerning Cordillera Vilcanota, Cordillera Blanca, Cordillera Real. The climatic context of the three cordilleras is not so different.

The reconstructed data for Santa Rosa must be revised. The correlation coefficients between the climate records must be given. The arithmetic mean of different estimations is not a correct method to fill missing data. Were the lapse-rate values used to reconstruct the Santa Rosa missing temperatures with the surrounding stations at different altitudes? Were the lapse-rate values used to reconstruct the precipitations at Santa Rosa? In the discussion, the limit between liquid and solid precipitation is an interesting comment that could be quantitatively presented: what are the values and what about the seasonality of this liquid-solid limit?

SPECIFIC COMMENTS

In the abstract, the specific humidity trends are questionable and should not be introduced in the abstract. The results on the glacier areal changes must be emphasized.

388-17 and throughout text: “precipitation” and not “precipitation sums” In the description of the study area, a general map of Peru (linked to Fig. 1) is needed in order to locate Cordillera Vilcanota (CV), and also to point out: Cusco, Cordillera Blanca, Laguna Sibinacocha, Nevado Ausangate, Lago Titicaca, Atlantic Ocean, Apurimac... I am not convinced that the description of the drainage system is useful for the present paper (page 390, lines 25...).

391-6 to 7: skip these lines because they are also given in the introduction.

391-9: in this part, you must give a good estimation of the glacier area and not an erroneous estimation (579 km2) from Morales-Arnao and Hastenrath (1999). Explain the comment (page 401, line 28) on the “differently defined spatial domain of the CV” in the present study and in Morales-Arnao and Hastenrath. The difference is huge, more than 100 km2 and needs a precise explanation!

391-28: the influence of ENSO is briefly mentioned but not further analysed, whereas two strong events (1982-83 and 1997-98) concern the period. Is ENSO a possible explanation of some glacier changes?

392-18: it is not “more than half a century” from 1962 to 2006?

395-12: do debris covered glaciers represent an important area in CV?

396-2: units of every variable in Equation (1) must be given (units of hf, tau?).

398-3: explain “sigma levels” NCEP/NCAR Reanalysis?

399-17 to 29: the analysis of the GPR campaign has to move out of this paragraph on the glacier changes (area and volume), perhaps into the estimation of the thickness (paragraph 4.1.2). The analysis of GPR needs to introduce the elevation of the ice cap in the Fig. 2 (where is the summit of the ice cap?).

401-22: the Coropuna glacier is part of the Cordillera Ampato. What is the meaning of “considerably different climatic regimes” for the three Cordillera: CV, Coropuna, Cordillera Blanca?

407-5: Reference for UNFCCC?

Brecher, HH., Thompson, LG. (1993). Measurement of the retreat of Qori Kalis Glacier in the Tropical Andes of Peru by terrestrial photogrammetry. Photogrammetric and Remote Sensing, 59, 6, 1017-1022.

Thompson, LG., Mosley-Thompson, E., Brecher, H., Davis, M., Leon, B., Les, D., Lin, PN., Mashiotta, T., Mountain, K. (2006). Abrupt tropical climate change: Past and present. Proceedings of the National Academy of Sciences of the United States of America, 103, 28, 10536-10543.

Soruco, A., C. Vincent, B. Francou, Gonzalez J.F. (2009), Glacier decline between 1963 and 2006 in the Cordillera Real, Bolivia, Geophys. Res. Lett., 36, L03502, doi:10.1029/2008GL036238.

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