

Comments on “Glacier changes in the Pascua-Lama region, Chilean Andes (29°S): recent mass-balance and 50-year surface-area variations”, by A. Rabatel et al., *The Cryosphere Discussions*, 4, 2307-2336 (2010):

J. Graham Cogley, March 2011

This paper documents in detail a set of measurements of mass balance and shrinkage of mountain glaciers in the subtropical Andes of Chile. Balance measurements began in 2003/04 and areal extents have been determined from imagery at four dates going back to 1955. The shrinkage rate has varied, but was greatest during the most recent period, while the average mass balance over six recent years has approached -1 m water equivalent per year. The smallest glaciers have shrunk most rapidly and have the most negative mass balances. There is a detailed discussion of climatic forcing. It focuses on the Pacific Decadal Oscillation (PDO), the ENSO phenomenon being mentioned only briefly.

The work reported appears to have been technically competent. It derives significant added value from having been done in a region with very few existing quantitative records of glacier evolution. This is therefore an important contribution. I found the weakest part of the paper to be the discussion of the PDO. The records from the Pascua-Lama glaciers are short or have low temporal resolution, and the paper resorts to comparisons with longer series from Echaurren Norte Glacier and elsewhere. But, as far as I can see, the glaciological records do not match particularly well with the PDO index, so the discussion is at best not very persuasive.

This criticism does not reduce the value of the Pascua-Lama measurements themselves. I recommend that the paper be accepted for publication subject to consideration of the idea of reducing the emphasis on the PDO, and to addressing the substantive and stylistic points raised below. The most important of these points are i) providing additional tabular information on the measurements and ii) removing a few hundred hyphens.

Substantive Comments

P2308

L22 Explain “arid diagonal”, or remove the reference to it.

L2309

L24 The definition of “glacieret” should be referenced in more detail. I am a bit surprised that small size is not part of the definition, and the Pascua-Lama glacierets do not seem to fit the definition anyway.

L2310

L17 On which glacier was the speed of 2.0 m a^{-1} measured? Provide an address for Golder Associates, or other details that would enable the reader to obtain more information.

L18-20 Explain how the thicknesses were measured, and give mean as well as maximum thicknesses in Table 1 if they are available.

L2313

L17 Presumably this should be “(root of the quadratic sum ...)”.

L2314

L15-18 Perhaps “halting melting” should be “inhibiting melting”. I do not understand “isolating the glacier ... ice temperature”. It should be “isolating the body of the glacier ...”, but the rest of the clause is unclear.

P2315

L2 “Figure 3 presents”: these data are sufficiently important that they ought also to be tabulated, in full.

L9 Define the coefficient of variation briefly.

P2316

L13 What is ρ ? It looks like $(1-p)$, where p is the probability that r differs from zero. p would be a more usual way to present this information.

L14 Change “decreasing with altitude” to “increasing with altitude”. Ablation is implicitly a negative quantity in all of the graphs.

- L16-17 I would have thought that shelter from high winds might discourage melting. It would certainly favour deposition of windborne snow. Why cannot stronger melt at low elevation be due simply to higher temperatures (i.e. more time spent above the freezing point)?
- L24 Change “This means” to “This suggests”, to reduce the strangeness of the sums exceeding 100%. Consider also deleting the parentheses and ending the sentence with “, while for the glacier the corresponding percentages are 64% and 51%”; the parenthesis trick saves space, but it also reduces readability and impact.
- P2317
- L19 I do not understand “elevation-driven temperature-dependent contrast”. Expand and clarify what is being referred to.
- L20-21 Surely the penitents could be a *result* of enhanced ablation?
- L24 “The consistent formation of penitents”: this argument seems illogical to me, or at least not thought out in sufficient detail.
- P2319
- L11 Make the red and blue boxes in Figure 7 two (or four) standard deviations high, and explain the height in the caption.
- L27 “These data reveal ...”: I do not agree, and suggest deleting this and the next sentence. In fact, the PDO could be removed from the paper altogether. I cannot see the connection. It is clear from Figure 7 that the balance of Echaurren Norte was slightly positive on average during the early part of the positive phase of the PDO. But there was a striking shift at about 1989 to strongly negative balance for the remainder of the positive phase, and the balance has been stable or slightly positive during the current negative PDO phase. In Figure 7, the cumulative balances for Echaurren Norte and Guanaco should both be set to zero at the same reference date, probably 2003/04.
- P2320
- L8 Explain why the geodetic balance for 2002/03 on Guanaco has lower accuracy than the corresponding glaciological balance for Echaurren Norte.
- L13 I doubt the value of this long semi-quantitative discussion of links with the PDO. At the least, it should be shortened by focussing on the numbers (Pascua-Lama shrinkage rates, and average Echaurren Norte balance rates and PDO indices for periods that are synchronized as closely as possible with the dates of Pascua-Lama imagery).
- P2321
- L9-10 The value of the remark about standard deviations is doubtful. About one in 40 should be in excess of $\pm 2\sigma$ if the precipitation anomalies are distributed normally, but it is clear that the distributions are not normal.
- L16 This paragraph about the lack of dependence of balance on temperature would be stronger if correlation coefficients and slopes (i.e. dB/dT) were presented. I am surprised that the trend of $+0.19^\circ\text{C}/\text{decade}$ is not significant, because it accumulates to a T that is higher by 0.9°C in 2007 than in 1958.
- P2323
- L1 This conclusion could be deleted.
- P2329
- Table 4 I would expand this table to give the important facts: the area of each ice body at each of up to four dates.

Stylistic Comments

P2308

- L3 This paper is marred by some hundreds of mistaken uses of the hyphen. It has been written without regard for the simple distinction between adjectival nouns and phrasal adjectives. See Moxham, K., 2007, Notes from the production team, *Ice*, **144**, 14. Every single hyphen in the paper must be checked. The great majority, including some in figure captions and even in figures themselves, are wrong. Here “ice-bodies” is the first of the mistakes. “ice” is an adjectival noun (a noun doing the work of an adjective) and should not be coupled to the noun “bodies” that it qualifies.

- L4 “high-elevation” is a phrasal adjective (a noun phrase doing the work of an adjective) and is hyphenated as it should be. (“high” qualifies “elevation”, not “area”.)
- L6 The text contains many numerals for numbers less than 10, such as this “6”. They should all be written out as words.
- L12 “Based on these datasets”.
- L25 “to”, not “from”
- L26 Delete “found on” and “on”.
- P2309
- L8 “have so far produced only ...”.
- L19 Delete “extent of”.
- L23 Delete “Glacier”.
- L28 Delete “better”.
- L29 End this sentence at “50 years”.
- P2310
- L10 Delete “network”.
- L15 “leeward sides”.
- L18 “Their surface areas range ...”.
- P2311
- L25 “precipitation”.
- P2312
- L23 Should “INFOSAT society” be “INFOSAT company”? An alternative would be to give the full name in Spanish. See also P2313 L4-5.
- L26 “on average”. This also needs to be corrected in some other places later in the paper.
- P2313
- L6 “on 27 April”. At L8-9, “on 1 March 2005 and 26 March 2007”.
- L14 “manual identification and delineation of”. Delete “and the ability to identify the glacier contour”.
- L16 “accurate visual identification”. Delete “, estimated visually”.
- L18 Delete the sentence “This total ...”.
- L19 Delete “the calculation of” and change “corresponds to” to “is”.
- P2314
- L1 Delete “available”.
- L4 Delete the comma after “glaciological” (or move it to follow “monitoring”).
- L14 Delete “processes”.
- L19 “Accumulation results ...”.
- P2316
- L9 Delete “on the ice-bodies”.
- L20 Delete “respective”.
- L29 “role ... in”. You can say “impact ... on”, but “role ... on [a dramatic performance]” is a misuse of the metaphor.
- P2317
- L1 “stronger”, not “higher”. “mid-latitude”.
- L16 “on the glacierets, which extends to a lower elevation than on the glacier”.
- L18 “explanations of”
- L21 Comma needed after “penitents”.
- L25 “to widespread surface dust deposits, as ...”.
- L27 “Laboratory measurements ... that dust-covered snow forms penitents more readily, and has ...”. What does “peak separations” mean (vertical, or horizontal)?
- P2318
- L2 “at near-infrared” (not “for”).
- L3 “is crucial”. “irradiance at these wavelengths is likely to be greater at the borders”.
- L5 Delete “heated”.
- L22 “e.g. for 1981”.
- P2319
- L4 Delete “individual”.

- L9 “with glaciological and climatological data series, including PDO variations”.
- L11 “The PDO shifts between ...”.
- L15 “because of the lack”.
- P2320
- L14 Delete “annual”.
- L15 “south”.
- P2321
- L6-7 The two semicolons after “m a.s.l.” should both be commas.
- L12 “between the sites”.
- L20 The abbreviation for “millibar” is “mbar”, not “mb”. See also L5 of caption of Figure 7.
- P2322
- L1 “... melting is limited. Hence, ...”.
- L4 “at the glacier surface”.
- L5 Delete “in this region”.
- L21 “annual equivalent” is redundant, and “shrinkage” would be shorter and clearer than “glacier surface-area recession”.
- P2326
- Fig7 The light grey boxes are invisible when printed.