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The Cryosphere Discussions

Interactive comment on "Glacier contribution to streamflow in two headwaters of the Huasco River, Dry Andes of Chile" *by* S. Gascoin et al.

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Reply to Anonymous Referee #2

1) Abstract: Five glaciers in the text when six are cited including Toro 1 and Toro 2.

That was an unfortunate error, corrected.

2) Last sentence: give quantitative results rather than just "revealing large differences".

The following text was added: "(from 1mm w.e./h to 6 mm w.e/h)"

3) p. 2376; l. 8 : Escobar et al. 1995 : not found in references.

added

4) p. 20 to 27 : high value of sublimations are cited in %, it would be interesting in mm/year.

The values are 327 mm/y for Tapado, 77 mm/y for the High Atlas and were added in parenthesis. Sublimation rates in mm/y depend on the accumulated snow amount and therefore should be compared with caution. For example the value from Schulz and de Jong (2004) was calculated for the ablation of 171 mm accumulated SWE between November and December only (we presume the rate would be larger considering the whole snow season).

5) p. 2377, l. 5 : precise what is different in the seasonal variability between Tropical and Dry Andes (different and interesting for the purpose of the present work).

We added "seasonal variability is less pronounced"

6) l. 10 : "the mean annual discharge measured " => the mean annual discharged is estimated (computed) not measured.

Changed.

7) l. 11 : "We also present direct measurements of meltwater discharge" => direct measurements can be done in terms of length, time, weight ... not in terms of m3/s (that result of computation - transformation of direct measurements) and moreover it is not clear how direct measurements of meltwater discharge could be carried on. That could be possible if it was clear how to make the difference between meltwater and other contribution to the discharge.

We agree with Referee 2 that what we call here "discharge measurement" is the result of a calculation (horizontal and vertical integration of the river flow velocity field). However we believe that this calculation is accepted as a standard procedure by the hydro and glaciology communities and can be presented as a measurement? The term "discharge measurement" is used throughout the "Guide to hydrological practices" of the WMO (1994, e.g. "Chapter 11 – Discharge measurements").

Regarding the meltwater contribution, we can only provide our experience from the field. As we responded to Referee 1, measurements were made in January and February, when the seasonal snow cover has almost completely melted all over the study area (except on the glaciers). We are confident that snout water comes almost exclusively from the glaciers. Even if some small snow patches can persist in summer, their contributing area is very small in comparison with the glacier surface at each measurement location.

8) l. 25 : precipitation occurs almost exclusively as snowfall : what is the argumentation for that (see for example paper from Lhote et al, 2005, HSJ). And precise the months of summer time

We added a reference to Favier et al. (2009) and indicated the summer months ("between December and February").

9) p. 2379, l. 19 : what is recorded is the water level. Precisions on possible errors of the discharge estimation based on these measurements would be useful.

The conversion of water level to discharge are done routinely by the mine staff. Unfortunately we could not assess the accuracy of the rating equations to provide more information on that uncertainty (see response to Referee 1). Note that the data we used are the official data distributed by the mine company to governmental agencies.

10) l. 21 : "assumed to be a direct measure of the glacier meltwater discharge" => precise what can be not taken into account, groundflow below the glacier ? see for example paper from Favier et al. on a glacier in Ecuador.

We agree that subsurface flow is not taken into account and this point was acknowledged in the discussion. However, the hydrogeological setting in Pascua-Lama seems to be quite different from what was reported by Favier et al., (2008), in the Antizana, where glacial streams disappear and reappear between the glacier snout and the gauge station. In Pascua-Lama the surface runoff is always apparent and confined to small gullies from the glacier to the gauging site.

11) In general, in the section 3.2 Data of Hydrology, considerations on data and on interpretation of data are combined before the presentation of Methods in section 4. It would be clearer to limit in section 3 the presentation of data.

We included this paragraph in the data section as from our perspective it is a simple description of the runoff regimes in the study area. We leave it to the Editor to decide if this is appropriate.

12) p. 2381 l. 1 : give an example of the variation of the actual area of a glacier now and five years before.

For all glaciers the average area reduction is 1.07% over 1996-2005 and 1.75% over 2005-2007 (added to the text). More details can be found in Rabatel et al. (2010), e.g. Fig. 6.

13) l. 5-9 : even if the data of accumulation and ablation are presented in Rabatel et al. (2010) some more informations should be recalled here : are the data collected over the whole area of the glacier ? once a year ?

We added the following text: "Accumulation data were collected once a year in late winter (late summer for ablation). Due to the small size of the studied glaciers, the stake network is relatively evenly distributed on the glacier."

14) l. 11-15 : measurements of sublimation by twelve experiments on lysimeters are not convincing: no precipitation during the experiment ? effect of the lysimeter ?

Lysimeter experiments that were affected by precipitation were excluded from the dataset presented here. Lysimeters were placed in holes as described by Winckler et al. (2009) to limit the effect of the lysimeter rims on the turbulent fluxes. Hence we assumed that lysimeter surface is representative of the surrounding surface, as done previously by Hastenrath (1978), Wagnon et al. (1999), Ginot et al. (2001), and Winckler et al. (2009) among others.

15) l. 16 : precisions needed on how these experiments from lysimeters give information on sublimation + melting rates.

We added the following description: “Lysimeters are composed of a top plastic container with small holes drilled at its bottom, embedded onto a second, lower hermetic container used to collect meltwater percolating from the top container. The apparatus is inserted so that the top container is flush with the snow surface. Surrounding snow was used for snow experiments while refrozen water was used for ice experiments. Melting is measured by weighting water accumulated in the bottom container, while sublimation is calculated from mass loss in the top container (total ablation) minus the melting amount. Experiments that experienced snowfall, or that had water refreezing inside the top container, were excluded.”

16) l. 24 : hydrological year in general begin from the lower monthly discharge (not melt season)

We agree and it is the case. We added it to the text.

17) p. 2382, l. 7 => precise the area considered for te equation F=Ab-S (the whole glacier, cf area in table 1 ?)

As indicated in Sect. 3.3 we took the areas from the glacier inventory of the Huasco valley by Nicholson et al. (2010) and an orthorectiïňĄed Ikonos image of the Pascua-Lama area. The whole glacier area was considered.

18) How S vary from one experiment to another ?

The sublimation rates are 2.5 mm/d for S1 and 77% of the total ablation for S2 (mean of the values given in Tab. 3). This was added to the text.

19) Table 3 give “Ablation fraction “ and not sublimation. That is not clear. And how data from lysimeters are used (applied) on an overall glacier (and why? – whith which assumptions ?).

The table caption was modified to make it clear: “Lysimeter (. . .) giving the sublimation rate in mm/d and as a fraction of the ablation rate”. We explained in Sect. 4.2.4 how lysimeter data were processed to obtain an estimation of the mean annual sublimation of Eq. (1). The underlying assumption is that lysimeter experiments made at four different sites can be extrapolated to the 74 ice bodies found in the study area.

20) l. 23 : ablation rates inversely proportional to glacier size : papers from Francou et al. on the disappearance of Chacaltaya glacier in Bolivia could be cited.

The reference Francou et al. (2003) was added to the text in Sect. 6.3.

21) p. 2383, l. 21 : precisions needed on how absolute sublimation rates are estimated from lysimeter experiments.

See response to comments 14 and 15.

22) p. 2388, l. 22-23 : justify why the evaporation is assumed negligible (when sublimation is not). See for example, paper from Favier etl. On groundwater from glacier that take into account estimation of evaporation.

By “evaporation” we meant evapotranspiration from the snow- and ice-free areas. It is explained that “vegetation cover is very sparse” in the studied catchment. As for the non-vegetated area, we added to the text that “the bare soil evaporation was presumed negligible because there is no soil layer to store water.”

23) p. 2389, l. 25 : “hydrological system is not in equilibrium with climate". A discussion would be welcome in the section 1. 2. Or 3. On the elevation of the equilibrium line of glaciers in the area (from generic studies as for example Condom et al. over the Andes). It sounds that presently the glacier in these dry Andes are not in equilibrium with present climactic conditions. And thus, the equilibrium line can be over the altitude of the summit of the glaciers . . . (?)

We have discussed in this section the origin of this transient state (a combination of long term and short term tendencies). As mentioned in Sect. 4.2.3 the concept of equilibrium line is not applicable in the Pascua-Lama context, hence we believe that it would be confusing here to refer to Condom et al?

24) Table 1. precise the period (2002 – 2008 ?) and check area and glacier cover, especially between Toro and Potrerillo. On figure 1 (Map) The Area of the Potrerillo catchment (VIT-3) sounds larger than the one of Toro (when in table 1 it is the contrary).

The period was added. The error (570 instead of 5.70 km2) was corrected (also noted by referee 1).

25) Table 2. precise number of stakes and period of measurements and range of altitudes of the stakes

We think it is unnecessary as all these data are given in Tab. 1 in Rabatel et al. (2010).

26) Table 3. Precise how the ablation fraction (last column) is computed. Figure 2. Would be interesting to have the mean value of monthly precipitation (max in June – August when the max monthly discharges are in January – February (exact ?).

See response to comment 15 for the ablation fraction.

As for the precipitation we have given in introduction the mean annual precipitation at El Indio (and indicated that 81% occurs between May and August), which is the nearest reliable precipitation record (45 km from the study area, altitude is comparable to Pascua-Lama). The monthly data are not required for our study which focused on annual contribution of glaciers to streamflow. Moreover, the reader can refer to Favier et al. (2009), (cited in introduction) to get further information on the precipitation seasonality. We let the Editor decide if we should provide these monthly data in a new table?

27) Figure 5. a) precise the number of glaciers under consideration : 74 ? b) indicate the name of the glaciers, which is the one with more than 1.8 10 6 m2 ? no one of such area is listed in table 2.

It is because we indicated in this table the contributing area of the glacier to the VIT-3 catchment, which was indeed confusing. The actual Guanaco area (1.84 km2) is now indicated in the table, and we added to the caption that “For the Guanaco glacier we indicated in parenthesis the area of the glacier which is within the VIT-3 catchment area.”

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