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# *Interactive comment on* "Assessing glacier contribution to river runoff in the Andes of central Chile: Analysis of in situ weather station data, runoff measurements and melt modelling at Universidad glacier (34°40′ S, 70°20′ W)" *by* Claudio Bravo et al.

**Anonymous Referee #1**

Received and published: 17 November 2016

General comments: The authors present an important contribution of glacial hydrology in the Andes of central Chile using both direct in-situ measurements and remote sensing data in order to force satisfactorily a distributed degree-hour model and estimate glacial melt contribution to river runoff in the ablation period 2009-2010.

While the scientific significance is high regarding the research lack of information of in-situ glacier streamflow contribution measurements and the methods are well-applied, the conclusion/discussion and scope of the research should be improved.



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The authors must contextualize their findings with more studies about glacial hydrology, discussing more thoroughly the current status of Universidad glacier (area decrease of the last decades?) and its possible future point of peak water considering current shrinkage rates as well as local and downstream impacts of changing river runoff (in the region). It is not clear, if the results should be seen as a first short snapshot (only 5-6 months measurements) at the beginning of an anomalous period of drought (2010-2015) or if they can be brought into a wider context (ideally with longer in-situ data). While relative glacier melt fraction to river runoff might be high particularly in dry periods and the upper Tinguiririca catchment, relative contribution is expected to decrease with increasing distance from headwaters, i. e. for the low-lying coastal cities and water users. The mention of (the insignificance of) groundwater flows, probably difficult to estimate without direct measurements / tracing methods, should be revised as many different hydrological models have not been capable to adequately represent groundwater flows. Some studies of the last years suggest that they represent an important driver (e. g. Baraer et al., 2014 for the outer tropical Andes of Peru).

Furthermore, several typing and grammatical errors and imprecisions can be identified. For publication, English (errors, vocabulary, redundancies) should be improved.

The manuscript contains multiple tables and figures, most of them helpful for further comprehension, others less substantial. In order to reduce total paper volume, I would skip e.g. Table 1 and Figure 4. However, all anomalies / data gaps in the plots should be briefly indicated and explained in the text or subtitles.

In summary, I recommend a thorough minor revision.

Specific comments: 1 / 10-11: is that true that glacier melt represents more than the half of total streamflow contribution in lowlands during dry years in Chile? I would rather expect a reduction of relative contribution with increasing distance from the glacier and headwaters converting glacier streamflow to an important but not the main contributor in the lowlands. 2 / 38 – 3 / 1: what about glacier area and (estimated) volume changes





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and current retreat rates of Universidad glacier and/or in the region? 3 / 7-8: you identify the year 2009/2010 as (just) the beginning of a longer dry season (2010-2015) but it is unclear why you did not incorporate a longer period of measurements into your study 3 / 18-19: again, you do not explain why your study only covers six months of data measurements 3 / 33-34: how did you discriminate snow from ice with the NDSI? Thresholds and techniques should be mentioned 4 / 3: clarify which images were selected with a cloud cover threshold: Landsat 5 TM? 4 / 14-15: the explanation of how to convert hourly to daily format is very basic and can be neglected 10 / 29-31: again, be careful that you distinguish upstream from downstream (lowland) glacier streamflow contribution, the latter possibly less significant; what about flow contribution in austral winter? Although you have only worked in the ablation period, it would be good that the reader gets a general idea of glacier streamflow contribution changes during a whole hydrological year 11 / 3-6: the point of (future) peak water is not sufficiently investigated in many mountainous regions worldwide but an increasingly important research question, particularly for future water management, can you examine this question about the possible peak water of Central-Andean glaciers in Chile a bit more? More literature? 11 / 13-14: is it true that melt rates are generally reduced further north (until where?) of Universidad glacier? Sublimation process are strongest with a pronounced water vapor gradient which is true for the dry season of e. g. the outer tropics (Peru/Bolivia) but not for glaciers in the inner tropics. 11 / 37 – 12 / 1: is Universidad glacier really such a particular glacier with highest melt rates in Chile? cite comparing literature 12 / 2-3: this affirmation is obsolete as it represents a typical mechanism of glacier energy budget and mass balance 12 / 15: does groundwater flow really become depleted? any studies (e. g. tracers: Rodriguez et al., 2014)? in other parts of the Andes (where reduced ablation also takes place during the winter season) groundwater has been identified to be a strong contributor and generally underestimated in many studies 12 / 24: the last argument should be more developed. The region is important for multiple water users. As an example, just some kilometers downstream, the hydropower plants La Higuera / La Confluencia are situated and possibly strongly

affected by annual/seasonal changes in river runoff 16 / Table 1: this table does not contribute substantially to the study comprehension, therefore I would take it out 18 / Table 3: indicate period in the title "(2009-2010) 20 / Figure 1: upper left: the three gauges are not clearly identifiable; the map text "CECs HydroChile" confuses; also, the abbreviations "CECs" and "DGA" in the legend are not proper; text of the figure: add "(orange outline)" after "Universidad glacier" 21 / Figures 2-13: indicate altitude (m asl) for ALL station data 23 / Figure 4: in order to reduce paper volume, I would skip this graph as it does not substantially contribute for a further process comprehension 25 / Figure 6: eliminate "[dd-mmm-yyyy]" at x-axis legend; you also do not use this definition in Figure 7 26 / Figure 7: indicate gaps which are present between November 21-22 31 / Figure 12: no runoff measurements from March on? explain this data gap

Technical corrections: 1 / 1-3: with 28 words, the title is too long and complicated. A more concise title would be: "Glacier melt contribution to river runoff at Universidad glacier, central Andes of Chile" 1 / 11: eliminate "the" before "glacier melt" 1 / 13: insert "within the" before "central Andes of Chile" 1 / 19: replace "altitude part" by "ablation area" 1 / 28: insert "a" before "crucial resource" 2 / 21: change order "Mediterranean climate type" 2 / 26: use directly the previously introduced abbreviation "AWS" 2 / 32: correct "altitudinal range" 2 / 33: improve "which converge at an altitude" 2 / 35-37: change order considering a clockwise aspect of glaciers (north to the west) 3 / 2-3: "fastest period" does not exist, improve 3 / 9-10: three times the word "measurements", replace 3 / 14-15: not a full phrase, a verb is missing! 3 / 16: correct "net all-wave radiation" 3 / 32: insert "spatial" before "resolution" (there are also other types of resolutions) 3 / 33: better specify "Landsat 5 TM (30 m spatial resolution)" 4 / 1-2: eliminate the long parenthesis "(Advanced Spaceborne. . . Version 2)" 4 / 30-31: improve phrase: it is not "melt overestimation" which is dominated by melt from the ablation zone; instead of "however" you could use "as it" 5 / 5: "and the afternoon maximum" could be the beginning of a new phrase and needs a verb 5 / 14: include "shortwave" before "radiation" 5 / 21: insert "to be" before "a constant" 5 / 22: add "a" before "function" 8 / 2: eliminate "(100% relative humidity" – very basic 8 / 4: correct "was covered" 8 / 21-22:

improve phrase, you could separate it into two phrases from “fluxes calculated by” on inserting a new verb 10 / 3: eliminate “a” before “suitable” 10 / 4: use also the word “correlation” instead of only “agreement” 10 / 8: improve, e. g. “an hourly calibrated lapse rate at the glacier” 10 / 19: maintain the same terms, here “Universidad glacier” 10 / 37: replace “that” by “than” 11 / 14: add “cover” after “cloud” 11 / 20: eliminate “the” before “each” 11 / 24: add “the” before “central Andes” 11 / 25: correct “depends on”; insert “as” before “2013” 11 / 26: correct phrase “while in dry years” 11 / 28: better write “climatic conditions” instead of “meteorology” 11 / 29: insert “model” after “melt” 11 / 34: a final point is missing before “The ablation” 11 / 37: improve phrase avoiding the semicolon with e.g. “and are thus greater” 12 / 2: “latitudinal” instead of “latitude” 12 / 3: “persistent” instead of “persistence” 12 / 11: add “km” after “1.7” 12 / 12: a space is missing before “The total” 12 / 13: improve phrase: “Universidad glacier only represents 36%” 12 / 14: add the year “2010” after “March” 12 / 20: insert “the” before “zero-degree”

References: Baraer, M, J. Mckenzie, B. G. Mark, R. P. Gordon, T. Condom, J. T. Bury, J. Gomez, S. Knox, and S. Fortner, “Contribution of groundwater to the outflow from ungauged glacierized catchments: a multi-site study in the tropical,” Hydrol. Process., 2014.

Rodriguez, M., Ohlander, N. and McPhee, N.: Estimating glacier and snowmelt contributions to stream flow in a Central Andes catchment in Chile using natural tracers, HESS Discussion papers, 2014.

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