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The Cryosphere Discussions

Interactive comment on "Glacier runoff variations since 1955 in the Maipo River Basin, semiarid Andes of central Chile" *by* Álvaro Ayala et al.

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GENERAL COMMENTS

The study examines the glacier mass balances for the upper Maipo, central Chile, between years 1955 and 2000/13 and the corresponding melting water contributions to runoff over that period. This is done by physically-based modelling of selected glaciers and its extrapolation to the entire basin. The approach has been tested abroad and now adapted for the Andes setting for a period that concurs the largest observed retreat rates in historical times.

Input glaciological data are two main glacier inventories separated by 48 years, originated from very different type of sources, resolution, precision, etc, but properly cor-

rected and processed for the purposes of direct comparison as best as possible. These were complemented to Digital Elevation Models (DEMs) of same dates, distributed ice thicknesses obtained from modelling & geodetical balances, and several types of hydro-meteorological datasets (mostly downscaling reanalysis and remotely-sensed data i.e. input local observations are limited). Extrapolations (spatially and temporarily), calibrations and verifications are careful. It is clear, however, that lack of direct radar measurements and AWS data over glaciers must have committed the results at some extent. This is particularly true when authors raised datasets discrepancies and provide sublimation estimates without in situ verification. In that sense, TOPKAKI-ETH would require more field measurements than applied for an optimal hydrological simulation.

Ice volume and runoff values and trends are given in reasonable orders of magnitude and complement former studies in the region. The authors raised that typical increasing or decreasing phases of peak water cannot be observed over the period 1955-2016, however there is a bulk of facts (i.e. areal and ice volume losses, negative mass balances and elevation changes, observed runoff trends and conservative committed ice losses up to year 2100) that suggests this peak is hidden somewhere within 2000-10. In contrast, authors argue a possible transient equilibrium with climate of some glaciers to justify some short periods of positive/neutral mass balances, hyphotesis which is not really supported.

Apart from that, the study is clearly explained from beginning to end, it is a well- structured & written manuscript. Figures, tables and supplementaries are generally all informative and of appropriate visual quality, but with some improvements and clarifications I would recommend. I particularly missed a table providing mass balance and runoff values per each sub-basin, which would make more explicit and/or highlight possible influence of factors such as elevation range and latitude.

The study settled the hydrological role of glaciers together with those of snow and rain, both on annual and seasonal basis. This is helpful in current times when concerns

on water security are quite high and general public receives distorted information from environmental NGOs. It additionally provides the main forcing factors of hydrological trends and predicts the decreasing glacier buffer capacity even at the conservative scenario. By themselves, these points suggest an important impact in the scientific community, likely for stakeholders and decision makers as well.

There are much more strengths than weaknesses that make this manuscript suitable for going from TCD into TC after very minor editing.

SPECIFIC COMMENTS

Lines 23-26: "If glaciers in the basin were in equilibrium with the climate of the last two decades, their volume would be reduced to 81$\pm$38% of the year 2000 volume, and glacier runoff during dry periods would be 61$\pm$24% of its maximum contribution in the period 1955-2016, considerably decreasing the drought mitigation capacity of the basin". This sentence refers an optimistic scenario based on minimum ice volumetric loss and minimum decrease of glacier runoff contribution, but it is rather confusing and probably needs improvement in redaction, probably in a way like this or similar: "Assuming conservative ice losses of 81% under a constant climate...glacier runoff during dry periods..."

Lines 83-84: "Unrealistic" mentioned several times seems awkward.

Lines 127-128: Inventories error assignments of 5 (year 2000) and 10% (year 1955) seem rather arbitrary. Can you explain better?

Lines 161-173: When calculating ice thicknesses in 1955 based on Huss and Farinotti complemented to geodetic balances 1955-2000 and area-volume ratio, there is an intrinsic assumption of no basal melting. I think this could be mentioned.

Lines 176-177: Uncertainty of 15% in average for 1955, 2000 and 2013? 1955 is clearly more uncertain, maybe you could clarify.

Lines 179-203: Is there any particular reason why fluviometric data elsewhere available

upstream El Manzano was not used for feeding or verifying the model results?

Lines 204-212: Modis datasets used in calibration of snow processes have minor resolution than the model output. Something to say about that?

Lines 237-240: "To calculate ice melt under supra-glacial debris we also use the ETI model but with reduced melt factors (see section 4.1.3). Although TOPKAPI-ETH includes a melt module..." I understand it, but be aware there is a bias. Debris impact on melt can be variable depending on thickness, mineralogy, etc.

Lines 282-287: Because of different conditions of elevation ranges, air humidity, winds, etc, among 5 sub-basins, I disagree with the representativeness of 34 mm/yr of sublimation, at least in the case of the higher ones. I think authors should raise there is a limitation of SWE information from Landsat.

Lines 288: "...and is in the order of the model uncertainties (see Figure 2)." You mean 34 mm/yr in comparison to 49.9 mm of RMSE? Please clarify.

Lines 317-319: "We suspect that this is an expression of the fact that some of the processes not included in TOPKAPI-ETH (namely permafrost, sublimation, snow dynamics or geothermal fluxes) may play a role governing the mass balance of these glaciers". Then it is partially contradictory to this sentence: "...which is a reasonable estimate of sublimation amounts for this region...".

Lines 333-335: "Interestingly, several of the glaciers show a positive or near-neutral mass balance over the entire period, which might be an indication that these glaciers have already retreated close to a new equilibrium." This seems to contradict evidence of glacier mass balances in the entire Andes.

Lines 410: Authors report an important and larger ELA elevation than reported in Carrasco et al (2005). It should be highlighted.

Lines 419-410: "In general, glaciers in southern catchments show more positive mass balance than those in northern catchments." This occurs despite elevations are much

lower. Any explanation other than precipitation?

Lines 424-440: This is the core of this research. It compares the contributions of ice, snow and rain in annual and summer basis. Is the 3% decrease of glacier summer contribution (entire study period versus current drought) a possible indication peak water was already reached?

Lines 441-455 & Figure 9c: Maybe a “realistic” projection could have complemented this analysis.

Lines 481-485: As raised by the authors, difference in mass balances among sub-basins can depend on many climatic and morphological factors, however it is doubtful that precipitation increases that much in semiarid Andes to lead positive mass balances in southern basins. Unless there is data enough to support this statement.

TECHNICAL CORRECTIONS

Line 164: “ a meaningful 1955 ice thicknesess. . .” Delete “a”

Lines 256-261: I think this sentence repeats information from section 3.3.

Lines 514-542 Uncertainties of modelling I particularly find this could have been assessed in summary at the end of methods section.

Figure 1 (a): Maipo outline may be better recognised if Chile and Argentina are just outlined (without color filling); (b) debris-free areas could be coloured in blue because white is difficult to distinguish over yellow; (c) I would recommend sub-basins labels to be horizontally oriented with brackets, so far I cannot tell where are the boundaries between them; (d) Why Volcán label and number of glaciers are in light grey?

Legend Figure 1: “a) Maipo River Basin next to the city of Santiago, in central Chile; (b) the basin outlet and the sub-catchments, rivers, main glaciers, and hydro-meteorological stations. . .” These are not all glaciers, nor the 26 modelled glaciers, just main ones.

Figure 2 (a): It is Cortes et al 2016 or Cortes and Margulis 2017? Please clarify.

Figure 3. I am not sure if this is necessary (instead they could be shown in Figure 1(a). In any case, glaciers in white are difficult to distinguish over yellow. Maybe blue is more appropriate. Name of main glaciers could be added.

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