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Peak water in the semiarid Andes: modelling the past 60 years of glacier runoff

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Glacier retreat and related ice melt can lead to positive trends of annual runoff in heavily glacierized catchments. Once the ice volume has significantly shrunk, annual glacier runoff will experience gradual decrease. In between these opposite trends, a period of maximum water discharge, often referred to as “peak water”, is expected. Several gauging stations of the European Alps and the Himalaya have exhibited a phase of increasing runoff during the last decades, and several studies prognosticate peak water for the coming decades. Conversely, future projections for the semiarid Andes show only a decreasing trend, suggesting that peak water is either occurring at present or has already passed. To date, however, no regional study has focused on the topic.

The objective of this study is to identify past and present trends of annual glacier runoff and a probable period of peak water in the Upper Maipo River catchment, in the semiarid Andes of central Chile. The catchment has an area of almost 5000 km^2, and more than 800 glaciers covering about 377 km^2. Roughly half of the glaciers are debris-covered or rock glaciers. While the study focuses on glacier runoff, wet and dry cycles resulting from precipitation inter-annual variability are quantified as well, and are used to identify periods in which the ice melt contribution has played a significant role for water supply. We simulate glacier evolution and runoff in the period 1955-2016 with the TOPKAPI-ETH glacio-hydrological model. TOPKAPI-ETH has been previously used in this region and combines physically-oriented parameterizations of snow and ice ablation, gravitational distribution of snow, snow albedo evolution, glacier dynamics, runoff routing and the ablation of debris-covered ice. The model is calibrated, validated and forced using a combination of glacio-meteorological datasets, a local hydro-meteorological network, climate reanalysis and remote sensing products. While glacier outlines and surface topography in the year 1955 are estimated based on datasets collected by Chilean public offices, glacier bed topography is calculated using current DEMs and a mass conserving approach for ice thickness estimation.

We found that the total glacierized area in the catchment has decreased from about 412.3 km^2 to 377.5 km^2 (-8.4%) in the period 1955-2016. Preliminary results show a decreasing trend since at least the year 2000 and a probable period of peak water between 1955 and 2000. More extensive sensitivity and uncertainty analyses are ongoing to better constrain the timing of peak water. At the catchment scale, annual ice melt runoff-share has varied around 4%, reaching peaks of 8% during droughts. We discuss how catchment-scale hydrological studies focusing on long-term variations of glacier runoff can contribute to a more solid understanding of changes in water availability of alpine regions. These results can offer also a glimpse to possible future scenarios of glacier retreat in catchments of the Alps and the Himalaya, in which peak water is still to come.