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Combining synoptic tracer analyses with hydrological modelling to assess seasonal runoff generation from semi-arid Andean headwater catchments

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Andean headwater catchments are the main water source to supply downstream semi-arid irrigation dependent communities in the Limari Basin (11.696 km^2), central Chile. Only little information is available about catchment characteristics, cryosphere and hydrological processes for these remote areas to support water management with discharge predictions.
Based on hydro-climatic time series of almost 50 years at the catchment outlets and in situ measurements, runoff processes in two perennial Andean headwater catchments of an elevation from 1000 to 4000 m – the Rio Grande and Rio Tascadero in central Chile – were assessed using statistical analyses, conceptual modelling, field observations and synoptic tracer surveys.
Statistical and modelling analyses of hydro-climatic time series at the catchment outlet indicated a high spatio-temporal variability of climate variables. The spatial and seasonal distribution of the stable isotopic composition (δ18O and δ2H) and hydrochemistry of stream and ground waters was used to distinguish various sources and components of stream flow. A marked spatial and seasonal variability of all measured parameters was observed. Hydrochemistry in ground water and surface water samples suggests that there is no fossil groundwater contribution to the baseflow with very low mineralization of headwaters and geothermal influences at around 3000m of elevation. Subperiod calibration with HBV light was carried out to address the strong seasonality. Results showed that streamflow response is mostly consistent with fluxes from groundwater storage, while only a small fraction comes from direct routing of snowmelt. Variation of model parameters such as the groundwater rate coefficient was detected consistent with differing recharge in wet and dry years. The resulting snow melt-groundwater model serves as a tool to describe hydrological processes in these complex, data scarce and semi-arid Andean catchments and will be used to predict seasonal water availability. Based on the findings further observation, modelling and sampling strategies were developed for current research.