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Coupling stable isotope and satellite to inform a snow accumulation and melt model for data poor, semi-arid watersheds

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At the most basic level watersheds catch, store, and release water. In semi-arid northern central Chile (29°–32°) snow and glacier melt dominate these basic hydrological stages. In this region precipitation is typically limited to three to five events per year that falls as snow in the High Cordillera at elevations above 3000 m a.s.l. The rugged topography and steep gradient makes snowfall rates highly variable in space and time. Despite its critical importance for water supply, high elevation meteorological data and measurements of snowpack are scarce due to limited winter access above 3000 m a.s.l. Due to the critically limited understanding of catch, store, and release processes most conceptual watershed models for this region remain speculative, are prone to over-parameterization, and greatly inhibits hydrological prediction in the region.

Focused on two headwater watersheds of the Elqui River basin (1615–6040 m a.s.l., 429–566 km2) this study couples stable isotope and Moderate Resolution Imaging Spectrometer (MODIS) data to develop an improved conceptual model of how semi-arid mountain watersheds catch, store, and release water. MODIS snow-cover and land surface temperature data are used to inform an enhanced temperature-index Snow Accumulation and Melt (SAM) model. The use of remotely-sensed temperature data as input to this model is evaluated by comparison with an interpolated dataset derived from a few available meteorological stations. The outputs from the SAM model are used as inputs to a conceptual catchment model including two water stores (one standing for surface/subsurface processes and the other for deeper groundwater storage). The model is calibrated and evaluated from a Bayesian perspective using discharge data measured at the catchment outlets over a 15-year period (2000–2015). Stable isotope data collected during 2015–2016 is applied to better constrain model outputs. The combination of MODIS-based and isotope-based information proves very useful in understanding how different water sources are involved at different times of the year and constraining water storage compartments. However, further checks indicate that errors in precipitation inputs may be difficult to isolate from structural inadequacies in the representation of deep water transfers, as a significant fraction of groundwater flow actually bypasses the gauging stations. While this model focuses on watersheds in northern central Chile, this data and modeling framework would be of potential value in other data poor arid and semi-arid mountain watersheds.