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Combining multiple data sources for the quantification of snow and glacier melt contributions to streamflow over the last 100 years

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High alpine headwater catchments are important source areas for many large rivers. There is considerable interest in understanding and predicting the changing hydrological processes in these catchments due to climatic changes. At the same time, high elevation regions tend to be data scarce. The aim of the study is a re-analysis of the changing contributions of snow and glacier melt to streamflow in the river Rhine over the entire 20th Century. The success of quantifying these contributions across scales and over such a long time period depends on the use of all available information. We present the challenges and benefits of combining multiple regional data sources (i) to analyze these changes empirically and (ii) to constrain hydrological modeling in the headwater basins. The reconstruction of gridded meteorological variables for the period 1901-1950 based on an analogue resampling technique created a consistent meteorological forcing over the entire period. Glacier extents from maps of the early 20th Century defined the starting conditions to bridge the time to existing glacier volume and area change data. The analysis of the co-variability and trends in a set of long time series of climate variables and streamflow in unregulated headwaters provided insight into different phases of changing climate-hydrology relations. These signatures, together with the snow water equivalent maps for the last 30 years produced by the SLF and the collection of all available streamflow records provided important benchmarks for model calibration and validation. This work improves the understanding of climate sensitivity in high mountain environments and demonstrates important challenges when modeling partly compensating effects of a changing climate.