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Glacier melt contribution to streamflow during extremely dry summers

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Extreme dry (and hot) summers, such as observed in Europe in the years 2003, 2015, 2018 and 2019, cause meteorological, hydrological and soil moisture droughts. These different types of droughts can have a range of negative impacts on, for instance, agricultural yield, water supply and hydropower production. The European Alps, also known as Europe's water tower, potentially play an important role during such extreme summers by providing (extra) water from the melt of snow and ice. In this research study, we analyzed the streamflow conditions from a large sample of glacierized headwater catchments in the Swiss Alps during low flow years (1976, 1985, 1991, 2003, 2011, 2015, 2018 and 2019) observed downstream. Streamflow and its components (snow, ice and rain) were modelled with the HBV-light model for the period 1973-2020. These simulated streamflow components, together with observed total streamflow records, were compared between different catchments and different drought years. For each drought year, the winter conditions were examined, and the development of the drought situation over the summer was evaluated. To estimate the streamflow contribution of headwaters in the European Alps in such drought years in a situation without any glaciers, we also performed a model simulation where glaciers were assumed to have disappeared entirely. The results showed that glacier- and snowmelt contributed substantially to streamflow during these extreme years in the glacierized headwater catchments. In some cases, glacier ice provided up to three times as much melt than usually during summer. Catchments with a high glacier cover fraction usually showed a positive streamflow anomaly during these years. In 1991 and 2003, all catchments had an increased ice melt contribution, while in the other extreme years some catchments provided less ice melt contribution than average. Overall, this study shows that glaciers play an important role during low flow years and that a reduced glacier cover, or even completely retreated glaciers, will substantially reduce the buffer capacity of Europe's water tower in the situation of meteorological drought.