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Hydrological response to warm and dry extremes in glacierized catchments: when and how are glaciers compensating?

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Extreme warm and dry summer conditions often cause low-flow situations due to the precipitation deficit and increased evapotranspiration. In glacierized catchments, however, the same extreme weather conditions can lead to a very different hydrological response, namely increased streamflow because of increased glacier melt. In larger combined rainfed and glacierfed catchments, meltwater from glaciers can, thus, buffer the adverse hydrological effects of warm and dry spells. The question is how much glacier cover in a catchment is needed to counterbalance the hydrological processes that cause a decline in streamflow. Moreover, due to climate change, glaciers have been retreating, which affects the hydrological response and the buffering effect of glaciers. In this study, we analysed long-term streamflow records of around 60 glacierized catchments in Switzerland, Austria, Norway and Canada with varying glacier coverage. In addition, a few catchments were modelled to analyse some extreme events in more detail and perform sensitivity tests. Warm and dry spells were selected based on weather data for the catchments and the corresponding hydrological responses were investigated. The events were analysed taking into account catchment characteristics, such as glacier cover and elevation information, and antecedent conditions, such as snowfall in winter and precipitation amounts in the period before the warm and dry event. Results show that during extreme warm and dry spells small glacier cover fractions (< 10%) can already alleviate the otherwise emerging streamflow drought. Moreover, we see a clustering of warm and dry periods in recent years and a decreasing trend of summer streamflow in many catchments. Antecedent conditions appear to shape the individual summer streamflow responses. Overall, understanding the hydrological responses to warm and dry spells is essential due to projected increases in weather extremes. Especially in glacierized catchments, our results imply that with changing glacier cover due to global warming, changes in the buffering capacity of glacierized catchments during warm and dry periods can be expected.