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Mass balance of a highly active rock glacier during the period 1954 and 2016

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Active rock glaciers are creep phenomena of permafrost in high-relief terrain moving slowly downwards and are often characterised by distinct flow structures with ridges and furrows. Active rock glaciers consist of ice and rock material. The ice component might be either congelation (refreezing of liquid water) or sedimentary ('glacier') ice whereas the rock material might be either of periglacial or glacial origin. The formation period of rock glaciers lasts for centuries to millennia as judged from relative or absolute dating approaches. The input of ice and debris onto the rock glacier mass transport system over such long periods might change substantially over time. Long-term monitoring of mass transport, mass changes and nourishment processes of rock glaciers are rare. In this study we analysed on a decadal-scale mass transport (based on photogrammetric and geodetic data; series 1969-2016), mass changes (geodetically-based mass balance quantification; series 1954-2012), and mass input (based on optical data from an automatic digital camera; series 2006-2016) onto the Hinteres Langtal Rock Glacier. This rock glacier is 900 m long, up to 300 m wide, covers an area of 0.17 km^2 and is one of the most active ones in the Eastern European Alps. Mass transport rates at the surface indicate relatively low mean annual surface velocities until the beginning of this millennium. A first peak in the horizontal surface velocity was reached in 2003/04 followed by a period of deceleration until 2007/08. Afterwards the rates increased again substantially from year to year with maximum values in 2014/15 (exceeding 6 m/a). This increase in surface velocities during the last decades was accompanied by crevasse formation and landslide activities at its front. Mass changes show for all six analysed periods between 1954 and 2012 a clear negative surface elevation change with mean annual values ranging from -0.016 to -0.058 m/a. This implies a total volume decrease of -435,895 m^3 (averaging to -7515 m^3/a) over the 58-year period at the rock glacier system. The only area of substantial surface elevation gain was during all periods the rock glacier front indicating a rock glacier advance. Mass input onto the rock glacier transport system was assessed analysing 2044 terrestrial images taken automatically between September 2006 and August 2016 from the main rooting zone of the rock glacier. Results indicate that neither snow and ice nor rock material have been transported in large quantities to the rock glacier system during the 10 year monitoring period. Notable mass movement events have been detected only six times. Perennial snow patches in the rooting zone of the rock glacier only survived on average every second summer. We conclude that the rates of rock glacier mass transport and volumetric losses of the rock glacier are far higher than debris and ice input. This rock glacier is clearly in a state of detachment from its nourishment area and prone to starvation which will eventually lead to rock glacier inactivation. This is a feasible fate for many currently active rock glaciers in the European Alps.