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60 years of rock glacier displacements and fluxes changes over Laurichard Rock glacier, French Alps.

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Recent acceleration of rock glaciers has been largely documented in the European Alps, hence highlighting an increase in flow speed of stable rock glaciers and some anomalous behaviors called destabilization (development of landslides-like features on the rock glacier surface). In this study, we focus on Laurichard active rock glacier, 225 m long, up to 75 m wide, which covers an area of 0.084 km2 and has the longest measurement time-series in the French Alps. Here we aim to understand the causes of the changes in ice velocity of Laurichard rock glacier. We investigate the changes in the fluxes of ice masses across longitudinal and transversal profiles in order to be able to analyze in details the differences between the upper part and the front of the glacier. Using a combination of remote sensing data from 1952 (historical aerial images) until 2018 (Pléiades high-resolution satellite images), we documented the three-dimensional evolution of the Laurichard rock glacier during the last 60 years. We calculated the surface flow velocity between 1952 and 2018 using a feature-tracking algorithm at a resolution of 1 m and a precision of 0.5 m. Digital elevation models were assembled using the SfM techniques for aerial images, and the AMES stereo pipeline for Pléiades data. In addition, we made the analysis using in-situ annual velocities and temperatures data allowing to understand better which factors mostly explain the kinematic behavior. We reconstructed a time series of changes in surface elevation by systematically co-registering and differencing DEMs between 1952 and 2018, with an average precision of 1 m. We first observed that the average annual horizontal velocity measured had increased progressively from 0.65 m yr^{-1} to 1.1 m yr^{-1} to 1.5 m yr^{-1} for the periods 1952-1960, 1994-2003 and 2013-2018, respectively. On the other hand, the surface mass changes and long term monitoring of mass transport show for all analyzed periods a clear negative surface elevation change of 2 m on average, between 1952 and 2018. The area with most of the elevation changes is the frontal part of the glacier, which is consistent with the increase in speed, which represents a mass exchange from the upper part to the front. We conclude that the rates of rock glacier mass transport have increased during the last 20 years and hypothetize, for this rock glacier, a transition state controlled mainly by local topographical factors which will eventually lead to high speed rock glacier or rock glacier destabilization.