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How does rock glaciers deactivate? Geomorphic and activity states of French Alpine rock glaciers in transition

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Rock glaciers are the visible expression of mountain permafrost. The deformation of internal ice and basal horizon make them creeping downward, which allows their detection. Their geomorphological characteristics tend to evolve as a response to degrading permafrost conditions. If the internal ice is melting, the surface creeping gradually decreases until the landform stabilizes. This gradual deactivation has led to the definition of "rock glaciers in transition". Recent studies highlighted a general trend of active rock glaciers' increasing surface velocity in the last decades. In this context, we are asking if remaining ice in rock glaciers in transition could allow an increase of surface velocity trend similar to active rock glaciers? This study aims to describe rock glaciers in transition geomorphic settings and their present-day kinematics, and explore how their intrinsic and extrinsic characteristics can explain their activity.

To answer this question, we applied remote sensing techniques from a French inventory of rock glaciers such as i) High resolution differential radar interferometry images to describe present days surface velocities for all "inactive" inventoried rock glaciers and reveal global trends at a large scale. ii) Geomorphic mapping of the rock glaciers characteristics such as their geometry, geomorphological and geological settings (rock glacier system, slope, latitude/longitude, altitude, concavities, vegetation cover, exposition, aspect and lithology of the blocks…). iii) By combining a dataset with i) and ii), we analyze correlations and dominant parameters using an MCA factorial analysis and a multimodal linear regression.

Over 521 rock glaciers, 305 present displacements detectable from 30 InSAR images during summer period between 2016 and 2018. Most of them have velocities rates lower than 10 cm. yr^{-1} (N=184), and for 1/3 (N=120) it ranges from 10 to 50 cm. yr^{-1}. Higher rates only concern 11 rock glaciers. For 80% of them (N=247), the mean surface area of displacements is lower than a half of the rock glacier surface area. The most represented geomorphic criteria are related to sagging landforms. Indeed, more than 50% of rock glaciers have a concave transversal profile matching with subsidence, whereas the others face with a high asymmetric topography. We support the hypothesis that lithology, exposition and the slope could be external factors that explains the most

the heterogeneity of rock glaciers responses to a global climatic impact. The concavity/convexity index of transversal profiles, the surface slope and the vegetation cover should be the best parameters to describe the state of a transitional rock glacier in accordance with its activity. However, for many of rock glaciers with velocities ranging between 10 and 50cm. yr^{-1} these criteria are met.

Morphodynamical approaches are essential to better understand the link between external parameters and morphological settings of rock glaciers in transition, in responses to their activity. Nonetheless, the ice content and amount of water input can be essential drivers of rock glaciers activity. It is therefore important to complement such morphodynamical studies with an analysis of the subsurface in order to correlate these characteristics with the actual internal properties of rock glaciers.