



## **Climatically-driven rockfalls in high-alpine steep rockwalls: the North side of the Aiguilles de Chamonix (Mont Blanc massif) since the end of the Little Ice Age**

Ludovic Ravanel and Philip Deline

EDYTEM Lab., Université de Savoie, CNRS, Le Bourget-du-Lac, France (ludovic.ravanel@univ-savoie.fr)

Rockfall is one of the main process that affect rockwalls, with related risks for people and infrastructures. Nevertheless, the process and its relation with the permafrost degradation remain insufficiently understood, partly due to the lack of data. By comparing old, recent and present photos, and using geomorphological field data, we propose an inventory of the main (volume > 500 m<sup>3</sup>) rockfalls that affected the North face of the Aiguilles de Chamonix since the end of the Little Ice Age (LIA, c. 1860 AD).

We documented 42 rockfalls on this emblematic ridge of the Mont-Blanc massif, ranging in volume from 500 m<sup>3</sup> to 65,000 m<sup>3</sup> (total volume: 390,000 ± 60,000 m<sup>3</sup>). The affected rockwalls are mostly with N to NW aspect, ranging in elevation from 2615 m to 3500 m a.s.l.. This suggests that the area is likely characterised with permafrost, of which degradation could trigger a part of the surveyed rockfalls.

We observe a very good correlation between rockfall frequency and the air temperature: periods of years with the highest temperatures between 1860 and 2009 AD experienced the highest frequency; 70 % of rockfalls occurred during the two last decades, characterized by an accelerated increase of the warming in the Alps. Warm summers in 1947, 1976, 1983, and 2003, experienced the highest rockfall frequency, which was maximal during the 2003 Summer heatwave. Average elevation of rockfall scars is 3130 m a.s.l., suggesting that the lower limit of permafrost was affected, where degradation is active.

For the most part, triggering of the surveyed post-LIA rockfalls in the Aiguilles de Chamonix was probably controlled by the current permafrost degradation.