Statistical study of topographical and glaciological parameters controlling the glacial retreat in the French Alps since the end of the 1960s

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Glacial retreat is one of the most evident impacts of climate change in high mountain areas. In the French Alps, data about glacier extensions were recently updated in the context of the new French glacier inventory.

This inventory is based on manual delineation of the French National Geographical Institute (IGN) 50-cm-pixel orthophotographies from 2006 to 2009 and IGN 1/25 000 topographical maps from the end of the 1960s (1967-1971). Data are integrated in a GIS and topographic parameters are extracted from the IGN 25-m-DEM for the glacier surface extension of the end of the 1960s and the ASTER 30-m-GDEM for the 2006-2009 extension.

The present (2006-2009) glacier surface area in the French Alps is 275.5 km^2. This surface decreased by 26% since the end of the 1960s when the glacier extension was 373 km^2. The surface area of 82% of the glaciers is < 0.5 km^2 and covered 19 % of the total glaciated area, whereas glaciers > 2.5 km^2 account for 3.5 % of the glacier number and 47 % of the total glacier area. Glaciers with a length < 1 km represent 76 % of the total glacier number while glaciers > 2 km in length represent 10 % of this total. Glaciers > 1 km^2 have a gentle mean slope than glaciers < 0.1 km^2 (22° and 33°, respectively). Most of the present glaciers are exposed to NW-N-NE (60 % in surface area and >70 % in number). Average minimal (i.e. fronts), mean and maximal elevation of French Alpine glaciers is 2840 m ($\sigma = 286$ m), 3019 m ($\sigma = 240$ m), and 3210 m ($\sigma = 289$ m), respectively. Finally, more than 11 % of the surface area of the present glacier is debris-covered.

Retreat rate mainly seems related on the glacier size classes or the aspect, and varies from one massif to another: glacier shrinkage in the Ecrins massif was more than three times stronger than in the French area of the Mont Blanc massif.

We use a statistical approach in order to pinpoint topographical and glaciological controls on the glacier retreat. First, a bivariate analysis was used to study the correlation between the glacial retreat from 1967-1971 to 2006-2009 and several topographical parameters (surface area, minimal, maximal and mean elevations, glacier length, mean glacier slope angle, mean aspect, latitude). Glacial retreat is controlled by a combination of these parameters. In order to identify which are the most important variables, we use multivariate analysis. Several Principal Component Analyzes were carried out at the scale or level of massifs, size classes or mean aspects. Results from these analyses are presented.