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Analysis of the glacier retreat in the French Alps since the 1960s based on the new glacier inventory

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One of the most obvious impacts of climate change in high mountain areas is the glacial retreat. Since the French glacier inventory carried out by R. Vivian in the late 1960s within the context of the WGI, there was no updated data from the overall French alpine glaciers. We present here the first results of a new diachronic inventory of the French alpine glaciers based on different sources.

Glacier outlines were manually delineated using 1/25,000 topographic maps of the french National Geographical Institute (IGN) from the end of the 1960s, and IGN 50-cm-pixel orthophotographs from 2006 to 2009. For Landsat 5 TM images (30 m resolution) dating from 1985-1986, and Landsat 5 TM and Landsat 7 ETM+ images (30 and 15 m resolutions) dating from 2003, an automatic delineation with the common NDSI method was used to determine glacier limits. Each glacier has been individually checked, with a special care for debris covered and shadowed areas to adjust the delineation, using a 542 spectral bands combination. For compounded glaciers, the same limits were manually adjusted for each period. Data were integrated into a GIS and a database including all the common items (surface area, minimal and maximal elevations, aspect, debris covered area, slope…) was generated. Topographic parameters were extracted from the IGN DEM (resolution of 25 m) for the topographic maps and Landsat images from the mid-80s, and the ASTER GDEM (resolution of 30 m) for the Landsat images of the early 2000s and the orthophotographs. .

Current extension of the 593 French alpine glaciers is about 275 km^2. It is $\sim$20 % less than in 1985-1986 (end of the last glacial advance period), when glacier extension was 340 km^2, and $\sim$26 % less than at the end of the 1960s, when glacier coverage was about 375 km^2. Different trends are observed across the French Alps, with a stronger glacial retreat in the southern massifs: for instance, glacier shrinkage in the Ecrins massif is more than three times stronger than in the French area of the Mont Blanc massif. The size distribution of the glaciers has changed within the last 40 years: the proportion of glaciers < 0.1 km^2 increased from 31% to 51%, while glaciers 0.1-0,5 km^2 and >1 km^2 decreased from 41% to 31%, and 28 % to 18 %, respectively. The average minimal elevation of glacier fronts has risen from about 2670 m a.s.l. at the end of the 1960s to 2760 m (+ 90 m). Results from the analysis of the relationship between glaciers retreat and their aspect and elevation will be also presented.

Finally, the reconstruction of glacier extensions at the end of the Little Ice Age, based on ancient maps and geomorphological study of the proglacial margins will be presented. As an example, glacier extension in the Vanoise massif has decreased by more than 50% since the end of the LIA.