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Recent changes of very small glaciers in the Swiss Alps

Mauro Fischer, Matthias Huss, and Martin Hoelzle
Department of Geosciences, University of Fribourg, Switzerland (mauro.fischer@unifr.ch)

Present knowledge about Alpine glaciers is not representative in terms of glacier size distribution. More than 80% of all Swiss glaciers are smaller than 0.5 km2 and hence belong to the class of very small glaciers. In the context of fast glacier wastage in the European Alps, the near-future development of the size class distribution will most probably be in favour of very small glaciers which will comparably increase in number. However, there has been little research carried out about very small glaciers so far. It is not clear whether findings and theoretical concepts elaborated for medium and large valley glaciers (> 3 km2) can be directly transferred to very small glaciers, whose accumulation patterns are, for instance, characteristically exceptional because winter precipitation is multiplied by wind drift and avalanching.

The extent of glaciers in the European Alps has recently been mapped and inventoried spatio-temporally consistently. Nevertheless, such glacier outlines derived by satellite remote-sensing techniques are not accurate enough for the special case of investigating changes in very small glaciers. Therefore, glacier outlines are digitized manually using high-resolution (25 cm) orthophotographs covering the entire Swiss Alps acquired twice for every scene (both in the early and late noughties). In contrast to the known shortcomings of satellite remote-sensing based approaches, the margins of very small glaciers are (with few exceptions) clearly distinguishable on these orthophotos, even in shaded, snow- or debris-covered areas.

For the eastern Swiss Alps (east of the rivers Reuss and Ticino), about one third of all glaciers has vanished since 1973. The total area presently still glacierized amounts to 140 km2, whereof very small glaciers cover only 25% but account for almost 90% of the total number of glaciers. Retreat rates are highest for very small glaciers but seem to be stabilizing or even decreasing since the early noughties, implying that many of them have retreated far back into shaded cirques and below headwalls. Downwasting and disintegration into different ice patches has become the dominant process of mass loss.

Furthermore, we evaluate changes in ice volume over the last three decades for a large set of Swiss glaciers by combining the glacier outlines for the late noughties with a new precision DEM (swissALTI3D) for the same date with outlines and elevation information from around 1980. Ice volume changes are compared to measured and estimated total glacier ice volume in order to quantify relative volume losses over the last decades. Moreover, annual surface mass balance was determined for three very small glaciers complementing the analysis of recent changes in this glacier size class. Very small glaciers in the Swiss Alps show fast mass loss but the picture is not uniform both in space and time.