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Changes in area and volume of all Swiss glaciers over the last 25 years

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Since the mid-1980s, glaciers in the European Alps have shown widespread and accelerating mass losses. These glacier changes have been investigated in several studies both focusing on area and length changes as well as on volume losses. Because the Alps are dominated by relatively small glaciers, we argue that a sound analysis of glacier elevation changes can only satisfactorily be done if source data of sufficient quality is available. For the Swiss Alps, these prerequisites are now given with the new Swiss Glacier Inventory INVGLAZ10MF derived by manual digitization from high-resolution (50cm) aerial orthophotographs and a new digital elevation model swissALTI3D of the same acquisition dates.

By comparing the DHM25 level1 Digital Elevation Models (DEMs) acquired during the 1980s with the swissALTI3D DEMs from 2008-2011 and combining the former with the 1973 inventory and the latter with the 2010 inventory, we present glacier-specific changes in area, surface elevation, volume and geodetic mass balance for every single glacier in Switzerland. Because there are – depending on the individual acquisition dates of the source data – significant differences in the observation period over which glacier elevation changes have been derived by DEM differencing, we present an approach to temporally homogenize resulting changes. This is necessary for directly comparing individual glaciers or glacierized catchments. Furthermore, we validate our results using volume changes calculated over the same periods from photogrammetrically derived DEMs.

According to the latest Swiss Glacier Inventory, the total area still glacierized in Switzerland by 2010 amounts to 944 km^2 (-28% or 366 km^2 since 1973). Very small glaciers (< 0.5 km^2) account for 82% of the total number, but in relative terms even more glacierized area (and volume) belongs to fewer glacier entities compared to 1973. Observed area changes are largest between 2800-2900 m a.s.l. and still significant even above 3500 m a.s.l.

The resulting geodetic mass balance data reveals that the area-weighted mean of 1420 still existing glaciers amounts to -0.73 m w.e. a^{-1} for our reference period 1986/87-2009/10. For some main hydrological catchments the mean mass balances range from -0.60 m w.e. a^{-1} for more maritime areas on the north-facing slopes of the Alps to -1.17 m w.e. a^{-1} for more continental and inner-Alpine valleys in the southeast of Switzerland. Our comprehensive dataset shows that there is no significant correlation between average glacier surface area and geodetic mass balance. However, the surface slope of the glacier tongue (lowermost 10%), median glacier elevation and mean aspect can – to some extent – explain the observed mass changes. The overall volume loss calculated over the analyzed period is -22.1 km^3.