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Large scatter and multidecadal fluctuations in the 20th century mass loss of 30 Swiss glaciers

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The ongoing retreat of mountain glaciers strongly impacts on the hydrological cycle, might cause economic losses in alpine regions and is expected to dominate eustatic sea level rise over the next century. Long-term time series of glacier mass balance represent a key to projecting future glacier changes and understanding the glacier-climate linkage, in particular glacier response to large-scale climatic forcings. However, mass balance is only measured on some selected glaciers, and the typical length of the records is a few decades.

We present thirty new time series of glacier surface mass balance, accumulation and melt over the past 100 years in the Swiss Alps. The data set includes different glacier sizes, exposures and regions, and thus constitutes the first long-term mass balance time series being representative on a mountain range scale. Our results are based on a comprehensive set of field data and modelling. For each glacier, up to 10 high-accuracy digital elevation models covering the last 100 years were established providing ice volume changes in subdecadal to semicentennial periods. In addition, more than 8000 direct observations of annual mass balance and winter accumulation are available. This data base was used to constrain a distributed mass balance model driven by daily air temperature and precipitation for the period 1908-2008.

All glaciers show considerable mass loss, but rates differ strongly between individual glaciers. 100-year cumulative mass balance varies between –11 m water equivalent (Allalingletscher) and –65 m w.e. (Griesgletscher). These strong differences in the response of glacier mass balance to changes in climate forcing are attributed to an interaction of several complex processes. Large and flat glaciers tend to have more negative mass balance due to their long reaction time. Positive and negative albedo feed-back mechanisms, as well as changing winter precipitation, variable on smaller spatial scales than air temperatures, might also explain some of the differences.

Mass loss is particularly rapid in the 1940s and late 1980s to present, while short periods of mass gain occurred in the 1910s and late 1970s. This indicates that glacier mass loss over the 20th century was not linear, but exhibits important long-term variations. We find oscillations in the rate of glacier mass loss in the Swiss Alps with a period of 65 years. Glacier mass balance is significantly anticorrelated to the Atlantic Multidecadal Oscillation (AMO) index. The AMO refers to anomalies in the sea surface temperature in the North Atlantic that are linked to thermohaline ocean circulation. We show that North Atlantic variability had a recognizable impact on glaciers in the European Alps for at least 250 years.