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Glacier recession in the Upper Rhine river catchment between 1850 and 2000 and its importance for regional runoff

R. Frauenfelder (1, 2), M. Maisch (2), F. Paul (2)

(1) Currently at: Department of Geosciences, University of Oslo, Norway, (2) Department of Geography, University of Zürich, Switzerland

Glacier recession in the Upper Rhine river catchment was analysed for the period between the end of the 'Little Ice Age' (around 1850) and 'today' (2000), in the context of an assignment of the Swiss Federal Office for Water and Geology, to determine the influence of melting glaciers to the long-term runoff. Glacier area changes as well as glacier volume changes were assessed and analysed using three existing glacier inventories dating from 1850 (based on glacier reconstructions), 1973 (based on aerial photography) and 2000 (based on satellite imagery).

In 1850, 121 individual glaciers were mapped and inventoried in the study area. In 2000, only 86 of these glaciers remained. Of these 86 glaciers 74 (or 85%) were smaller than 0.5 km2 (entire Alps: 82% $<$ 0.5 km2), the largest glacier was 1.95 km2 in size.

The total glacier coverage of the study area in 1850 can be calculated to 68.5 km2. In the year 2000 it was shrunken to 21 km2, i.e. 2.7% of the total catchment area. Total loss in glacier area from 1850 to 2000 amounted to 47.5 km2 (or 69.4% as compared to 1850). A major influence of glacier size distribution can be seen when the data is differed in 13 glacier regions (hydrological sub-catchments): the highest percental area loss ($>$ 80%, as compared to a mean of 69%) is found in regions with a large number of small glaciers already in 1850. The explanation for this is the enhanced sensitivity of small glaciers towards the shift in equilibrium line altitude of around +100 m since 1850 together with their hypsometric conditions becoming more an more unfavourable for surviving also under future climate scenarios. Large glaciers, with more extended accumulation zones, in contrast, are comparably less affected by

the climatic change observed since 1850.

Depending on the two calculation methods used here, the total ice volume loss between 1850 and 2000 amounts to 1.3-1.36 km3 (-72.6 to -76% as compared to the volume in 1850). This corresponds to 1.16 km3 water equivalent and equals ca. 111% of the annual water runoff measured at the gauging station Ilanz at the lower border of the study area. Overall, the melt water discharge caused by the glacier recession between 1850 and 2000 contributed max. 1% to the existing mean annual runoff due to precipitation and snowmelt of the Upper Rhine catchment area. These general numbers should not conceal, however, that the relative significance of glacier meltwater increases with decreasing distance of the brooks to the glaciers and that the discharge from glaciers can be much higher in very dry and hot summers as e.g. in 2003.