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Strong Alpine glacier melt in the 1940s due to enhanced solar radiation

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Changes in climatic forcing are directly reflected by the mass budget of snow and ice surfaces. Observed strong glacier wastage throughout the 20th century was mainly attributed to changes in air temperature. However, changes in solar radiation at the earth's surface were rarely considered to explain cryospheric variability on decadal time scales. This is due to the scarcity of both long-term radiation measurements and unbiased time series of snow and ice melt.

We present a 94-year time series of annual glacier melt rates at four high elevation sites in the Swiss Alps derived from the longest direct observations of glacier surface mass balance worldwide. Since 1914 winter snow accumulation and summer ablation were observed almost every year at two sites on Claridenfirn, and one site each on Aletschgletscher and Silvrettagletscher located at elevations between 2700 and 3350 m a.s.l. Using a statistical model the field data are homogenized and the mass balance components – accumulation and melt – are separated. Records of global solar radiation since the late 1930s are available for the inner Alpine station at Davos. It could be shown that the time series is spatially representative for the Alpine mountain range.

Melting conditions have undergone strong temporal variations throughout the last century. Snow and ice melt at the four high elevation sites was stronger by 4% in the 1940s compared to the last decade. This is intriguing because air temperatures during the 20th century never were as high as today. The radiation time series reflects the tendency towards a dimming of global radiation between 1950 and 1980 and brightening during the last two decades, both recognizable on a global scale and related to the aerosol content of the atmosphere. Maximal global radiation was recorded during the 1940s. Summer (JJA) radiation was 8% above the long-term average and 18 $\mathrm{W\,m^{-2}}$ higher than over the last decade. The positive summer radiation anomalies between 1940 and 1960 provide evidence that the extreme glacier melt rates in the 1940s were favored by above average incoming global radiation and only to a lesser extent by high air temperatures. Between 1960 and 1980 high cloudiness, low global radiation and low air temperatures in the European Alps are in line with strongly reduced melt rates, resulting in a short period of balanced mass budget of alpine glaciers. The data set also indicates a prolongation of the melting season at high elevations by almost one month since the 1970s. Simultaneously, the calculated fraction of snowfall relative to the total annual precipitation has decreased by 12% on average at the study sites. These processes have the potential to considerably accelerate future glacier wastage, have strong impacts on the hydrological cycle and could offset the effect of currently lower global radiation compared to the 1940s.

We provide evidence that the extraordinary melt rates in the 1940s can be attributed to enhanced global radiation in summertime. Models for past and future glacier changes should take into account the effect of decadal variations in radiation at the earth's surface as they significantly alter the relationship between glacier melt and air temperature.