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Testing geographical and climatic controls on glacier retreat

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Glacier melt provides an important part of the summer discharge in many mountainous basins. The understanding of the processes behind the glacier mass losses and glacier retreats observed during the last century is therefore relevant for a sustainable management of the water resources and reliable models for the prediction of future changes. The changes in glacier area of 49 sub-basins of the Rhine River in the Alps were analyzed for the time period 1900-2010 by comparing the glacier areas of Siegfried maps for the years 1900 and 1940 with satellite derived glacier areas for the years 1973, 2003 and 2010. The aim was to empirically investigate the controls of glacier retreat and its regional differences. All glaciers in the glacierized basins retreated over the last 110 years with some variations in the sub-periods. However, the relative changes in glacier area compared to 1900 differed for every sub-basin and some glaciers decreased much faster than others. These observed differences were related to a variety of different potential controls derived from different sources, including mean annual solar radiation on the glacier surface, average slope, mean glacier elevation, initial glacier area, average precipitation (summer and winter), and the precipitation catchment area of the glacier. We fitted a generalized linear model (GLM) and selected predictors that were significant to assess the individual effects of the potential controls. The fitted model explains more than 60% of the observed variance of the relative change in glacier area with the initial area alone only explaining a small proportion. Some interesting patterns emerge with higher average elevation resulting in higher area changes, but steeper slopes or solar radiation resulting in lower relative glacier area changes. Further controls that will be tested include snow transport by wind or avalanches as they play an important role for the glacier mass balance and potentially reduce the changes in glacier area. The derived predictors will be further analyzed and the observed general patterns will be compared to modeling studies of glacier changes.