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Oblique photography for short-term monitoring of glacier mass balance

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Glacier mass balance is an important indicator of climate change. Mass balance monitoring programs mostly report annual values because field measurements are laborious. For climatic interpretation, the separation of the components of mass balance – accumulation and melt – is important. This can be achieved by performing seasonal mass balance surveys. However, the monthly or even daily glacier mass change over one year, which is crucial for analyzing e.g. the importance of glacier melt contribution to the hydrological cycle, can so far only be modelled, and not be easily observed directly in the field.

Here, we outline a method that allows a temporally continuous monitoring of glacier mass balance over the summer season. The method is primarily based on repeated digital photography of the glacier, i.e. a data source that can be acquired without direct field site access. The snowline in selected photographs of an automatic camera is delineated, and the images are deskewed, orthorectified and georeferenced. Thus, the percentage of the glacier covered with snow can be determined. The relation between glacier-wide mass balance and the snow-covered area fraction (SAF) mainly depends on (1) the quantity and the spatial distribution of snow, and (2) the glacier geometry. Rating curves of the SAF versus glacier mass balance are inferred using a mass balance model driven by daily meteorological variables averaged over the period 1961-1990. This allows an estimate of mass balance evolution throughout the summer at high temporal resolution based on repeated terrestrial photography.

The method is tested for Findelengletscher (13.4 km^2), Switzerland, for the ablation season of the year 2010. Direct mass balance measurements using the glaciological method provide an independent data set for validating mass balances estimated using repeated oblique photographs. A good agreement is found indicating the potential of the presented method for high-resolution mass balance monitoring of remote or inaccessible glaciers. We present an application to Gornergletscher (39.0 km^2), Switzerland, the second largest glacier of the European Alps. Using repeated photography for 2004-2009, glacier-wide mass balance and the dynamics of snow and ice melt throughout the summer are determined for six years.