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Automated processing of terrestrial photographs for glacier monitoring at Hoher Sonnblick (Austria)

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High-alpine regions react sensitively to climate change. The most obvious consequence of warming temperatures is glacier retreat, a direct effect of negative mass balances over a number of years. Continuous monitoring of glaciers is important for the quantification of indicators such as changing snow cover patterns. An easy-to-handle and inexpensive way to do so is the analysis of terrestrial photos taken by automatic cameras.
Photos from two cameras, operated by the Climate Research Department of the Central Institution for Meteorology and Geodynamics (ZAMG) in Vienna, Austria are installed at the high-alpine observatory on Hoher Sonnblick in the Austrian Alps. They are used to continuously monitor two glaciers (Kleinfleisskees and Goldbergkees) at high spatial and temporal resolution. Photos for the period 2014–2018 are available.
The aim of the present work is to investigate on the spatio-temporal evolution of the snow cover patterns on these two glaciers, thereby providing and evaluating a prototype of an automated image processing framework facilitating the work flow. We explore four research questions: (i) How did the patterns of snow cover evolution on the analyzed glaciers change in the period 2014–2018? (ii) Which level of automation can be achieved in processing terrestrial photos for the detection of glacier changes, in particular snow-free areas on the glacier? (iii) What are the limitations and the key challenges in doing so? (iv) How large is the loss of accuracy with increasing degree of automation?
The image processing framework developed operates in two steps: (i) The existing georectification tool PRACTISE is applied to automatically georectify all the terrestrial photographs. (ii) The newly developed routine GLACIERIZER, combining ArcGIS, Python, and the R software, is employed for image classification. A supervised classification method is applied, building on training areas mapped manually for a number of user-defined points in time. The entire framework is flexible enough to be applicable on other cameras, too. The results allow for quantitative statements on, for example, the evolution of snow-free areas on the glacier during each ablation period covered by the automated photographs.
The derived snow cover patterns on the investigated glaciers show highly dynamic intra- and inter-annual variations, which can be clearly linked to the recorded current and antecedent weather patterns. Reduced melting in 2014 was reflected in increased 2015 firn snow cover. Even though we clearly demonstrate that the automated image processing framework leads to scientifically relevant results, we would like to emphasize that the manual definition of training areas remains imperative. We further identify a clear trade-off between the accuracy of the results and time efficiency: the accuracy – using manually mapped patterns as reference – increases with the number of points in time at which training areas are defined. This pattern is seen as an invitation for further research towards improving time efficiency while maintaining a high accuracy of the results.