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Combination of photogrammetry and airborne laser scanning to derive horizontal flow velocities and volume changes of rockglaciers

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Creeping mountain permafrost, best represented by rockglaciers, is basically defined by its thermal conditions, material properties and its internal deformation. Knowledge of the three dimensional surface velocities of rockglaciers contributes decisively towards detecting and understanding the dynamic processes involved in rock glacier creep. Rockglaciers typically creep at surface velocities between a few centimetres up to a few meters per year. In recent years, high resolution remote sensing methods gained attention for measuring surface deformation of rock glaciers. Optimal investigations of rockglacier creep requires: (i) area-wide information on kinetics to account for 3D effects, (ii) in view of the low deformation rates, the application of precise high-resolution mapping techniques, and (iii) long-term monitoring for documentation of slow temporal changes at a sufficient level of accuracy.

In our study we combine methods of digital photogrammetry and airborne laser scanning (ALS) to quantify horizontal flow velocities as well as volume changes of the Äußeres Hochebenkar and Reichenkar rockglaciers over the time period between 1953 and 2009. The combination of digital photogrammetry and ALS is done for the first time for this kind of application.

The data used in our study are black and white stereoscopic photographs with a scale ranging between 1:16.000 and 1:30.000. For the Hochebenkar and Reichenkar rockglaciers, analogue aerial stereoscopic pairs are available for the years 1953, 1969, 1973, 1977, 1990 and 1997. To extend the time series of available aerial photographs, we used ALS data from 2006, 2007 and 2009 which were acquired within the C4AUSTRIA project.

From both the stereoscopic photographs and the ALS data we computed digital terrain models (DTM) with 1m resolution and subsequent shaded relief images of the rockglacier areas.

In a first step, the generated multi-temporal DTMs are subtracted from each other to derive volume changes of the rockglaciers. Secondly, we used shaded relief images as input data for the image correlation software IMCORR to determine the horizontal flow velocity of the rockglaciers over different time spans. Our results are validated using available in-situ dGPS measurements. Regarding the criteria for high quality rock glacier monitoring our results show: (i) that the use and combination of photogrammetry and ALS allows high quality area-wide monitoring and quantification of rockglacier surface kinetics, (ii) that the geometric accuracy of our input data and applied methods is appropriate to calculate rockglacier creep with low deformation rates and volume changes, (iii) that the combination of digital photogrammetry and ALS is a promising tool for a long term monitoring of rockglacier dynamics.

This method allows recognition of intact rockglaciers and differentiation of active and inactive rockglaciers without detailed field investigations. Active and inactive rockglaciers may be easily monitored over long time periods. The method also may be applied for the determination of unstable slopes in high-alpine areas, particularly related to the degradation of permafrost.