Quantitative analysis of rock glacier creep by means of digital photogrammetry using multi-temporal aerial photographs: Two case studies in the Austrian Alps

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Abstract

This poster presents a special measuring method of surface deformation and flow velocity of creeping rock glaciers based on digital photogrammetry. The underlying concept of automatic measurement of 3-D surface displacement vectors in time-series of multi-year digital aerial photographs is explained. In contrast to photogrammetric standard procedures image matching is not carried out in the space of the original photos but in quasi-orthophotos derived therefrom using rough and preliminary digital terrain models. A software package called ADVM (Automatic Displacement Vector Measurement), which is written in Visual C++ for running on a Windows-based PC, has been developed. The software has been tested within the framework of two case studies which comprised the spatio-temporal analysis of the kinematic behavior of three active rock glaciers in the Austrian Alps, i.e. the adjacent Inneres and Aeusseres Hochebenkar rock glaciers in the Oetztal Alps and the Hinteres Langtalkar rock glacier located in the Schober group, Hohe Tauern range. Some selected results of the photogrammetric evaluation are presented numerically and graphically.

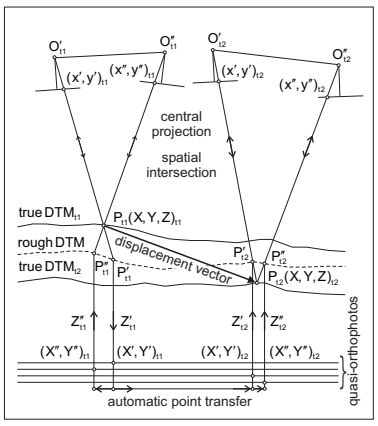
1. Introduction and outline of the proposed digital photogrammetric method

Quantitative information about the kinematic behavior of rock glaciers can be obtained either by field survey or by means of airborne or spaceborne remote sensing techniques. Aerial photogrammetry is presently the most powerful technique for obtaining precise and reliable geometric information about the surface of a rock glacier. Digital photogrammetry is the latest and most promising development.

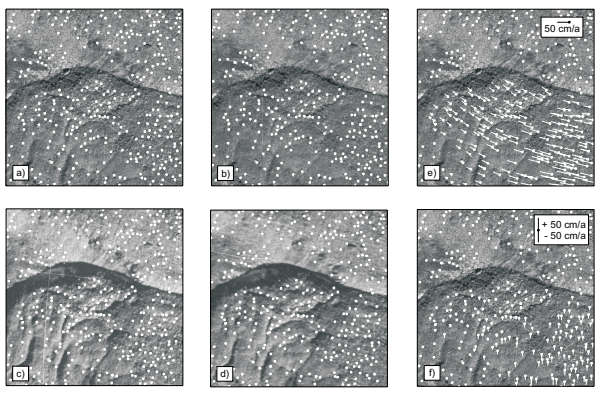
If we consider the mapping of the 3-D surface velocity field of a rock glacier, identical terrain features, e.g. large boulders, have to be tracked in the given multi-temporal aerial photographs. This can be best accomplished by means of digital image matching.

Change detection between multi-temporal quasi-orthophotos is the task of the ADVM software. Quasi-orthophotos offer at least two advantages, i.e. aerial photographs of any scale and orientation can be considered in the monitoring task and disk space can be kept comparatively low.

The core of the ADVM-software consists of four main modules, i.e. 1) computing of interest points, 2) prediction of corresponding points, 3) point transfer by means of least-squares matching, and 4) spatial intersection.



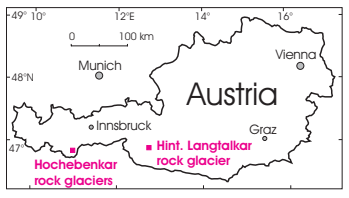
Computation of 3-D displacement/flow vectors using quasi-orthophotos



a) Quasi-orthophoto (no 2825) of 1953
b) Quasi-orthophoto (no 2826) of 1953
c) Quasi-orthophoto (no 4366) of 1969
d) Quasi-orthophoto (no 4367) of 1969
e) Horiz. component of the flow vectors
f) Vert. component of the flow vectors

2. Two case studies

The applicability of the proposed digital photogrammetric method for mapping, i.e. detection and quantification, of rock glacier creep has been tested and assessed within two case studies. Three rock glaciers located in two different study areas in Austria have been investigated.

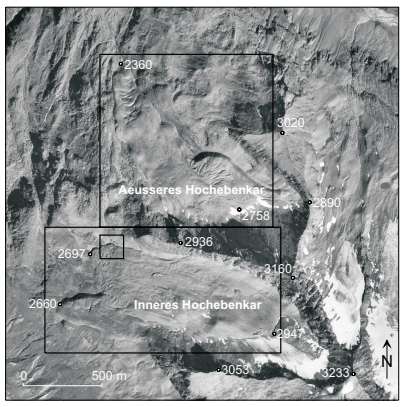


Location map of both study areas

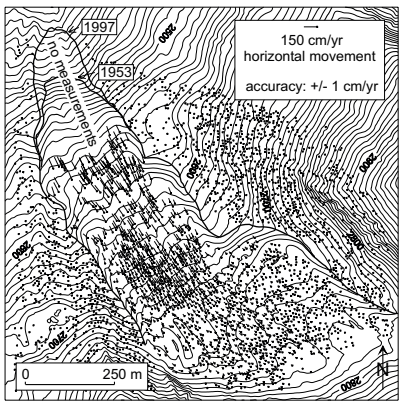
2.1 Hochebenkar rock glaciers

In the first case study we have analyzed two rock glaciers, which are located in adjacent cirques, i.e. Aeusseres and Inneres Hochebenkar, in the Oetztal Alps. Haeberli & Patzelt (1982) have carried out detailed permafrost mapping in the region of the Hochebenkar rock glaciers. Aerial photographs (8 different surveys between 1953 and 1997) were evaluated in this case study.

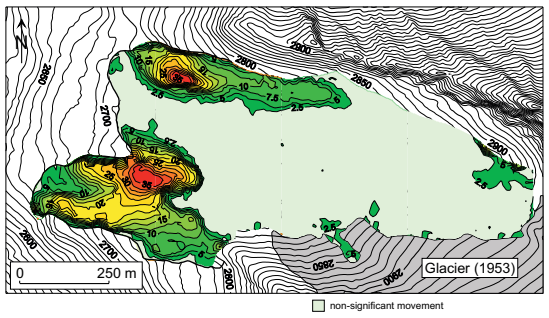
In this poster we present the graphical representations of the spatial distribution of the mean annual horizontal movement (flow velocity) of both rock glacier surfaces for the time period 1953-1997.



Orthophoto (11.9.1997) showing both Hochebenkar rock glaciers. The boxes delineate the areas shown in Figures above and on the right hand. Aerial photographs: © BEV-2000, Vienna.



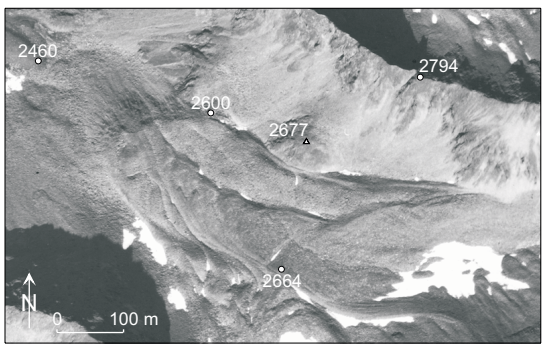
Flow vector field at Aeusseres Hochebenkar rock glacier for the time period 1953-1997.



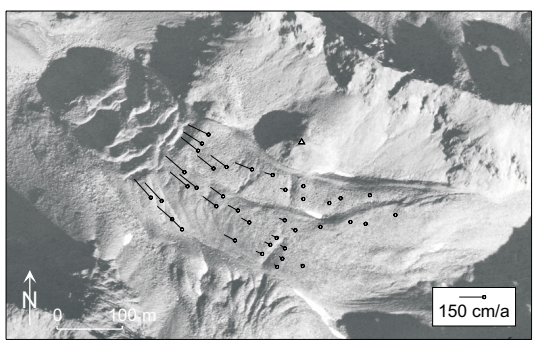
Mean annual horizontal flow velocity (cm/yr) at Inneres Hochebenkar rock glacier for the time period 1953-1997.

2.2 Hinteres Langtalkar rock glacier

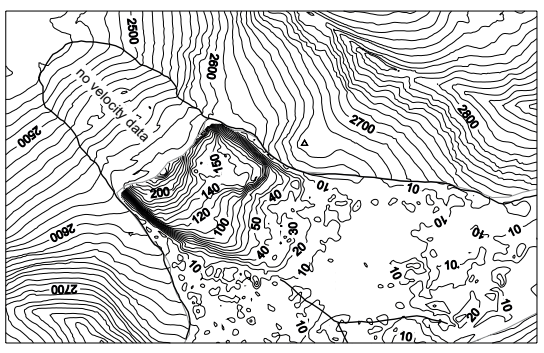
The Hinteres Langtalkar rock glacier is located in the Schober group, Hohe Tauern range. In order to study the rock glacier morphodynamics (past, present, future) in more detail 4 different observation methods, i.e. geodetic surveying, photogrammetry, terrestrial laser scanning and DInSAR were applied. Aerial photographs from 9 different years between 1954 and 1999 were made available. Based on this information the landslide (see below) must have happened between 1992 and 1997. The volume of the landslide is photogrammetrically estimated at 170,000 m^3.



Orthophoto (4.9.1991) showing the Hinteres Langtalkar rock glacier. Photos: © BEV-2001, Vienna.



Horizontal displacement vectors (1999-2000) derived from geodetic measurements. Orthophoto: 12.9.1999.



Mean annual horizontal flow velocity (cm/yr) at Hinteres Langtalkar rock glacier for the time period 1997-1998 derived from photogrammetric measurements.

3. Conclusions

We have introduced a digital photogrammetric concept for monitoring rock glacier surface deformation using digitized multi-temporal aerial photographs in this poster. A special software package ADVM has been developed and successfully tested in the framework of two case studies in the Austrian Alps. We are planning to upgrade the ADVM software with additional features, e.g. multi-photo geometrically constrained matching, which will also include a simplified rock glacier flow model.