Glacier monitoring by means of terrestrial photogrammetry: A case study in the Hohe Tauern National Park

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Abstract: The mapping of glacier fluctuations is an important task of environmental research. Several methods of glacier mapping on a local, regional and global scale are available. From a historical point of view, terrestrial photogrammetry was the first powerful tool in obtaining reliable metric information about glaciers in mountainous landscapes. Today, however, terrestrial photogrammetry is only applied occasionally in glacier studies, if at all. In this paper we seek to show that the availability of low-cost high-resolution digital (consumer) cameras opens up new perspectives in glacier monitoring. Since digital photogrammetric software is readily available for 3D data capture, we conclude that there is a good chance of a revival of classical terrestrial photogrammetry in the digital domain. The potential of a fully digital approach using a low-cost digital consumer camera has been investigated in a case study. The main task of the study was to obtain parameters quantifying the retreat of the Goessnitzkees glacier from ground-based photographs taken at three different time periods (1998, 1999, 2003).

1. Introduction

Goessnitzkees (12°45' E, 46°58' N) is a small debris-covered cirque glacier located in the Schober group of the Hohe Tauern range, Austrian Alps. The glacier covered an area of some 0.75 km² in 1997. In 1992 Goessnitzkees was included into the network of annual glacier measurements at the Austrian Alpine Club (ÖAV). Since 1992 until now all annual measurements (mid-September) on Goessnitzkees have been carried out by members of the Institute of Geography and Regional Science of the University of Graz (Un Graz). From 1996 to 1998 a glacier study under the leadership of G.K. Lieb (Institute of Geography and Regional Science, Un Graz) was carried out in order to reconstruct the glacier history of Goessnitzkees from 1855 (maximum extent of glaciation) until 1997. In 1996 the former Institute of Geodesy of the Graz University of Technology selected Goessnitzkees as a test site for high-mountain studies. A freely-dimensional geodetic network was installed for this purpose, comprising also some reference points of the previously described annual measurements for ÖAV.

2. Data acquisition

2.1 TAL - Glacial stage 1988

Zeta TAL, photorealistic principal distance: 55.62 mm glas plates: 6.5 cm x 9 cm

Photography: R. Kastl and V. Kaufmann, August 7, 1988

2.2 Rolleiflex 6006 - Glacial stages 1997 and 2003

Rollei camera Rolleiflex 6006 principal distance: 151.608 mm format: 6 cm x 6 cm (roll film)

Photography: V. Kaufmann et al., August 11, 1997; V. Kaufmann, A. Fauner and R. Neumayr, August 23, 2003

Remarks concerning 2.1 and 2.2:
- Scanning with Ultrascan 5000 (Vexcel Imaging Austria) at 10 um
- Making of usually crosses
- Geometric and radiometric pre-processing (e.g. correction of film shrinkage, film unsharpness and chromatic aberration)
- TAL: appr. 800 x 690 pixels
- Rolleiflex: 6001 x 6001 pixels

2.3 Nikon D100 - Glacial stage 2003

Digital camera Nikon D100 principal distance: 51.579 mm
CCD array: 3008 x 2000 pixels

Photography: V. Kaufmann, A. Fauner and R. Neumayr, August 23, 2003

3. Geodetic measurements 1997 and 2003

Since 1996 annual glacier measurements have been carried out every year (mid-August) until the present time:
(1) terminus of the glacier (2) shoreline of the proglacial lake (3) velocity markers (4) longitudinal profile (salinitm 154.5 gon) 1997: B. Marx 2003: R. Rothlauf

Photogrammetric orientation of all image data was carried out using an ImageStation SSK of 22 Imaging. The Rolleiflex 6006 stereo model of 2003 was selected as a reference model for subsequent absolute orientation of the other stereo models. The absolute orientation of this reference model was performed using the photogrammetric control points (N) measured geodetically at the same time of data collection. Some 56 tie points (T) were selected in areas of the deglaciated forefield of Goessnitzkees and in the steep back wall of the cirque glacier.

5. Results

Digital elevation models (DEMs) were obtained for all four stereo pairs through manual measurement of a selected list of points (T) were selected in areas of the deglaciated forefield of Goessnitzkees and in the steep back wall of the cirque glacier. These points (T) were used for the evaluation of the accuracy of the DEMs. The accuracy was calculated as the RMSE of the differences between the DEMs and the reference model. The RMSE values of the DEMs are smaller than ±22 cm. The accuracy of the DEMs is therefore sufficient for the present study.

6. Discussion

The usefulness of low-cost SLR digital consumer cameras for terrestrial photogrammetric glacier surveys was demonstrated in respect to Goessnitzkees. We conclude that the annual change of ice thickness can be computed with an accuracy of ±20 cm using the Nikon D100 digital camera. Assuming a mean annual surface lowering of about 2 m, an absolute measurement error not worse than ±10 cm can be expected. In summary, it can be said that terrestrial photogrammetry, as described in this paper, can be applied successfully in long-term monitoring projects for small glaciers or isolated areas of a glacier, e.g. outline of the terminus, if a sufficient number of stable points is available in the vicinity of the area of interest.

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