PHOTOGRAMMETRICAL MONITORING OF THE TRIGLAV GLACIER IN SLOVENIA

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Abstract: *The Triglav glacier lies on the northeast side of the highest Slovenian peak Triglav. Near the glacier base there is a meteorogical station, which gives also important data on the weather conditions on the glacier. The Anton Melik Geographical institute is monitoring its disappearance from the middle of the 20th century. The Geodetic institute of Slovenia was invited to perform photogrammetrical measurements of the Triglav glacier in the years: 1999, 2001, 2003 and 2005. The comparison of photogrammetrical and other data collected by the Anton Melik Geographical institute reveals the disappearance of the glacier. In this paper the photogrammetrical measurements of Triglav glacier will be described in detail.*

INTRODUCTION

The Triglav glacier lies at an altitude of approximately 2400 m on the northeast side of the highest Slovenian peak Triglav. It is one of just two small Slovenian small glaciers, the other glacier is under the Skuta mountain. Both are remnants of Europe's cold periods in the years from 1400 to 1800. The Triglav glacier has a long history of monitoring of its size by the Anton Melik Geographical institute, where measurements on yearly basis have been performed since the year 1946 (Šifrer, 1976). Results of these measurements are described in detail in Šifrer (1976, 1986), Gabrovec (1998) and Gabrovec & Peršolja (2004). Near the glacier base there is the Kredarica meteorogical station (2514 m), which gives important data on the weather conditions on the glacier. The Anton Melik Geographical institute, with help of meteorological staff constantly present at the meteorological station, has regulary photographed the glacier on monthly basis with the camera Horizont from two standpoints since the year 1976. The camera Horizont is a panoramic nonmetrical small frame camera.

The Geodetic Institute of Slovenia was invited to perform the photogrammetrical measurements of the Triglav glacier in the years: 1999, 2001, 2003 and 2005. Some additional work has been done to check the usefulness of the Horizont photographs. At first the calibration of the camera was performed at the Technical university of Vienna, then the photos were oriented and a special method was proposed to acquire 3D data from the Horizont photos (Triglav et al., 2000). Afterwards the photoclinometric method was tested too (Triglav Čekada, 2004). The research on acquisition of 3D data from Horizont continues, with the purpose of getting more accurate results.

Figure 1: The camera Horizont (left). The Horizont photograph from May 8, 1998, after the transformation into the central projection (left). The Horizont photographs are archived at the Anton Melik Geographical institute.

For the comparison of older data also older archive aerophotogrammetric stereopairs perfromed by the state in the process of filming the whole area of Slovenia (CAS – cyclical aerophotographing) were found in the Surveying and mapping authority of the Republic of Slovenia archives (1975, 1992, 1994, 1998). On the basis of the 1992 stereopair a DTM was made. Also the circumference of the glacier was acquired from the 1992 and 1998 stereopairs (Triglav et al., 2000). The oldest stereopair from 1975 was also oriented and used for acquisition of data.

The purpose of this paper is to present the photogrammetrical work of the Geodetic institute of Slovenia. The results of this work are 3D topographic charts of the glacier for the years 1999, 2001, 2003 and 2005. These 3D charts are shown in the same national coordinate system and can be directly comparable. Because of its 3D nature they can be used for different kinds of visualisations and GIS investigations.

PHOTOGRAMMETRICAL ACQUISATION OF DATA

Photogrammetrical filming

In the first three years (1999, 2001 and 2003), photogrammetrical filming was performed by hend-held Rolleiflex 6006 metric camera from a helicopter. This type of filming was used because the glacier covers a relatively small area. The area of interest includes the glacier and its immediate surroundings with an area of a few hectares. In the year 2005 the decision was made to acquire data on a wider area around the remnants of the glacier, so that this data could be used for future comparison of older maps and charts. The filming of wider area was performed with a classical aerophotogrammetric camera Leica RC30 camera (performed by Geodetski zavod Slovenije, d. o. o).

The control points for the orientation of stereopairs were measured every year when the filming was performed.

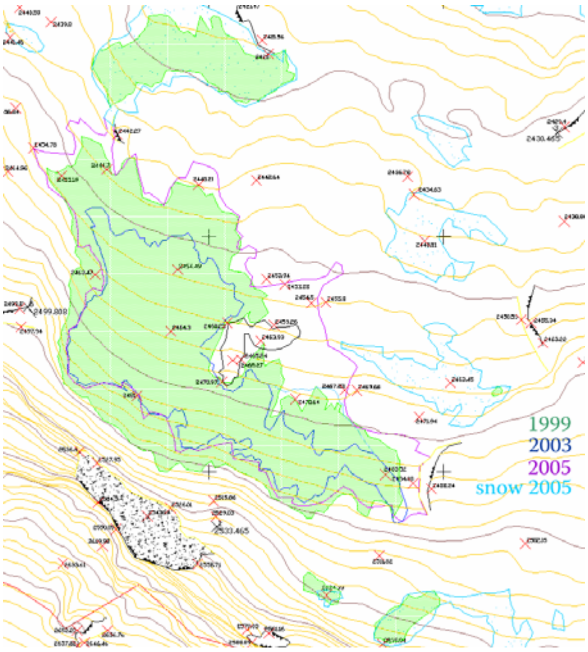
The photogrammetric filming and all geodetic measurements for the year 1999 were performed on September 13-15. At that time no snow from previous winter remained on the glacier, so the interpretation of the glacier from photographs was performed easily. The glacier lies in the Triglav national park with special protection demands, therefore temporal control points were used. These control points were painted on the rock with non-permanent colour without stabilisation and were measured in the local coordinate system. As these points were not stabilised, they disappeared in the next two years before the next new filming of the glacier. Nevertheless a few points remained, as we used already stabilised points from previous geographical measurements and fixed standpoints for nonmetric camera Horizont. The photogrammetric filming in 1999 was performed from a helicopter and from ground. The stereopars made from helicopter were used to acquire a topographic map (Figure 3a).

The filming of the glacier was again performed in October 16-17, 2001. At that time new snow already covered the glacier and surroundings (Figure 2), so a direct comparison to the year 1999 cannot be made. We again performed hand-held filming from helicopter. In 2001 new control points were stabilised and equipped with circular signals of 0.5 m diameter. The signals were mounted on the glacier a day before each filming. These points were measured with GPS in national coordinate system. Afterwards the transformation of the 1999 measurements made in local coordinate system through common points of 1999 and 2001 stereo models was performed.

Figure 2: A view through the helicopter door when approaching the glacier in 2001. At the right side of the photo the objective of the Rolleiflex camera can be seen. The whole slope around the glacier is covered with new snow.

In the year 2003, the campaign for measuring and filming was performed on August 26-27. The snow from previous winter already disappeared. For first time a comparison between two photogrammetrical models (from 1999 and 2003) of the glacier could be made (Figure 3). For the purpose of getting better reference frame of the photogrammetrical measurements, additional control points were stabilised and measured in global coordinate system with classical geodetic measurements. These points were stabilised only with screws and marked with non-permanent colour. Again photogrammetric filming was performed from a helicopter.

a)



b)

Figure 3: The state of the main part of the glacier in 1999, 2003 and 2005 as presented on topographical map (a). The same area as seen on the 2005 aerophotograph (b).

In 2005 the area of photogrammetric measurements was extended to capture a broader area of approximately 1.5 km^2 around the current size of the glacier, with a purpose to get bare ground presentation of the surroundings of the glacier. This will enable the study of volume changes of different older profile data. Therefore classical aerophotographing has been performed in two scales (1:4000 and 1:5000). For the acquisition of data only the scale of 1:4000 was used. A lot of snow has fallen in previous winter and there has been a relatively cold and rainy summer, so at the time of the August 24-25 campaign, the intended area was still covered with some snow patches. This means that the surroundings of the glacier was not always presented with bare ground. Old and new points were measured with precise GPS measurements. The new points were stabilised with small screws and marked with non-permanent colour (Figure 4). New transformation parameters for the transformation from ETRS89 to the national coordinate system were calculated for the area around the glacier.

Figure 4: An example of a control point stabilised with a screw (green arrow) and marked with a non-permanent colour made in 2005 for the filming in the scale of 1:5000 (photograph taken by Blaž Barborič and Matija Klanjšček).

The data were acquired from photographs with an analytical photogrammetrical instrument in all these cases. Each stereopair was oriented separately on the basis of the measured control points. The conture lines were measured at the 5 m ekvidistance. Additionally the detail points were measured at the terrain characteristic locations (the curvature changes of the terrain), also the circumference of the glacier or the snow remenents from the previous winter and other topographic content was shown on the 3D topographic map, which can be seen on Figure 3a.

Measuring the old aerophotographs from CAS (cyclical aerophotographing)

Some work has already been done on the 1992 and 1998 cyclical aerophotographing (CAS) stereopairs, which was presented in the introduction of this paper. CAS were usually filmed in the scale of 1:17500, which allows the acquisition of data for the charts of the scale 1:5000. The whole Slovenia is covered with CAS in an approximately 4-5 year period.

Here we will describe in detail the work on the oldest stereopair of CAS where the Triglav glacier is represented. This is the stereopair filmed in the October 29, 1975. These photographs were filmed in autumn, so the majority of the terrain is already covered by new snow. Therefore the results are not directly comparable with the newer photogrammetrical data. From CAS 1975 we can get a general view on the volume changes on the area where the glacier was at that time, as the area size can be verified on other types of data (different kinds of other archive photographs, old maps). As the notes on the original control points used for the orientation of that stereopair has been already lost, we used as control points identical points of the relief seen on the 1975 and 2005 stereopairs. Care was taken to identify control points, which would stay identical in all these years (rock summits…) and were not covered by snow in the year 1975. The orientation of the stereopair was made for local area around the glacier on 6 identical points seen on the 1975 and 2005 stereopairs. Some more control points were used to check the success of the orientation which gave an accuracy assessment of 0.5 m.

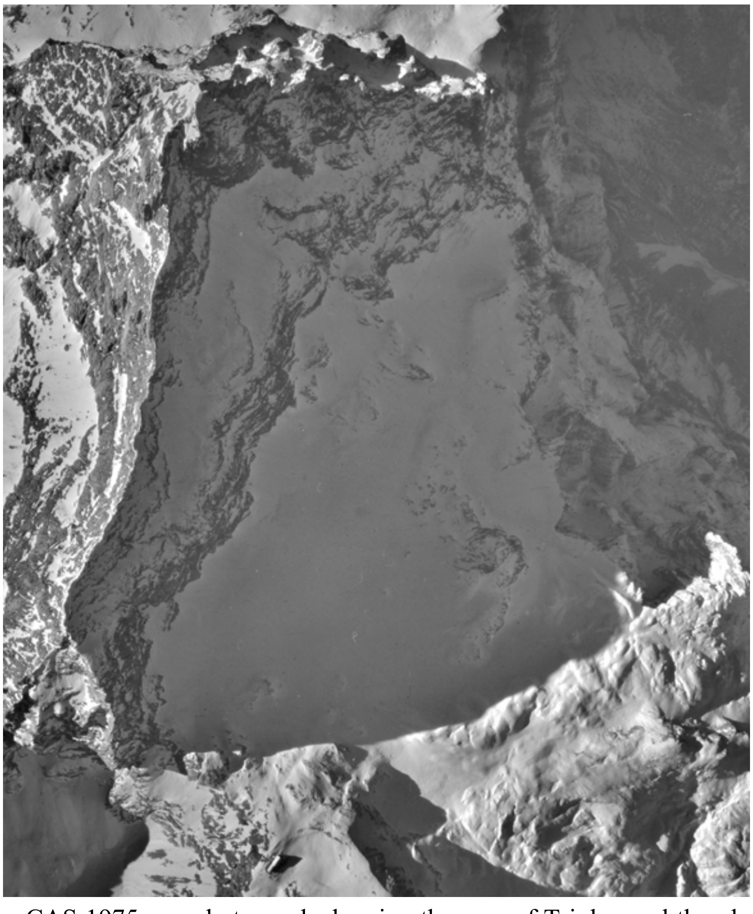


Figure 5: A part of the CAS 1975 aerophotograph showing the area of Triglav and the glacier which is covered by snow (the CAS 1975 is the product of SMA).

A 3D topographical map was made from the 1975 stereopair, with the same contents, as described in the previous section. In the area where the glacier has remained in the last few years the stereorestitution was difficult, as the area showed no texture.

RESULTS AND DISCUSION

Photogrammetrical measurements have still a priority when surface representation is concerned. Classical monitoring and terrestrial measuring of the glaciers is a time-consuming work, which can be minimised when photogrammetry is used. Unfortunately when aerophotogrammetry is employed a lot of care should be taken for the organisation of the mission, as the filming depends very much on the weather condition. Usually we needed two days for the campaign: in the first day we arrived at the site of the glacier, marked and measured the control points and in the second day the helicopter or the aeroplane arrived and filmed the area. As the glacier lies on the northeast side of the Triglav mountain the glacier soon gets into the shadow of the mountain, what is not ideal for photogrammetrical purposes. Therefore filming of the glacier should be made in the morning hours.

From 3D topographical charts we can derive the surface area of the glacier dropped to the plain. In 1999 the glacier had 1.1 hectares, the year 2001 cannot be compared because of a lot of old snow, then the glacier reduced in size to 0.7 hectares in the year 2003. Afterwards the snow-abundant winters followed, so the glacier had 1.1 hectares again in the year 2005.

3D topographical charts make it possible to do different kinds of visualisations (Figure 6) and GIS operations with the purpose of comparisons of different data.

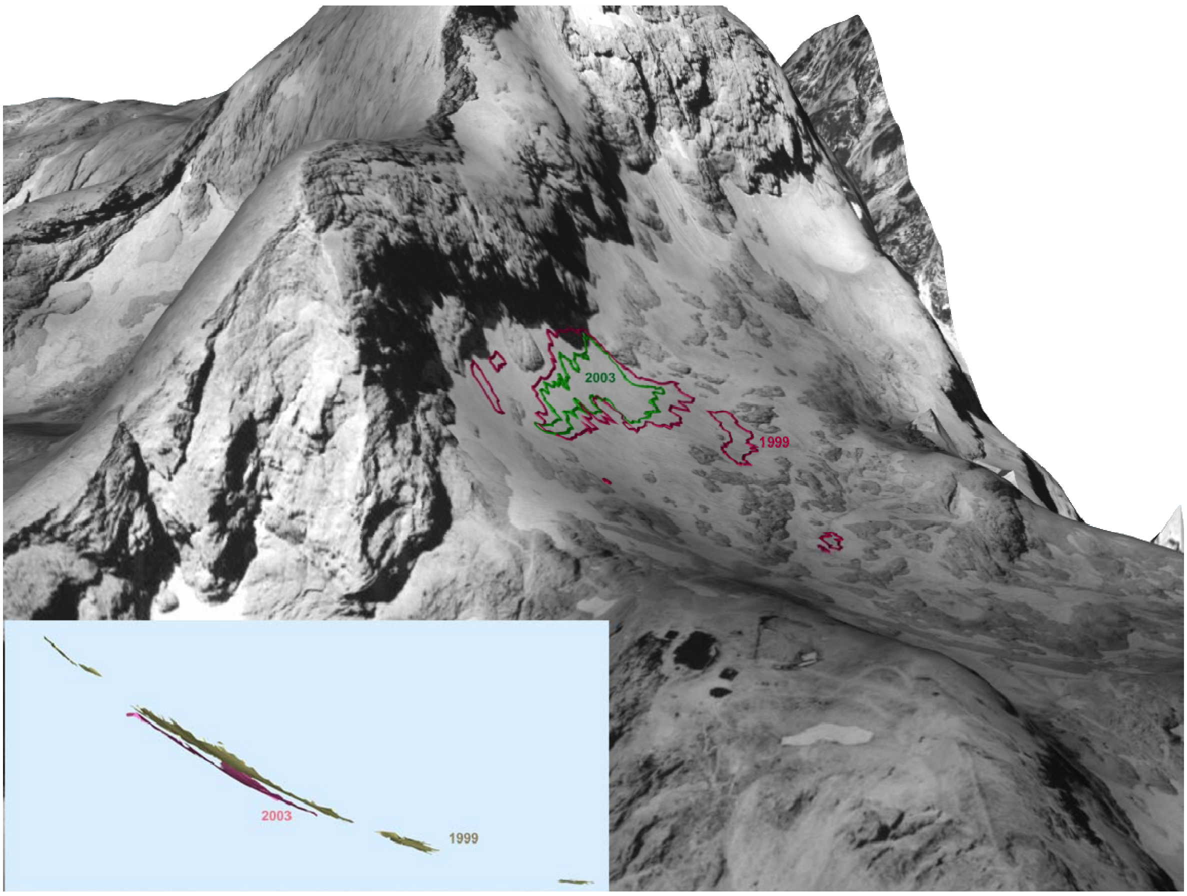


Figure 6: A 3D visualisation of the top of the mountain Triglav, with the glacier circumference lines from 1999 and 2003. The side view on the 3D surface models (in the left corner) evidently shows that the 2003 glacer surface lies under the 1999 glacier surface.

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