

The Austrian glacier inventory: status and first results

G. Patzelt

Abstract. The Austrian glacier inventory is based on vertical aerial photographs made especially in September and October 1969. The inventory is compiled uniformly for 1969 according to TTS instructions from photogrammetrically evaluated large scale maps. In addition, areal losses since 1920 and 1850 are evaluated for 100 m intervals. The work should be complete in late 1979. The total area of the 918 glaciers in the Austrian Alps is estimated to be $540 \pm 10 \text{ km}^2$ and the volume, assuming a mean thickness of 40 m, is 19 km^3 of water. By September 1978, 624 glaciers with a total area of 463 km^2 have been inventoried. The areal losses since 1920 have been evaluated for 47 per cent of all glaciers and those since 1850 for 68 per cent. In the Zillertaler Alps (163 glaciers) the total area has decreased by 17 per cent from 1850 to 1920 and 44 per cent from 1850 to 1969.

L'inventaire des glaciers autrichiens: état actuel et premiers résultats

Résumé. L'inventaire des glaciers autrichiens est élaboré sur la base de photographies aériennes prises essentiellement en septembre et en octobre 1969. L'inventaire est compilé uniformément pour l'année 1969 et conformément aux directives TTS à partir de cartes à grande échelle obtenues par restitution photogrammétrique. En supplément, on procède à l'évaluation de la diminution des aires englacées intervenue à partir de 1920 et 1850 pour des intervalles hypsométriques de 100 m. L'achèvement des travaux est prévue pour fin 1979. La superficie totale des 918 glaciers dénombrés dans les Alpes autrichiennes est estimée à $540 \pm 10 \text{ km}^2$ et le volume, en admettant une épaisseur moyenne de 40 m, à 19 km^3 d'eau. Au mois de septembre 1978, 624 glaciers d'une superficie totale de 463 km^2 avaient déjà été inventoriés. La diminution des aires intervenue depuis 1920 a été évaluée pour 47 pour cent, celle intervenue depuis 1850 pour 68 pour cent des glaciers. Dans les Alpes du Zillertal (163 glaciers), la diminution est de 17 pour cent pour la période 1850-1920 et de 44 pour cent pour la période 1850-1969.

INTRODUCTION

The first inventory of the glaciers of the Eastern Alps was evaluated by Richter (1888) who had at his disposal the official topographical maps showing the state of glaciers in 1870/1871. Since that time the glaciers of most mountain groups have been resurveyed, in part repeatedly, but never completely nor simultaneously. Thus, it is not surprising that even in recent textbooks (Liboutry, 1965; Wilhelm, 1974) the total area of the Austrian glaciers exceeds the true value by 55 per cent since use had to be made partly of the material of 1870/1871. The need for a new inventory was obvious.

The general preparations for the Austrian glacier inventory were initiated and organized by the late Prof. H. Hoinkes in 1967. Since April 1975, the author has continued the work in cooperation with G. Gross. This paper reports on the present state of the evaluation and on the first results.

THE WORKING METHOD

The Austrian inventory is based on vertical aerial photographs taken in September and October 1969 for this particular purpose. The mean picture scale of these photographs is about 1:30 000. Large scale maps are produced from them by stereo-autographs of as many glaciers as possible: up to date 87 per cent of all glaciers have been mapped at scales of 1:10 000 and 1:15 000 with contour intervals of 20 m. Firn edge and firn

line are photogrammetrically mapped as well as the moraines of 1850 and 1920, as far as possible, and the areas that have become ice free since. For the remaining 13 per cent, official topographic 1:25 000 maps with the state of glaciers in 1969 have been used.

From these maps, data are read according to the new TTS instructions (TTS, 1977). All areal and altitude data have the accuracy index 1, which means that areal data are accurate within 5 per cent and altitude data within 25 m.

In addition, the maps permit an accurate evaluation of the glacier areas of 1969 in altitude intervals of 100 m. For 75 per cent of all glaciers the areas of the 1920 and 1850 stages can be evaluated in the same way. Areal reductions and volume loss between these years can thus be computed not only for entire glaciers but also for discrete altitude intervals. Although this has been tested on a few glaciers at different times, the evaluation of an entire drainage area for a uniform time interval was not feasible until now. The material of the Austrian glacier inventory will thus be an important base for the investigation of problems related to climatic variations and glacier response.

The ice volume will be determined to a good approximation by empirical relations gained from direct seismic determination of ice thickness for 26 glaciers of the Austrian Alps by E. Brückel, Vienna, in the Austrian IHD project 'Gletscherseismik'.

STATUS OF THE WORK

In the Austrian part of the Eastern Alps there are 918 glaciers with an estimated total surface area of $540 \pm 10 \text{ km}^2$. For the reference year 1969, data for 624 glaciers (68 per cent) with a total area of 463 km^2 (86 per cent) have been completely compiled up to now (September 1978). The losses of surface areas since 1920 have been evaluated for 47 per cent and those since 1850 for 68 per cent of all glaciers. The inventory of the following groups is now completed: Dachstein, Ankogel, Glockner, Granatspitze, Venediger, Zillertaler, Stubai. The glaciers of the Ötztaler group have been two-thirds evaluated. Computer processing of this material has now begun. It seems justified to expect that the inventory will be completed by the end of 1979.

A completely new bibliography of the Austrian glaciers has been compiled which is not keyed solely to the year of print. It is indexed according to authors, subjects and places and contains 1600 titles.

FIRST RESULTS

Some 32 (4 per cent) of the 918 Austrian glaciers are situated in the drainage basin of the River Rhine and 886 (96 per cent) in that of the River Danube to which the drainage basin of the River Inn contributes 668 or 73 per cent of all Austrian glaciers. The three largest glaciers are the Pasterze (Glockner) with 19.78 km^2 , Gepatschferner (Ötztaler Alps) with 17.69 km^2 and Obersulzbachkees (Venediger) with 11.57 km^2 . 25 glaciers (3 per cent) are larger than 4 km^2 and 805 (88 per cent) of the 918 are smaller than 1 km^2 .

The total area of the Austrian glaciers of 540 km^2 is still uncertain by $\pm 10 \text{ km}^2$ or ± 2 per cent. Assuming a still questionable mean ice thickness of 40 m one finds an ice volume of 21 km^3 or a water equivalent of 19 km^3 .

For the first time it is possible to determine for an entire mountain group the areal loss of glaciers since the advances of 1850 and 1920. In 1850 the total area of glaciers in the Zillertaler Alps was 78 km^2 , in 1920/1925 it was 17 per cent less and in 1969 it was 44 per cent less than in 1850. In the Zillertaler Alps the glaciers having an area smaller than 1 km^2 now have lost an average of 64 per cent of the area they had in 1850, those having an area larger than 5 km^2 now have decreased by 32 per cent. In

the dry central Ötztal Alps small glaciers (1 km²) have lost 55 per cent since 1850 and those larger than 10 km² have lost 25 per cent.

For many glaciers, the area of 1969 means a minimum extent. According to the statistics of length measurements (Patzelt, 1977) a tendency towards growth was noticed in 1965 and became stronger in 1970. Since 1974 more than 50 per cent of the observed glacier tongues are advancing. Although the areal changes in the region of the terminus stayed small and usually less than the accuracy of evaluation, ± 1 per cent, in the case of continued advance the inventory of 1969 would become a specially valuable glaciological document.

REFERENCES

- Lliboutry, L. (1965) *Traité de Glaciologie*, tome II: Masson et Cie., Paris
 Patzelt, G. (1977) Statistik der Längenmessungen an den österreichischen Gletschern. *Z. Gletscherk. Glazialgeol.* 12 (1976), no. 1, 91-94.
 Richter, E. (1888) *Die Gletscher der Ostalpen*: Engelhorn, Stuttgart.
 Wilhelm, F. (1974) *Schnee- und Gletscherkunde*: Walter de Gruyter, Berlin.

DISCUSSION

Vivian:

You report that glaciers in the Zillertaler Alps have retreated by 44 per cent since 1920. Is this percentage true for all Austrian glaciers? In France, we register a retreat of 25 per cent for all the French glaciers. Can you explain this difference?

Patzelt:

The loss of 44 per cent in the areas of the glaciers in the Zillertaler Alps has occurred since 1850. From 1920 to 1969 the areal reduction of all glaciers was about 33 per cent from the 1920 extent. Reduction values depend on the glacier size and were smaller for large glaciers than for small ones.

Müller:

The 1920 and 1850 assessments make your glacier inventory particularly interesting and valuable for relating glacier fluctuations and climatic change.

Ommanney:

How do you deal with the problem of glacier numbering when glaciers have disappeared over the time period that you are considering?

Patzelt:

Glacier numbering is based upon the glaciers still existing in 1969. Glaciers which disappeared since 1850 were not considered.

Jordan:

The accuracy of your data depends very much on the maps used. Can you please give us some information as to how you are doing this work?

Patzelt:

The maps for the inventory were plotted with a stereo-autograph with the geodetical accuracy which is possible in map scales between 1:10 000 and 1:15 000. The accuracy is higher than in the official topographic maps.

