# THE HOT EUROPEAN SUMMER 2003
# AND ITS IMPACT ON THE GLACIER RETREAT IN AUSTRIA

**H. Holzmann[1*] , G. Koboltschnig[2], W. Schöner[3]**

*[1]University of Natural Resources and Applied Life Sciences (BOKU), Vienna, Austria*
*[2]Provincial Government of Carinthia, Klagenfurt, Austria*
*[3]Central Institute for Meteorology and Geodynamics (ZAMG), Vienna, Austria*
**hubert.holzmann@boku.ac.at*

In the year 2003 Central Europe suffered from a very warm and dry summer period. The impact of the high temperatures and low precipitation lead to plant stress and crop loss, shortage of drinking water supply and low discharges in the rivers. One further consequence was a strong melt and depletion of the high alpine glaciers. As a positive effect this melt water contribution significantly increased the discharge of the alpine rivers, but on the other hand it lead to a dramatic reduction of the glacier volume. In the frame of a research project entitled SNOWTRANS - *Regionalisation of snow- and ice melt processes in the Hohe Tauern mountains in Austria (Holzmann et al., 2008)* the authors monitored the small partly glaciered basin of Goldbergkees glacier (2.7 km$^2$). Meteorological data were provided by the alpine observatory at the summit of the basin. Temporal snow courses and glacier ablation probes were conducted for the period 2003 to 2006 and continuous discharge was observed by means of a gauging station. Figure 1 shows the retreat of glaciered areas in the test basin between 1979 and 2003, where the climate conditions of the year 2003 contributed most significantly to the melt process.

Besides the monitoring activities different types of melt and rainfall runoff models were developed and applied by the authors for comparison and evaluation purposes (Holzmann *et al*. 2007). Glacier runoff and its temporal occurrence are strongly related to the diurnal pattern of the energy input and dependant on the geometry (altitude, length, slope, depth) of the glaciers. The modelling of the runoff contribution of glaciers has high relevance e.g. for climate change assessments or for operational runoff forecast systems in high alpine environments.

This contribution especially refers to (a) the monitoring techniques to assess the water balance components in high alpine environments, (b) to the identification of the relevant processes for runoff formation and (c) to the simulation of runoff and the design requirements for sufficient hydrological modelling. Special emphasize will be given on the conditions of the extreme year 2003.

## Monitoring

The Goldbergkees basin (2300 – 3100 m a. sl.) has a long tradition in observing meteorological and hydro-glaciological data. For the project SNOWTRANS the time period from 2002 to 2006 was considered for field measurements and modelling experiments. During that period several additional surveys were carried out. With respect to the needs of SNOWTRANS the following variables were monitored:

– Meteorological data (precipitation, air temperature, global radiation),
– snow depth (GPS tracks and satellite images),
– snow density and snow water equivalent,
– snow depletion,
– ice and snow ablation,
– glacier depth and glacier size,
– discharge and water levels (rating curves),
– stream water temperatures.

## Process identification

In the period from November until May air temperatures tend to be below zero degrees due to the high elevation of the basin. Therefore the precipitation is accumulated and stored as snow during this time. In the melt period starting with May snow cover has to be depleted to enable ice melt of the glacier. These processes are strongly spatially distributed as we observe spatial patterns of air temperature according to the elevation. The total runoff comprises direct rainfall contribution, snowmelt and icemelt. Baseflow can be neglected as the area is covered by rock and no significant soil layers developed in the basin. It can be shown from the data, that snow covered areas have the capacity to retain rainfall where blank glacier ice transform runoff quicker to the basin outlet. In the year 2003 glacier debris accumulation on the ice surface was much stronger as the impounded debris layers were released by melting. This reduced the albedo and increased the melt rates.

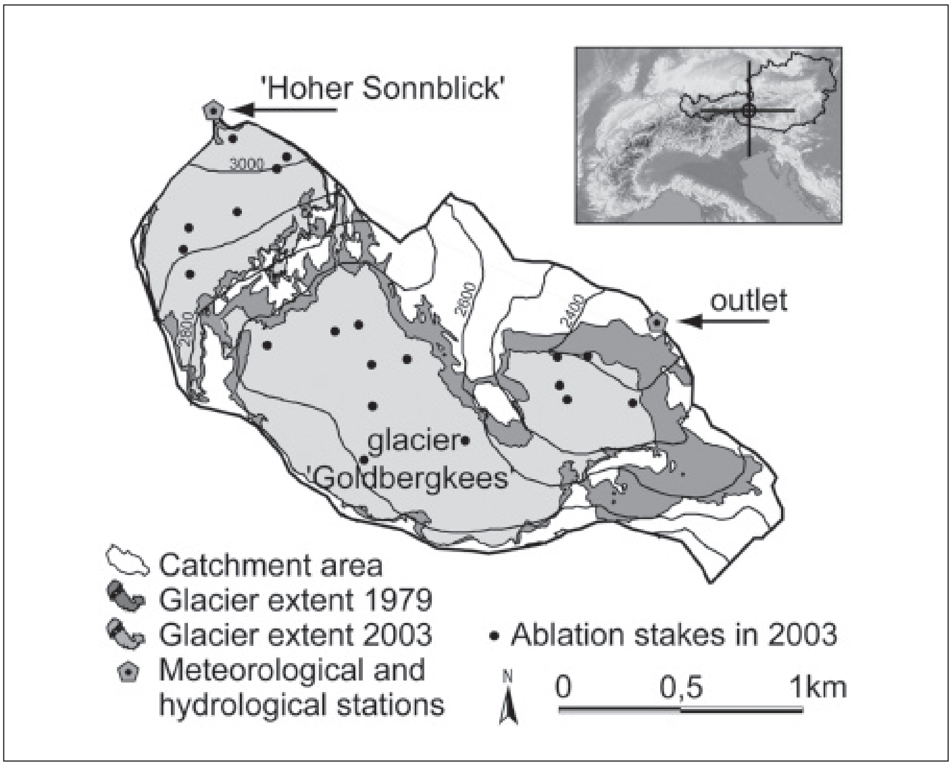


Figure 1. Glaciered areas 1979 (dark grey) and 2003 (bright grey) of Goldbergkees glacier. Black dots show snow stakes of ablation period 2003 (Koboltschnig, 2007).

## Melt modelling

Different types of indexed based snow- and icemelt models were applied. It could be shown, that for mean daily time steps temperature index models (day degree type models) worked sufficiently. For hourly time resolution combined temperature - radiation index models exhibit better performance with respect to the strong diurnal variability of melt. Figure 3 shows the runoff contribution of glacier melt on total runoff during the summer period of 2003. During August almost 95% were based on this type of source.

Also the daily amplitudes of discharge varied much higher in 2003 in comparison with other years. The daily maxima reached approximately 4 $m^3 \cdot s^{-1}$, where in regular years the peaks range around 2 $m^3 \cdot s^{-1}$ (Figure 2). In the presentation some further consequences for runoff are given with special focus on the change of glaciered areas based on remote sensing.

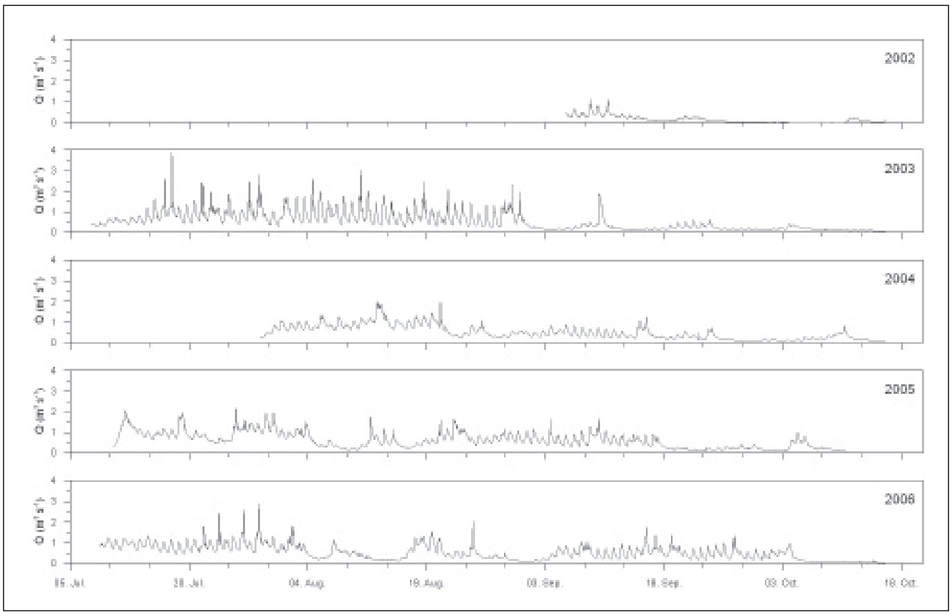


Figure 2. Discharge observations 2002–2006 (Koboltschnig, 2007).

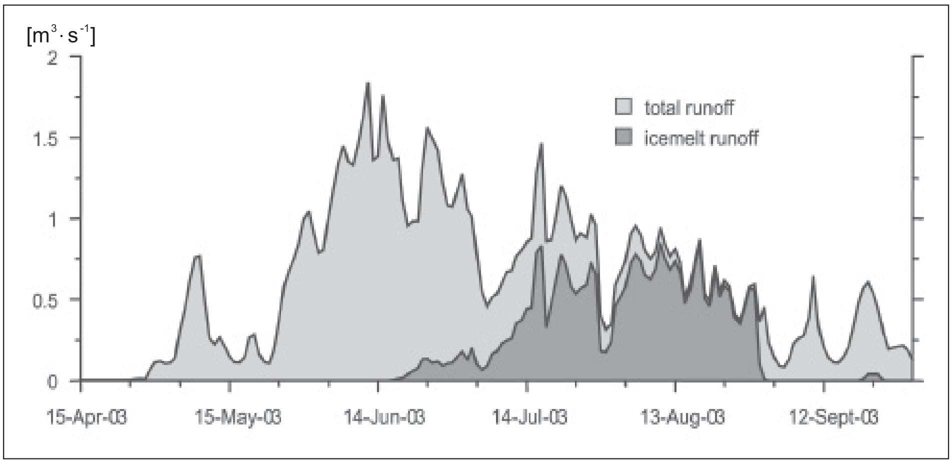


Figure 3. Simulated runoff at Goldberg gauge for the year 2003 (Koboltschnig, 2007).

## Acknowledgment

The authors give their special thanks to the Austrian Academy of Sciences for funding the research project *SNOWTRANS - Regionalisation of snow- and ice melt processes in the Hohe Tauern mountains in Austria* in the frame of IHP.

### References

Holzmann, H., W. Schoener, 2008: *Modeling and exterpolation of snow and ice melt processes in alpine environments.* Final report of SNOWTRANS project funded by the Austrian Academy of Sciences. Österr. Wasser- und Abfallwirtschaft, (In German), (in prepariation).

Koboltschnig G., 2007: *Multivalidation approach of hydrological snow- and icemelt models for high alpine glacierized basins*. Dissertation at the BOKU-University Vienna, in German.

Schöner W., Auer I., Böhm R., Hynek B., Holzmann H., Koboltschnig G., 2004: *Extreme glacier melt in Hohe Tauern region (Austrian Alps)*. In: A. Herrmann: International Conference on Hydrology of Mountain Environments, 27. Sept- - 1. Okt 2004, Berchtesgaden, Deutschland; Landschaftsökologie und Umweltforschung, Extended Abstracts, 47, 191-195; Selbstverlag Institut für Geoökologie der Technischen Universität Braunschweig, Braunschweig.