VERNAGTFERNER 1979-1982, AUSTRIA, 1:10,000

(Thematic map)

O. Reinwarth, Commission for Glaciology,
Bavarian Academy of Sciences, Munich

The map series of the Vernagtferner/Oetztal Alps, starting in 1889 with the famous map by Sebastian Finsterwalder (K. Brunner, this volume), was continued in 1912 and 1938 with repeated terrestrial photogrammetric surveys as well as in 1954, 1969, 1979, 1982 and 1990 on the basis of aerial photography. This ongoing effort is not only aimed at documenting the changing state of the glacier but also at contributing to the development of methods for preparing glacier maps.

Until 1969, all maps represented conventional topographic maps (1889, 1969) or thematic maps combining the contour line system of two successive mappings (1889/1912, 1912/38, 1938/69) to demonstrate growth or shrinkage of the glacier. Later maps were produced as orthophoto maps (1979, 1982, cf. Rentsch 1985, 1990, Heipke and Rentsch, this volume). The progress in preparing these maps mainly concerns the methods of evaluating the aerial photographs, proceeding from online-plotted contours to data acquisition by applying the progressive sampling method (PROSA) allowing for the generation of contour lines with arbitrary intervals, digital terrain models (DTM) or other derived representations. For these computations, the HIFI software (Height Interpolation by Finite Elements, Ebner and Reinhardt 1984) is being used.

With the DTMs of the glacier surface as a most valuable tool, it became possible to substitute the so-called "Finsterwalder method" of computing mean volume or elevation changes by computerized numerical subtraction of the DTMs from successive glacier topographies (Reinhardt & Rentsch 1986). This method not only provides the amount of volume or elevation changes for the entire glacier as well as for distinct altitude intervals with a rather high accuracy and in particular with a reasonable and economic amount of computational work, but also allows mapping of the areal distribution of elevation changes by constructing lines of equal elevation change using plotted values of the difference in altitude for each grid point of the DTM.

The map "VERNAGTFERNER/Höhenänderung (elevation change) 1979-1982" at a scale of 1:10,000, issued by the Commission of Glaciology Munich is a first example of such a cartographic representation of elevation changes. The elevation changes are divided into 5 classes for each sign with 4 intervals of 2 meters up to ± 8 m and a further interval for changes greater than ± 8 m. Yellow to brown colours indicate lowering of the surface, and blue to violet colours are used for rising parts of the surface. The different shadings of the scaling colours and the line signatures were made possible by printing the map in four colours.

The construction of isolines is based on the grid point values of a regular DTM of 40 m grid width. The isolines were drawn manually because variation of the values was demanding a certain smoothing to derive a reasonable pattern. Nevertheless, some details of the analysis still cause problems for interpretation, for instance, the nearly regular (wave-like) intersection of shrinking and rising areas downslope from "Hinterer Brochkogel". The block diagramm, which helps to illustrate the areal distribution of elevation changes with respect to sign only (rising surface indicated in blue, lowering surface in red), represents the 40 m grid of the DTM, transformed into a view of central perspective.

The behaviour of Vernagtferner since the beginning of direct (glaciological) mass balance measurements in 1965 is characterized by an overall mass increase between 1965 and 1980 interrupted by some negative mass balances between 1969 and 1973. The summer of 1982 marks the beginning of continuous mass loss, starting with the most negative mass balance value in 1981/82 for the period 1965-1990, in particular with the highest amount of summer runoff measured so far. The short time-interval of 1979-1982 was especially chosen for cartographic demonstration of elevation changes because of the unusual, nearly "surge-like" behaviour of the glacier during this period.

A quantitative comparison of mean annual mass and elevation changes for 50 m altitude intervals for the three-year period clearly reveals the inverse distribution of elevation changes and net mass balance with altitude:

Area (1979), mean annual elevation changes (ΔEL) and mean annual specific net balance values (BN/BA) of Vernagtferner for the period 1979-1982 for 50 m altitude intervals and for the entire glacier.

Altitude from to	Area $10^3 m^2$	ΔEL mm/a	BN/BA mm WE/a
3600 - 3650	4.7	- 500	6
3550 - 3600	8.2	- 642	- 33
3500 - 3550	40.9	- 382	103
3450 - 3500	159.5	- 89	579
3400 - 3450	261.1	- 174	287
3350 - 3400	311.3	- 783	78
3300 - 3350	581.3	- 454	157
3250 - 3300	1086.9	- 681	326
3200 - 3250	1126.5	- 611	78
3150 - 3200	1332.8	- 567	38
3100 - 3150	1274.2	- 314	- 96
3050 - 3100	1162.2	- 289	- 327
3000 - 3050	875.7	- 89	- 594
2950 - 3000	626.2	314	- 1189
2900 - 2950	390.2	591	- 1656
2850 - 2900	208.0	627	- 1838
2800 - 2850	77.3	861	- 1002
2750 - 2800	23.0	1473	- 2338
Sum/Mean	9550.0	- 291	- 249

The total amounts accord quite well, in particular regarding the rather high firn ablation in this period, which demands an excess of volume change as compared with mass change. Thus, with the comparison of mass and volume changes in mind, the map representing the areal distribution of elevation changes also indicates, to a certain extent, the dynamic processes causing these alterations.

* * *