

## CARESER GLACIER, 1967–1990, ITALY, 1:10,000

(Thematic Map)

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An aerial survey carried out in October 1990 on the Caresèr Glacier allowed comparisons with a previous survey of 1967. Further determinations of the area, elevation and volume variations during the period 1966–1967 and 1989–1990 could be made. These measurements coincide with 24 years of direct glaciological measurements to evaluate annual mass balance.

The survey methods used were similar to those already adopted for the 1967–1980 comparisons and improved for 1980–1985 (Giada and Zanon 1985; 1991). Aerial photogrammetry was used to produce digital models of the glacier surface, referring to a local system of coordinates. The survey model for 1967 was obtained by analytical photogrammetry, the one for 1990 done directly by stereo-restitution. In both cases, two sets of data were produced, arranged in matrices of elevation values having the same frame of reference and the same grid size (50 m). Thus the two digital models coincide. Comparisons between the two matrices (algebraic sums of coincident grid values) gave a third matrix containing the global elevation differences in the period 1967–1990. The elevation difference matrix was directly used to produce the thematic map using CAD tools. The process itself consisted of the automatic evaluation of different contour values and the subsequent hatching of the areas between two consecutive contour lines.

Comparisons of data from the two aerial surveys produced the thematic map 1:5000, with isolines expressing elevation variations of the glacier surface according to the classes shown in the legend. The map also shows variations in glacierized area for the same period.

Glaciological analysis:

The lowest altimetric zone (2840–2900 m) clearly shows the great increase in area (73.45% of the initial 1967 value) due to the reduction in thickness of this part of the glacier, falling entirely within the 30 m class of negative variation on the map. The greatest reductions occur in the zone between 3150 and 3350 m, which represents 93.13% of the 1967 area. The overall reduction between 1967 and 1990 is 18.30% of the pre-existing surface area.

The 1967–1990 elevation variations were all negative and range between -27.19 m (2840–2900 m zone) and -6.46 m (3200–3350 m zone). The mean variation for the entire surface is -13.76 m. Therefore, in the zone between 3000 and 3150 m, 68% of the overall volume loss occurred. This value corresponds to the 1980–1990 loss, which was 67% (Giada and Zanon 1991). Table 1 shows these variations and the corresponding volumes, according to the 1967 area.

Data obtained from the 1967 and 1990 aerial surveys were compared with the results of direct glaciological measurements for 1966–1967/1989–1990 balance years (Giada and Zanon 1995). Altitude and volume values were converted into water equivalents (WE),

with reference to the 1967 area. For the sake of homogeneity, the calculation of net balance volumes refer to the 1967 area, without considering the area changes which occurred between 1967 and 1990. Instead, these variations were considered in the mass balance computations (Zanon 1992). Comparisons between the two sets of data may be considered satisfactory: the overall difference, expressed as water depth, is only -0.34 m or -2.7%. However, there are considerable differences in the data for single altimetric zones, in particular in the range 3200–3350 m. In this zone, due to its topographical and morphological configuration, comparisons must be viewed as purely indicative.

Of particular interest are the variations in the 3050–3100 m zone, where mean and medium elevation, and ELA with zero balance are found. Thus the variations in this zone must be considered critical for the glacier. The variation in 1990 was -13.20 m WE, with a volume loss of  $14.1110 \times 10^6 \text{ m}^3 \text{ WE}$ , or 24% of the  $8.53 \text{ m}$  and  $-11.1230 \times 10^6 \text{ m}^3 \text{ WE}$ , or 19% of the total. The losses observed in the next zone at 3100–3150 m ( $-8.53 \text{ m}$  and  $11.1230 \times 10^6 \text{ m}^3 \text{ WE}$ , or 19% of the total) and the already mentioned reduction in surface area, clearly indicate the considerable state of disequilibrium which arose in the glacier at the beginning of the 1990s. This originates almost exclusively in the period of accelerated negative variations which took place between 1980 and 1990 on the southern slope of the Central Alps (for other details, see Giada and Zanon 1995).