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The mass balance of a cirque glacier in the Italian Alps (Ghiacciaio della Sforzellina, Ortles–Cevedale Group)

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ABSTRACT. The net mass balance (1986/87–1989/90) was calculated for a small cirque glacier in the Italian Alps (Ghiacciaio della Sforzellina, 0.42 km^2, Ortles–Cevedale Group). Four annual mass balances are presented here. All four balances were negative (mean value: $-0.90\,m\,year^{-1}$), with a maximum deficit of $-1.16\,m\,year^{-1}$ in 1989–90. The climatic conditions (which are analyzed using data from the S. Caterina Valfurva Station) consisted of a succession of cold, dry winters with little snowfall. Frontal-variation data available since 1925 show a constant retreat until 1966, followed by a brief advance period which has already terminated.

INTRODUCTION

The Ortles–Cevedale Group is located in the central sector of the Italian Alps and borders the regions of Lombardy, Trentino and Alto-Adige. It represents the most highly glacierized group on the Italian side of the Alps. In 1986–87, mass-balance data began to be collected for a glacier on the Lombard side of this group, Ghiacciaio della Sforzellina (Catasta and Smiraglia, 1988). This paper gives the most recent results of this work.

GHIACCIAIO DELLA SFORZELLINA

The glacier selected is located in Gavia valley (Alta Valtellina). It is a small glacier (0.42 km^2), situated in a cirque at the foot of Corno dei Tre Signori (3360 m) (Fig. 1). The surface area ranges in altitude between 2789 and 3150 m. A geo-electric survey carried out in 1988 indicated a maximum thickness of 40 m (Resnati and Smiraglia, 1989).

MASS-BALANCE METHODS AND RESULTS

The mass-balance data were obtained according to the well-known methods of Østrem and Stanley (1966). A network of 11 aluminium poles was positioned along the glacier surface at 2800–2970 m at the end of September 1986, before the autumn snowfalls. In the following years, the network was extended to 15 measurement sites. Snow- or ice-height variations at each site were measured only during the summer, or more specifically, at the end of September, due to the difficulty and risks involved in reaching the glacier at the end of the accumulation period. The measurements obtained therefore represent net accumulation and net ablation. The mass balance was calculated as the algebraic sum of the amount of snow remaining at the end of the ablation period and the amount of ice or snow that melted in that same period. All values are expressed in units of water equivalent (w.e.), assuming a density of 0.91 $Mg\,m^{-3}$ for ice and using the measured values for the snow density. The "Carta Tecnica Regionale della Lombardia" at a scale of 1 : 10 000 was used as a topographical basis. Using the measurements obtained at each pole, accumulation and ablation isolines were drawn on the map. The balance amounts expressed in cubic metres were obtained by multiplying the net mass-balance values by the corresponding areas. The sum of the balance amounts, divided by the area of the glacier, represents the specific annual mass balance expressed in mm.

RESULTS

The results pertaining to the mass balance for the 4 years from 1986–87 to 1989–90 are reported in Tables 1 and 2.

It clearly emerges from Tables 1 and 2 that the mass balance of Ghiacciaio della Sforzellina was negative for each year considered. However, there are marked

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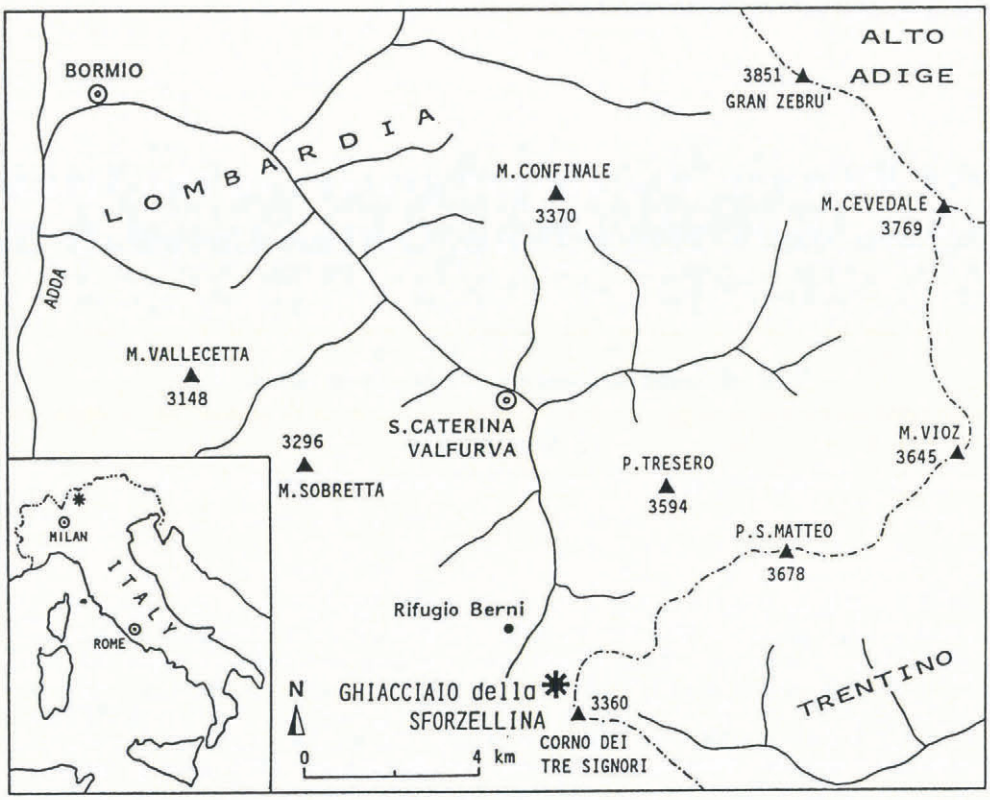

Fig. 1. The location of Ghiacciaio della Sforzellina (Italian Alps) and of meteorological station (S. Caterina Valfurva).

differences between the balances, which may be attributable either to variations in climatic conditions or to the morphological features of the glacier surface. First of all, one may note that for each year of observation, ablation was most intense not throughout the entire lower region of the glacier but only in its left frontal sector. In fact, in the central part of the front, the glacier was covered with debris, the extension of which increased each year. The debris protects the underlying ice from direct incident solar radiation. Ablation proved to be greater at the highest altitudes, from 3050 to 3150 m, than at slightly lower altitudes (in 1988–89 there was less accumulation at 3050–3150 m, with respect to the regions directly below those altitudes), as there is an ice wall on the western slope of Corno dei Tre Signori, the steepness of which does not favor accumulation. Small patches of snow were observed in the upper central region of the glacier at 2900–3000 m in a slightly concave area. It should be stressed that, in each of the 4 years of observation, the glacier surface was almost completely free of winter snow at the end of the ablation period. A strip of snow consisting of numerous cones was visible only at the base of the Corno dei Tre Signori wall along avalanche tracks. Ablation in this area therefore proved to be lower because

Table 1. Net mass-balance data for 1986–87 and 1987–88

Altitude	*Area*	*1986–87*		*1987–88*	
		Total	*Specific*	*Total*	*Specific*
m a.s.l.	km^2	m^3	mm	m^3	mm
2780–2800	0.0030	–7250	–2420	–5100	–1700
2800–2850	0.0640	–126 500	–1980	–125 440	–1960
2850–2900	0.1160	–178 260	–1540	–151 960	–1310
2900–2950	0.1290	–59 945	–460	–107 070	–830
2950–3000	0.0720	–8100	–110	–10 800	–150
3000–3050	0.0250	–1600	–60	–2250	–90
3050–3100	0.0070	–1750	–250	–2100	–300
3100–3150	0.0030	–750	–250	–960	–320
2780–3150	0.4190	–384 155	–920	–405 680	–970

Table 2. Net mass-balance data for 1988–89 and 1989–90

Altitude	*Area*	*1988–89*		*1989–90*	
		Total	*Specific*	*Total*	*Specific*
m a.s.l.	km^2	m^3	mm	m^3	mm
2780–2800	0.0030	–4200	–1400	–5700	–1900
2800–2850	0.0640	–84 480	–1320	–141 440	–2210
2850–2900	0.1160	–143 840	–1240	–199 520	–1720
2900–2950	0.1290	–56 760	–440	–110 940	–860
2950–3000	0.0720	+ 33 840	+ 470	–22 320	–310
3000–3050	0.0250	+ 11 250	+ 450	–3000	–120
3050–3100	0.0070	+ 2310	+ 330	–2800	–400
3100–3150	0.0030	+ 1020	+ 340	–1140	–380
2780–3150	0.4190	–240 860	–570	–486 860	–1160

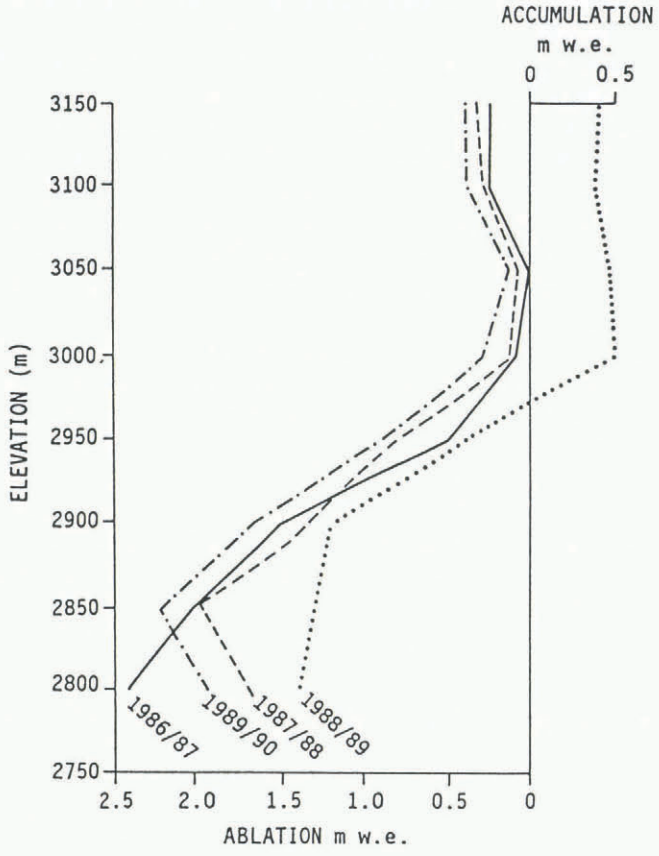

Fig. 2. Ghiacciaio della Sforzellina: net balance versus altitude.

of the greater compactness of the snow and because the area is overshadowed by high back walls.

Equilibrium-line altitudes

The equilibrium-line altitude (ELA) for Ghiacciaio della Sforzellina was calculated by means of field observation (for temperate glaciers, the ELA may coincide approximately with the snow line at the end of the summer) (Paterson, 1981), and by plotting the elevation versus mass-balance amounts. As shown in Tables 1 and 2, none of the altitude intervals showed an increase in volume for 3 years (1986–87, 1987–88, 1989–90). In addition, in the areas where accumulation occurred (mainly at the foot of the rock wall of Corno dei Tre Signori), the areas and volumes involved are so limited that their weight in the mass balances of the individual areas are also very slight. Therefore, the curves (Fig. 2) for the 3 years mentioned above do not exceed zero. Field observations showed that the 1989–90 snow line was situated at 2940 m on 6 August 1990 and at 2980 m on 27 August. The entire glacier was virtually free of accumulation at the last observation (23 September). It is possible to determine the ELA from the figure only for 1988–89 (2975 m, 23 September 1989).

CLIMATIC CONDITIONS

Contrary to plans, it was not possible to set up a meteorogical station near the glacier. The general climatic conditions were drawn from the data collected at S. Caterina Valfurva, the nearest station. This is situated at the mouth of upper Valfurva where the lower section of the Gavia valley ends, at 1740 m in altitude and about 7 km from the glacier. The balance year 1986–87 reportedly opened with a dry autumn and a cold, dry winter, followed by a cool summer. The greatest difference in the balances was found between 1988–89 and 1989–90, and in both years the winters were cold and dry and the summers cool and dry. In a comparison of the monthly temperatures for the four balance years with the normal monthly temperatures (derived from a long statistical series), it was observed that the temperature in August 1990 (the year with the greatest mass-balance deficit) was higher than normal and than the 1987, 1988 and 1989 August temperatures. At any rate, it is possible

to note that in all 4 years, there were dry winters with snowfall clearly below the normal levels (19–30% less).

CONCLUSIONS

The mass balance for Ghiacciaio della Sforzellina for the period 1986/87–1989/90 is clearly a negative one with a mean of $-0.90\ \mathrm{m\ year^{-1}}$ for the entire period, which seems to be due to a succession of dry winters with little snowfall. Frontal fluctuations of Ghiacciaio della Sforzellina have been measured since the late 1920s by the Comitato Glaciologico Italiano. The data reveal a constant retreat of the front from 1925 to 1966 for a total of 330 m (Desio, 1967). After a phase of stability, there was an advance of the front with a maximum of 20 m in 1979. The glacier began to advance in 1976–77, almost exactly corresponding to an increase in winter precipitation and a drop in summer temperatures; thereafter, the glacier began to undergo a series of retreats and advances (Pelfini and Smiraglia, 1990). During the years for which the mass balance has been calculated, the glacier advanced (1986–87, +16 m; 1987–88, +4 m) and then retreated (1988–89, –4 m; 1989–90, –11 m). Thus, Ghiacciaio della Sforzellina seems to conform to a reduction in the retreat tendency and the period of expansion of glaciers as reported for the Alps for the period between 1960 and 1980, and which already seems to have come to a close (Patzelt, 1985). It is therefore important that frontal variation and, above all, mass balances continue to be calculated and are extended in scope throughout the Italian Alps (at present, mass balances are calculated only for two glaciers). This is the only way comparisons are possible with phenomena in progress in other sectors of the Alpine chain and the Northern Hemisphere.

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